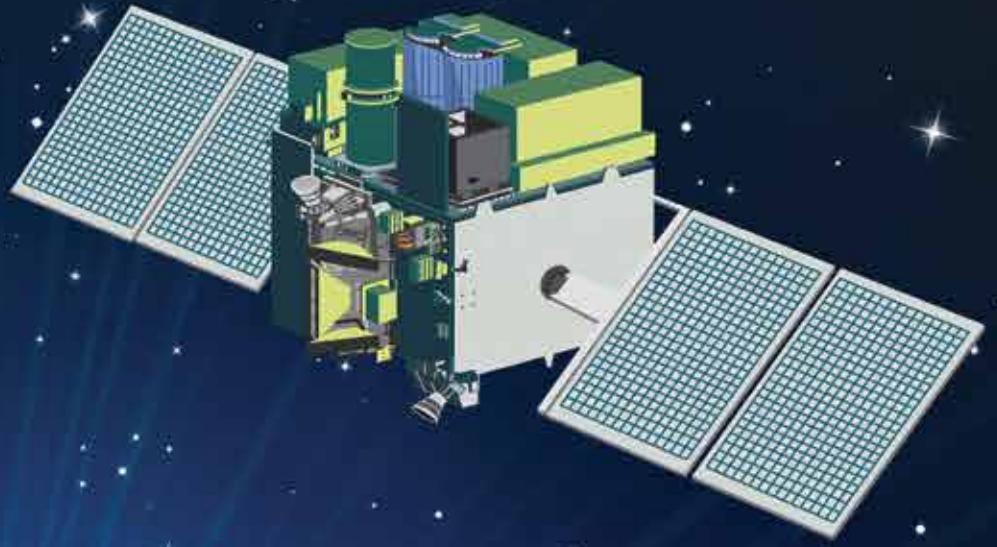


Tata Institute of Fundamental Research

Annual Technical Report
(2015-16)



Edited, Designed and Published by
Dr. Punita Punia

Printed by
SM Enterprises, Mumbai

Photography
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Web: <http://www.tifr.res.in/>

AstroSat, India's first multi-wavelength Astronomical satellite,
was launched on 28 September 2015



The fully assembled satellite is seen during the tests before launch.
The scientific instruments are mounted on the top of the satellite and three of them
(LAXPC, SXT and CZTI) are built by teams lead by TIFR



Balloon-borne experiment for Asian Tropopause Aerosol Layer (BATAL) conducted from balloon facility, Hyderabad

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Council of Management

Mr. Ratan N. Tata (*Chairman*)
Chairman, Sir Dorabji Tata Trust

Mr. R.K. Krishna Kumar
Trustee, Sir Dorabji Tata Trust

Dr. Ratan K. Sinha (*till October 23, 2015*)
Dr. Sekhar Basu (*Since October 24, 2015*)
Chairman, Atomic Energy Commission & Secretary to the Govt. of India
Department of Atomic Energy

Mr. Sudarsanam Srinivasan (*till January 31, 2016*)
Mr. Vinod Kumar Thakral (*Since February 1, 2016*)
Member (Finance), Atomic Energy Commission

Prof. C.N.R. Rao, F.R.S.
Hon. President, Jawaharlal Nehru Centre for Advanced Scientific Research

Mr. Nand Kumar (*till December 31, 2015*)
Principal Secretary, Govt. of Maharashtra

Dr. Shekhar Mande (*Since January 1, 2016*)
Director, National Centre for Cell Science, Nominee of the Govt. of Maharashtra

Dr. K. Kasturirangan, F.A.Sc., F.N.A
Trustee, Raman Research Institute Trust

Prof. Sandip P. Trivedi (*till 21.4.2015*)
Officiating Director, Tata Institute of Fundamental Research

Prof. E.V. Sampathkumaran (*22.04.2015 to 07.07.2015*)
Officiating Director, Tata Institute of Fundamental Research

Prof. Sandip P. Trivedi (*Since July 8, 2015*)
Director, Tata Institute of Fundamental Research

Honorary Fellows

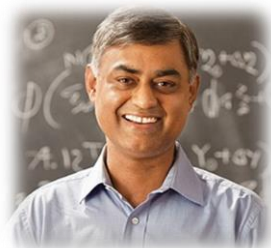
Present

Prof. Sir Michael Atiyah
 Prof. K. Chandrasekharan
 Prof. P.R. Deligne
 Prof. Richard Ernst
 Prof. Murray Gell-Mann
 Prof. David Gross
 Prof. Anthony Hewish
 Prof. Leon M. Lederman
 Prof. G.A. Margulis
 Prof. Andre Martin
 Prof. M.G.K. Menon
 Prof. S. Miyake
 Prof. D. Mumford
 Prof. M.S. Narasimhan
 Prof. T.V. Ramakrishnan
 Prof. C.N.R. Rao
 Prof. B.V. Sreekantan
 Prof. James Dewey Watson
 Prof. Sir Arnold Wolfendale
 Prof. Samuel C. C. Ting
 Prof. C.S. Seshadri
 Prof. S.R.S. Varadhan
 Prof. E.C.G. Sudarshan
 Mr. Ratan N. Tata
 Prof. Govind Swarup
 Prof. M.S. Raghunathan

Past

Prof. H. Alfvén
 Prof. P.M.S. Blackett
 Prof. Felix Bloch
 Prof. Niels Bohr
 Prof. Armand Borel
 Prof. S.N. Bose
 Prof. Harish Chandra
 Prof. S. Chandrasekhar
 Sir John Cockcroft
 Prof. Francis Harry Compton Crick
 Prof. R.H. Dalitz
 Prof. P.A.M. Dirac
 Prof. S. Dhawan
 Prof. P.L. Kapitza
 Prof. Jacques L. Lions
 Dr. John Mathai
 Shri Jawaharlal Nehru
 Prof. Bernard Peters
 Prof. Lord Porter
 Prof. C.F. Powell
 Prof. C.V. Raman
 Dr. R. Ramanna
 Prof. G.N. Ramachandran
 Prof. B.B. Rossi
 Prof. A. Salam
 Prof. L. Schwartz
 Prof. C.L. Siegel
 Shri J.R.D. Tata
 Prof. Andre Weil
 Prof. A. Selberg
 Prof. H.N. Sethna
 Prof. V.L. Ginzburg
 Prof. D. Lal
 Prof. Obaid Siddiqi

Preface



The year 2015-16 has been a fruitful one for the Tata Institute of Fundamental Research (TIFR). Important scientific findings have been made, several key results have been obtained, and some new areas of research have opened up.

In Astronomy and Astrophysics a major achievement was the successful launch of ASTROSAT satellite in September 2015, carrying five science payloads on board. Of these, three were built in TIFR. At the National Centre for Radio Astronomy (NCRA), the first results from the GMRT High Resolution Southern Sky (GHRSS) survey for pulsars and transients have discovered ten new pulsars, one of which is a millisecond pulsar. The TIFR Balloon Facility designed and fabricated a two-ton balloon for carrying a heavy payload up to an altitude of 11 km.

In Condensed Matter Physics detailed experimental evidence for a new class of materials, which can be termed as a “Composite Nanoglass” has been established. High-quality bulk crystals of the rhenium series of transition-metal have been synthesized. An important achievement has been made by demonstrating the ability to manipulate the vibrations of a drum of nanometer scale thickness - realizing the world's smallest and most versatile drum.

In High Energy Physics, TIFR has significantly contributed to the CMS experiment going on at the Large Hadron Collider (LHC) by analysing data to confirm the presence of the standard model Higgs boson which was discovered earlier. Under the Indian Neutrino Observatory (INO) project the industrial production of 2m × 2m glass Resistive Plate Chamber (RPC) gaps for the 600 ton engineering prototype of the Iron Calorimeter (ICAL) detector has begun.

In Nuclear and Atomic Physics, high spin states of an isotope of Tellurium, which has a neutron rich nucleus, have been investigated using fission fragment spectroscopy. Experiments with highly

charged ions impacting with large molecules have revealed giant plasmon resonance. Accelerator based condensed matter research has led to the first observation of a cross over from itinerant to localized magnetic moment in a nano-sized Silver matrix.

In Theoretical Physics, promising results were obtained in Cosmology and Astroparticle Physics, Condensed Matter and Statistical Physics, High Energy Physics, String Theory and Mathematical Physics. The Cray XC-30 which delivers over half a Petaflop of computing power and is ranked the 114th most powerful computer in the world (as of May 2015), was installed in the Hyderabad data center of the Indian Lattice Gauge Theory Initiative. It will be used to computationally study properties of the strong interactions, including phase transitions in the early universe, and other properties to be tested in collider experiments.

In Chemistry, novel complexes involving hydrogen bonds were characterized by zero kinetic photoelectron spectroscopy. Identification and characterization of unconventional hydrogen bonded system was achieved, and novel hybrid materials were synthesized by methods involving efficient carbon dioxide capture.

In Biology, the study on malaria parasite has led to important progress in the identification of an epitope with the potential to emerge as a broad spectrum multistage malaria vaccine candidate. Research has also resulted in new findings in the fields of Metabolism, Skin and Embryonic development, Spermatogenesis, Quantitative genetics and Lipid transport. At the National Centre For Biological Sciences (NCBS), research covers a diverse set of subjects broadly falling in the areas of Biochemistry, Bioinformatics, Neurobiology, Cellular Organisation & Signalling, Genetics & Development, Theory & Modelling of Biological Systems and Ecology and Evolution. Several significant results have been obtained in many of these areas in the past year.

In Mathematics, at the main campus in Colaba, research has been carried out in the fields of Algebra and Algebraic Geometry, Differential Geometry, Number Theory and Combinatorics, and some significant results have been obtained. At

the Centre for Applicable Mathematics (CAM), Bengaluru, key findings have been made in the study of partial differential equations and stochastic differential equations. The School Of Technology and Computer Science (STCS) has pursued the study of important topics in the areas of computer science as well as systems science.

The Homi Bhabha Centre for Science Education (HBCSE), in its endeavor to enhance science education started ten new Collaborative Undergraduate Biology Education (CUBE) nodes in different Indian cities. The HBCSE is the nodal Centre in the country for the International Olympiads. This year, of the 30 students who represented India in the International Olympiads, 27 bagged medals including 10 gold. The open house at HBCSE on National Science Day (NSD) witnessed over 2000 visitors.

A major science discovery in the world this year was the first direct detection of gravitational waves, predicted by Albert Einstein's general theory of relativity, and the first observation of a binary black hole merger. This was achieved by the two detectors of the Laser Interferometer Gravitational-wave Observatory (LIGO). TIFR scientists, both at the International Centre for Theoretical Sciences (ICTS) and the main campus in Colaba, have played an important role in these discoveries. At the ICTS, the group working on Astrophysical Relativity made direct contributions to this discovery by establishing the consistency of the observed signal with a binary black hole merger predicted by general relativity. Also at the ICTS, significant results were obtained in several other areas including, the study of Complex Systems,

Interdisciplinary Mathematics, String Theory and Quantum Gravity.

The TIFR Centre For Interdisciplinary Sciences (TCIS), Hyderabad, carries out research on several aspects of Condensed Matter Physics, Nuclear Magnetic Resonance and Laser physics. In Material Science progress has been made on atomically thin layers and their assembly. Significant results have also been obtained in the field of theoretical and computational physics. This year TCIS expanded its research horizon by starting programmes in Biological Sciences as well. A research study has been initiated related to cancers, and a cell culture facility has been set up.

Other than scientific research, TIFR this year also made significant contributions towards Science Popularization. The Frontiers of Science 2015 programme, saw close to 1500 visitors on campus, including students and teachers from more than 80 schools. A wide cross section of schools participated in the programme, including orphanages in Mumbai and two Adivasi ashram schools from Thane and Palghar district. The open house at HBCSE on National Science Day (NSD) witnessed over 2000 visitors.

We look forward to the coming year with anticipation and eagerness, for the opportunities it will offer to take our scientific research to greater heights and to making our nation more globally competitive in the scientific arena.

I would like to thank Punita Punia for her help in preparing the Annual Report.

Sandip Trivedi
Director, TIFR

[Back to Contents Page](#)

Awards and Distinctions

A. K. Ray

- Fulbright Nehru Fellowship for Academic and Professional Excellence 2014(Washington DC and New Delhi) visit to Harvard University, Feb-Oct 2015

A. Raveendran

- *Kusum* Mathradas Kothari Fellowship, Hemendra Kothari Foundation, 2015

Abhilasha Pawar

- Awarded Rhodes Fellowship 2015

Adimurthi

- Dr. Zakir Hussain award by Indian Society of Industrial and Applied Mathematics, 2016

Ankona Datta

- ACS Emerging Investigators in Bioinorganic Chemistry, 2015

Barma Mustansir

- G. M. Modi Award for Innovative Science and Technology, 2015

Basudeb Dasgupta

- Kavli Frontiers Fellow 2015 of the US National Academy of Sciences.

C.S. Rajan

- Elected Fellow, Indian National Science Academy

Chandra Poonam C.

- Swarna Jayanti Fellowship, 2015

D. K. Ojha

- Elected Fellow, National Academy of Sciences, 2015

Deepa Khushalani

- DST Young Career Award in Nanoscience and Technology 2016
- Fellow of the Royal Society of Chemistry

E. Krishnakumar

- DEA (Dissociative Electron Attachment) Club distinguished service award, 2015

G.D. Veerappa Gowda

- Elected Fellow, Indian National Science Academy, 2016

- Elected Fellow, National Academy of Sciences, 2015

- ISIAM award for Applied Mathematics, 2016

Gaiti Hasan

- Elected Fellow, The World Academy of Sciences, 2015

K. K Mishra

- Rajbhasha Gaurav Award, Dept. of Official Language, Min. of Home Affairs, Govt. of India, 2015

K. Sandeep

- Shanti Swarup Bhatnagar Prize in Mathematical Sciences, 2015

K.V.R. Chary

- Elected Council Member, National Academy of Sciences, 2016-18
- Elected Member, International Advisory Board, International Council on Magnetic Resonance in Biological Systems (ICMRBS), 2014-16
- Elected Treasurer and Steering Committee Member, Asian Biophysics Association, 2013-present
- Elected Fellow, The World Academy of Sciences

Kalobaran Maiti

- Elected Fellow, Indian National Science Academy
- Outstanding Investigator Award, DAE Science Research Council, 2015

Kedar Damle

- Elected Fellow, Indian Academy of Sciences, 2016

Krishnamurthy M.

- DAE-SRC Outstanding Investigator award, 2015

Mahan Mj

- Infosys Award for Mathematical Sciences, 2015

Mondal Jagannath

- Ramanujan Fellowship, 2015

- Young Associate, Indian Academy of Sciences

Narayanan T.N.

- Associate of Indian Academy of Sciences – July 2015 –December 2018

P. K. Madhu

- International Advisor, European School on Solid-state NMR

P. S. Joshi

- Saraswat Gaurav Award, Ahmedabad, 2015
- Distinguished Scientists Fellowship for Foreign Researchers, Osaka City University, 2016

R. Vaze

- Young Scientist Award, National Academy of Science, 2015

R.V. Hosur

- Elected to the ISMAR Council
- Distinguished Alumnus Award of IIT-Bombay, 2015

Radhika Vankatesan

- Ramanujan Fellowship, SERB, 2015

Rajesh Gopakumar

- Elected Fellow, The World Academy of Sciences, 2015

Raman Karthik V.

- PACIFICHEM Early Career Research Award, 2015

Ravi Venkatramani

- Fellow of the Royal Society of Chemistry, UK

S. Naik

- *Kusum* Mathradas Kothari Fellowship, Hemendra Kothari Foundation, 2015

Sandip P. Trivedi

- TWAS Prize for Physics, 2015

Satyajit Mayor

- Foreign Associate, US National Academy of Sciences, 2016
- Margdarshi Fellowship, 2015

Shannon Olsson

- Ramanujan Fellowship, DBT, 2016

Shiraz Minwalla

- Distinguished Alumni Award 2015, IIT Kanpur

Shobhona Sharma

- Elected Fellow, Indian National Science Academy

Shubha Tole

- National Leadership award in Science and Technology, Lakshmi Pat Singhania-IIM Lucknow, 2015

Subhabrata Majumdar

- Simon Fellow, ICTP, Trieste

Sushil Mujumdar

- Swarnajayanti Fellowship, DST, 2015

Tuhin S. Roy

- Early Career Research Award, SERB, DST

U. Bhaskar

- Ramanujan Fellowship, DST, 2016

Uma Ramakrishnan

- Fulbright Nehru Academic Fellow, Parker Gentry Conservation award, 2016
- Bass Fellow of Field Museum of Natural History, Chicago, 2015

V. Srinivas

- Einstein Visiting Fellow, 2016-19, Freie Universität, Berlin
- Elected Fellow, The World Academy of Sciences

Vidita Vaidya

- Shanti Swarup Bhatnagar Award in Medical Sciences, 2015

Vijay Kumar Krishnamurthy

- Ramalingaswami re-entry fellowship, DBT, 2015

Vivek Polshettiwar

- Selected as one of the 175 Faces of Chemistry Worldwide by Royal Society of Chemistry (RSC), 2015

Faculty

Sandip Trivedi (Director) (*till 21.4.2015*) (*July 8, 2015 onwards*)
 Prof. E.V. Sampathkumaran (Officiating Director) (*22.04.2015 to 07.07.2015*)

School of Mathematics

Indranil Biswas	N. Saradha
N. Fakhruddin	J. Sengupta
E.P. Ghate	Raja Sridharan
Anish Ghosh	S. Subramanian
V. Srinivas	V.G. Trivedi
Y.I. Holla	G.R. Vijaykumar
Amalendu Krishna	A. Sankaranarayanan
Ritabrata Munshi	A.J. Parameswaran
A.N. Nair	T.N. Venkataramana
Nitin Nitsure	Siddhartha Bhattacharya
Dipendra Prasad	Amitava Bhattacharya
C.S. Rajan	Radhika Ganapathy (from 15/7/15)
Ravi A. Rao	Mahan Mj (from 16/11/15)
S.E. Rao	Tanmay Deshpande (from 1/12/15)
S.K. Roushon	R.V. Gurjar (till 31/10/15)
Sandeep Varma V.	Amit P Hogadi (till 6/1/16)

Adjunct Faculty, SOM

Jean Fasel, Institut Fourier, France
 Abhishek Saha, University of Bristol, UK
 Aravind Asok, University of Southern Californ
 Angelo Vistoli, Scuola Normale Superiore, Italy
 Sanju L. Velani, University of York, UK

TIFR Centre for Applicable Mathematics, Bangalore

Adimurthi	G.D. Veerappa Gowda
C.S. Aravinda	Ujjwal Koley
K.T. Joseph	Venkateswaran P. Krishnan
Mythily Ramaswamy	Praveen C
K. Sandeep	Sreekar Vadlamani
P.K. Shrinivasan	M.Vanninathan
A.S. Vasudevamurthy	P. S. Datti (till 31/12/15)
Imran H. Biswas	P.N. Srikanth (till 30/9/15)

Adjunct Faculty, CAM

Mokshay M. Madiman, University of Delaware, USA
 Malabika Pramanik, University of British Columbia, Canada

School of Technology and Computer Sciences

P. Harsha	V. M. Prabhakaran
S.K. Juneja	N. Raja
T. Kavitha	R. Vaze
P.K. Pandya	Manoj Gopalkrishnan
J. Radhakrishnan	Naresh Sharma
P.G.D. Sen	U. Bhaskar (from 1/6/15)
A. Chattopadhyay	Subir K. Ghosh (till 31/7/15)
A. Gupta	

School of Natural Sciences

Department of Astronomy and Astrophysics

H.M. Antia	M.N. Vahia
P.S. Joshi	J.S. Yadav
Bhaswati Mooketjea	A. Gopakumar
D. Narasimha	Sudip Bhattacharyya
D.K. Ojha	Manoj Puravankara
A.R. Rao	Shravan M. Hanasoge
K.P. Singh	A.K. Ray
T.P. Singh	Arunav Kundu (till 1/7/15)

Department of Biological Sciences

Shobhona Sharma	Shubha Tole
G.K. Jarori	Vidita A. Vaidya
Sandhya P. Koushika	Mithilesh Mishra
Roop Mallik	Sreelaja Nair
R. Maithreyi Narasimha	Mahendra S. Sonawane
B.J. Rao	Himanshu Sinha
Krishanu Ray	Shamik Dasgupta (from 3/3/16)
Ullas Kolthur Seetharam	

Department of Chemical Sciences

S.J. Wategaonkar	A. Sri Rama Koti
K.V.R. Chary	Ankona Datta
Ranjan Das	Jyotishman Dasgupta
R.V. Hosur	Vivek Polshetiwar
Deepa Khushalani	Ravindra Venkatramani
P.K. Madhu	H.M. Sonawat
Sudipta Maiti	G. Krishnamoorthy (till 31/5/15)
S. Mazumdar	

Department of Condensed Matter Physics and Materials Science

Pushan Ayyub	P.L. Paulose
S.K. Dhar	S. Ramakrishnan
Arnab Bhattacharya	Pratap Raychaudhuri
S. Bhattacharya	E.V. Sampathkumaran
Mandar M. Deshmukh	Arumugam Thamizhavel
Sandip Ghosh	Achanta Venu Gopal
Shankar Ghosh	S.S. Prabhu
A.K. Grover	R. Vijayaraghavan
Kalobaran Maiti	Somnath Bhattacharyya (till 7/7/15)
A.K. Nigam	

Department of High Energy Physics

Sudeshna Banerjee	Kajari Mazumdar
B.S. Acharya	Gagan B. Mohanty
Tariq Aziz	C.S. Unnikrishnan
S.R. Dugad	V.R. Chitnis
Monoranjan Guchait	N. Krishnan
S.K. Gupta	P.K. Mohanty
Gobinda Majumder	N.K. Mondal

Department of Nuclear and Atomic Physics

S.N. Mishra
 E. Krishnakumar
 M. Krishnamurthy
 Deepak Mathur
 Indranil Mazumdar
 Sushil A. Mujumdar
 Vandana S. Nanal
 Subrata Pal

Rudrajyoti Palit
 R.G. Pillay
 G. Ravindra Kumar
 L.C. Tribedi
 Deepankar Misra
 Vaibhav S. Prabhudesai
 S.V.K. Kumar (till 31/1/16)

Department of Theoretical Physics

R.V. Gavai
 Kedar S. Damle
 Saumen Datta
 Deepak Dhar
 Amol S. Dighe
 Sourendu Gupta
 Gautam Mandal
 Nilmani Mathur
 Shiraz Minwalla
 Sreerup Raychaudhuri
 K. Sridhar
 Vikram Tripathi

Sandip P. Trivedi
 Subhabrata Majumdar
 Tuhin S. Roy
 Rajdeep Sensarma
 Rishi Sharma
 Basudeb Dasgupta
 R.S. Bhalerao
 Rishi Khatri (from 3/8/15)
 S. Mukhi (till 30/11/15)
 M. Barma (till 31/12/15)
 S.R. Wadia (till 31/7/15)

Adjunct Faculty, SNS

Umesh V. Waghmare, Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore
 S. Dutta Gupta, University of Hyderabad
 Umesh Garg, University of Notre Dame, USA
 Dr. Laurent Gizon, Max Planck Institute for Solar System Research, Germany.
 Sumit Ranjan Das, University of Kentucky
 Gautam Bhattacharyya, Saha Institute of Nuclear Physics
 Satya N. Majumdar, Universite Paris-Sud, France
 Alexandre Refregier, Institute of Astronomy, Switzerland
 Deepto Chakrabarty, Massachusetts Institute of Technology, USA
 Jean-Yves Ollitrault, Institut de physique theorique, France
 Amnon Horovitz, Weizmann Institute, Israel
 Daniel Huster, University of Leipzig, Germany

Homi Bhabha Centre for Science Education

K. Subramaniam
 S.I. Chunawala
 S.A. Ladage
 Anwesh Mazumdar
 K.K. Mishra
 Jayashree Ramadas
 Rekha R. Vartak
 G. Nagarjuna
 J. Vijapurkar

Sanjay Chandrasekharan
 Prithwijit De
 P.K. Joshi
 R.B. Khaparde
 A.P. Sule
 Ankush Gupta (from 1/5/15)
 Karen Haydock (till 29/2/16)
 B.J. Venkatachala (till 31/10/15)

National Centre for Biological Sciences

Satyajit Mayor
 Upinder S. Bhalla
 Sumantra Chattarji
 Gaiti Hasan
 Sandeep Krishna

Sudhir Krishna
 M.K. Mathew
 Raghu Padinjat
 M.M. Panicker
 Sanjay P. Sane

Mahesh Sankaran
 Apurva Sarin
 R. Sowdhamini
 Jayant B. Udgaonkar
 K. VijayRaghavan
 Shannon B Olsson
 Ranabir Das
 Shachi S. Gosavi
 Krushnamegh Kunte
 Uma Ramakrishnan
 Aarti Ramesh
 P.V. Shivaprasad

Varadharajan Sundaramurthy
 Mukund Thattai
 Vatsala Thirumalai
 Radhika Venkatesan
 Aswin Sai Narain Seshasayee
 Hiyaa S. Ghosh (from 17/8/15)
 Yamuna Krishnan (till 31/7/15)
 Deepak T. Nair (till 30/6/15)
Young Investigator Programme members
 Deepa Agashe
 Axel Brockmann

National Centre for Radio Astrophysics

Jayaram N. Chengalur
 Swarna Kanti Ghosh
 Yashwant Gupta
 C.H. Ishwara Chandra
 Bhal Chandra Joshi
 Nissim Kanekar
 Nimisha G. Kantharia
 P.K. Manoharan
 Dipanjan Mitra

D.J. Saikia
 Poonam Chandra
 Tirthankar Roy Choudhury
 Dharam Vir Lal
 Divya Oberoi
 Jayanta Roy
 Subhashis Roy
 Sandeep K. Sirothia
 Yogesh G. Wadadekar

International Centre for Theoretical Sciences

Abhishek Dhar
 Avinash Dhar
 Amit Apte
 P. Ajith
 Pallab Basu
 Suvrat Raju
 Vijay Kumar Krishnamurthy

Rajesh Gopakumar (from 1/4/15)
 Rukmini Dey (from 1/4/15)
 Subhro Bhattacharjee (from 28/4/15)
 Anupam Kundu (from 6/5/15)
 Samriddhi Sankar Ray (from 1/7/15)
 R. Loganayagam (from 28/10/15)

TIFR Centre for Interdisciplinary Sciences

Sriram Ramaswamy
 Surajit Sengupta
 Smarajit Karmakar
 Prasad Perlekar
 Anukul Jana
 Kanchan Garai
 Pramodh Vallurupalli

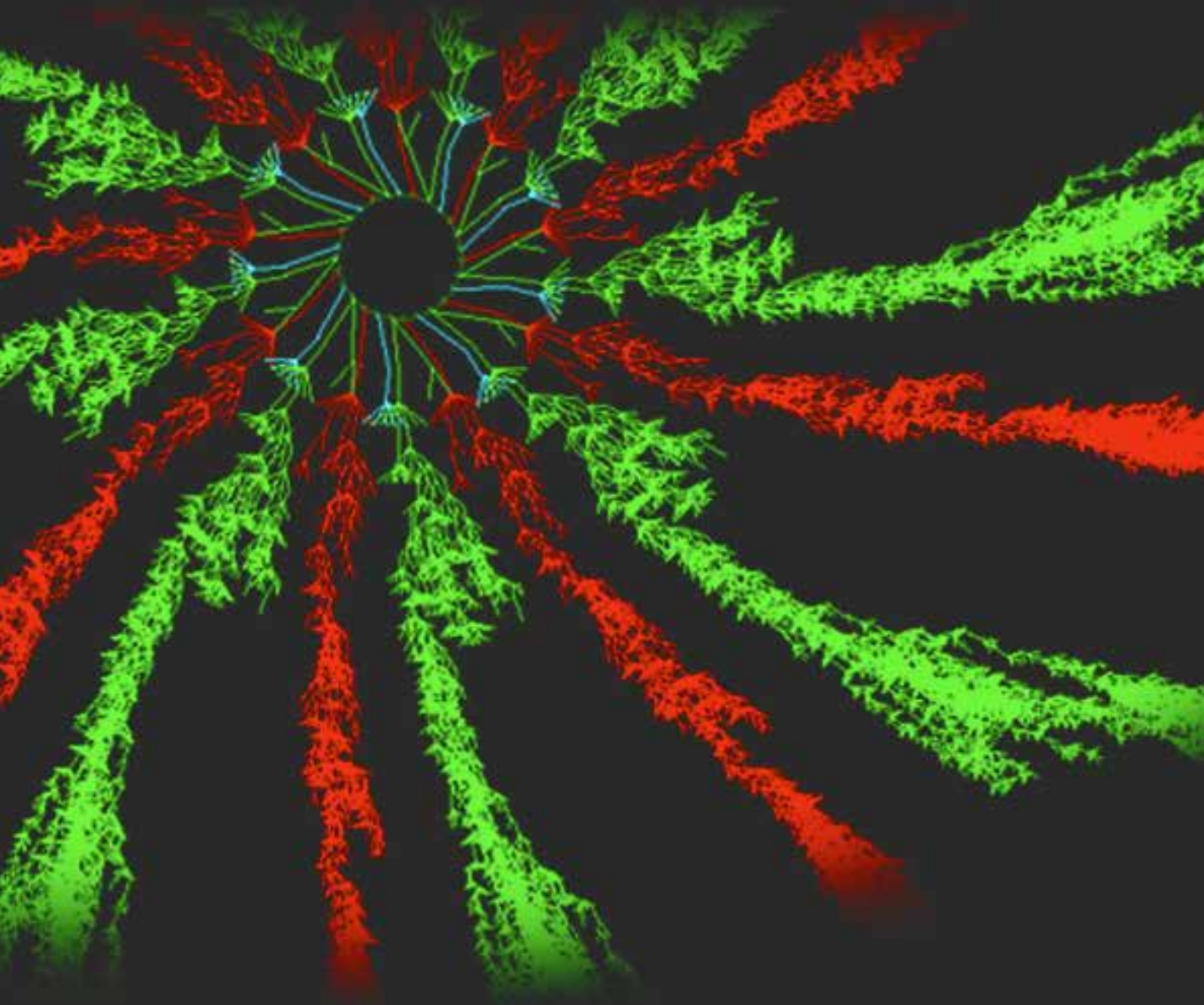
T.N. Narayanan
 Aprotim Mazumder
 Karthik V Raman
 Vipin Agarwal (from 5/5/15)
 Jagannath Mondal (from 30/6/15)
 Shubha Tewari (till 24/8/15)
 Rajat Varma (2/11/15 to 24/11/15)

Academic Council

- Prof. Sandip P. Trivedi** (*Director & Chair, ACM*)
Prof. J. Ramadas (*Centre Director, HBCSE,*) **Prof. K. Subramanian** (*from Mar 2016*)
Prof. S. Mayor (*Centre Director, NCBS*)
Prof. S. K. Ghosh (*Centre Director, NCRA*)
Prof. Sriram Ramaswamy (*Centre Director, TCIS*)
Prof. Rajesh Gopakumar (*Centre Director, ICTS*)
Prof. H.M. Antia (*Dean, NSF*)
Prof. Amol S. Dighe (*Dean, GS*)
Prof. Ravi Rao (*Dean, MF*), **Prof. A.J. Parameswaran** (*from February, 2016*)
Prof. P.K. Pandya (*Dean, TCSF*)
Prof. K. Subramanian (*Dean, HBCSE*) **Prof. Sugra Chunawala** (*from March 2016*)
Prof. J. Chengalur (*Dean, NCRA*)
Prof. Surajit Sengupta (*Dean, TCIS*)
Prof. Abhishek Dhar (*Dean, ICTS*)
Prof. G.D. Veerappa Gowda (*Dean, TIFR CAM*)
Prof. Upinder S. Bhalla (*Convenor, BSB/ Dean, NCBS*)
Prof. Ranjan Das (*Convenor, CSB*)
Prof. Eknath Ghate (*Convenor, MSB*) **Prof. Nitin Nitsure** (*from February, 2016*)
Prof. Sreerup Raychaudhari (*Convenor, PSB*)
Prof. T. Kavitha (*Convenor, TCSF*) **Prof. Prahladh Harsha** (*from February, 2016*)
Prof. Jayashree Ramadas (*Convener, HBCSE*)
Prof. D. Ojha (*Chair, DAA*)
Prof. Shobhona Sharma (*Chair, DBS*)
Prof. Pushan Ayyub (*Chair, DCMP*)
Prof. S. Wategaonkar (*Chair, DCS*) **Prof. S. Mazumdar** (*from February, 2016*)
Prof. Sudeshna Banerjee (*Chair, DHEP*)
Prof. S.N. Mishra (*Chair, DNAP*)
Prof. R.V. Gavai (*Chair, DTP*)
Wg. Cdr. George Antony (Retd) (*Registrar*)
Prof. Rajendra Bhatia (*ISI, Delhi*)
Prof. D. Balasubramanian (*Director, LV Prasad Eye Inst.*)
Prof. Vikram M. Gadre (*IIT, Mumbai*)
Prof. R. Ramaswamy (*JNU, Delhi*)

Administration and Services

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Purchase Officer Shekhar G.K.	Head, Administration & Finance NCRA, Pune J.K. Solanki
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Security & Fire Officer Bharat B. Joshi	Administrative Officer (D), National Balloon Facility, Hyderabad D. Manohar
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Chief Engineer, Technical Services S.N. Iyer	Chief Engineer, Central Workshop Sangam Sinha
Head, Information System Development Group Nihita Goel	Physician & Head, Medical R.Y. Agarkar (<i>till August 31, 2015</i>) Head, Medical Section Sandhya Raghavan (<i>from September 1, 2015</i>)
Scientific Officer (F), Low Temperature Facility K.V. Srinivasan	Head, SIRC R. Prabakaran



School of Mathematics



International Colloquium on K-Theory, January 2016



40 Years of the Eta Invariant, Lectures by P.F. Baum and E. Van Erp, August 2015

SCHOOL OF MATHEMATICS

Algebra and Algebraic Geometry

A partial affirmative answer to a conjecture of V.L. Popov about equidimensional representations was given.

It was proved that a positively graded domain is determined by its completion at its vertex. As a corollary it was proved that the log Kodaira dimension of the smooth locus of a quotient of an affine space modulo a reductive algebraic group is ∞ .

Some new results about quotients of a 3-dimensional smooth affine variety modulo the action of a one dimensional unipotent algebraic group were proved.

Complete classification of doubly saturated subgroup scheme of a reductive group with the characteristic of the base field, p , more than the coxeter number h_G , is obtained as a generalization of the theorem Deligne, who proved the classification of doubly saturated sub group schemes once G has a faithful representation of dimension $< p$. As consequence of this one also obtained an étale slice theorem in positive characteristic.

A notion of a relative canonical reduction for families of principal bundles in higher dimensions was defined and the existence of a schematic Harder-Narasimhan stratification for such families in characteristic zero was proved.

The elementary Dickson-Siegel-Eichler-Roy subgroup $EO(Q, H(P))$ of the orthogonal group $O(Q \perp H(P))$ of a non-singular quadratic form Q , is a normal subgroup if $\text{rank}(P) \neq 2$.

The invertible matrix that Krusemeyer associated to an invertible Alternating matrix, is used to prove that a certain class of projective modules given by unimodular rows of length three are isomorphic.

In joint work with Jose-Ignacio Burgos, begun during a visit to ICMAT, Madrid, analogues in Arakelov geometry were considered for some results in surface theory, like Nagata's theorem on

ruled surfaces. This is still an ongoing work.

Joint work with M. V. Nori and Deepam Patel saw progress; this is an attempt to relate the Milnor K-

theory of a ring of convergent power series with a generalisation of mixed Hodge structures, introduced by Bloch and Srinivas some years ago. This is also an ongoing work.

Work on the stratified fundamental group is in progress. Here we give some applications of the invariant *Hilbert-Kunz density function*, in the graded setup. In particular we study the asymptotic behaviour of the HK multiplicity with respect to the powers of the maximal ideal, and we answer a question of Brenner-Miller-Li, giving a more direct approach to the Hilbert-Kunz multiplicity in characteristic 0.

Differential Geometry, Lie Groups and Related Areas, Topology

Let $\mathfrak{g} = \mathfrak{gl}_N$. For each $k > 0$ let T_k be a Gelfand invariant. It is known that T_k belongs to center of $U(\mathfrak{g})$. Fix a positive integer n . Let j_1, j_2, \dots, j_k be such that $1 \leq j_i \leq n$. Then we define operators $T_k(j_1, \dots, j_k)$ which act on any n tensor product \mathfrak{g} -module and commutes with \mathfrak{g} action. In general they take one highest weight vector to a new highest weight vector. In a sense it is an algorithm which produces new highest weight vectors once we know one highest weight vector.

$$T_k = \sum_{1 \leq j_1, j_2, \dots, j_k \leq n} T_k(j_1, j_2, \dots, j_k)$$

Further

It is a classical and important method to compute invariants of groups in terms of the computations of the invariants of some subgroups of the group. A concrete example of such a situation is when the group acts on a tree and one knows the computation of the invariants of the vertex and edge stabilizers of the group action on the tree. We are continuing the study of K- and L-theory of groups in this set up.

Investigated an old question of Erdos-Szusz-Turan in Diophantine approximation. Using dynamics on homogeneous spaces we prove a comprehensive

framework to analyse their question and use equidistribution results to settle higher dimensional analogues of their conjecture.

Investigated D. Sullivan's "logarithm law" in the context of semisimple group actions on homogeneous spaces using the ergodic theoretic approach of Ghosh-Gorodnik-Nevo. As an application, we prove effective theorems for integer values of generic binary and ternary quadratic forms.

Proved that almost every point on "nondegenerate" varieties in positive characteristic, is not Dirichlet improvable. This uses dynamics of unipotent flows in positive characteristics.

Presented a wide ranging and new approach to counting solutions to Diophantine inequalities on homogeneous varieties of semisimple groups. In particular we prove analogues of the classical theorem of W. M. Schmidt and also address discrepancy estimates for rational points on varieties.

Number Theory and Automorphic Forms

Gave a new proof of, the classification of algebraic Lauricella functions.

A natural appearance of unramified mixed Tate motives in the cohomology of the moduli space of abelian varieties was found and studied using automorphic forms. An optimal Lefschetz property for the cohomology of noncompact congruence ball quotients was proved.

A complete description of the reductions of certain crystalline Galois representations of slopes 1 was given.

For (G, G') a dual pair of subgroups of a metaplectic group, the dual pair correspondence is a bijection between (subsets of the) irreducible representations of G and G' , defined by the non-vanishing of $\text{Hom}(\omega, \pi \times \pi')$, where ω is the oscillator representation. Alternatively one considers $\text{Hom}_G(\omega, \pi)$ as a G' -module. It is fruitful to replace Hom with Ext^i , and general considerations suggest that the Euler-Poincare characteristic $EP(\omega, \pi)$, the alternating sum of $\text{Ext}^i(\omega, \pi)$, will be a more elementary and more flexible object. We prove that $EP(\omega, \pi)$ is a well defined element of the Grothendieck group of finite length representations of G' , and show that it is indeed more elementary than $\text{Hom}(\omega, \pi)$. We expect that computation of EP, together with vanishing results

for higher Ext

groups, will be a useful tool in computing the dual pair correspondence, and will help to elucidate the structure of $\text{Hom}(\omega, \pi)$.

Worked on a project on a universal Torelli type theorem for elliptic surfaces. We show that an effective, base change compatible family of isometries between the Neron-Severi groups of two elliptic surfaces arises from an isomorphism of the elliptic surfaces.

The mean-square upper bound estimate of the error term related to the sum of the squares of the n^{th} Fourier coefficient of holomorphic Hecke eigenform for the full modular group was improved. Higher moments of Fourier coefficients of cusp forms for the full modular group were studied in detail. The error term estimate of the general k -th Riesz mean of the arithmetical function $\frac{n}{\phi(n)}$ was improved for any large integer k .

We establish upper bounds for the number of primitive integer solutions to inequalities of the shape $0 < |F(x, y)| \leq h$, where Z

$$F(x, y) = (\alpha x + \beta y)^r - (\gamma x + \delta y)^r \in [x, y], \alpha, \beta, \gamma$$

and δ are algebraic constants with $\alpha\delta - \beta\gamma \neq 0$, and $r \geq 3$ and h are integers. As an important application, we pay special attention to binomial Thue's inequalities $|(ax^r - by^r)| \leq c$. The proofs are based on the hypergeometric method of Thue and Siegel and its refinement by Evertse.

The first moment of Fourier coefficients of $GL(r)$ cusp forms was investigated where $r \geq 2$ is arbitrary. Sign changes of Fourier coefficients of a Siegel cusp form of degree two, on a Hecke congruence subgroup was studied. Results were obtained on the first sign change as well as the number of sign changes in a given interval.

Combinatorics

In continuation of the studies of dominating functions, total dominating functions, closed packing functions, and open packing functions of the countable graphs, it has been proved that for any real number $r \geq 2$, there exists a countable graphs whose clique index is r .

Members

I. Biswas, A. Bhattacharya, S. Bhattacharya, Tanmay Deshpande, N. Fakhruddin, Radhika Ganapathy, E. Ghate, Anish Ghosh, R. V. Gurjar, Y. I. Holla, Amalendu Krishna, Mahan Mj, Ritabrata Munshi, A. Nair, N. Nitsure, A. J. Parameswaran (Dean), D. Prasad, C. S. Rajan, Ravi A. Rao, S. Eswara Rao, S. K. Roushon, A. Sankaranarayanan, N. Saradha, J. Sengupta, Raja Sridharan, V. Srinivas, S. Subramanian, V. Trivedi, T. N. Venkataramana, Sandeep Varma, G. R. Vijayakumar.

Adjunct Faculty

Madhav Nori (The University of Chicago), Tomas Gomez (ICMAT, Spain), T.R. Ramadas (CMI, Chennai), Jean Fasel (University of Duisberg-Essen), Sanju Velani (University of York, UK), Abishek Saha (University of Bristol, UK), Aravind Asok (University of Southern California), Angelo Vistoli (Scuola Normale Superiore, Italy).

Visiting Fellows

Ambily A. A. (till 31.07.2015), Seshadri Chintapalli (till 31.07.2015), Ananyo Dan, Omprokash Das, Shane D'Mello (till 31.07.2015), Souvik Goswami, Sagar Kolte (till 31.07.2015), Ritwik Mukherjee, Santosh Nadimpalli, Anuradha Nebhani, Tali Pinsky, B. Ravinder, Sachin Sharma (till 31.07.2015), Chaitanya Senapathi (till 30.11.2015), Vivek Sadhu, Husney Parvez Sarwar, R. Sivaguru, Rohith Varma

Research Scholars

Shalini Bhattacharya (till 31.12.2015), Sagnik Chakraborty (till 31.07.2015), Ch. Vineeth Reddy (till 31.07.2015), Devika Sharma (till 31.07.2015), Saurabh K. Singh (till 31.07.2015), Arijit Ganguly, Rahul Gupta, Anupam Mondal, Mandira Mondal, Pratyush Nath, Arjun Paul, Rakesh R. Pawar, Charanya Ravi, Arideep Saha, Divyum Sharma, K.V. Shuddhodan, Lovy Singhal, Bhamidi S. Sreedhar, Utkarsh Tripathi (till 31.01.2016), Kuntal Chakraborty, Sampat Kumar Sharma, Vangala Ravitheja, Ankit Rai, Chandranandan Gangopadhyay, Amith Shastri K., Ashutosh Choudhary, Pritam Majumder, Vivek Kumar Rai, Gobinda Sau, Sujoy Chakraborty, Rijul Saini, Abhishek Gupta, Mainak Ghosh, Shreyasi Datta.

Scientific Staff

V. Nandagopal, Vishal Sailor.

Administrative Staff

PB. Bundele, M.R. Mehwala, M. Pilankar, A.L. Prajapati, S. Shaikh, S. Sawant, V.V. Vengurlekar.

National and International Involvement

E. Ghate 1) Mathematical Sciences Research Committee, CSIR, 2015-2018; 2) Project Advisory Committee, SERB, 2015-2018. **Anish Ghosh** External Expert consulted on European Research Council 2015 Grant Evaluations. **Mahan Mj** 1) Adjunct Faculty, IIT Mumbai; 2) Editor, Proceedings of the Indian Academy of Sciences, Mathematical Sciences; 3) Editor, Ramanujan Mathematical Society - Lecture Note Series; 4) Associate Editor, The Indian Math. Consortium Newsletter; 5) Member, National Board of Higher Mathematics; 6) Member, AFS syllabus committee; 7) Member, SERB PAC committee in Mathematical Sciences; 8) Member, IMU National Committee, INSA. **Arvind N. Nair** Member, Apex Committee of National Centre for Mathematics (NCM) **N. Nitsure** 1) Editor, Proc. Math. Sciences of the Indian Academy of Sciences; 2) Member, Apex Committee, National Center for Mathematics, 3) Member, Governing Council, CMI Chennai; 4) Member, Governing Body, Bhaskaracharya Pratishthana, Pune. **D. Prasad** 1) Editor: Journal of Ramanujan Mathematical Society; 2) Editor: Journal of Number Theory; 3) Editor: Mathematische Zeitschrift; 4) Visitor's nominee in JNU, Delhi; 5) Board of Governor's nominee at IISER Bhopal, IISER, Mohali, and IISER, Pune; 6) DST, INSPIRE program. **C.S. Rajan** 1) Editor: Proceedings of the Indian Academy of Sciences (Mathematics) 2) Adjunct Faculty, Centre For Excellence in Basic Sciences. **Ravi A. Rao** 1) Fellow, Indian Academy of Science 2014; 2) Adjunct Faculty, Bhaskaracharya Pratishthana, Pune. **A. Sankaranarayanan** 1) Life member of the Hardy-Ramanujan Society, Bangalore, India; 2) Life member of the Ramanujan Mathematical Society, Chennai, India; 3) Fellow of "The National Academy of Sciences (Allahabad), India"; 4) Life member of the Indian Mathematical Society, Delhi, India; 5) Member of the Editorial Board of the Journal NASI Letters (Allahabad); 6) Member of the Editorial Board of the International Journal of Mathematics and Scientific Computing (IJMSC, Vel Tech Dr. RR & Dr.SR Technical University, Chennai, India). **V. Srinivas** 1) Editorial memberships: (i) *Mathematische Annalen* (ii) Journal of Algebra (iii) Algebra and Number Theory (iv) Journal of the Indian Mathematical Society (v) Texts and Reading in Mathematics Series (TRIM); 2) Office bearership: International Mathematical Union, Member at Large of Executive Committee; 3) Chairman, National Board for Higher Mathematics; 4) INSA National Committee for Mathematics, Ex-officio Member; 5) INSA Sectional Committee-I: Secretary and Convener. **T.N. Venkataramana** Member of sectional committee for INSA INSPIRE fellowships, and the Indian Academy of Sciences

Visits

Indranil Biswas visited Nice University, France during Jan. 9 – Feb. 8, 2016; PUC Chile, Santiago during Nov. 22 – Dec. 6, 2015; Germany, Poland during Oct. 10–25, 2015; ICMAT, Madrid during Sep. 12–20, 2015; Jussieu, Paris: Jun. 23–Aug. 15, 2015. **Tanmay Deshpande** visited Tongji University, Shanghai, China from Dec. 7-11, 2015. **Radhika Ganapathy** visited Conference and workshop on New Developments in Representation theory, National University of Singapore, Mar. 6-26, 2016. **E. Ghate** visited Princeton University, April-June, 2015; University of British Columbia, Vancouver, Oct. 2015. **Anish Ghosh** Visited University of Strasbourg; Jawaharlal Nehru University; University of York; King's College London;

University of Bristol **R.V. Gurjar** visited the Banff Center for Innovation, Banff, Canada, August 21-30, 2016. **Arvind N. Nair** Visited Erwin Schroedinger Insitut, Vienna, Austria, May 10, 2015 – May 26, 2015; Indian Statistical Institute, Bangalore, Dec. 10-22, 2015. **A.J. Parameswaran** visited University Nice, France from Dec. 12-16, 2015 and Jan. 16-23, 2016. **D. Prasad** visited Univ. of Paris under an Indo-French program in June 2015; Jean- Morlet Chaire Professor at CIRM, Marseille from Jan 01 to June 30, 2016. **S.Eswara Rao** visited HRI, Allahabad for two weeks in Jan. 2016. **S.K. Roushon** visited Goa University, Goa, 17-18 Oct., 2015. **A. Sankaranarayanan** visited as a Guest Professor at the Department of Number Theory and Probability Theory, University of Ulm, Germany from Jun. 1 to Aug. 31, 2015; Dept. of Math, University of Wuerzburg, Germany from 05.08.2015 to 06.08.2015; Institute of Mathematical Sciences (IMSc), Chennai, India, Dec. 14-18, 2015 in connection with the “International Conference on Number Theory”; Harish-Chandra Research Institute (HRI), Allahabad, India, from March 01-05, 2016 in connection with the “International Conference on Number Theory: Triveni@HRI-Number Theory”. **N. Saradha** visited University of Oregon, Eugene, Oregon, USA - June 15-26, 2015; Harish-Chandra Research Institute, Allahabad, Feb 23- March 9, 2016. **J. Sengupta** visited the University of Lille in France under the Indo-French project no.4601-2 during May 2015; ISI, Kolkata during June, 2015. **V. Srinivas** visited ICMAT, Madrid, Spain, May 1-31, 2015, visit under project IRSES-MODULI; TWAS Annual meeting, Austrian Academy of Sciences, Vienna, Austria (November 17-21, 2015); Capital Normal University, Beijing, Eightieth Anniversary Meeting of the Chinese Mathematcal Society (22-24 Nov. 2015); Mathematical Sciences Research Institute, Berkeley, CA, USA (Jan.15-Feb.15, 2016); Research Institute of Mathematical Sciences, Kyoto University; IMU Executive Committee Meeting and related activities (Mar. 26 – April 5, 2016). **Vijaylaxmi Trivedi** visited ICMAT from May 1-31, 2016. **T.N. Venkataramana** visited Oberwolfach meeting in July 2015 on interplay of topology and discrete groups. **G.R. Vijayakumar** Visiting Professor at “Ramanujan Research Center in Mathematics”, Madurai, Tamil Nadu from Sep. 1- Dec. 31, 2015.

Workshops/Conferences Organized by the School

Geometric and Ergodic Aspects of Group Actions, 20-24 April, 2015, T.I.F.R.

Siddhartha Bhattacharya and Anish Ghosh were the organizing committee members for this conference. Several mathematicians from India and abroad participated in the conference. Following is the list of speakers with the title of their talk:

<i>C. S. Aravinda</i>	: <i>Dynamics of geodesic conjugacies</i>
<i>N. Agarwal</i>	: <i>Equivariant dynamical systems</i>
<i>G. Bharali</i>	: <i>The dynamics of holomorphic correspondences on Riemann surfaces: the Fatou set</i>
<i>O. Sargent</i>	: <i>Values of linear maps at integral points on quadratic surfaces</i>
<i>Mahan Mj</i>	: <i>Introduction to Hyperbolic geometry, i.e. geometrically finite and infinite surfaces</i>
<i>Omri Sarig</i>	: <i>Horocycle flow on hyperbolic surfaces</i>
<i>F. Maucourant</i>	: <i>Orbit distribution for discrete subgroups acting on R^2</i>
<i>S.G. Dani</i>	: <i>Use of continued fraction expansion in dynamics and Diophantine approximation</i>
<i>K. Biswas</i>	: <i>Loewner evolution of invariant compacts and 2-conformal measures of analytic circle diffeomorphisms</i>
<i>Riddhi Shah</i>	: <i>Distality</i>

40 Years of the Eta Invariant – A meeting to remember V. K. Patodi 3–7 August, 2015, T.I.F.R.

Prof. Paul F. Baum and Prof. Erik van Erp gave a lectures on *INDEX THEORY AND K-HOMOLOGY*

Workshop-cum-Conference on Algebraic Surfaces and Related Topics, 21–30 Nov. 2015, ICTS Bangalore

Mario Chan, Jinwon Choi, R.V. Gurjar, DongSeon Hwang, JongHae Keum, Sagar Kolte and Ravi Rao were the organizing committee members for this conference. Several mathematicians from India and abroad participated in the conference. Following is the list of speakers with the title of their talk:

Workshops

<i>Margarida Lopes</i>	: <i>On the algebraic fundamental group of surfaces of general type</i>
<i>Sheng-Li Tan</i>	: <i>Chern numbers of families of algebraic curves and ordinary differential equations</i>
<i>Miles Reid</i>	: <i>Unprojection and applications to constructing varieties</i>
<i>Masayoshi Miyanshi</i>	: <i>Unipotent structures of algebraic varieties</i>
<i>Marius Koras</i>	: <i>The BMY inequality and its applications</i>
<i>Rajendra Gurjar</i>	: <i>A positively graded domain is determined at its vertex.</i>
<i>Rajendra Gurjar</i>	: <i>An application to Invariant Theory; a new property about the quotient $An // G$.</i>
<i>Rajendra Gurjar</i>	: <i>On a Conjecture of V. Popov.</i>

Conferences

<i>Zbigniew Jelonek</i>	: <i>On the group of automorphisms of a quasi-affine variety</i>
<i>Insong Choe</i>	: <i>Maximal isotropic subbundles of symplectic and orthogonal bundles over a curve</i>
<i>Adrien Dubouloz</i>	: <i>Fake real euclidean planes</i>
<i>Karol Palka</i>	: <i>Almost minimal log surfaces and the logMMP with half-integral coefficients</i>
<i>Jinhyun Park</i>	: <i>On algebraic cobordism version of Grothendieck standard conjecture D</i>
<i>Young-Hoon Kiem</i>	: <i>Moduli spaces of sheaves on curves and Calabi-Yau 3-folds</i>
<i>Donghoon D. Hyeon</i>	: <i>Generic semistability of representations of reductive groups</i>
<i>Neena Gupta</i>	: <i>Projective modules over the kernel of a locally nilpotent derivation on a polynomial ring</i>
<i>Junmyeong Jang</i>	: <i>A lifting of an automorphism of a K3 surface over odd characteristic</i>
<i>Giancarlo Urzua</i>	: <i>Geography in positive characteristic and connections with Kawamata-Viehweg vanishing theorem</i>
<i>Hideo Kojima</i>	: <i>Some results on open algebraic surfaces of non-negative logarithmic Kodaira dimension</i>

Dongseon Hwang : *Log del Pezzo surfaces of rank one*
 D.S.Nagraj : *Tangent bundle of P^2 and morphism to $Gr(2, 4)$.*

International Colloquium on K -theory, 6-14 January, 2016, T.I.F.R.

V. Srinivas, A. J. Parameswaran, Ravi A. Rao, Amalendu Krishna & S. K. Roushon were the organizing committee members for this conference. Several mathematicians from India and abroad participated in the conference. Following is the list of speakers with the title of their talk:

AravindAsok : *Motivic vector bundles on projective spaces*
 Samik Basu : *Twisted Homology theories*
 Spencer Bloch : *Mixed motives and mixed Hodge structures associated to algebraic cycles*
 Utsav Choudhury : *Motivic Galois groups and Stanard conjectures*
 Frédéric Deglise : *Dimensional homotopy t -structure*
 Dan Edidin : *Strong regular embeddings of stacks and applications*
 Helene Esnault : *Chern classes of crystals*
 Thomas Geisser : *Some remarks on étale motivic cohomology*
 Christian Haesemeyer : *The K -theory of monoid algebras in mixed characteristic*
 Masaki Hanamura : *Integrals of logarithmic forms on semi-algebraic sets and generalized Cauchy formula*
 Marc Hoyois : *Cdh descent for the homotopy K -theory of tame stacks*
 Roy Joshua : *Equivariant Algebraic K -theory and Derived completion*
 Bruno Kahn : *Cycles of codimension 2 and Chow-Knneth decompositions*
 Wataru Kai : *A moving lemma for algebraic cycles with modulus and contravariance*
 Amalendu Krishna : *Some K -cohomology of singular surfaces and applications*
 Marc Levine : *Torsion indices of smooth projective varieties*
 James Lewis : *The regulator map from Bloch's simplicial higher Chow groups to Deligne cohomology*
 Arvind Nair : *Mixed motives in A_g*
 Amnon Neeman : *Grothendieck duality via Hochschild homology*
 Kapil Paranjape : *Modular Forms and Calabi-Yau varieties*
 Jinhyun Park : *Algebraic cycles and crystalline cohomology*
 Holger Reich : *Algebraic K -theory of group algebras and topological cyclic homology*
 Oliver Röndigs : *The first motivic stable homotopy groups of spheres*
 Andreas Rosenschon : *Torsion in the Lichtenbaum Chow group of arithmetic schemes*
 Kay Rilling : *Higher Chow groups with modulus and relative Milnor K -theory*
 Shuji Saito : *Motives with modulus*
 Anand Sawant : *AI -connectedness in reductive algebraic groups*
 Ramesh Sreekantan : *Cycles on Abelian surfaces*
 J. L. Colliot-Thélène : *Stable irrationality for some rationally connected varieties : a survey*
 Charles Weibel : *Relative Cartier Divisors and Laurent Polynomials*

Groups, Orbits and Diophantine Approximation, 1–5 Feb, 2016, The International Centre, Goa

Anish Ghosh, Alexander Gorodnik and Amos Nevo were the organizing committee members for this conference. Several mathematicians from India and abroad participated in the conference. Following is the list of speakers with the title of their talk:

Jinpeng An : *Bounded orbits in the space of unimodular lattices*
 Jayadev Athreya : *Diophantine approximation on translation surfaces*
 Victor Beresnevich : *Sums of reciprocals of fractional parts and applications to Diophantine approximation (Part 2)*
 E. Breuillard : *Metric diophantine approximation in matrices and on Lie groups*
 Yann Bugeaud : *Exponents of Diophantine approximation*
 Manfred Einsiedler : *Positive entropy and (multiple) quantitative unipotent recurrence*
 Alexander Gorodnik : *Logarithmic improvements in Diophantine approximation*
 Dmitry Kleinbock : *On Dirichlet's theorem for inhomogeneous approximation*
 Philippe Michel : *On the second moment of twisted L -functions*
 Frédéric Paulin : *Counting and equidistribution of arithmetic points in local fields of positive characteristic*
 Tali Pinsky : *On the volumes of modular geodesics*
 Mark Pollicott : *Representations of surface groups, Higher Teichmüller theory and ergodic theory*
 Nimish Shah : *On equidistribution of expanding translates of curves on homogeneous spaces*
 Uri Shapira : *The distribution of lattices orthogonal to best approximations*
 A. Strombergsson : *On the low-density limit of the Lorentz gas for general scatterer configurations*
 Nicolas de Saxce : *Diophantine approximation and product of linear forms*
 Naser T. Zadeh : *Optimal strong approximation for quadratic forms*
 Sanju Velani : *Sums of reciprocals of fractional parts and applications to Diophantine approximation (Part 1)*
 Barak Weiss : *Badly approximable vectors on fractals*
 Lei Yang : *Exponential mixing higher rank affine actions on S -adic nil manifolds and smooth classification of higher rank expanding actions*

Non DAE Research Projects

Indranil Biswas

J.C. Bose Fellowship of the DST (2013-18)

Anish Ghosh

ISF-UGC grant 2014-2017. PI's A. Ghosh and A. Nevo (Technion, Israel) funded by the Israel Science Foundation and the University Grants Commission.

Amalendu Krishna

Swarna Jayanti Fellowship (2012-17)

Ritabrata Munshi

Swarna Jayanti Fellowship (2011-16)

D. Prasad

J.C. Bose Fellowship for (2015-19)

J. Sengupta

Continuing Indo-French project no: 4610-2 on "Analytic aspects of modular forms".(July 2015)

V. Srinivas

J.C. Bose Fellowship of the DST (2013-18)

T.N. Venkataramana

J.C. Bose Fellowship of the DST (2013-18)

Mahan Mj

J.C. Bose Fellowship for (2015-19)



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TIFR Centre for Applicable Mathematics, Bangalore

Many important results have been obtained in the theory and numerics of partial differential equations and stochastic differential equations. Here are some highlights.

A comparative study between two-scale asymptotic expansion for periodic homogenization and Taylor expansion in the Bloch wave method was undertaken and it was shown that they differ in the fourth order terms for elliptic equations while for the wave equation no such difference was found, this has led to an unambiguous definition of the dispersion tensor. Large N behaviour of certain random graph which can be viewed as a realisation of quantum Curie-Weiss model was studied. It was shown that the flat cylinder is conjugacy rigid among two different classes of metrics on the cylinder, namely among the class of rotationally symmetric metrics and among the class of metrics without conjugate points.

$C^{1,\alpha}$ estimate for non-local elliptic HJB equations with critical order non-locality was established. Existence of at least two solutions globally with respect to a natural parameter for steady state solutions of combustion problem with exponential reaction terms was shown. A conformally invariant Adams inequality establishing a sharp embedding of the Sobolev space of the Hyperbolic space was obtained. Uniqueness of positive solutions in a ball for Trudinger-Moser Embedding was obtained for the large solutions. Approximate and exact

controllability results for viscoelastic flow models include Maxwell or Jaffreys types of fluid flow were obtained.

Optimal controllability for hyperbolic conservation laws with discontinuous flux was studied and the solution was obtained using the backward construction. Viscosity-Capillary limit under the assumption of self-similarity for scalar conservation laws was studied.

Role of common midpoint versus common offset acquisition geometry in seismic imaging was studied. Singularities in the inviscid linear theory of sea breezes was studied. Well-balanced schemes for Euler equations with gravitational effects are developed to cover the case of general equation of state and general grid systems. Lagrangian-Eulerian discontinuous Galerkin method for one dimensional compressible Euler equations was developed to improve the resolution of the solution.

Operator splitting for the Benjamin-Ono equation was analysed the convergence of both Godunov and Strang splittings. Fully-discrete schemes for the numerical approximation of diffusive-dispersive hyperbolic conservation laws with a discontinuous flux function was considered and its convergence was studied.

Members

Adimurthi, C. S. Aravinda, P S Datti (relieved on 31.12.2015), Imran Habib Biswas, K. T. Joseph, Mythily Ramaswamy Prashanth Kumar Srinivasan, C. Praveen, K Sandeep, Sreekar Vadlamani, P N Srikanth (relieved on 30.09.2015), M Vanninathan, A.S.Vasudeva Murthy, G D Veerappa Gowda Venkateswaran, P. Krishnan, Ujjwal Koley

Adjunct Faculty Members

Mokshay M. Madiman (University of Delaware, Newark, USA); Malabika Pramanik (University of British Columbia, Vancouver, Canada)

Inspire Faculty

Prosenjit Roy

Post doctoral Fellows

Tanmay Sarkar, Haradhan Maity, Pritam Giri; NBHM- Suprio Bhar, Vijay Kumar Sohani, Daisy Dahiya

Research Scholars

Souvik Roy, Ananta Kumar Majee, Anupam Pal Choudhury, Manoj Choudhuri, Debanjana Mitra, Debayan Maity, Abhishek Sarkar, Madhuresh

Integrated Ph.D. Students

Ananta Kumar Majee, Anupam Pal Choudhury, Souvik Roy, Tuhin Ghosh, Debanjana Mitra, Debayan Maity, Abhishek Sarkar, Debabrata Karmakar, Deep Ray, Indranil Chowdhury, Rohit Mishr, Sombuddha Bhattacharya

M.Sc. Students

Amrita Ghosh, Arka Mallick, Arnab Roy, Manish Kumar Singh, Manmohan, Sourav Mitra, Amit Kumar, Jayesh Vinay Badwaik, Neelabja Chatterjee, Prashant Kumar, Abhishek Das, Neeraj Singh Bhauryal, Nilasis Choudhuri, Saibal Khan, Saikatul Haque, Suman Kumar Sahoo, Vikash Kumar, Ganesh Kiran Vaidya

Scientific and Technical Staff

Shrikant Gaikwad, T. Viswanathan, Veena K.

Administrative Staff

Shri Kannan C J, Shri G Kannan, Pramila Kumari M., Mahalakshmi S K, Fariya Suhael

Auxillary Staff

A Shivakumar, A. Abraham, Joyce Devaraj, S Shanthi, P Desaiiah, H Ramanjanaiah (demise on 17th May 2015), B R Somashekar, M. V. Venkatachalaiah

National and International Involvement

C.S. Aravinda- in the Editorial Boards of: (1) Hardy Ramanujan Journal, (2) RMS Newsletter, (3) Mathematics Student, and (4) Bhavana, was in the Executive Committee of The Indian Mathematics Consortium (TIMC). K.T. Joseph- 1. INSA Sectional Committee I Mathematical Sciences, 2. Inspire Selection Committee, Mythily Ramaswamy- • Membership in Professional Associations, Associate Editor, Boundary Value Problems, A Springer open journal. Member, Editorial Board, JI Ramanujam Mathematical Society, India, Member, Editorial Board, Proceedings of Mathematical Sciences, Indian Academy of Sciences, Membership in academic and national committees, Member, Board of Governors, IIT Gandhinagar, since March 2016, Member, Standing Committee on the IISERs, since March, 2016, Member, Core Committee, Project Advisory Committee, SERB, since September 2015, Member, Technical Advisory Committee of Theoretical Statistics and Mathematics, ISI, for 2014- 2016.

Visits

Adimurthi- 1. GRAN SASO SCIENCE INSTITUTE, L. Aquila, Italy, September 2015, 2. University of Pau, France, October to December 2015, 3. University of Rome L'Sapienza, Rome, October 2015, C. S. Aravinda- (1) Ventotene, Italy for a conference in Geometric and Analytic Group Theory during 7-12, September, 2015, (2) Department of Mathematics, Central University of Kashmir, Srinagar for a series of 5 lectures during 26-29 October, 2015, (3) The Department of Mathematics, Indian Institute of Technology, Kanpur during 15-29 February, 2016, Imran H. Biswas- 1. Visited University of Pau, France under IFCAM project in June, 2015 for a period of two weeks, Mythily Ramaswamy- 1. March 8th to June 6, 2015, CNRS Visiting Professor at University of Paul Sabatier, Toulouse, France, 2. Visited Beijing, China, for ICIAM 2015, from August 9 to 14, 2015, as a member of Olga Taussky-Todd Lecture selection committee and the Subcommittee for Su Buchin Prize, 3. Visited Mathematics Dept, City University of New York, from September 21 to November 30, 2015, 4. Visited ICMS, Edinburgh, UK from October 25 to 28, 2015, to participate in the conference on "Mathematics, Mechanics and Physics for Tomorrow's materials", EPSRC-DST Indo-UK Initiative in Applied Mathematics at ICMS, Edinburgh from October 26 to 30, 2015, 5. Visited Mathematics Dept, Technion, Haifa in Israel from March 1 to 10, 2015, Prashanth Kumar Srinivasan- Visited Department of mathematics, CUNY, New York and University of Pau during July-August, 2015, Praveen C.- 1. Visit to Dept. of Mathematics, University of Würzburg, Germany, 3 April to 3 May, 2015, 2. Visit to Chair of Scientific Computing, TU Kaiserslautern, Germany, 3-10 May, 2015, 3. Workshop on "Higher Order Numerical Methods for Evolutionary PDEs: Applied Mathematics, Meets Astrophysical Applications (15w5134)", BIRS, Banff, Canada, 10-15 May 2015, K. Sandeep- 1. Visited the Department of Mathematics, University of Rome 3, Italy during September 8-18, 2015, 2. Visited the department of Mathematics, Polytecnico di Turin, Italy during September 19-25, 2015, 3. Visited the department of Mathematics, University of Basel, Switzerland during September 26-October 2, 2015, Sreekar V.- (a) Visited Prof. Marie Kratz at ESSEC Business School in Paris as part of our joint research project funded by the Indo-French Centre for Applied Mathematics, (b) Visited Prof. Kais Hamza at Monash University, Melbourne, G.D. Veerappa Gowda- 1. University of Pau, France from July 1-15, 2015, 2. University of Würzburg, Germany from 7th-15th Nov. 2015.

Invited Talks*Adimurthi*

Title: Structure of Entropy solutions and controllability, Place: ISIAM, 31st December 2015.

C.S. Aravinda

1. Discussion meeting in TIFR, Mumbai during 20-24 April;

2. International Workshop on Differential Geometry held at Sri Sathya Sai Institute of Higher Learning, Puttaparthi during 10-11 July;

3. Workshop on 'Some High Points of Undergraduate Mathematics Education', held at IISER, Mohali on 14 May;
4. Chief guest at the National Workshop on Algebra held at the Department of Mathematics, University of Mysore on 22 August;
5. National meet of Research Scholars in Mathematical Sciences held at Gauhati University during 24-28 November;
6. Plenary talk at the conference on Topology and Dynamics here at IISER Bhopal during, December 7-16;
7. Talk at Karnataka State Council for Science and Technology during 'National Mathematics Day' on 22 December;
8. Talk on 'Mathematics in Nature' at Sir M. Visvesvaraya Rain Water Harvesting Theme Park, Bangalore on 21 January.

Imran Habib Biswas

Conservation laws driven by Levy white noise, Evolutionary equations, theory and numerics,
University of Würzburg, Würzburg, Germany; 28th June-4th July, 2015.

K. T. Joseph

Gave an invited talk "Zero pressure gas dynamics system" in 19th Ramanujan Symposium on Recent trends in nonlinear partial and fractional differential equations, at Ramanujan Institute of advanced study, Chennai, March 02-04, 2016.

Mythily Ramaswamy

1. "Control of Compressible Navier-Stokes System in one dimension", 7th April, 2015 at University of Pau, France.
2. "Ingham Inequality and Applications to PDE" 4th June, 2015, University of Toulouse 1, France.
3. "Stabilization of Compressible Navier-Stokes System", 30th June, 2015, Workshop on Interaction of Fluid-Structure Interaction at TIFR CAM, June 29 to July 1, 2015.

4. "Fluid Flow Problems and their Control", 27th October, 2015 in the Indo-UK conference on
5. "Mathematics, Mechanics and Physics for Tomorrow's materials", EPSRC-DST Indo-UK Initiative in Applied Mathematics at ICMS, Edinburgh from October 26 to 30, 2015.
6. "Control of Compressible Navier-Stokes System" 24th November, 2015, CUNY Graduate
7. Center, City University of New York, USA.
8. "Control of some Compressible Fluid Models" 29th December, 2015 at the International Conference on Current Trends in PDEs : Theory and Computations, South Asian University, Delhi, 28-30 December, 2015.
9. "Control of Compressible Fluids" at the Mathematics Department, Technion, Haifa, Israel on 8th March, 2016.

Praveen C

"Well-balanced discontinuous Galerkin method for the Euler equations with gravity", Workshop on Higher Order Numerical Methods for Evolutionary PDEs: Applied Mathematics Meets Astrophysical Applications (15w5134), BIRS, Banff, Canada, 10-15 May 2015

Sandeep C.

Sandeep k, Moser-Trudinger and Adams Inequalities, current trends in PDEs: Theory and computations, South Asian University, Delhi, during 28-30th December 2015.

Sreekar V.

1. Sreekar Vadlamani, *CLT for Lipschitz-Killing curvatures of excursion sets of Gaussian random fields*, 9th International Conference on Extreme Value Analysis at University of Michigan, Ann Arbor, June 15-19, 2015
2. Sreekar Vadlamani, *Kinematic fundamental formulae: past, present and future*, Conference on Stochastic Processes and Random fields in honour of Robert

Adler and hana Kaspi, Technion, Israel, June 29 - July 3, 2015

M.Vanninathan

"Convergence Relative to a Microstructure and Applications", International Conference on Current Trends in PDE, South Asian University, New Delhi, December 29, 2015.

A.S. Vasudeva Murthy

1. International Conference on nonlinear dynamics, analysis and optimization, Jadavpur University, December 9, 2015, "Dispersion and dissipation with the Hilbert transform".
2. Recent developments in mathematical analysis and applications, Pondicherry University, February 25, 2016, "Revisiting the slow manifold of the Lorenz-Krishnamurthy quintet".
3. Recent developments in differential equations and their applications. PSGR Krishnammal College for Women, Coimbatore, March 4, 2016, "Revisiting the slow manifold of the Lorenz-Krishnamurthy quintet".
4. Mathematical modeling, differential equations and scientific computing, IIT Kanpur, March 29, 2016, "Revisiting the slow manifold of the Lorenz-Krishnamurthy quintet".

G.D. Veerappa Gowda

1. Exact controllability of scalar conservation laws with strict convex flux, Conference on current trends in PDEs: Theory and computations, South Asian University, 28-30th December 2015
2. Godunov type numerical methods for a model of granular flow, International conference on the occasion of the silver jubilee of ISIAM, Sharada University, Delhi, 29-31, January, 2016.
3. Structure of entropy solutions to scalar conservation laws with

strictly convex flux, International Conference on "Mathematical modeling, Differential equations, Scientific computations and Applications, IIT Kanpur, 27-29, March 2016

Workshops/Conferences Organized by the Centre

Sreekar V.

Workshop and conference on Stochastic Partial Differential Equations, at IISc Bangalore, December 14 - 23, 2015.

This workshop-cum-conference was organised jointly by TIFR-CAM, IISc Bangalore and IISER Thiruvananthapuram

to bring together researchers working in the area of stochastic analysis the world over, and to discuss the recent developments in this area like the theory of rough

path. There were short courses given by Prof. D. Elworthy, Prof. Z. Brzezniak, Prof. X-M Li and Prof. M. Hairer.

Conferences and Workshops held at TIFR-CAM

(1) *Advanced Summer School on Control and Numeric for Fluid-Structure Interaction Problems*

Dates: 22 - 26 June, 2015

Organisers: 1. Praveen C, TIFR-CAM, Bangalore
2. Mythily Ramaswamy, TIFR-CAM, Bangalore
3. Jean-Pierre Raymond, Universite de Toulouse III
4. M Vanninathan, TIFR-CAM, Bangalore

(2) *International IFCAM Workshop on Control and Numeric for Fluid-Structure Interaction Problems*

Dates: 29 June-1 July, 2015

Organisers: 1. Praveen C, TIFR-CAM, Bangalore
2. Sashikumar Ganesan, SERC, IISc. Bangalore
3. Mythily Ramaswamy, TIFR-CAM, Bangalore
4. Govindan Rangarajan, IISc. Bangalore
5. Jean-Pierre Raymond, Universite de Toulouse III
6. M Vanninathan, TIFR-CAM, Bangalore

(3) *ATMW Partial differential equations of fractional order*

Dates: 6-18 July, 2015

Organisers: 1. Sandeep K, TIFR-CAM, Bangalore
2. Imran H Biswas, TIFR-CAM, Bangalore

(4) *Instructional School for Teachers on Analysis and Differential Equations*

Dates: 7-19 December, 2015

Organisers: 1. Mythily Ramaswamy, TIFR-CAM, Bangalore
2. Venkateswaran P. Krishnan, TIFR-CAM, Bangalore
Conference on Computational PDE 2015 Dates: 21-23 December, 2015

Organisers 1. G D Veerappa Gowda, TIFR-CAM, Bangalore
2. A S Vasudeva Murthy, TIFR-CAM, Bangalore
3. Praveen C, TIFR-CAM, Bangalore
4. Ujjwal Koley, TIFR-CAM, Bangalore

Compact courses held at TIFR-CAM

(1) *Compact course on Aeroacoustics: Physical principles and modeling approaches*

Date: 20-21 May 2015

Prof. Karthik Duraisamy
Department of Aerospace Engineering, University of Michigan, Ann Arbor, MI

Non DAE Research Projects

Imran H Biswas

Evolutionary partial differential equations with Lévy noise. Funding Agency: INSA.

Mythily Ramaswamy

1. Managing AIRBUS Corporate Foundation Chair Funds together with Prof. Spenta Wadia, ICTS-TIFR, for 4 years from 2013.
2. Project on "PDE- Control" jointly with Sylvain Ervedoza funded by Indo-French Center for

Applied mathematics for 3 years from 2012.

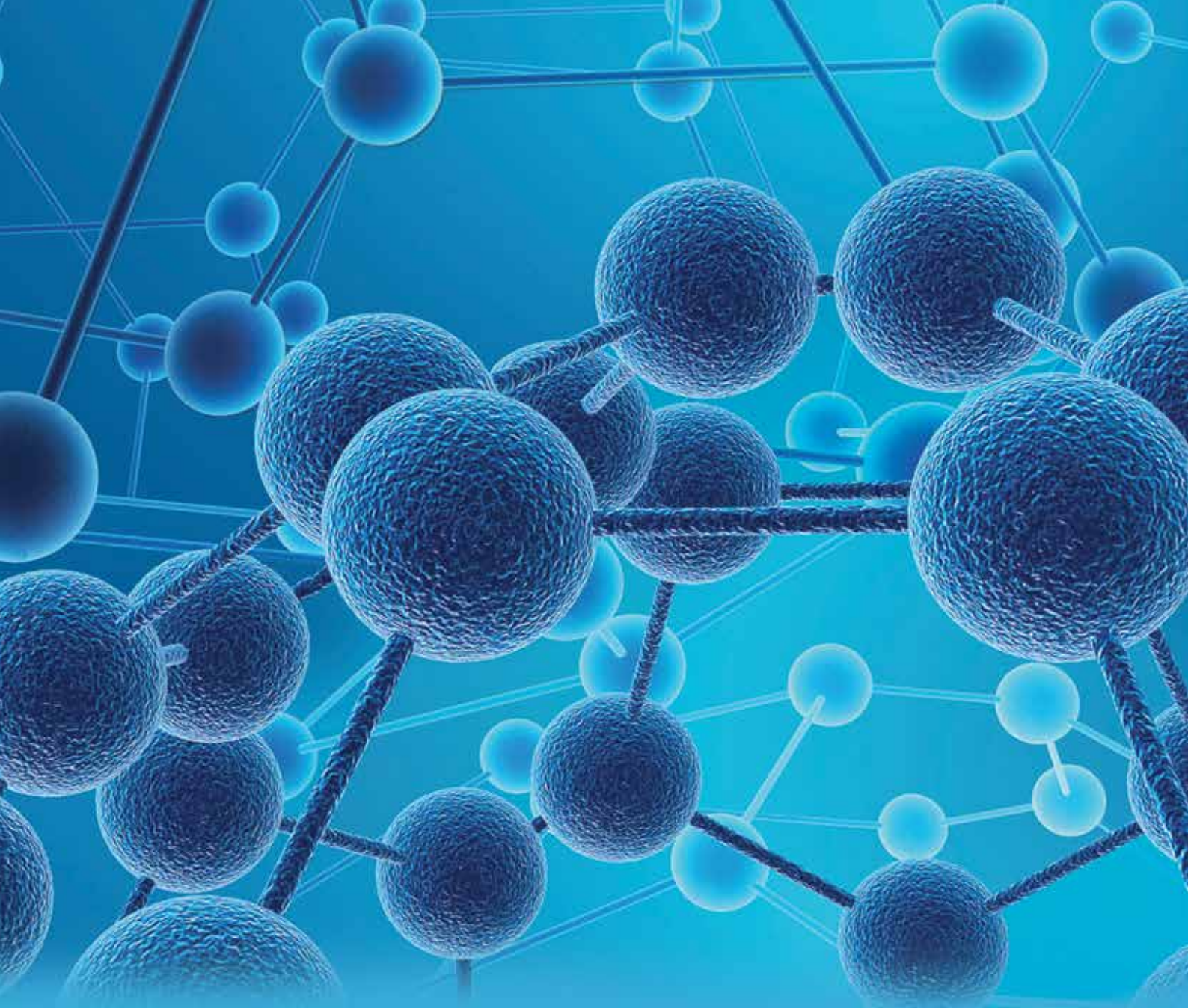
V. P. Krishnan & A. S. Vasudeva Murthy

Synthetic Aperture Sonar Image Formation. Funding Agency: NPOL Cochin

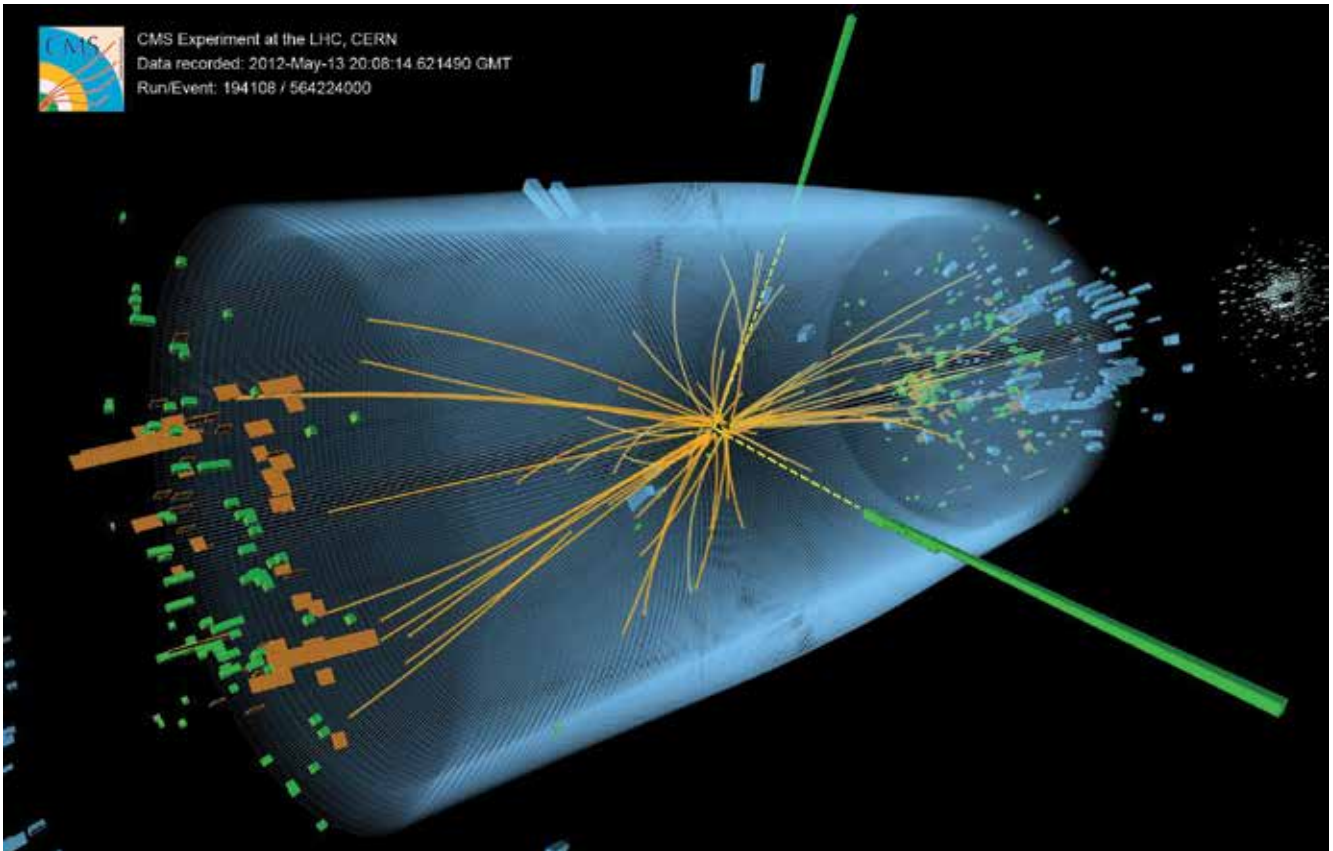
Sreekar V.

Geometry of excursion sets of random fields. Funding Agency: Indo-French Centre for Applied Mathematics





School of Natural Sciences



Results from LHC

Observation of new particle with a Mass of 125 GeV

Department of Astronomy and Astrophysics

Theoretical Astrophysics

Solar Physics

Spatio-spectral concentration of convolutions

Differential equations may possess coefficients that vary on a spectrum of scales. Because coefficients are typically multiplicative in real space, they turn into convolution operators in spectral space, mixing all wavenumbers. However, in many applications, only the largest scales of the solution are of interest and so the question turns to whether it is possible to build effective coarse-scale models of the coefficients in such a manner that the large scales of the solution are left intact. Here we apply the method of numerical homogenisation to deterministic linear equations to generate sub-grid-scale models of coefficients at desired frequency cut-offs. We use the Fourier basis to project, filter and compute correctors for the coefficients. The method is tested in 1D and 2D scenarios and found to reproduce the coarse scales of the solution to varying degrees of accuracy depending on the cut-off. We relate this method to mode-elimination Renormalisation Group (RG) and discuss the connection between accuracy and the cut-off wavenumber. The trade-off is governed by a form of the uncertainty principle for convolutions, which states that as the convolution operator is squeezed in the spectral domain, it broadens in real space. As a consequence, basis sparsity is a high virtue and the choice of the basis can be critical. [Hanasoge, S. M.]

Multi-layered Neural Networks Infer Fundamental Stellar Parameters

The advent of space-based observatories such as CoRoT and Kepler have enabled the testing of our understanding of stellar evolution on thousands of stars. Evolutionary models typically require five input parameters, the mass, initial Helium abundance, initial metallicity, mixing-length (assumed to be constant over time) and the age to which the star must be evolved. These parameters are also very useful in characterizing the associated planets and in studying galactic archaeology. How to obtain the parameters from observations rapidly and accurately, specifically in the context of surveys of thousands of stars, is an outstanding question,

one that has eluded straightforward resolution. For a given star, we typically measure the effective temperature and surface metallicity spectroscopically and low-degree oscillation frequencies through space observatories. Here we demonstrate that statistical learning, using multi-layered neural networks, is successful in determining the evolutionary parameters based on

spectroscopic and seismic measurements. Our trained networks show robustness over a broad range of parameter space, and critically, are entirely computationally inexpensive. This method is both computationally cheap and inferentially accurate, paving the way for analyzing the vast quantities of stellar observations from past, current and future missions. [Verma K., Hanasoge S. M., Bhattacharya J., Antia H. M. and Krishnamurthi G.]

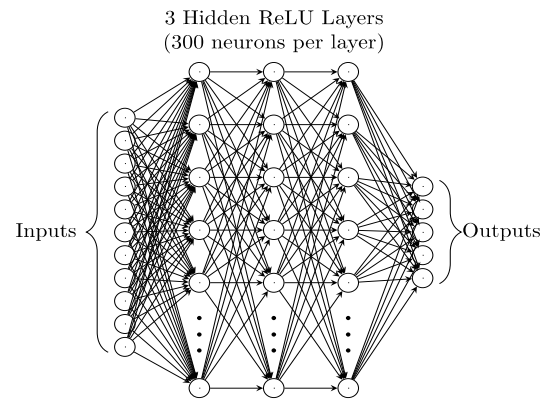


Figure: Sketch of neural network with inputs and outputs. The output of a rectified linear unit (ReLU) is equal to the input if positive and otherwise zero. We use neural networks to infer fundamental stellar parameters from measurements of oscillation frequencies of stars.

Seismic Sounding of Convection in the Sun

Thermal convection is the dominant mechanism of energy transport in the outer envelope of the Sun (one-third by radius). It drives global fluid circulations and magnetic fields observed on the solar surface. Vigorous surface convection excites a broadband spectrum of acoustic waves that propagate within the interior and set up modal resonances. These acoustic waves, also called seismic waves in this context, are observed at the surface of the Sun by space- and ground-based telescopes. Seismic sounding, the study of these seismic waves to infer the internal properties of the

Sun, constitutes helioseismology. Here we review our knowledge of solar convection especially that obtained through seismic inference. Several characteristics of solar convection, such as differential rotation, anisotropic Reynolds stresses, the influence of rotation on convection, and supergranulation, are considered. On larger scales, several inferences suggest that convective velocities are substantially smaller than those predicted by theory and simulations. This discrepancy challenges the models of internal differential rotation that rely on convective stresses as a driving mechanism and provide an important benchmark for numerical simulations. [Hanasoge, S. M., Gizon, L. and Sreenivasan, K. R.]

Strategies in seismic inference of supergranular flows on the Sun

Observations of the solar surface reveal the presence of flows with length scales of around 35 Mm, commonly referred to as supergranules. Inferring the sub-surface flow profile of supergranules from measurements of the surface and photospheric wavefield is an important challenge faced by helioseismology. Traditionally, the inverse problem has been approached by studying the linear response of seismic waves in a translationally invariant background to the presence of the supergranule (Gizon & Birch 2002; Švanda et al. 2011; Dombroski et al. 2013); however it is believed that an iterative approach that doesn't assume translational invariance might perform better since it lets us analyze the misfit post iterations (Hanasoge 2014). In this work, we construct synthetic observations using a reference supergranule, and invert for the flow profile using surface measurements of travel-times of waves belonging to modal ridges f (surface-gravity) and p_1 through p_7 (acoustic). We study the extent to which each mode and their combinations contribute to infer the flow. We show that this method of non-linear iterative inversion tends to underestimate the flow velocities as well as infers a shallower flow profile, with significant deviations from the reference supergranule near the surface. We carry out a similar analysis for a sound-speed perturbation and find that analogous near-surface deviations persist, although the iterations converge faster and more accurately. We conclude that a better approach to inversion would be to expand the supergranule profile in an appropriate basis,

thereby reducing and regulating the parameters being inverted for. [Bhattacharya, J. and Hanasoge, S. M.]

Numerical analysis of the lattice Boltzmann method for simulation of linear acoustic waves

We analyze a linear lattice Boltzmann (LB) formulation for simulation of linear acoustic wave propagation in heterogeneous media. We employ the single-relaxation-time Bhatnagar-Gross-Krook (BGK) as well as the general multi-relaxation-time (MRT) collision operators. By calculating the dispersion relation for various 2D lattices, we show that the D2Q5 lattice is the most suitable model for the linear acoustic problem. We also implement a grid-refinement algorithm for the LB scheme to simulate waves propagating in a heterogeneous medium with velocity contrasts. Our results show that LB performs slightly better than the classical second-order finite-difference schemes. Given its efficiency for parallel computation, the LB method can be a cost effective tool for the simulation of linear acoustic waves in complex geometries and multiphase media. [Dhuri, D., Hanasoge, S. M., Perlekar P. and Robertsson, J.]

Helioseismology

Meridional circulation (North-South component of velocity field) plays an important role in solar dynamo theories and hence it is crucial to determine the meridional flow profile in the solar convection zone. Surface observations show the flow from equator towards poles in both hemisphere, but it is not known at what depth the return flow from poles to equator occurs. In particular, recent attempts to determine this flow field have found some evidence of multiple cells in radius or latitude which may pose some problems to conventional theories of solar dynamo. Using 4 year time-distance helioseismic data from the Helioseismic and Magnetic Imager, meridional flow in the solar convection zone was studied. An important improvement over the previous studies was use of mass conservation constraint. The results show that data are consistent with single-cell meridional circulation with return flow beneath about 0.77 solar radius.

General Relativity, Cosmology and Quantum Mechanics

Primary Black Hole Spin In OJ 287 As Determined By The General Relativity Centenary Flare

OJ 287 is a quasi-periodic quasar with roughly

twelve year optical cycles. It displays prominent outbursts that are predictable in a binary black hole model. The model predicted a major optical outburst in 2015 December. We found that the

outburst did occur within the expected time range, peaking on 2015 December 5 at magnitude 12.9 in the optical R-band. Based on Swift/XRT satellite measurements and optical polarization data, we find that it included a major thermal component. Its timing provides an accurate estimate for the spin of the primary black hole to be one third of the maximum spin rate allowed in Einstein's general relativity. The present outburst also confirms the established general relativistic properties of the system such as the loss of orbital energy to gravitational radiation at the two percent accuracy level. The latest observation of a predicted impact flare opens up the possibility of testing the black hole no-hair theorem with ten percent accuracy during the present decade. [M. J. Valtonen, S. Zola, S. Ciprini, A. Gopakumar, et al.]

Frequency and time-domain inspiral templates for comparable mass compact binaries in eccentric orbits

Inspiraling compact binaries with non-negligible orbital eccentricities are plausible gravitational wave (GW) sources for the upcoming network of GW observatories. We advanced two prescriptions to compute post-Newtonian (PN) accurate inspiral templates for such binaries. This included our efforts to adapt and extend the post-circular scheme of Yunes et al. [Phys. Rev. D 80, 084001 (2009)] to obtain a Fourier-domain inspiral approximant that incorporates the effects of PN-accurate orbital eccentricity evolution. This provided a fully analytic frequency-domain inspiral waveform with Newtonian amplitude and 2PN-order Fourier phase while incorporating eccentricity effects up to sixth order at each PN order. The importance of incorporating eccentricity evolution contributions to the Fourier phase in a PN-consistent manner is also demonstrated. The other effort provided an accurate and efficient prescription to incorporate orbital eccentricity into the quasicircular time-domain TaylorT4 approximant at 2PN order. New features include the use of rational functions in orbital eccentricity to implement the 1.5PN-order tail contributions to the far-zone fluxes. This leads to closed form PN-accurate differential equations for evolving eccentric orbits, and the resulting time-domain approximant is accurate and efficient to handle initial orbital eccentricities up to 0.9. Preliminary GW data analysis implications were probed using match estimates. [S. Tanay, M. Haney and A. Gopakumar]

An effective eccentric version of inspiral-merger-ringdown waveform for constraining the orbital eccentricity of GW150914

We computed and implemented an appropriate

code that provide an eccentric version of TaylorF2 approximant while incorporating in its Fourier phase the leading-order eccentricity corrections up to 3PN order. This approximant was one of the crucial inputs for our ready-to-use 'effective eccentric variant' of the IMRPhenomD waveform, developed in the LIGO Scientific Collaboration (LSC). We invoked our waveform family to constrain the initial orbital ellipticity of the GW150914 black hole binary and to justify the assumption of binary evolution along circular orbits for the event. [M. Haney and A. Gopakumar]

Relativistic gravitational lensing

Quantum gravity effects can manifest at macroscopic scales at the photon sphere of a black hole due to the degrees of freedom of the space time and this will modify the relativistic gravitational lens phenomenon. Though for spherically symmetric case, the magnification of the images is very small, a more generic system might be observable. [S. Sahu, K. Lochan and D. Narasimha]

General Relativity

Timescale for trans-Planckian collisions in Kerr spacetime

We make a critical comparison between ultra-high energy particle collisions around an extremal Kerr black hole and that around an over-spinning Kerr singularity, mainly focusing on the issue of the timescale of collisions. We show that the time required for two massive particles with the proton mass or two massless particles of GeV energies to collide around the Kerr black hole with Planck energy is several orders of magnitude longer than the age of the Universe for astro-physically relevant masses of black holes, whereas time required in the over-spinning case is of order ten million years which is much shorter than the age of the Universe. Thus from the point of view of observation of Planck scale collisions, the over-spinning Kerr geometry, subject to their occurrence, have distinct advantage over their black hole counterparts. [Mandar Patil, Pankaj S. Joshi, Ken-ichi Nakao, Masashi Kimura, Tomohiro Harada]

Finite escape fraction for ultrahigh energy collisions around Kerr naked singularity

We investigate the issue of observability of high-energy collisions around Kerr naked singularity and show that results are in contrast with the Kerr black hole case. We had shown that it would be possible to have ultrahigh energy collisions between the particles close to the location $r = M$ around the Kerr naked singularity if the Kerr spin parameter transcends unity by an infinitesimally small amount

$a \rightarrow 1+$. The collision is between initially ingoing particle that turns back as an outgoing particle due to angular momentum barrier, with another ingoing particle. We assume that two massless particles are produced in such a collision and their angular distribution is isotropic in the center-of-mass frame. We calculated the escape fraction for the massless particles to reach infinity. We showed that the escape fraction is finite and approximately equal to half for the ultrahigh energy collisions. Therefore, the particles produced in high-energy collisions would escape to infinity providing the signature of the nature of basic interactions at those energies. This result is in contrast with the case of extremal Kerr black hole where almost all particles produced in high-energy collisions are absorbed by the black hole rendering collisions unobservable. [Mandar Patil, Pankaj S. Joshi]

Destroying a near-extremal Kerr black hole with a charged particle: Can a test magnetic field serve as a cosmic censor?

We investigate effect of a test magnetic field on the process of destroying near-extremal Kerr black hole with a charged test particle. It has been shown that it would be possible to throw a charged test particle into the near extremal rotating black hole and make it go past the extremality i.e. turn Kerr black hole into the Kerr-Newmann naked singularity. Typically in an astrophysical scenario black holes are believed to be surrounded by a magnetic field. Magnetic field although small, affects motion of charged particles drastically due to the large Lorentz force, as the electromagnetic force is much stronger than the gravity. Thus a test magnetic field can affect the process of destroying black holes and restore the cosmic censorship in the astrophysical context. We show that a test magnetic field would act as a cosmic censor beyond a certain threshold value. We try to gauge the magnitude of the magnetic field by comparing its energy density with that of the change in the curvature induced by the test particle. We find that the magnetic field required is only as strong as or slightly stronger as compared to the value for which its effect on the background geometry is comparable to the tiny backreaction as that of the test particle. In such a case however one has to take into account effect of the magnetic field on the background geometry, which is difficult to implement in the absence of any exact near-extremal rotating magnetized black hole solutions. We argue that magnetic field would still act as a cosmic censor. [Sanjar Shaymatov, Mandar Patil, Bobomurat Ahmedov, Pankaj S. Joshi]

All black holes in Lemaitre-Tolman-Bondi inhomogeneous dust collapse

Within the Lemaitre-Tolman-Bondi formalism for gravitational collapse of inhomogeneous dust we analyze the parameter space that leads to the formation of a globally covered singularity (i.e. a black hole) when some physically reasonable requirements are imposed (namely positive radially decreasing and quadratic profile for the energy density and avoidance of shell crossing singularities). It turns out that a black hole can occur as the endstate of collapse only if the singularity is simultaneous as in the standard Oppenheimer-Snyder scenario. Given a fixed density profile then there is one velocity profile for the infalling particles that will produce a black hole. All other allowed velocity profiles will terminate the collapse in a locally naked singularity. [Pankaj S. Joshi, Daniele Malafarina]

Cosmology

Quantum Theory and Gravity

General relativity, torsion and quantum theory

We reviewed some of the obstacles which arise when one tries to reconcile the general theory of relativity with quantum theory. We considered the possibility that gravitation theories which include torsion, and not only curvature, provide better insight into a quantum theory of gravity. We speculated on how the Dirac equation and Einstein gravity could be thought of as limiting cases of a gravitation theory which possesses torsion. [T. P. Singh]

Quantum discord as a tool for comparing collapse models and decoherence

The quantum to classical transition maybe caused by decoherence or by dynamical collapse of the wave-function. We proposed quantum discord as a tool for comparing and contrasting the role of a collapse model (Continuous Spontaneous Localization) and various sources of decoherence (environmental and fundamental), for an experimentally demonstrated macroscopic entanglement. We discussed the experimental conditions under which the detection of either Continuous Spontaneous Localization or fundamental decoherence becomes possible. [Shreya Banerjee, Sayantani Bera, T. P. Singh]

Constraints on fourth order gravity from binary pulsars and gravitational waves

We had earlier proposed a fourth order gravity model as a possible explanation for late time cosmic acceleration, and for flattened galaxy rotation curves. The model has a free length

parameter whose value depends on the scale of the system under study (e.g. the whole Universe, a galaxy, or a compact binary pulsar). A second free parameter arising as a constant of integration is also fixed using observational data. In this work, we investigated the constraints imposed on the two free parameters of the model by binary pulsar data: periastron advance; and emission of gravitational waves and consequent period decay. For three different binary pulsar systems (PSR B1913+16, PSR J0737-3039, PSR J1518+4904) it was shown that for a suitable choice of parameters the model is consistent with the observations.

Quantum nonlocality and the end of classical spacetime

Quantum non-local correlations and the acausal, spooky action at a distance suggest a discord between quantum theory and special relativity. We proposed a resolution for this discord by first observing that there is a problem of time in quantum theory. There should exist a reformulation of quantum theory which does not refer to classical time. Such a reformulation is obtained by suggesting that space-time is fundamentally non-commutative. Quantum theory without classical time is the equilibrium statistical thermodynamics of the underlying non-commutative relativity. Stochastic fluctuations about equilibrium give rise to the classical limit and ordinary space-time geometry. However, measurement on an entangled state can be correctly described only in the underlying non-commutative space-time, where there is no causality violation, nor a spooky action at a distance. [Shreya Banerjee, Sayantani Bera and T. P. Singh]

Bounce and cyclic cosmology in weakly broken galileon theories

We investigated the bounce and cyclicity realization in the framework of weakly broken galileon theories. We studied bouncing and cyclic solutions at the background level, reconstructing the potential that can give rise to a given scale factor, and presenting analytical expressions for the bounce requirements. We proceeded to a detailed investigation of the perturbations, which after crossing the bouncing point give rise to various observables, such as the scalar and tensor spectral indices and the tensor-to-scalar ratio. Although the scenario at hand shares the disadvantage of all bouncing models, namely that it provides a large tensor-to-scalar ratio, introducing an additional light scalar significantly reduces it through the kinetic amplification of the isocurvature fluctuations. [Shreya Banerjee, Emmanuel N. Saridakis, USA]

A novel adiabatic regularization method for spin 1/2 fields in FLRW spacetimes

We constructed a simple algorithm to derive number density of spin 1/2 particles created in spatially flat Friedmann-Lemaître-Robertson-Walker spacetimes and resulting renormalized energy-momentum tensor within the framework of adiabatic regularization. Physical quantities thus found were in agreement with the known results. This formalism can be considered as an appropriate extension of the techniques originally introduced for scalar fields, applicable to fermions in curved space. We applied this formalism to compute the particle number density and the renormalized energy density and pressure analytically (wherever possible) and numerically, in two interesting cosmological scenarios: a de Sitter spacetime and a radiation dominated universe. Results proved the efficiency of the methodology. [Suman Ghosh]

Supernovae, Globular Clusters

Nearby extragalactic supernovae

We have completed the analysis of SN 2013ej and SN 2011dh with multiple Chandra exposures and based on radio observations with GMRT. We use multiple Chandra and Swift observations of this SN to probe the history of mass loss from the progenitor in its last millennium before explosion. We model X-ray emission from the forward and reverse shocks self-consistently and find, at early times, unambiguous signatures of absorption of reverse shock emission by a cool shell predicted theoretically. More recently, we have observed with Swift X-ray Telescope (XRT instrument) a young type IIP SN2016cok (also known as ASASSN-16fq) a potentially good target which occurred in the nearby galaxy NGC3627 (Messier 66), which is only about 9.7 Mpc away. Even after subtracting the contribution of a previously present source in the nearby parts of the sky, we found no X-rays from the SN position at a level of unabsorbed flux of 1.6×10^{-15} erg/cm/cm/s in the 0.3-10 keV band, for a soft spectrum with a photon index = 2 [S. Chakraborti, N. Yadav, F. Sutaria, A. K. Ray, et al.]

Globular Clusters as possible cradles of advanced civilizations in the galaxy

We are investigating the factors such as the high stellar densities that are advantageous as well as deleterious for the emergence of intelligent life and long term survival of technological civilizations. We are including the effects of stellar collisions and exchange as well as gradual changes of eccentricity of planetary orbits on these considerations as well as interstellar messaging, navigation and travel within intercluster habitats [Rosanne DiStefano, A. K. Ray].

X-ray Astronomy

ASTROSAT: Indian Multiwavelength Astronomy Mission

Besides testing LAXPC flight detectors (LAXPC10, LAXPC20 & LAXPC30), we also made ready LAXPC-E flight spare detector as stand-by in case of any flight detector faces catastrophe before the launch. The calibration of the flight spare detector was carried out in the two meter Thermovac chamber at ISAC during August, 2015. Three radioactive sources, Iron (Fe55), Cadmium (Cd109) & Americium (Am241), were used for the calibration of the LAXPC flight spare detector and same procedure was followed as in case of flight detectors.

Assembly Integration & Testing (AIT) clean room Activities and Space Craft Level TVAC test in ISITE

After the completion of dis-assembled mode testing, the payloads were cleared to mount on the satellite frame in AIT lab at ISAC. The functional tests for all the LAXPC units were carried in AIT lab after complete satellite integration. Various tests of LAXPC chains in which data was acquired for various modes, testing of commands, purifier operations etc. were carried out and confirmed the functionality by monitoring the telemetry parameters apart from the health parameters. The spacecraft level TVAC tests were carried out at ISITE, Bangalore during June 18 to July 4, 2015. The test continued for over two weeks with a temperature profile of one long cycle of 120 hrs cold soak at -10°C for processing electronics and $+5^{\circ}\text{C}$ for detectors and hot soak at $+50^{\circ}\text{C}$ for processing electronics and $+35^{\circ}\text{C}$ for detectors followed by a short cycle of 18 hrs. During TVAC tests, various health parameters of the LAXPC payload were monitored continuously and other tests like commands, purifier etc were carried out. After the completion of the test the chamber was brought to ambient. [J. S. Yadav, H. M. Antia, D. K. Dedhia, V. B. Kadam, T. C. Kotoch, V. N. Kurhade, P. P. Madhwani, T. K. Manoj, V. A. Nikam, Jai Vardhan Chauhan, A. Pandya, J. V. Parmar, D. M. Pawar, P. B. Shah].

Switching on of Large area X-ray Proportional counter (LAXPC) instrument in orbit

The Large Area X-ray Proportional Counter (LAXPC) is one of the major payloads on AstroSat with total eight flight packages (three flight LAXPC detectors, three corresponding flight processing electronics packages, System Based Time Generator (STBG) and the bellow pump driving flight electronics package for purification system.

On 30th September 2015 (2nd day after AstroSat launch), STBG package of LAXPC payload was powered ON first, since STBG provides not only the satellite mission time, but also time to all other payloads on the AstroSat to correlate their package time with UTC. On 3rd day after the launch, all three Processing Electronic (PE) packages and low voltage detector electronics were put ON one by one. Due to out-gassing, it was decided not to put ON the detectors High Voltage (HV) until 21 days after the launch of AstroSat.

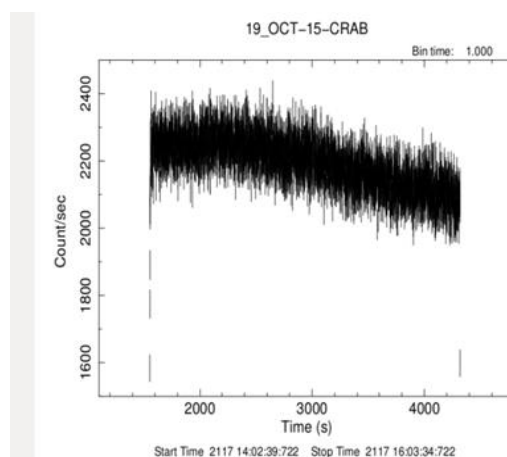


Figure: Light curve of Crab Nebula with LAXPC detector taken on 19 October 2015; first day of observation.

The LAXPC payload was fully functional on 19th October, 2015 when HV of all three LAXPC detectors was switched on. The last package the bellow pump for detector gas purification was operated first time during 20-22 October, 2015. During HV switching on sequence satellite was pointing to blank sky. The background was stable. After the switching on sequence, satellite was pointed to Crab Nebula; a bright hard X-ray source in the sky often used as standard source for instrument calibration. Crab pulsar is at distance of about 2 kpc in the Perseus Arm of our galaxy and spin rate of the pulsar is 30.2 times per second. The source was detected within seconds as it appears in live LBT data.

The Crab flux on 19th October 2015 was initially stable for few hundred seconds and then starts dropping. This source is very stable and not expected to show such decline. We looked into various possible explanations like any detector issue, partly Earth acculturation and stability of satellite platform. It was satellite platform issue as satellite was drifting with 0.1° per hour. This has happened as Moon came in the FOV of one of the star sensors. Thereafter, it was corrected and Crab

flux became stable. UVIT was switched on in 1st week of December, 2015 which provides better pointing accuracy. [J. S. Yadav, H. M. Antia, D. K. Dedhia, T. C. Kotoch, V. N. Kurhade, P. P. Madhwani, T. K. Manoj, V. A. Nikam, Jai Vardhan Chauhan, A. Pandya, J. V. Parmar, D. M. Pawar, P. B. Shah].

Purification of LAXPC detectors in orbit

We have taken utmost care by keeping evacuated all the three detectors with the top cover when detectors are not being tested in AIT, ASITE and at Shar. However LAXPC10 was last purified in November 2013 (while other two were purified during August-October 2014) and was likely to absorb more impurities. Also all the LAXPC detectors were kept without cover many times in labs specially for about 20 days at SHAR prior to AstroSat launch. The purification pumps were operated during 20-22 October, 2015 & 23-24 November, 2015 and energy resolution was measured at each stage. The degradation of energy resolution was maximum in LAXPC10 as expected. Energy resolution of LAXPC10 had degraded to around 21 % at 30 keV when measured in orbit before purification and improved to around 11% after gas purification in orbit. [J. S. Yadav, H. M. Antia, D. K. Dedhia, T. C. Kotoch, V. N. Kurhade, P. P. Madhwani, T. K. Manoj, V. A. Nikam, Jai Vardhan Chauhan, A. Pandya, J. V. Parmar, D. M. Pawar, P. B. Shah].

Pointing of LAXPC detectors

It is important to know how well three LAXPC detectors are aligned to each other as well as how much is their offset for individual detectors with respect to the pointing axis of the satellite. LAXPC instrument is non imaging instrument and hence a scans across the Crab; a standard X-ray source was used to estimate the field of view as well as pointing offsets. The FWHM of the detector is found to be about 55' which is close to what was estimated by GEANT4 simulations. Three Crab scan were carried out during October 2015 to March 2016 along RA and DEC axes within ± 3 degrees. One such cross scans were carried out on 25th October 2015 and results are shown for a scan along RA axis. Scan was done with a speed of 0.01^o per second from +3^o to -3^o along RA. These scans provide offsets of individual LAXPC detectors. [J. S. Yadav, H. M. Antia, D. K. Dedhia, T. C. Kotoch, P. P. Madhwani, T. K. Manoj, Jai Vardhan Chauhan, P. B. Shah].

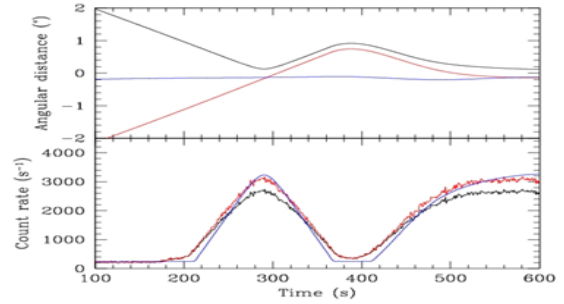


Figure: Top panel shows plot of RA (red), DEC (blue) and net angle (black). Bottom panel shows the count rate observed (black), count rate corrected for dead time (red) and count rate expected from GEANT4 simulation of the Field of View (FOV) for a point source (blue). All data is for LAXPC30.

LAXPC observations during Payload Verification phase and first science results

Payload Verification phase observations for LAXPC instrument were carried out from 19th October, 2015 to 31st March, 2016. Initially there were issues with level 1 data and these were resolved by interacting with ISAC and RRI groups. Initial issues in LAXPC pipeline level 2 software were resolved by interacting with SAC and RRI groups. LAXPC data was evaluated by verifying the file size and data quality of the each detector data files. We have observed large number of X-ray sources during PV phase which includes pulsars, micro quasars, LMXBs, HMXBs, clusters, supernova remnants, AGNs and other. Data is being analyzed and will be published shortly. Our results suggest that LAXPC instrument has advantage over NASA's RXTE/PCA for 1) better statistics at energy > 20 keV, 2) fine time information in event mode, and 3) a larger energy range of 3-80 keV. [J. S. Yadav, H. M. Antia, V. Chitnis, D. K. Dedhia, T. C. Kotoch, V. N. Kurhade, P. P. Madhwani, T. K. Manoj, V. A. Nikam, Jai Vardhan Chauhan, A. Pandya, J. V. Parmar, D. M. Pawar, P. B. Shah, B. Paul, P. C. Agrawal, R. K. Manchanda].

Soft X-ray Focusing Telescope (SXT) for Astrosat: Post-launch performance and calibrations

The Soft X-ray focusing Telescope (SXT) was launched successfully by ISRO onboard Astrosat by a PSLV-C30 rocket into a near-Earth circular orbit at a height of 650 kms and latitude of 6 degrees on September 28, 2015 from Shriharikota. SXT has a focal length of 2 meters and uses conical foil mirrors in a configuration that requires double grazing incidence reflection by 1-alpha and 3-alpha conical sections corresponding to paraboloid and hyperboloid surfaces of Wolter-I geometry, and carries an X-ray (0.3 to 8.0 keV) sensitive CCD camera at the focal plane. The SXT electronics was switched on 3 days after the launch, the cooling of

the CCD in the camera was started after two weeks of venting of gases inside the camera. The CCD reached the temperature of -82°C and is held to within $\pm 2^{\circ}\text{C}$ of this temperature until today, as per the design. The performance of the CCD and a very thin optical blocking filter was checked using an internal LED source and five internal calibration sources (Fe-55). The performance of the CCD found to be as per the expectations. The telescope door was opened ~ 3 weeks after the launch. Finally the camera door was opened on October 26th, 2015, and the first light from a preselected cosmic X-ray source: PKS2155-304 excellent (a blazar) was detected on the CCD to the delight of the SXT team. This was a defining moment as it showed an excellent performance of the telescope and the camera with an X-ray image having a core of ~ 2 arcmin (FWHM) on the CCD. It also showed the readiness of the SXT software, as the data from the satellite received at the ISSDC in Bengaluru was transferred to TIFR Bangalore and the software team in TIFR could verify the data and show the image and spectra of the source within a couple of hours.

Since the first light, the SXT has been pointed at several different types of sources (stars, supernova remnants and quasars) during the Performance Verification (PV) phase that lasted until March 31, 2015. Most of these data have been analyzed and also compared with contemporaneous observations with other satellite thus establishing the imaging capability in X-rays, X-ray sensitivity and X-ray spectral performance of the SXT. It has been shown that the SXT is the most sensitive X-ray instrument onboard Astrosat and would be able to detect sources as weak as 10 micro-Crab in an observation lasting a day. It is also the instrument with the highest energy resolution in X-rays. The low noise performance has shown that its low energy threshold may be extended to as low as 0.2 keV (lower than the 0.3 keV that was planned) and thus extending its power to detect low energy absorption by interstellar, circum-stellar or intergalactic medium.

An X-ray image of a young supernova remnant, known as Tycho, taken with SXT is shown below.

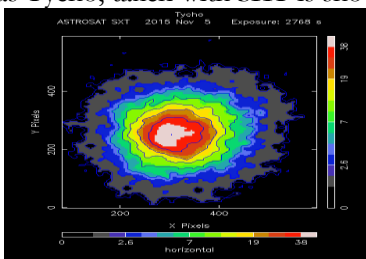


Figure: An X-ray image of a young supernova remnant, known as Tycho, taken with SXT.

As examples of the spectral performance of the SXT: we show here spectra obtained from two supernova remnants (see below) – a) Tycho from SXT (top) and Swift XRT (NASA Satellite). The g0 and g0-12 represent different types of grades of events in the CCD that represent genuine X-rays. b) Casseopia A (bottom) from SXT (black curve), Swift XRT (red curve) and NuStar (green curve) (NASA satellite). All the line features from various ionised atoms (Ne, Mg, Si, S, Ar, Ca and Fe) match up perfectly and are well fit to all the data using a common model, with the differences in normalisations being due to different areas/efficiencies of the instruments.

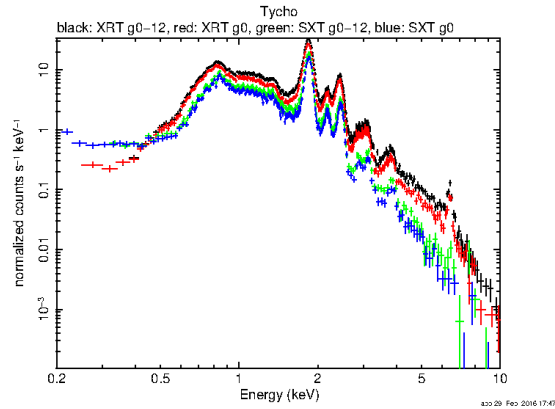


Figure: Spectra of Tycho supernova remnant from SXT and Swift XRT (NASA Satellite).

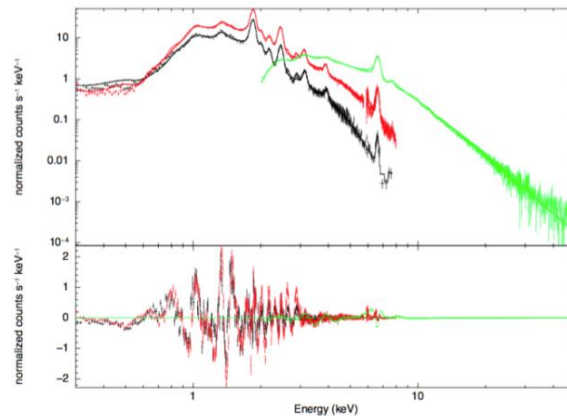


Figure: Spectra of Casseopia A from SXT (black curve), Swift XRT (red curve) and NuStar (green curve) (NASA satellite).

A series of maneuvers of the satellite have been conducted to establish the bore-site of the SXT vis-à-vis that of the spacecraft and the results are being analysed to parameterize its vignetting. At the same time, we have planned and proposed a series of observations during our guaranteed time to carry out some multi-wave observations of many different kinds of cosmic ray sources. [K. P. Singh (SXT Project Manager), S. Bhattacharayya, K. Mukerjee, S. Chandra, V. Chitnis, N. Kamble, S. Kotak, J. G. Koyande, S. L. Vishwakarma, D. P. Pathare, I. R. Mirza, B. G. Bagade, V. J. Mhatre, V. M. Risbud, H. Shah]

Cadmium Zinc Telluride Imager (CZTI) of Astrosat

The Cadmium Zinc Telluride Imager (CZTI) is one among the four X-ray instruments onboard ASTROSAT. It is used for hard X-ray spectroscopy in the energy range 10 - 100 keV; additionally, it can provide photometry and polarisation in the 100 - 300 keV region.

After full space qualification at Vikram Sarabhai Space Centre, Thiruvananthapuram, CZTI instrument was shipped to ISRO Satellite Centre, Bengaluru, in a specially designed transportation container. The full satellite integration tests of Astrosat were completed in a record time of three months. The tests included the open mode interface tests, full assembled tests, satellite thermo-vacuum tests, vibration tests, transportation to the launch site at Sriharikota (SHAR) and the final integrated tests at SHAR. The CZTI was so designed that all these tests could be done and the performance of the instrument evaluated with ease. Astrosat was successfully launched on September 28, 2015. CZTI was made fully operational on October 5, one week after the launch of Astrosat. CZTI uses large area pixelated semiconductor detectors and one of the challenges was to keep them at a steady temperature in the range of 0 - 15 C. Heaters were used to keep them above 0 C, but there was an orbital swing of 2 to 8 C. Once the instrument was switched ON, extra care was taken to keep the temperatures steady, and all four quadrants of the instrument gave a stable temperature within a degree, vindicating the elaborate thermal modelling and the care taken to operate the instrument. The structured onboard software worked in an autonomous fashion and the general health of the instrument could be evaluated from the low bit rate satellite telemetry and the instrument behaved as designed. The main detectors were switched on and examined in a staggered way, detector by detector and quadrant by quadrant, critically examining the full instrument data, dumped every orbit. CZTI has 64 detector modules, and each module has 256 individual X-ray sensors called pixels. Thus the geometric area of CZTI (1000 cm²) is made of 16384 individual pixels: each is an independent X-ray sensor. Depending on the manufacturing and handling care, it was noticed during the ground calibration, that a small fraction of these pixels (3 - 5%) can be noisy giving a large number of false triggers and flooding the data. About 4% of the pixels were already 'disabled' before launch and one of the important tasks was to identify further 'bad' pixels, understand their behavior, disable a small fraction of them (~0.5% - about 100 pixels), and tune the thresholds. After an elaborate operation, a stable

and steady operation of CZTI detectors was achieved.

The observed background count rate was much higher than anticipated, resulting in large data volume. The expected background rate is about 100 counts per second per quadrant; however, the observed counts exceeded it by a factor of 10 - 20. This was understood to be due to multiple events recorded during Cosmic Ray interaction. A software patch to suppress such unwanted events was written, tested in the ground model of the instrument, and uploaded successfully into the flight instrument.

From the first day of operation itself, hard X-ray image of the Crab Nebula was obtained. The timing analysis of the Crab Pulsar demonstrated the very high timing accuracy (about a micro-s) of the instrument. Several gamma-ray bursts were detected by CZTI (several of them off-axis) and the utility of CZTI to localize and measure the spectra of off-axis GRBs was demonstrated. [A. R. Rao, M. K. Hingar, A. P. K. Kutty, M. H. Patil, R. Khanna, A. Rananaware along with the Avionics Group, VSSC, Thiruvananthapuram, IUCAA, Pune, and PRL, Ahmedabad]

Development of Multi-layer Optics for Hard X-ray Astronomy

We are continuing our programme to produce mirrors for hard X-rays (upto 80 keV) reflectivity necessary for making a telescope for hard X-ray astronomy in our laboratory. We have set up procedures for thermal slumping to shape the glass and then to coat them with multi-layers for hard X-ray reflection. In the past one year we have achieved the following:

1. Shape measurement of thermally formed glass was done using laser light source, and analyzing data using MATLAB. Parameters for slumping were finalized using the results obtained from these experiments.
2. Stress measurement of the thermally formed glass was done using polariscope arrangement. It was observed that most of the glasses formed were stress free.
3. Calibration of the sputtering system for multi-layer coatings was completed using single layers of tungsten and silicon. XRR testing and AFM testing was done for all the samples. Analysis for all single layer samples was completed using PARRAT and IMD software.
4. Multilayer samples were coated using the same calibrated data for single layers. So far 3, 6, 10 and 20 bilayers having equal thickness have been deposited. The XRR results for multilayer match very well with the single layer data for tungsten.

Etching of silicon is observed when tungsten layer is deposited on the top.

5. Work on developing the model for the hard x-ray optics is being done currently using ZEMAX software. Using the theoretically calculated layer thickness, PSF for each shell of mirrors can be calculated using the same software.

6. Depth graded multilayer structure for a hard X-ray telescope will be deposited and studied using XRR. [K. P. Singh, V. Navalkar, V. Mhatre, H. Shah, V. M. Risbud (TIFR), and S. Rai (RRCAT, Indore)]

Study of multi-wavelength variability in a blazar: PKS1510-89

Blazars are a subset of powerful quasars with strong continuum emission across the entire electromagnetic spectrum from radio to γ -rays. The emission is believed to come from a superluminal jet powered by an accreting supermassive black-hole with the jet pointed almost directly towards the observers on the Earth. The emission from the jet swamps the emission lines from the regions (ionized clouds, tori etc.) surrounding the accretion disk around the nucleus in the blazars. The emissions seen in the different parts of the em spectrum are believed to be produced by synchrotron emission from electron or protons, and inverse-Compton processes on a huge variety of seed photons coming from the various regions. Unraveling the dynamics of these processes requires simultaneous observations across the em spectrum. We have studied the variability properties of the multi-wavelength (IR-optical-X-ray- γ -ray) long-term (up to 15 years) light curves of a flat spectrum radio quasar PKS 1510-089 and presented evidence that the distributions of fluxes (except in X-rays) follow a bimodal log-normal distribution. The multi-wave data for the past 15 years were obtained from the archives and analyzed by us. Considerations of this nature (lognormal flux distribution and related statistical properties of the light curves) have previously led to a significant progress in understanding the origins of variable X-ray emission from X-ray binaries and Seyfert galaxies and it is likely that a similar progress will be achieved with time variability studies in the case of other classes of

accreting black holes (as in blazars) and in other energy bands. This makes this study particularly interesting and these results could lead to an important contribution to the field. This work has been accepted to appear in the *Astrophysical Journal (Letters)*. [P. Kushwaha, S. Chandra, K. P. Singh, (TIFR), R. Mishra (IUCAA), S. Sahayanathan (BARC), and K. S. Baliyan (PRL)]

Prompt emission in Gamma-ray bursts

The understanding of the radiation mechanism involved in the prompt emission of gamma-ray bursts (GRBs) is quite important to pin down the elusive jet ejection mechanisms in black hole sources. The major difficulty is getting good quality X-ray spectral data during the prompt emission phase. This has been circumvented by using special statistical techniques like tied spectral fitting and connecting prompt spectral data to the early afterglow data obtained by good spectroscopic detectors. Thermal components are identified in two GRBs viz. GRB090618 and GRB 130925A. A pair of smoothly evolving blackbodies, from late prompt emission to early afterglow phase, with temperatures monotonically decreasing with time, is found in GRB 090618. This is understood as an evidence for a Spine-Sheath jet in this GRB. Similarly, thermal emissions spanning the prompt and the afterglow phases of the Ultra-long GRB 130925A were identified and it is suggested that black body emission is a generic feature of all GRBs. [Rupal Basak, and A. R. Rao]

Extreme physics of neutron stars and black holes

We pursued research on the extreme physics of neutron stars and black holes. We did detailed theoretical study of how millisecond pulsar evolution depends on transient accretion. We also computed the structures of rapidly spinning compact stars including the full effect of general relativity, and explored possible ways to constrain interacting quark matter parameters. We also analytically explored the tilt of accretion disk close to a spinning black hole. Finally, we were involved in a research work on broad relativistic iron line from an accreting neutron star. [S. Bhattacharyya, C. Chakraborty]

Infra-red Astronomy

Instrumentation

Science Observations with TIFR Near Infrared Spectrometer and Imager (TIRSPEC) for

Himalayan Chandra Telescope

TIRSPEC was installed at the 2-meter Himalayan Chandra Telescope (HCT) during June 2013 for the engineering and scientific runs on the telescope.

TIRSPEC provides for various modes of operation which include photometry with broad and narrow band filters, spectrometry in single order mode with long slits of 300 arcsec length and different widths, with order sorter filters in the Y, J, H and K bands and a grism as the dispersing element as well as a cross dispersed mode with slit lengths of 50 arcsec to give a coverage of 1.0 to 2.5 μm at a resolving power R of 1200. TIRSPEC is available to the worldwide astronomical community for science observations since May 2014. Currently, about 40% of the observing proposals on HCT use TIRSPEC as the focal plane instrument. A number of science papers using TIRSPEC data have been published in various peer-reviewed refereed journals during the past one year. [D.K. Ojha, S.K. Ghosh, J.P. Ninan, T. Baug, S.L. D'Costa, M.B. Naik, P.R. Sandimani, S.S. Poojary, S.B. Bhagat, R.B. Jadhav, G.S. Meshram, S.M. Gharat, C.B. Bakalkar]

Completion of the Laboratory Model of Infra-Red Spectroscopic Imaging Survey (IRSIS) Payload

The laboratory model of the IRSIS satellite experiment has been extensively tested in the lab. Characterization of the infrared detector has been completed. The cryogenic tests of the IRSIS Laboratory Model are in progress using spectral lines from a calibration lamp, and spectral data has been obtained and analysed. The infrared fiber bundle has been designed and is under fabrication. It is anticipated that by the end of 2016, a detailed report on the performance of the IRSIS Laboratory Model will be submitted to ISRO (Space Science Office). [S.K. Ghosh, D.K. Ojha, M. Puravankara, S.L. D'Costa, M.B. Naik, P.R. Sandimani, S.S. Poojary, S.B. Bhagat, R.B. Jadhav, G.S. Meshram, S.M. Gharat, C.B. Bakalkar]

A competitive Optical-NIR 0.6 - 2.5 microns medium resolution spectrograph (TANSPEC) for the ARIES 3.6-meter telescope

TANSPEC Preliminary Design Review (PDR) involving national and international experts was carried out during July 20 to 24, 2015 at ARIES, Nainital. After the successful completion of the PDR, the Critical Design Review (CDR) of TANSPEC was held during October 2015. The science grade infrared arrays were ordered in November 2015. M/s MKIR has already received the H1RG science grade array and the H1RG MUX. The H2RG science grade array will be shipped by the end of this month depending on the testing. M/s MKIR will have all of the parts for the cold test by June 2016. The radiation shield and the main cold block will be delivered by the end of May 2016. The computers have arrived and M/s MKIR is setting up for the warm MUX tests in

May 2016. The fabrication of TANSPEC is in an advanced stage and the spectrometer is expected to be commissioned by the first quarter of 2017. [D.K. Ojha, S.K. Ghosh, M. Puravankara, S.L. D'Costa, M.B. Naik, S.S. Poojary, P.R. Sandimani, S.B. Bhagat, R.B. Jadhav, G.S. Meshram, S.M. Gharat, C.B. Bakalkar]

Star formation

Multiwavelength Study of Galactic Star Forming Regions

We have presented multiwavelength study of several Galactic star-forming and H II regions. These include: S235 complex, Sh2-138, W42, and S254-S258 OB complex. The data comprise of optical and near-infrared (NIR) photometric and spectroscopic observations from the 2-m Himalayan Chandra Telescope, radio observations from the Giant Metrewave Radio Telescope (GMRT), and archival data covering radio through NIR wavelengths. Optical spectroscopic observations are used to constrain the spectral type of ionizing stars. The nature of these H II regions is characterized by estimating parameters such as electron density and emission measure, using the radio continuum observations. To understand local star formation, we identified young stellar object (YSO) candidates using grism slitless spectroscopy and NIR observations. The NIR analysis is complemented with GMRT low-frequency observations, molecular line observations of H₁₃CO⁺ (J=1-0), and archival Chandra X-ray observations. Thermal dust emission modelling, using the FIR data from Herschel and performing modified blackbody fittings helped us construct the temperature and column density maps of the HII regions. We have suggested that multi-generation star formation is present in several star-forming complexes. The molecular outflows are detected in few subregions, further confirming the ongoing star formation activity. Together, all these results are interpreted as observational evidence of positive feedback of a massive star. [D.K. Ojha, T. Baug, J.P. Ninan, S.K. Ghosh, L.K. Dewangan (PRL, Ahmedabad), M.R. Samal (LAM, France), A.K. Pandey (ARIES, Nainital), B.C. Bhatt (IIA, Bangalore)]

V899 Mon: An Outbursting Protostar with a Peculiar Light Curve, and Its Transition Phases

We presented a detailed study of V899 Mon (a new member in the FUors/EXors family of young low-mass stars undergoing outburst), based on our long-term monitoring of the source starting from 2009 November to 2015 April. Our optical and

near-infrared photometric and spectroscopic monitoring recorded the source transitioning from its first outburst to a short-duration quiescence phase (< 1 yr), and then returning to a second outburst. We reported the evolution of the outflows from the inner region of the disk as the accretion rate evolved in various epochs. Our high-resolution ($R \sim 37,000$) optical spectrum could resolve interesting clumpy structures in the outflow traced by various lines. Change in far-infrared flux was also detected between two outburst epochs. Based on our observations, we constrained various stellar and envelope parameters of V899 Mon, as well as the kinematics of its accretion and outflow. The photometric and spectroscopic properties of this source fall between classical FUors and EXors. Our investigation of V899 Mon hints at instability associated with magnetospheric accretion being the physical cause of the sudden short-duration pause of the outburst in 2011. It is also a good candidate to explain similar short-duration pauses in outbursts of some other FUors/EXors sources. [J.P. Ninan, D.K. Ojha, T. Baug, B.C. Bhatt (IIA, Bangalore), V. Mohan (IUCAA, Pune), S.K. Ghosh, A. Men'shchikov (CEA Saclay, France), G.C. Anupama (IIA, Bangalore), M. Tamura (NAOJ, Japan), Th. Henning (MPIA, Germany)]

The Disk-outflow System in the S255IR Area of High-mass Star Formation

We reported the results of our observations of the S255IR area with the Submillimeter Array (SMA) at 1.3 mm in the much extended configuration and at 0.8 mm in the compact configuration as well as with the IRAM 30 m at 0.8 mm. The best achieved angular resolution is about 0.4 arcsec. The dust continuum emission and several tens of molecular spectral lines are observed. The majority of the lines is detected only toward the S255IR-SMA1 clump, which represents a rotating structure (probably a disk) around the young massive star. The achieved angular resolution is still insufficient to make any conclusions about the Keplerian or non-Keplerian character of the rotation. The temperature of the molecular gas reaches 130-180 K. The size of the clump is about 500 AU. The clump is strongly fragmented as follows from the low beam-filling factor. The mass of the hot gas is significantly lower than the mass of the central star. A strong DCN emission near the center of the hot core most probably indicates a presence of a relatively cold ($\lesssim 80$ K) and rather massive clump there. High-velocity emission is observed in the CO line as well as in lines of high-density tracers HCN, HCO+, CS and other molecules. The outflow morphology obtained from a combination of the SMA and IRAM 30 m data is significantly different from that derived from the SMA data alone. The

CO emission detected with the SMA traces only one boundary of the outflow. The outflow is most probably driven by jet bow shocks created by episodic ejections from the center. We detected a dense high velocity clump associated apparently with one of the bow shocks. The outflow strongly affects the chemical composition of the surrounding medium. [I. Zinchenko (IAP, Russia), S.-Y. Liu, Y.-N. Su (Taiwan), S.V. Salii, A.M. Sobolev, P. Zemlyanukha (Russia), H. Beuther (Germany), D.K. Ojha, M.R. Samal (France), Y. Wang (China)]

Star formation in the filament of S254-S258 OB complex: a cluster in the process of being created

Infrared dark clouds are ideal laboratories for studying the initial processes of high-mass star and star-cluster formation. We investigated the star formation activity of an unexplored filamentary dark cloud (size ~ 5.7 pc \times 1.9 pc), which itself is part of a large filament (~ 20 pc) located in the S254-S258 OB complex at a distance of 2.5 kpc. Using Multi-band Imaging Photometer (MIPS) Spitzer 24 μ m data, we uncovered 49 sources with signal-to-noise ratios greater than 5. We identified 45 sources as candidate young stellar objects (YSOs) of Class I, flat-spectrum, and Class II natures. Additional 17 candidate YSOs (9 Class I and 8 Class II) are also identified using JHK and Wide-field Infrared Survey Explorer (WISE) photometry. We find that the protostar-to-Class II sources ratio (~ 2) and the protostar fraction ($\sim 70\%$) of the region are high. Comparison of the protostar fraction to other young clusters suggests that the star formation in the dark cloud possibly started only 1 Myr ago. Combining the near-infrared photometry of the YSO candidates with the theoretical evolutionary models, we infer that most of the candidate YSOs formed in the dark cloud are low-mass ($< 2 M_{\odot}$). We examine the spatial distribution of the YSOs and find that majority of them are linearly aligned along the highest column density line ($N(\text{H}_2) \sim 1 \times 10^{22}$ cm $^{-2}$) of the dark cloud along its long axis at the mean nearest-neighbour separation of ~ 0.2 pc. Using the observed properties of the YSOs, physical conditions of the cloud and a simple cylindrical model, we explore the possible star formation process of this filamentary dark cloud and suggest that gravitational fragmentation within the filament should have played a dominant role in the formation of the YSOs. From the total mass of the YSOs, the gaseous mass associated with the dark cloud, and the surrounding environment, we infer that the region is presently forming stars at an efficiency of $\sim 3\%$ and a rate $\sim 30 M_{\odot}$ Myr $^{-1}$, and it may emerge in a richer cluster. [M.R. Samal

(France), D.K. Ojha, J. Jose (China), A. Zavagno (France), S. Takahasi (Chile), B. Neichel (France), J.S. Kim (USA), N. Chauhan (Delhi), A.K. Pandey (Nainital), I. Zinchenko (Russia), M. Tamura (Japan), S.K. Ghosh]

Massive Young Stellar Object W42-MME: the Discovery of an Infrared Jet Using VLT/NACO Near-infrared Images

We reported on the discovery of an infrared jet from a deeply embedded infrared counterpart of the 6.7 GHz methanol maser emission (MME) in W42 (i.e., W42-MME). We showed that W42-MME drives a parsec-scale H₂ outflow, with the detection of a bow shock feature at ~ 0.52 pc to the north. The inner ~ 0.4 pc part of the H₂ outflow has a position angle of $\sim 18^\circ$ and the position angle of $\sim 40^\circ$ is found farther away on either side of the outflow from W42-MME. W42-MME is detected at wavelengths longer than $2.2 \mu\text{m}$ and is a massive young stellar object with an estimated stellar mass of $19 \pm 4 M_\odot$. We mapped the inner circumstellar environment of W42-MME, using Very Large Telescope (VLT)/NACO, adaptive optics Ks and L' observations at resolutions of $\sim 0.2''$ and $\sim 0.1''$, respectively. We discovered a collimated jet in the inner 4500 AU, using the L' band which contains prominent Br α line emission. The jet is located inside an envelope/cavity (extent $\sim 10,640$ AU) that is tapered at both ends and is oriented along the north-south direction. Such observed morphology of the outflow cavity around the massive star is scarcely known and is very crucial for understanding the jet-outflow formation process in massive star formation. Along the flow axis, which is parallel to the previously known magnetic field, two blobs are found in both the NACO images at distances of ~ 11800 AU, located symmetrically from W42-MME. The observed W42-MME jet-outflow configuration can be used to constrain the jet launching and jet collimation models in massive star formation. [L.K. Dewangan, Y.D. Mayya, A. Luna (Mexico), D.K. Ojha]

Energetics around the photon dominated region Sharpless 140

Study of the heating and cooling of dust and gas in the dense ($> 10^5 \text{ cm}^{-3}$) interstellar clouds in the presence of embedded infrared sources and UV radiation from external stars is important to understand the energetics of the interstellar medium. We studied the dense interstellar cloud associated with the photon dominated region (PDR) Sharpless 140, by observing dust continuum maps at wavelengths ranging from 37 micron to 450 micron and maps of a range of rotational transitions of CO (and its isotopologues). We determined the temperature and column density of

both dust and gas in the region accurately. Contrary to the expectation that in dense interstellar clouds are in thermal equilibrium, being coupled via collisions, we found that (i) even at the high densities of S140 the gas and dust temperatures are decoupled and (ii) the gas heating is very efficient most likely due to the deep penetration of UV radiation from the embedded sources in a clumpy medium and/or oblique shocks. We further explored the gas heating and cooling using the fine-structure lines of [OI] at 63 micron, [CII] at 158 micron and rotational transitions of CO. Comparing the line intensities with the far-infrared continuum we concluded that the main emission of the S140 region can be explained by a PDR structure around the embedded star cluster. The most striking result of this study was however the low line-to-continuum cooling ratios below 10^{-4} , matching the far-infrared line deficit seen in Ultra Luminous InfraRed Galaxies (ULIRGS). [B. Mookerjea]

Revisiting the OH-CH correlation in diffuse clouds

In the absence of permanent dipole moment of molecular hydrogen (H₂) has no permitted rotational transitions at the low temperatures (10-100 K) of the molecular clouds, hence H₂ cannot be directly traced in these regions. In the diffuse (H₂ number densities $< 1000 \text{ /cm}^3$) a strong correlation between H₂ and CH has been established and recently, a strong correlation between the column densities of OH and CH had also been suggested for a few sightlines. We analyzed archival data from the Ultraviolet and Visual Echelle Spectrograph (UVES) on the Very Large Telescope (VLT) to further explore the CH-OH relationship. We extended the sample of sightlines to 24, for which both CH and OH column densities are measured by using the equivalence of the column densities of CH derived from a combination of the transitions at 3137 and 3143 Angstrom, and a combination of transitions at 3886 and 3890 Angstrom. We found that with the exception of four diffuse clouds, the entire source sample showed clear correlation between the column densities of OH and CH similar to previous observations. We reproduced the observed correlation using simple chemical models which include gas-grain interaction and gas-phase chemistry. [B. Mookerjea]

Spitzer IRS Spectra of Debris Disks in the Scorpius-Centaurus OB Association

We analyzed spectra obtained with the Spitzer Infrared Spectrograph (IRS) of 110 B-, A-, F-, and G-type stars with optically thin infrared excess in the Scorpius-Centaurus OB association. The ages

of these stars range from 11 to 17 Myr. We fit the infrared excesses observed in these sources by Spitzer IRS and the Multiband Imaging Photometer for Spitzer (MIPS) to simple dust models according to Mie theory. We found that nearly all of the objects in our study can be fit by one or two belts of dust. Dust around lower mass stars appears to be closer in than around higher mass stars, particularly for the warm dust component in the two-belt systems, suggesting a mass-dependent evolution of debris disks around young stars. For those objects with stellar companions, all dust distances are consistent with truncation of the debris disk by the binary companion. The gaps between several of the two-belt systems can place limits on the planets that might lie between the belts, potentially constraining the mass and locations of planets that may be forming around these stars. [Jang-Condell H., Chen C. H., Mittal, T., Manoj P., Watson D. M., Lisse Carey M., Nesvold E., Kuchner M.]

The Herschel Orion Protostar Survey: Spectral Energy Distributions and Fits Using a Grid of Protostellar Models

We presented key results from the Herschel Orion Protostar Survey: spectral energy distributions (SEDs) and model fits of 330 young stellar objects, predominantly protostars, in the Orion molecular clouds. This is the largest sample of protostars studied in a single, nearby star formation complex. With near-infrared photometry from 2MASS, mid- and far-infrared data from Spitzer and Herschel, and submillimeter photometry from APEX, our SEDs cover 1.2-870 μm and sample the peak of the protostellar envelope emission at $\sim 100 \mu\text{m}$. Using mid-IR spectral indices and bolometric temperatures, we classified our sample into 92 Class 0 protostars, 125 Class I protostars, 102 flat-spectrum sources, and 11 Class II pre-main-sequence stars. We implemented a simple protostellar model (including a disk in an infalling envelope with outflow cavities) to generate a grid of 30,400 model SEDs and used it to determine the best-fit model parameters for each protostar. We argued that far-IR data are essential for accurate constraints on protostellar envelope properties. We found that most protostars, and in particular the flat-spectrum sources, are well fit. The median envelope density and median inclination angle decrease from Class 0 to Class I to flat-spectrum

protostars, despite the broad range in best-fit parameters in each of the three categories. We also discussed degeneracies in our model parameters. Our results confirm that the different protostellar classes generally correspond to an evolutionary sequence with a decreasing envelope infall rate, but the inclination angle also plays a role in the appearance, and thus interpretation, of the SEDs. [Furlan, E., Fischer, W. J., Ali, B., Stutz, A. M., Stanke, T., Tobin, J. J., Megeath, S. T., Osorio, M., Hartmann, L., Calvet, N., Poteet, C. A., Booker, J., Manoj, P., Watson, D. M., Allen, L.]

The Spitzer infrared spectrograph survey of protoplanetary disks in Orion A: I. disk properties

We presented our investigation of 319 Class II objects in Orion A observed by Spitzer/IRS and the follow-up observations of 120 of these Class II objects in Orion A from IRTF/SpEx. We measured continuum spectral indices, equivalent widths, and integrated fluxes that pertain to disk structure and dust composition from IRS spectra of Class II objects in Orion A. We estimated mass accretion rates using hydrogen recombination lines in the SpeX spectra of our targets. Utilizing these properties, we compared the distributions of the disk and dust properties of Orion A disks to those of Taurus disks with respect to position within Orion A (ONC and L1641) and to the sub-groups by the inferred radial structures, such as transitional disks vs. radially continuous full disks. Our main findings are as follows. (1) Inner disks evolve faster than the outer disks. (2) Mass accretion rate of transitional disks and that of radially continuous full disks are statistically significantly displaced from each other. The median mass accretion rate of radially continuous disks in ONC and L1641 is not very different from that in Taurus. (3) Less grain processing has occurred in the disks in ONC compared to those in Taurus, based on analysis of the shape index of the 10 micron silicate feature (F11.3/F9.8). (4) The 20-31 micron continuum spectral index tracks the projected distance from the most luminous Trapezium star, theta-1 Ori C. A possible explanation is the effect of UV ablation of the outer part of the disks. [Kim, K. H., Watson, Dan M., Manoj, P., Forrest, W. J., Furlan, E., Najita, J., Sargent, B., Hernández, J., Calvet, N., Adame, L., Espaillat, C., Megeath, S. T., Muzerolle, J., McClure, M. K.]

Archaeo-astronomy

Work on Megaliths and Rock Art in central India

The megaliths in Nagpur region are probably more than 2000 years old and have cup-marked stones

whose relevance is not understood. We began an extended programme of recording the megaliths and rock arts of various forms in that region. Similarly, there is significant and important rock art

around Bhopal that also needs to be studied. We visited the site in March and are now undertaking recording and documenting the art work as well as studying the composition of the pigments. [M N Vahia, Riza Abbas, Indian Numismatic Historical and Cultural Research Foundation, Nashik and Salim Shaikh, IISER, Mohali]

Studies of astronomical symbolism in rock art and coins

In collaboration with the Indian Numismatic Historical and Cultural Research Foundation, Nashik we have initiated work on identifying astronomical symbols on ancient coins. Similarly in collaboration with the Indira Gandhi National Centre for Arts, we have initiated work on identifying astronomical symbols on ancient rock art [Mayank Vahia, Nisha Yadav]

Studies of Harappan Civilisation

In our continuing studies of the Indus script, we have investigated the sensitivity or the nature of writing as a function its context in terms of location where writing is found and the medium on which it is written. We have also continued to debate the power and validity of the mathematical tools we have used in understanding the grammar of the script [Nisha Yadav and M N Vahia]

Simulation of movement of people

We have initiated a study of simulation of the movement of people in the Indian subcontinent based on detailed geography and human preferences to establish the patterns of movement of people. The programme is under development. As a case study, we studied early migration into the British Isles and compared it with the genetic data of early British to show that the parameters that govern such migration can be modelled with very few parameters. [M N Vahia, Nisha Yadav, Deepak Mathur, Uma Ladiwala, Centre for Basic Sciences, Mumbai]

Development of Instrumentation

In our continuing work on instrumentation, we have received funding of approximately ₹ 10 crore to set up an AMS based Carbon dating facility at the Mumbai University at Kalina. We have also continued to expand the development of a mobile XRF facility which is now being used to address a variety of problems such as the study of metal artefacts, bones, pottery and coins [Dushyant Kothari and M N Vahia]

Experimental work on carbon dating

In collaboration with Deccan College and Mumbai University we have initiated work on carbon dating of archaeological samples. We spent one week in

Inter University Centre for Accelerator Physics, New Delhi. Using charcoal samples of Rakhigarhi, we dated the samples to about 2,500 BC. This is consistent with other archaeological evidence. [M N Vahia, Pankaj Kumar and Sundeep Chopra, IUAC Delhi, Abhijeet Bhogale and D C Kothari University of Mumbai, Vasant Shinde, Nilesh Jadhav from Deccan College, Pune and Ranvir Shastri Haryana Department of Archaeology and Museums Haryana,]

Studies in origin of science

We have begun a study to understand the origin of science and scientific temper over the growth of human civilization dividing it into ad hoc, pragmatic and axiomatic period and show how the axiomatic approach is now reaching its limits [M N Vahia]

Organization of International Conference on Oriental Astronomy

We are organizing the 9th International Conference on Oriental Astronomy at IISER Pune in November 2016. Work on this conference includes not only the preparatory work for conference but also a preconference workshop on the subject as well as publication of a Reader on Ancient Indian Astronomy. The work for the proposed conference was initiated in this year [M N Vahia, Nisha Yadav and Aniket Sule]

International Collaborations in Archaeo Astronomy

India and South East Asia share considerable cultural connections. In order to explore the relation between Indian and South East Asian astronomy, Prof. Vahia was invited for a 2 week visit to National Astronomical Research Institute, Chiang Mai, Thailand and to a meeting of South East Asian Astronomical Association on history of astronomy at Krabi, Thailand in November 2015. [Mayank Vahia and Wayne Orchiston, National Astronomical Research Institute of Thailand, Chiang Mai, Thailand]

Indian Astronomy Olympiad programme

Prof. Vahia is the National Coordinator of the Indian Astronomy Olympiad Programme. The International Olympiad in Astronomy and Astrophysics is to be held in Bhubneshwar, India in December 2016. He is heavily involved in planning the programme [Aniket Sule and M N Vahia]

Studies on composition and homogeneities in ancient coins

In our continuing studies of the composition and manufacturing procedures for ancient coins we have analyzed punch mark coins of Magadha

dynasty in the collection of Numismatic Historical and Cultural Research Foundation, Nashik. [Shrikant Janawlekar and M N Vahia]

Astronomical cultures of ancient tribes

Visited Kozhikode, in February 2016, to meet one of the most isolated Indian tribes – the Cholanaikkans, to study their astronomy and other belief systems. [M N Vahia]

Members

Antia H.M., Bhattacharyya S., Ghosh S.K., Gopakumar A., Hanasoge S., Joshi P.S., Kundu A. (till July 17, 2015), Mookerjee B., Narasimha D., Ojha D.K., Puravankara M., Rao A.R., Ray A.K., Singh K.P., Singh T.P., Vahia M.N., Yadav J.S.

Bhagat S.B., D'Costa S.L.A., Dedhia D.K., Hingar M.K., Janawlekar S.B., Kamble N.S., Katoch T.C., Manojkumar T.K., Madhwani P.P., Mirza I.R., Mukerjee K., Naik M.B., Pandya A., Poojari S.S., Rodi A.A., Sandimani P.R., Shah P.B., Shah H., Vishwakarma S.K., Yadav N.

Bagade B.G., Bakalkar C.B., Gharat S.M., Jadhav R.B., Kadam V.B., Koyande J.G., Kurhade V.N., Kutty A.P.K., Meshram G.S., Mhatre V.J., Nikam V.A., Parmar J.V., Pathare D.P., Patil M.H., Pawar D.M., Risbud V.M.

Research Scholars

Kushwaha P. (till July 31 2015), Mallick K. (till April 10, 2015), Ninan J.P., Verma K., Chand V., Banerjee Shreya., Bhattacharya J., Bera S., Mandal S., Tanay S. (till January 19, 2016), Dey S., Kocherlakota P., Paul D., Ambhire S.C., Banerjee Srimanta, Mandal K., Chakrabarty S., Markande S. (till July 13, 2015), Dattaraj Dhuri, S. Abhimanyu, Srishti Tiwari, Lankeswar Dey, Mayank Narang.

Visiting Fellows

Baug T., Haney M., Sairam L. (till October 30, 2015), Guo J., Chandra S., Chakraborty C. (from August 3, 2015), Suman Ghosh (from August 3, 2015), Blesson Mathew (from February 1, 2016), Shabnam Ilyani (from January 8, 2016)

Junior / Senior Research Fellows

Navalkar V., Chauhan J., Navale N. (till April 16, 2015), Yash Bhargava (from September 23, 2015)

Project Staff

Yakub A. (till February, 2016), Ved Y. (till January 15, 2016), Kotak S., Bajpai A. (till August 21, 2015), Rakesh K.A., Rananaware A.R., Sonawane S., Ronit Dwivedi (from March 28, 2016)

Administration

Magnes S. Johny, Shenoy S.

National and International Involvement

H. M. Antia: Chairperson, National Committee of IAU, 2012-2015. *S. Bhattacharyya:* 1. Life member of "Indian Science Congress Association". 2. Member of "Astronomical Society of India". 3. Elected member of "International Astronomical Union". 4. Member of the "The National Academy of Sciences, India". 5. Lead Scientist, Indian "Large Observatory For X-ray Timing (LOFT)" science collaboration team. 6. Member of the "Astrosat Science Working Group". 7. Member of two "Square Kilometre Array (SKA)-India" Science Working Groups. 8. Member of two "Square Kilometre Array (SKA)-India" Executive Council. 9. Member of the Athena X-ray observatory science working group: "SWG 3.3: The End points of stellar evolution". 10. Member of the Thirty Meter Telescope (TMT) International Science Development Team (ISDT): "Time domain science". 11. Member of three "Large Observatory For X-ray Timing (LOFT)" Science Working Groups. 12. Member of Indo-China Cooperation Working Group for X-ray astronomy. *P. S. Joshi:* 1. Referee to Gen Relat and Grav Journal, IJMPD, and others. 2. Reviewer to Math Reviews and for Research Proposals submitted to the Polish and Czech Science Foundations. *D. Narasimha:* Editorial board of JAA. *D. K. Ojha:* 1. D.K. Ojha continued to be a member of Time Allocation Committees of IUCAA and IIA telescopes. Currently serving as Chairperson of IIA-TAC. 2. D.K. Ojha continued to be a member of the Scientific Advisory Committee (SAC) of ARIES, Nainital. 3. D.K. Ojha is a member of the International Science Development Team (Formation of stars and planets) of the Thirty Meter Telescope project. 4. D.K. Ojha continued to be a member of the TIFR Balloon Facility Management Board. *M. Puravankara:* Lifetime member, Astronomical Society of India. *A. K. Ray:* 1. I am serving as a co-Chair of the Scientific Organizing Committee of the International Astronomical Union (IAU) Symposium No. 331, "SN 1987A, 30 years later", to be held in La Reunion Island, France, February 20-24, 2017. 2. I have reviewed proposals for telescope time requests for GMRT Time Allocation Committee as a scientific referee in the area of pulsar astronomy. 3. I have also served as a scientific referee for academic staff at institutions in India for their career advancement reviews. 4. I am taking part in an ongoing basis on the Square Kilometer Array (SKA) Science Working Groups (SWGs) on "Neutron Stars and Pulsars" and "Transients" (two separate but interacting groups under SWG in India). *K. P. Singh:* 1. Member of Editorial Board, Journal of Astrophysics and Astronomy. 2. Member, Council of IUCAA, Pune. 3. Member, Astrosat Time Allocation Committee (ATAC). 4. Member of the TIFR Balloon Facility Management Board, Hyderabad. 5. Member of the Organising Committee of Division D, Commission 44 (Space and High Energy Astrophysics) of the International Astronomical Union (IAU). 6. Project Manager of the Soft X-ray Telescope for Astrosat, and Co-convenor of the Astrosat Science Working group for the Key and Multi-Wave programmes of Astrosat. 7. Manager, Astrosat budget in TIFR. *T. P. Singh:* T. P. Singh was Guest Editor for a Current Science Special Issue on 100 Years of General Relativity (December, 2015). He was a member of the Scientific Organizing Committee for ICGC-2015, IISER, Mohali. He is one of the organizers of the ICTS Program 'Fundamental Problems of Quantum Physics', Nov. 21 – Dec. 10, 2016.

Visits

S. Bhattacharyya: 1. Participation, Indo-China bilateral meeting on X-ray astronomy, IUCAA, Pune, India, March 04, 2016. 2. Visit, University of Amsterdam, Amsterdam, the Netherlands, February 09-12, 2016. 3. Invited participation and Chairing one session, "AEI-ICTS joint workshop on gravitational-wave astronomy", ICTS, Bangalore, India, November 05, 2015. 4. Participation, 3rd Beyond Astrosat meeting, Bangalore, India, 28 July, 2015. *A. Gopakumar*: 1. Albert-Einstein-Institut, Hannover, Germany during 05 July to 11 July 2015. 2. The Institute of Mathematical Sciences (IMSc), 06 March to 09 March 2016. *S. M. Hanasoge*: 1. High Altitude Observatory (Boulder), Argonne National Laboratories (Chicago), New York University (New York), June 4-18 2015. 2. International Astronomical Union (Honolulu, Hawaii), August 6-14, 2015. 3. New York University (Abu Dhabi, UAE), September 5-8, 2015. 4. New York University (Abu Dhabi, UAE), January 12-14, 2016. 5. New York University (Abu Dhabi, UAE), February 15-18, 2016. 6. Institute of Geophysics, ETH Zurich, May 1 – July 28, 2016. 7. IISER Pune, April 29, 2016. *P. S. Joshi*: 1. Visiting Professor at the Winston-Salem State University, NC, USA 18 April to 11 May 2015. 2. Visiting Professor at Osaka City University, Osaka, Japan, Sept 18-30, 2015. 3. Distinguished Scientists Fellowship for Foreign Researchers, Osaka City University, Osaka, Japan, March, 2016. *B. Mookerjee*: 1. Physikalisches Institut, University of Cologne, Germany between 01 to 31 May 2015. 2. University of Kassel, Germany between 10 May to 14 May 2015. *D. K. Ojha*: 1. D.K. Ojha visited the National Astronomical of Japan, Mitaka, Tokyo (Japan) from June 28 to July 2, 2015. 2. D.K. Ojha visited University of Raipur from November 24 to 26, 2015, M. B. Government Post Graduate College, Haldwani (Nainital) from December 11 to 12, 2015. 3. Banaras Hindu University from January 21 to 23, 2016. 4. Anand Engineering College, Agra from February 15 to 19, 2016, and University of Delhi on March 30, 2016. 5. D.K. Ojha visited Institute of Applied Physics, Russian Academy of Sciences, Nizhny Novgorod (Russia) from March 21 to 27, 2016. *M. Purwankara*: Max-Planck Institute for Astronomy, Heidelberg, Germany, visit during the period 17-24 October, 2015, for scientific collaboration. *A. K. Ray*: 1. During November 23-26, 2015 I visited New York University at Abu Dhabi, UAE and gave a Physics seminar on "X-ray and Radio from core collapse supernovae". 2. During November 2-5, 2015 I took part in a Workshop on "Current issues in Cosmology, Astrophysics and High Energy Physics" at Dibrugarh Univ, Assam and gave a plenary talk on "Red and Dead Supergiants". 3. During February- October 2015, professional visit is being undertaken on a sabbatical leave to the Institute of Theory and Computation, Center for Astrophysics, Harvard University. 4. In Feb 2015, I visited the Center for Cosmology and Astro Particle Physics at Ohio State University and gave a seminar on "X-ray and Radio Studies of type IIP Supernovae: what they reveal about the parents". 5. In March 2015, I visited the Dept of Astronomy at Columbia University, New York and gave a seminar on "Red and Dead Supergiants". 6. In March 2015, I visited the American Museum of Natural History, New York and gave a seminar on "Neutral hydrogen cavities as expanding supershells and the role of multiple supernovae: an example in M101". 7. In June 2015, I took part in the Dick McCray Symposium in University of Berne, Switzerland and presented a talk on Supernovae and their red supergiant progenitors. 8. In June 2015, I took part in TMT Science Forum Meeting, Washington DC, and presented a talk at the "Star Formation, MilkyWay and Nearby Galaxies" Workshop on "Supershells: What drives them and what role do they play in galaxies?". 9. In Nov 2014, I have taken part in the Workshop on Square Kilometer Array (SKA) Working Group meeting on Neutron Stars at NCRA, Pune and made a presentation on the future of Radio Transients and Neutron Stars research possible with SKA. 10. During January 18-29, 2016 I gave a talk at the DAA Interaction Meeting, TIFR on: "Globular Clusters as Cradles of Life and Advanced Civilizations". 11. On February 10, 2016 I gave a talk at the Physics Departmental Colloquium, Presidency University, Calcutta on "Globular clusters as possible cradles of life and advanced civilization". 12. During June 15-16, 2016, I took part in a meeting at NCRA, Pune on "Science with the upgraded GMRT". *K. P. Singh*: 1. South African Astronomical Observatory, Cape-town, and Johannesburg University, SA: June 16 - 21, 2015. 2. ISAC, Bengaluru: Several times for various review meetings. 3. SHAR, Sriharikota: Twice in September 2015 for integration of the SXT and the launch of Astrosat. 4. MSSL, Dorking and University of Leicester, UK: October 2015. 5. ISTRAC, Bengaluru: For the first light with SXT, October, 2015. 6. Dibrugarh University, Dibrugarh: November 3 – 5, 2015. 7. IISER, Mohali: November 15 – 20, 2015. 8. CSIO, Chandigarh, November 18, 2015. 9. Punjab University, Chandigarh, November 17, 2015. 10. IUCAA, Pune: IACHEC Meeting, Feb-March 2016. 11. Mata Gujari College, Fatehgarh Sahib, Punjab: March 15, 2016. *M. N. Vahia*: Professor Vahia visited the National Astronomical Research Institute of Thailand in November 2015 and the National Astronomical Observatory of Japan in March 2016. *J. S. Yadav*: 1. ISAC, Bangalore for "Overall CDR of AstroSat at ISAC, Bangalore" during 14-18, April, 2015. 2. ISAC, Bangalore for "AstroSat APMC meeting" at Bangalore during 20-22 May, 2015. 3. ISAC, Bangalore for "Meeting for final clearance of payloads for launch" during May 26-27, 2015. 4. ISAC, Bangalore for "AstroSat satellite level tests" during 30th June- 2nd July, 2015. 5. ISAC, Bangalore for "LAXPC instrument alignment" during 12-16 July, 2015. 6. ISAC, Bangalore for "Mission operation review 1 of AstroSat", during 02-05 August, 2015. 7. ISAC, Bangalore for "Pre shipment Review meeting", during 09-11 August, 2015. 8. Sriharikota for "LAXPC instrument testing at Shar", during 24-26 August, 2015. 9. ISAC, Bangalore for "ISAC Director's AstroSat review meeting", during 08-10 September, 2015. 10. Sriharikota for "AstroSat launch", during 27-28 September, 2015. 11. ISTRAC, Bangalore for "Switching on LAXPC subsystems 1st time", during 1-2 Oct., 2015. 12. ISTRAC, Bangalore for "LAXPC instrument first light", during 18-25 October, 2015. 13. ISTRAC, Bangalore for "LAXPC instrument PV phase 2", during 27-28 November, 2015. 14. Geneva, Switzerland to give invited talk in Texas Symposium; 14-18 December, 2015. 15. ISAC Bangalore for "100 days of AstroSat review" 4-5 January, 2016. 16. Hyderabad for "LAXPC workshop on timing and spectroscopy" 12-14 January, 2016. 17. IUCAA, Pune for "IACHEC international meeting" 28th Feb. - 3rd March, 2016. 18. IIT Kanpur to deliver "the Horizons lecture of Physics society of IIT Kanpur" 13-15 March 2016.

Invited Talks

H. M. Antia

1. Large Scale Flows in the Solar Interior, Asia Pacific Solar Physics Meeting, Seoul National University, South Korea, November 6, 2015
2. LAXPC Calibration in Orbit, Conference on Science with LAXPC/ASTROSAT, Hyderabad, January 13, 2016

Shreya Banerjee

1. Cosmological Constant, Quantum Measurement and The Evolution Of Quantum Universe, ICGC2015, IISER Mohali, Dec. 14-18, 2015; and MG14, University Of Rome, July 12-18, 2015.
2. Classicalization of Inflationary Perturbations Using CSLand MG14, University Of Rome, July 12-18, 2015.
3. Cosmic Hysteresis; MG14, University Of Rome, July 12-18, 2015

4. Explaining Late-time Acceleration in a Model of Fourth Order Gravity; MG14, University Of Rome, July 12-18, 2015.

Sayantani Bera:

A stochastic modification of the Schrodinger-Newton equation, ICGC 2015, IISER Mohali, December 14-18, 2015

Sudip Bhattacharyya:

1. Plenary talk, "ASTROSAT", "The X-Ray Spectral-Timing Revolution" workshop, Lorentz Center, Leiden, the Netherlands, February 03 2016.
2. Invited talk, "Transition pulsars", Neutron Star Workshop 2016, NCRA, Pune, India, January 14, 2016.
3. Invited talk, "Thermonuclear X-ray bursts with ASTROSAT", "Timing & Spectroscopy: Wideband X-Ray Astronomy" Workshop, TIFR Balloon Balloon Facility, Hyderabad, India, January 12-14, 2016.
4. Invited talk, "Thermonuclear X-ray bursts from neutron stars", "Novae and Accreting Binaries: A multi-wavelength study" workshop, CBS, Mumbai, India, December 02-06, 2015.
5. Invited talk, "Relativistic spectral emission lines from accreting neutron stars and black holes", "Novae and Accreting Binaries: A Multi-wavelength study" workshop, CBS, Mumbai, India, December 02-06, 2015.
6. Invited talk, CZTI mini workshop, "Neutron star science using hard X-rays", IUCAA, Pune, India, November 09, 2015.
7. Plenary talk, "Thermonuclear flame propagation on neutron stars", "International Workshop on Advances in Astroparticle Physics and Cosmology", SINP, Kolkata, India, October 15-17, 2015.
8. Invited colloquium, "Study of black holes and neutron stars in the ASTROSAT era", IISER Kolkata, India, May 15, 2015.

Suman Ghosh:

1. Creation of spin 1/2 particles and renormalization of stress tensor in various cosmological scenarios Field Theoretic Aspects of Gravity (FTAG-2016), S.N. Bose National Centre for Basic Sciences, Kolkata, 22-26 February, 2016.
2. On fermion creation and adiabatic regularisation in FLRW background 8th International Conference on Gravitation and Cosmology (ICGC), Indian Institute of Science Education and Research Mohali (IISERM), 14-18, December, 2015.

A. Gopakumar:

1. Post-Newtonian Analysis of Processing Convention, Session BN6, The Fourteenth Marcel Grossmann Meeting, Rome, Italy, July 12-18, 2015
2. Sub-micro Hertz GW Astronomy, Neutron Stars: A Pathfinder Workshop, 14--15 January, 2016, NCRA-TIFR, Pune
3. GW waveform modeling, Indo-Korean Gravitational Wave Meeting, 28--29 January, 2016, IUCAA, Pune
4. A transient gravitational wave event from a binary black hole merger, 07 March, 2016, IMSc, Chennai

S. M. Hanasoge:

1. Center for Space Science, New York University at Abu Dhabi: "Seismic Determination of Weak Convective Velocities in the Sun and Implications", February 17, 2016
2. BUKS conference in Brussels, Belgium: "Interpretation of Seismic Wave Measurements in the Solar Atmosphere" June 13 - 17, 2016
3. Manfred Schuessler retirement conference in Goettingen, Germany, August 9 - 12, 2016
4. IISER Pune, Department of Earth and Climate Sciences, "Interpretation of noise cross correlations", April 29, 2016

P. S. Joshi:

1. "The Final Fate of Massive Collapsing Stars in Einstein Theory of Gravity", Invited Plenary Talk at the Japan Physical Society Meeting, Osaka, Japan, 26 September, 2015.
2. 'Topology in General Relativity', a Course of three lectures, given at the Topology Seminar, University of North Carolina, Charlotte, NC, USA, April 18, 2015.
3. 'Gravitational Collapse and Black Holes', Colloquium given at the Univ of North Carolina, Greensboro, Dept of Mathematics and Statistics, April 20, 2015.
4. 'Can I see a Black Hole?' Colloquium given at the Winston-Salem State University, NC, USA, April 27, 2015.
5. 'Outstanding problems in General Relativity Today', Winston-Salem State University, USA, April 30, 2015.
6. 'Can I see a Black Hole?' Colloquium given at the Elon University, NC, USA, May 7, 2015.
7. 'Black Holes in General Relativity', discussion seminar at the Wake Forest University, USA, May 8, 2015.
8. 'Can I see a Black Hole? -Life and Death of Massive Collapsing Stars', CBS-DAE, Mumbai University, Mumbai, 11 August, 2015.
8. 'Key Concepts in Education', at the 'Vichar-Satra', Shreyas Foundation, Ahmedabad, 5 Jan 2016.
9. 'Can I see a Black Hole?', Invited Colloquium at the Physical Research Laboratory, Ahmedabad, 6 Jan 2016.
10. 'Event Horizon and Apparent Horizon Formation in Gravitational Collapse', Invited Theoretical Physics Seminar at the Physical Research Laboratory, Ahmedabad, 7 Jan 2016.
11. 'Cosmology in Indian Traditions', Invited Plenary Talk at the International Conference on 'Science and Jain Philosophy', IIT, Mumbai, 9 Jan, 2016.
12. 'Can I See a Black Hole?', Inspire Program, KIIT, Bhubaneswar, 23 Jan, 2016.
13. 'Recent developments on Gravitational Collapse Final States', Dept of Theoretical Physics, TIFR, 3 September, 2016.

D. K. Ojha:

1. Delivered invited talk on "Feedback from massive stars on smaller scales and modes of triggered star formation in molecular clouds", at NAOJ, Mitaka (Tokyo), Japan on July 30, 2015.
2. Delivered colloquium on "An Overview of Infrared Astronomy" at University of Raipur on November 26, 2015.
3. Delivered invited talk on "Star Formation in the Galaxy: An Observational Perspective" at Centre for Excellence in Basic Sciences, Mumbai on December 5, 2016.
4. Delivered colloquium on "The Universe at Infrared Wavelengths" at Motiram Baburam Government Post Graduate College, Haldwani (Nainital) on December 12, 2015.
5. Delivered invited talk on "The Universe at Infrared Wavelengths" at Banaras Hindu University on January 23, 2016.
6. Delivered invited talk on "Is the IMF of Stellar Clusters Universal?" at Anand Engineering College, Agra on February 16, 2016.
7. Delivered Colloquium at the Institute of Applied Physics, Russian Academy of Sciences, Nizhny Novgorod (Russia) on "Study of Galactic Structure using Ultra-violet Surveys" on March 24, 2016.
8. Delivered invited talk on "Star Formation in the Galaxy: An Observational Perspective" at University of Delhi on March 30, 2016.

Joe Philip Ninan:

1. Talk on 'Episodic high velocity outflows from an outbursting YSO: V899 Mon', Institute of Applied Physics, Russian Academy of Sciences, Nizhny Novgorod, Russia, (24th March, 2016)
2. 'Episodic accretion outbursts in protoplanetary discs and outflows', IISc Bangalore, Astro Seminar Talk, (10th November, 2015)

3. CLOUDY Workshop, IUCAA, Pune, India (September, 2015)
4. SALT Science 2015 Conference, South Africa. Poster on "SALT-HRS results showing structures in outflows during outburst" on June, 2015.

M. Puravankara:

1. Manoj Puravankara, "Infrared spectroscopy of protostars with Spitzer & Herschel: probing the earliest stages of star formation", Colloquium at NCRA, Pune, 20 April, 2015
2. Manoj Puravankara, "Evolution of mass accretion/ejection in protostars" invited talk at the Institute of Theoretical Astrophysics (ITA), University of Heidelberg, Heidelberg, 22 October, 2015

A. R. Rao:

1. Speaker: A R Rao, Title: Black Hole Binaries, Occasion: "Novae and accreting binaries: a multi-wavelength study" at UM-DAE-CBS (Mumbai), Place/Date: CBS, Mumbai, 2-6 December, 2015
2. Speaker: A R Rao, Title: X-ray burst science with Astrosat , Occasion: "40 years of X-ray bursts: Extreme explosions in dense environments", Place/Date: 17-19 June 2015 ESA/ESAC Madrid, Spain
3. Speaker: A R Rao, Title: Status of Astrosat , Occasion: Astrosat Workshop, Place/Date: 15 June 2015 University of Southampton
4. Speaker: A R Rao, Title: Hard X-ray spectro-polarimetry of Black Hole sources, Occasion: Recent Trends in the Study of Compact Objects (RETICO-II), Place/Date: May 6-8, 2015, ARIES, Nainital, India

K. P. Singh:

1. Performance of Soft X-ray Telescope onboard Astrosat, at the 11th meeting for International Astronomical Consortium for High Energy Calibration, (IACHEC 2016), IUCAA, Pune, Feb 29 - Mar 3, 2016.
2. AstroSat and AGN, at the workshop on "Jet Triggering Mechanism in Black Hole Sources" at TIFR, Mumbai, Jan 20 - 23, 2016
3. Astrosat and SXT, at Department of Astronomy and Astrophysics annual Interaction Meeting, TIFR, Mumbai, Jan 18-19, 2016
4. First results from SXT and joint SXT-LAXPC observations, at the Workshop on "Timing and Spectroscopy: Wide Band X-ray Astronomy", National Balloon Facility, Hyderabad, 12-14 January, 2016.
5. Soft X-ray imaging Telescope (SXT) onboard AstroSat, at ISAC, Bengaluru, at the 100th day of AstroSat in orbit, Jan. 5, 2016
6. Optics for X-ray Telescopes, at the Central Scientific Instruments Organisation, Chandigarh, November 19, 2015.
7. AstroSat - India's First Multi-Wavelength Astronomy Satellite, a Colloquium at the Physics Department, Punjab University, Chandigarh, November 18, 2015.
8. AstroSat - India's First Multi-Wavelength Astronomy Satellite, a Public Lecture at IISER, Mohali, November 17, 2015.
9. AstroSat - India's First Astronomy Satellite for simultaneous observations in multi-wave bands, at the High Energy Symposium at the Dibrugarh University, November 4, 2015.

10. AstroSat - India's First Multi-Wavelength Astronomy Satellite, Public Lecture on Founder's Day, HB Auditorium, TIFR, October 30, 2015.
11. ASTROSAT - India's Multi-Wavelength Astronomy Satellite, Mullard Space Science Lab, University College London, October 2015.
12. ASTROSAT - India's Multi-Wavelength Astronomy Satellite, Symposium on High Energy Astronomy in South Africa, Johannesburg University, South Africa, June 19, 2015
13. ASTROSAT - Science Programs, South African Astronomy Observatory, Cape-town, South Africa, June 17, 2015.

T. P. Singh:

1. 100 Years of General Relativity, Current Trends in Physics, BHU Varanasi, January, 2016.
2. Models of wave-function collapse, underlying theories, and experimental tests International School and Conference on Quantum Information, IOP Bhubaneswar, February, 2016.
3. Ricci identities, torsion, and the Dirac equation, ICGC2015, IISER Mohali, Dec. 14-18, 2015

M. N. Vabia:

1. Gave an invited talk on Origin and growth of astronomy in India at National Astronomical Research Institute of Thailand in November 2015.
2. Gave an invited talk Ancient Astronomy, Myths and Architecture in Indian Context at the 5th International Meeting on History of Astronomy hosted by the National Astronomical Observatory of Japan in March 2016.

J. S. Yadav:

1. "Large Area X-ray Proportional Counter (LAXPC) Payload" Standing Review committee meeting 27th May, 2015.
2. "Large Area X-ray Proportional Counter (LAXPC) instrument on board AstroSat" Aset colloquium at TIFR, 29th May 2015.
3. "LAXPC instrument and study of black holes" Astronomy talk at Sardar Patel Institute of Technology, Andheri, Mumbai, 11 September 2015.
4. "AstroSat; India's first Astronomy satellite" Physics Department, IIT Kanpur, 20 November, 2015.
5. "Enigmatic micro quasar GRS 1915+105" invited talk in workshop on "Novae and accreting binaries" 2nd December, 2015, Mumbai University.
6. "Large Area X-ray Proportional Counter (LAXPC) instrument on board AstroSat" invited talk in Texas 28th Symposium held at Geneva, Switzerland, 14-18 December, 2015.
7. "LAXPC performance in orbit and initial science results" in Review of 100 days-orbit operations of AstroSat", ISAC, Bangalore, 5th January, 2016.
8. "LAXPC performance in orbit and first science results" LAXPC workshop on timing and spectroscopy, Hyderabad, 12-14 January, 2016.
9. "X-ray astronomy with LAXPC instrument" in DAIM, TIFR, 18th January, 2016.
10. "Black hole binaries" International conference on Jet Triggering mechanism in black hole sources, at TIFR, 20th Januray, 2016.
11. "Large Area X-ray Proportional Counter (LAXPC) : Calibration and performance" in 11th IACHEC international conference at IUCAA, Pune, 29th February- 3rd March, 2016.

Conferences Organized by the Department

- 1) South East Asian Astronomy Association meeting on History of Astronomy, November 2015, Thailand
- 2) Advances in the Seismology of the Sun and Stars, December 7-11 2015, TIFR Mumbai (funded by the Max Planck Society, Max-Planck Institute for Solar System Research and the Indo-US Science and Technology Forum)

- 3) Workshop on “TIMING AND SPECTROSCOPY: WIDEBAND X-RAY ASTRONOMY” at TIFR Balloon Facility, Hyderabad, January 12-14, 2016. About seventy Indian and foreign scientists participated in this workshop.
- 4) DAA Annual Interaction Meeting (DAIM-2016), Mumbai, January 18 – 19, 2016.
The second edition of the DAIM-2016 was held during 18 and 19 January 2016. It was a two day long interaction meeting and few academic members / postdocs / senior PhD students made brief presentations about their on-going research programs to the wider audience of the department. Moreover, detailed poster presentations were an integral part of this meeting. Additionally, a couple of faculty members from other institutions were invited to participate in DAIM-2016.
- 5) Jet Triggering Mechanisms in Black Hole Sources, Place: TIFR, Mumbai, January 20 – 23, 2016.
Relativistic jets are ubiquitous in black hole sources at diverse settings: X-ray binaries, Active Galactic Nuclei and Gamma-ray bursts. The exact jet launching mechanism, however, has remained un-understood. The workshop attempted an in-depth study of the jet triggering mechanisms in black hole sources by bringing together several experts in this field. The following topics were discussed in detail: Observation of superluminal jet emission in Galactic black hole sources, Theoretical understanding of the last mile in accretion onto black holes, Connection between accretion disks and jets in blazars, Quasar/microquasar comparison of disk-jet properties, Jet triggering in gamma-ray bursts.

Non-DAE Research Projects

S. M. Hanasoge:

1. Shell Consultancy Project,
2. Indo-US Science and Technology Forum conference grant
3. Early Career Award, by the SERB
4. Ramanujan Fellowship, awarded by SERB

D. K. Ojha:

"Investigation of the distribution of various gas components (ionized, neutral atomic and molecular) in star-forming complexes", DST-RFBR Indo-Russian Joint Research Programme (Start date: May 2015; Duration: 24 months).

K. P. Singh:

PIs: K.P. Singh and D. Buckley (SAAO, Capetown, RSA). Multi-Wavelength Studies of Accretion Phenomena with ASTROSAT and SALT (South African Large Telescope). Department of Science & Technology, Govt. of India and National Research foundation, Republic of South Africa. Duration: 3 years.

T. P. Singh:

Hendrik Ulbricht (PI, Southampton), Angelo Bassi (Trieste) and T. P. Singh, Experimental and theoretical exploration of fundamental limits of quantum mechanics, John Templeton Foundation, 2013-2016



Department of Biological Sciences

Parasite Biology

Plasmodium falciparum P2 (PfP2) interacts with red blood cells

PfP2, an acidic ribosomal protein of *P. falciparum*, performs novel extra-ribosomal functions. We had shown earlier that at the onset of cell division in the erythrocytic stages, *Plasmodium* P2 translocates and resides on the red blood cell (RBC) surface as a homo-tetramer. Through incubation of RBCs with PfP2, it was observed that PfP2 protein binds to RBCs. A closely related P2 protein from *Toxoplasma gondii* did not exhibit this interaction, demonstrating the specificity of PfP2 and RBC binding. The PfP2 interaction with RBC is perturbed by trypsin, but not proteinase K or neuraminidase. These data indicate possible anchoring of the protein on RBCs using specific protein moieties that are sensitive to trypsin. Our group is also investigating the immune responses in patients from Mumbai and Orissa [Disha Sengupta, Aditya Patra, Mandar Patgaonkar, S. Pathak and S. Sharma in collaboration with R.V. Hosur]

Circumsporozoite protein structure

The circumsporozoite protein (CSP) is the major surface protein of the infective sporozoite stage of the malaria parasite. Despite over three decades of study of this protein, the structure and functions of the CSP remains elusive. Here we present the results of Single Molecule Atomic Force Microscope (SM-AFM) studies on the repeat region (CSP_{rep}) and the nearly full-length region (CSP Δ HP) recombinant protein constructs of *Plasmodium falciparum* CSP, to understand the folding-unfolding properties of CSP protein. The results reveal that CSP_{rep} peptide molecules exist as a vastly heterogeneous population. Half the molecules needed virtually no force for unfolding, while the remaining 50% were spread over weakly folded domains requiring 73 \pm 35 pN to unfold. SM-AFM studies of CSP Δ HP showed that it contained three distinct domains. The contour length data indicated that the protein exists in two conformations. It is speculated that these could be a) an elongated rod-like structure anchored at the C-terminus and b) close-looped bent structure, where the N and C terminals of the CSP protein lie in close proximity to each other, while the repeat region acts as an exposed loop. The elongated conformation may help the sporozoite to interact with the host cell receptors, while the close-looped conformation may protect the receptor binding domains, allowing the diverse repeat

domains to evade the host immune response [Aditya Patra, S. Sharma in collaboration with ASR Koti]

Effect of mild malaria in juvenile mice

A single episode of mild malaria in an adult mouse causes specific behavioural changes. Using a self-resolving murine mild malaria model, we show that a single *Plasmodium chabaudi adami* infection in adult mice causes effects on neurogenesis in the brain. We have earlier reported the changes in the cytokine levels. During the last years a large number of behavioural assays were carried out, and upon analysis the results revealed selective deficits in social and anxiety-like behaviors, with no change observed in locomotor, cognitive, and depression-like behaviors. The changes were transient and returned to baseline at recovery. Collectively, these findings indicate that even a single episode of mild malaria results in alterations of the brain cytokine profile, causes specific behavioral dysfunction, is accompanied by hippocampal microglial activation and redistribution, and a definitive, but transient, suppression of adult hippocampal neurogenesis [Suman K Guha, Ishita Sarkar, Suhasini Yellai, M. Patgaonkar, S. Pathak and S. Sharma; in collaboration with Ankit Sood and V. Vaidya]

Glutathione peroxidase like thioredoxin peroxidase of *Plasmodium*

The apicoplast, an endosymbiotic organelle in *Plasmodium falciparum*, is dependent on nuclear-encoded proteins for its function. These proteins contain signal and transit peptides and are trafficked via a pathway that traverses the ER, but not the Golgi. We have previously shown that glutathione peroxidase-like thioredoxin peroxidase (PfTP_{XGI}) is trafficked to the apicoplast through an unusual ER-Golgi route. In this report, inhibitors of the vesicular trafficking pathway indicate that trafficking of PfTP_{XGI} proceeds through vesicles. In contrast, these inhibitors do not affect the trafficking of classical apicoplast-localized protein, Acyl Carrier Protein (ACP), suggesting that, contrary to current models, vesicles do not play a role in classical apicoplast protein targeting. Further, we show that PfTP_{XGI} is localized to the outermost membrane of the apicoplast, suggesting that the protein is trafficked by its insertion in vesicle membranes. Our data show that multiple protein trafficking pathways exist in the parasite for the organellar localization of proteins. The vesicular trafficking pathway in

Plasmodium falciparum appears to be specialized for targeting not only secretory proteins, but also membrane proteins such as PfP₁₉GLI. [Rahul Chaudhury, S. Sharma in collaboration with Prof. Swati Patankar at IITB]

Biology of Host-Parasite Interactions

Understanding the molecular machinery involved in invasion of host system by pathogens invariably lead to identification of critical molecules blockade of whose function can abrogate the invasion process thereby resolving the infection. Antibodies that form the basis for immunity invariably bring about such functional neutralization. Earlier work from my lab has shown the unusual presence of a glycolytic enzyme, enolase on the surface of all invasive stages of the *Plasmodium*. It is also demonstrated that polyclonal anti-recombinant *P.falciparum* enolase (rPfeno) antibodies block the invasion of RBCs by merozoites and mosquito gut wall invasion by ookinetes (Marcelo et al from Johns Hopkins). This year, we have focused on identification of key structural domains of the enolase that are involved in host receptor interactions.

i) EWGWS Insert domain is involved in the recognition of peritrophic matrix proteins in mosquito mid-gut

Traversal of midgut wall by *Plasmodium* spp ookinete requires crossing the peritrophic matrix and epithelial cell linings in insect gut. We recently demonstrated that enolase on the surface of ookinete may be involved in recognizing matrix proteins, an essential step in invasion. Several peritrophic matrix proteins contain a protein-protein interaction domain PWWP (e.g. perlacan, laminin, peritrophin, spacran etc.). Investigation of the binding of PWWP domain containing peptides with WT-rPfeno and Δ^5 -rPfeno (lacking a parasite specific insert EWGWS) indicated that EWGWS is an essential element for such binding. Thus, EWGWS domain of enolase on ookinete surface, if blocked by specific antibodies, could result in transmission blockade of the *Plasmodia* through the vector [Debanjan Mukherjee and Gotam K. Jarori in collaboration with Pushpa Mishra, Mamata Joshi and R V Hosur]

ii) Merozoite invasion neutralizing antibodies are directed against EWGWS epitope of Pfeno

Our past observations showed that the anti-rPfeno antibodies are protective against malaria. However, Pfeno is highly homologous to host enolases and hence use of full Pfeno molecule for immunization could create auto-immune disorders. One of the unique structural element in Pfeno is an insert sequence EWGWS. In order to test whether this

domain is responsible for the parasite specific moonlighting functions of enolase, we made a number of monoclonal antibodies directed against EWGWS and tested them for their ability to block the invasion of RBCs with merozoites. Results showed almost (>95%) complete inhibition of parasite growth at ~100 ug/ml level of antibodies. These experiments have now been confirmed in another lab. Further, the effectiveness of these antibodies has been tested against multiple strains of *P. falciparum* and results indicate a strain independent growth inhibitory activity. [Sneha Dutta and Gotam K. Jarori; D. Sahal, ICGB, New Delhi]

iii) Understanding the biochemical functions of EWGWS in Pfeno

Site directed mutagenesis approach is being used to examine the effect of replacement of two Tryptophan residues with other aminoacids. We have made following variants of EWGWS in Pfeno viz. W105,107A; W105,107K and W105A/W107E. Kinetic and structural characterization of these variants indicated that the replacement of Trp residues resulted in dissociation of dimers in to monomers with a substantial decrease in activity (<5% of WT) and modest rise in Km. Interestingly, stabilization of subunit-subunit interface in GST-tagged form of these variants, restored substantial fraction of the enzymatic activity. [Anasuya Moitra, Sneha Dutta and Gotam K Jarori]

iv) Search for the identification of receptor(s) for Pfeno on human-RBC surface

Inhibition of merozoite invasion by anti-rPfeno antibodies and surface presence of Pfeno suggested that there must be a specific receptor for parasite enolase on HRBCs. To test this, we use multiple experimental protocols viz a) incubate rPfeno with hRBC ghost and analyze on SDS-Page for bound rPfeno if any; b) Separate hRBC ghost proteins on SDS-PAGE, blot it on a nylon membrane and overlay it with rPfeno (or its variants) and probe with specific antibody. Results so far are quite promising and suggest that there could be two proteins with MW~63 and 39 kDa that could be the rPfeno receptors. More definitive identification efforts are in progress. [Reena Verma and Gotam Jarori]

v) Purification and sequencing of Growth Inhibitory monoclonal antibodies

We are purifying mAbs from three different hybridomas. These will be used for protein sequencing as well as for passive immunization experiments. We are also getting mRNA of mAbs sequenced. [Ch. Balaji and Gotam K. Jarori]

Genomes and Physiology

Mechanism of Genome Dynamics and Cellular Adaptations

1. Replication restart critically depends on ATR signaling in mammalian nuclei

In this project, we demonstrated that hydroxyl urea (HU) mediated replication stress recovery in mammalian cells requires active ATR mediated activation of WIP1 phosphatase which removes active marks of ATR kinase thereby attenuating ATR signaling. ATR-inhibition (ATRi) leads to failure of cellular recovery following replication stress triggering fork collapses. ATRi phenotypes can be phenocopied by WIP1 RNAi or WIP1i treated cells suggesting the role of WIP1 phosphatase in regulating ATR signaling. In a parallel project we also showed that BRCA2^{-/-} cells exhibit hyperproliferation due to triggering of new replication origins arising from lowered pChk1 response [Debadrita Bhattacharya, Disha Hiregange, Sukrit Mahajan & BJRao]

2. Cellular and tissue homeostasis defects in *Drosophila* carrying atm or rad51 null mutations

Whole animal null mutants of atm or rad51 exhibit several tissue specific developmental defects, both leading to cell-death as well as accompanying adaptive compensatory cellular proliferations. atm and rad51 mutants exhibit two distinct adaptive responses, both leading to cellular proliferation in the backdrop of cellular death. In the latter, JNK acts as cell protective, cellular proliferative trigger whereas the same leads to cell death function in the former. Interestingly, rad51 mutants show activation of dronc that acts upstream of DNA-damage Response (DDR) via ATM that in turn leads to JNK mediated cellular proliferation [Chaitali Khan, Sonia Ray, Naini Chakraborty, Champakali Ayyub & BJRao]

3. Computational analyses of chromosomal organization during eukaryotic evolution

In this project we computationally modeled interphase chromosome spatial arrangements in non-random spatial territories referred to as chromosome territories (CT). Our method accurately predicted non-random arrangements of CTs. In a transcriptome study involving time-series cellular samples during DDR, we observed that spatially dynamic CTs contribute insignificantly in the coding transcriptome changes whereas the trend is reversed for non-coding transcriptome. Non-dynamic CTS contribute significantly in the

DDR transcriptome. We hypothesize that these results help us rationalize why select CTs exhibit dynamic excursions during DDR cycles [Sarosh Fatakia, Ishita Mehta (DAE-MU-CBS) & BJRao]

4. Mechanism of nuclear PARP-1 action in mammalian cells

In this project, we are studying Human foreskin fibroblast cells (SV-40 transformed): GMU6 (PARP +ve cell lines); GM-Sip (Stable PARP-1 knockout cell lines); and GMRSip (PARP-1 replenished cell lines). All of these cell lines are grown under hygromycin selection. We are testing the mechanistic basis of how PARP-1 knockout cells adapt to survive the loss of such crucial cellular regulator as PARP-1, the most abundant NAD⁺ requiring nuclear enzyme. Immunostaining showed that nucleolin punctas in GM-Sip cells (PARP^{-/-}) increase significantly as compared to that of GM-U6 cells (PARP control) and the puncta numbers revert back to normal level when PARP-1 restored in the mutant cells (GM-Rsip). We confirmed the same, by an immunoblot analyses for nucleolin protein and Q-PCR for nucleolin RNA. As expected of nucleolin upregulation, an anti-apoptotic regulator, we detected reduced apoptotic response during H₂O₂ stress induced oxidative stress in PARP^{-/-} cells compared to the control cells. However, PARP^{-/-} cells did exhibit delayed DNA repair as revealed by higher steady-state level of ss-DNA strand breaks. When we analyzed P-Chk1, it was found that PARP^{-/-} cells seem to avoid check-point control by down regulating the checkpoint kinase. We are now assessing detailed mechanistic angles to understand the nature of adaptive state PARP^{-/-} cells have reached during genotoxic stress responses. [Soumajit Saha, Ishita Mehta (DAE-MU-CBS), Dr. Girish Shah (CHUL, Quebec, Canada,) & BJRao]

5. Circadian regulation of carbon concentrating mechanism (CCM) and photorespiration (PR) genes expression in *Chlamydomonas reinhardtii* cells

We discovered that low inorganic carbon (C_i) and light serve as two independent triggers in triggering photorespiration (PR) and CCM responses, in parallel. Interestingly, these two triggers combined gives rise to circadian rhythmic behavior of PR and CCM gene transcript production, where some of the genes start expressing even in dark. Experiments involving “free-running regimes” reveal that PR and CCM transcripts are not under circadian clock control, but are subjected to a

cellular programme. The nature of such a programme is unclear. Future experiments are directed towards understanding the physiological

nature of such programme [Srikanth Tirumani & BJRao]

Distant control of insulin secretion and signaling regulated by Sir2/Sirt1

Signaling mediated by hormones is central in coupling organismal nutrient status with maintenance of organismal physiology and an aberration has been associated with several diseases. While local nutrient sensing within the insulinogenic tissue is well studied, distant mechanisms that communicate the organismal nutrient status to regulate metabolic-endocrine links are less understood. Earlier we have indicated a possible role for Sir2/Sirt1 in distant tissues in controlling insulin production and secretion. Insulin secretion has a profound effect on all the

tissues in the body by way regulating insulin signaling that determines glucose uptake/utilization. Clinical reports correlate dysfunctional central metabolic sensing by liver and brain with metabolic maladaptation in the intestine. In this context, our results indicate that master metabolic sensors, in central metabolic tissues employ varied mechanisms to communicate with peripheral organs, revealing an inherent diversity in the etiology of metabolic-syndrome-related disorders.[Kushal Banerjee, Champakali Ayyub]

Sirt4 is an evolutionarily conserved regulator of energy homeostasis

Mitochondrial oxidative phosphorylation is vital for regulating cellular and organismal energetics. The ability of mitochondria to couple metabolic inputs with ATP production and transport is needed to drive almost all the cellular processes. We have previously shown that mammalian Sirt4 controls cellular ATP via its interaction with ANT2. This finding has been a breakthrough and has generated several leads that we are currently pursuing. While

we are actively pursuing the mechanisms, we have addressed the importance of SIRT4 dependent energy homeostasis across tissues and across species. Importantly, we have found that the ability of SIRT4 to regulate ATP is evolutionarily conserved in flies. Moreover we have results to indicate that this determines organismal survival during starvation.[Sweta Parik and Champakali Ayyub]

Interplay between CNS and peripheral tissues

In collaboration with Prof. Vidita Vaidya, we have begun to investigate the complex interplay between metabolism and neuronal functions. Specifically, we have found that early life psychological stress leads to long-lasting metabolic alterations in peripheral tissues. Importantly, using a transient post-natal maternal separation model, we have found that

these animal show dyslipidemia, altered IGF-1 levels and perturbed muscle mitochondrial parameters that is persistent upto 4-8 months of age. This finding has immense clinical implications since metabolic syndromes and depression have been correlatively associated in the clinics. [Shreya Ghosh in collaboration with Prof. Vaidya]

Cell Biology

The establishment and maintenance of epithelial architecture depends upon cellular features such as cell morphology, cell polarity and cell adhesion. Our aim is to understand the mechanisms that regulate the acquisition and maintenance of these cellular features in the epidermis, the outer epithelial component of the skin. We also investigate the effect of loss of cell polarity and perturbations in cell size on tissue homeostasis. To achieve our aims, we use zebrafish embryonic and larval epidermis as the model, which is a simple bilayered epithelium having outer periderm and inner basal epidermis. Our approaches involve a) loss of function analysis by combination of forward

and reverse genetics, b) confocal microscopy at the cellular level, c) identification of downstream targets by transcriptome analysis and d) genetic interaction studies. In the recent past, we have shown that the function of a molecular motor, Myosin Vb is important for the maintenance of plasma membrane homeostasis, cell size regulation and tissue homeostasis (Sonal et al 2014). Our recent analysis suggests that, the link between cell size and cell proliferation is not specific to the myosin Vb mutant. In fact, any genetic condition or reagent, that affects plasma membrane homeostasis and cell-size, has an effect on cell-proliferation (Phatak et al, in preparation). We have

also been able to show that the epidermis retains the cells that are rounded up due to excessive endocytosis in myosin Vb mutant. This retention of rounded-up cells requires function of a transcription factor- grainyhead like 3, which executes its effect on cell adhesion and cell retention by modulating E-cadherin levels at the membrane. We propose that the prevention of cell extrusion is important to achieve the tissue homeostasis [Mandar Phatak, Shruti Kulkarni, Nazma Anjum]

In humans, mutations in myosin Vb genes are associated with a dreadful enteropathy called microvillus inclusion disease (MVID), characterised by lethal, intractable diarrhoea in newborn babies. The enterocytes in these patients exhibit microvillar atrophy and microvillar inclusion bodies in the cytoplasm. We have been able to show that the zebrafish myosin Vb mutant exhibits cellular attributes of the MVID disease and is a good animal model to study this enteropathy [Clyde Pinto]

Epithelia exhibit apical projections such as microvilli, microridges, stereocilia, which are important for secretion, absorption, mechanosensation, etc. However, it is not clear whether their formation is regulated by the pathways that establish and maintain the apical basal polarity. The microridges are present in several non-keratinised epithelial cells in vertebrates, including mammals and their presence is thought to be essential for mucous retention. Our analyses, suggest that that in the peridermal cells, function of Lgl, along with nonmuscle myosin II, is important to regulate elongation of microridges. aPKC controls the microridge elongation by maintaining low levels of Lgl at the apical domain. Thus, our analyses indicate that the basolateral regulator Lgl also has a function at the apical domain and its levels are stringently controlled by aPKC. We are currently analyzing variation in the ridge patterns along the zebrafish larval body and investigating how such variations are generated. Besides, we are analysing the functions of actin regulators in ridge formation and maintenance [Renuka Raman, Clyde Pinto, Ameya Khandekar]

Molecular Mechanisms in Cell Division

Ordered progression through the cell cycle requires sequential execution of DNA duplication, nuclear separation and cytokinesis. A contractile actomyosin ring which is made up of about 150 different proteins drives cytokinesis in most eukaryotes. Extensive research in various systems has uncovered important and conserved molecules that execute this event. We are interested in understanding how these proteins come together to form a contractile nanomachine that powers cell division and how this event is co-ordinated in space and time.[Mithilesh Mishra]

Structure and constriction mechanism of the actomyosin ring

Cytokinesis is orchestrated by a contractile actomyosin ring, but its structure and mechanism remain elusive. We used electron cryotomography to visualize the 3D structure of the ring in frozen-hydrated dividing yeast cells. Bundles of actin filaments running parallel to one another were seen “saddling” the septum, while no direct contact between actin and the membrane was observed, refuting the notion that F- actin is connected to the membrane at its plus end, or at nodes. The mechanistic implications of these findings were explored by 3D coarse-grained simulations involving individual molecules. After testing various actomyosin configurations, the model that best agreed with our and other published

experimental data included both bipolar and membrane-attached unipolar myosins that are distributed individually instead of concentrated in nodes. The results specifically suggest that the myosin isoform Myp2p takes on a bipolar configuration that drives constriction and recapitulates the distances between actin and the membrane observed by ECT, while Myo2p adopts a unipolar configuration that provides an essential connection between the ring and the membrane, and maintains membrane smoothness.

Involvement of nuclear-cytoplasmic transport in promoting robustness of cytokinesis

In a genome wide unbiased reverse genetic screen we have identified 19 genes required for proper coordination of completion of cytokinesis with other cell cycle events. Among these is Imp1, a member of the alpha importin adapter family involved in nuclear transport. Interestingly, we found that imp1 shows a strong synthetic interaction with cytokinesis mutants in particular with SIN mutants that are defective in maintenance and/or constriction of the contractile actomyosin ring. Imp1Δ cells also show a pronounced defect in the proposed “cytokinetic checkpoint” signalling. Mildly perturbing the actomyosin ring leads to rapid accumulation of nuclei and severe defect in completion of septum assembly in contrast to wild type cells that undergo a delayed but successful

cytokinesis. As the checkpoint signalling is shown to be dependent on SIN (septum initiation network) signalling this suggests *imp1*'s involvement in triggering and/or potentiating SIN signalling. Preliminary results indicate *imp1Δ* cells fail to potentiate SIN signalling as evidenced by

asymmetric localisation of Cdc7-GFP under these conditions. Together these data point towards an interesting role of an importin alpha and possibly nuclear-cytoplasmic transport in orchestrating cytokinesis.

Neural and Developmental Biology

The cortical hem is positioned by an interaction of transcription factors Lhx2, Foxg1, and Pax6

Transcription factors Foxg1, Lhx2, and Pax6 regulate critical early steps in patterning the dorsal telencephalon into discrete domains comprising the cortical neuroepithelium flanked by the hem and the antihem. The hem functions as a secondary organizer, responsible for inducing the hippocampus in adjacent cortical neuroepithelium. Based on the individual null mutant phenotypes of *Foxg1*, *Lhx2*, and *Pax6*, we hypothesized that these genes interact to pattern the cortical primordium. Here, we show that Pax6 functions to delimit the extent of "hem competent" neuroepithelium, but the additional loss of Lhx2 is required for ectopic hem to form. We also show that *Lhx2* is regulated by Foxg1. In the *Foxg1* null background, the presence of Lhx2 is sufficient to restrict the hem, and hippocampal markers appear selectively in *Lhx2* expressing adjacent regions. Therefore, these genes function as part of a synergistic network to position the hem and organize the cortical primordium. [(Geeta Godbole, Ashwin Shetty, Achira Roy, Shubha Tole] Collaborators: Bin Chen (University of California Santa Cruz), Goichi Miyoshi (NYU Neuroscience Institute), Gordon Fishell (NYU Neuroscience Institute).

Lhx2 interacts with the NuRD complex and regulates cortical neuron subtype determinants *Fezf2* and *Sox11*

In the developing cerebral cortex, sequential transcriptional programs take neuroepithelial cells from proliferating progenitors to differentiated neurons with unique molecular identities. The regulatory changes that occur in the chromatin of the progenitors are not well understood. During deep layer neurogenesis, we show that transcription factor Lhx2 binds to distal regulatory elements of *Fezf2* and *Sox11*, critical determinants of cortical neuron subtype identity. We demonstrate that Lhx2 binds to the NuRD histone remodeling complex subunits LSD1, HDAC2, and RBBP4, which are proximal regulators of the epigenetic state of chromatin. When Lhx2 is absent, active histone marks at the *Fezf2* and *Sox11* loci are increased. Loss of Lhx2 produces an increase, and

overexpression of Lhx2 causes a decrease, in layer 5 *Fezf2* and *Ctip2* expressing neurons. Our results provide mechanistic insight into how Lhx2 acts as a necessary and sufficient regulator of genes that control cortical neuronal subtype identity. [(Bhavana Muralidharan, Zeba Khatri, Upasana Maheshwari, Ritika Gupta, Basabdatta Roy, Shubha Tole] Collaborators: Saurabh J. Pradhan, Krishanpal Karmodiya, Sanjeev Galande (IISER-Pune), Hari Padmanabhan, Ashwin Shetty, Jeffrey D. Macklis (Harvard University), Chinthapalli Balaji, Ullas Kolthur-Seetharam (DBS, TIFR).

Neurocircuitry of emotion

The major research focus of our team is to study the neurocircuitry of emotion and the manner in which it undergoes modifications following (a) life-experience and (b) pharmacological drugs that treat anxiety and depression. In the past year we have identified the key role of driving Gq mediated signaling in excitatory cortical neurons to program long-lasting effects of mood-related behavior across the life-span. We have also shown that this is associated with both molecular and cellular changes within the neocortex and hippocampus. Further, we have identified several epigenetic marks associated with a history of early life trauma that emerge in an age-dependent manner in cortical neurocircuits, and also shown metabolic consequences of a history of early life stress. We have identified a key role for the neurotransmitter serotonin in the regulation of mitochondrial biogenesis. We also find that long lasting epigenetic changes are evoked within limbic circuits in response to rapid-action antidepressants. Our results add to our understanding of the molecular and cellular mechanisms that underlie the pathophysiology of mood disorders. [(Sashaina Fanibunda, Megha Maheshwari, Sneha Shah, Ankit Sood, Shreya Ghosh, Sthitaprajnya Pati, Minal Jaggard, Dwight Figueiredo, Sonali Salvi, Sukrita Deb]

Neurobiology of Depression

We observe long lasting metabolic consequences of early life stress, which evoke perturbation of the IGF-1 signaling pathway and cause mitochondrial

changes in muscle. (Shreya Ghosh, Vidita Vaidya, Ullas Kolthur)

Effect of DNA content on development of Vertebrate embryos

1. Previously we had standardized the developmental time point at which zebrafish embryos should be subjected to a mild heat shock early in development for optimal generation of tetraploids. We found that there are two 2 minute developmental windows between 12 to 26 minutes post fertilization during which maximum number of tetraploid embryos survive to ~6 days post fertilization. This is interesting because development of vertebrate embryos appears to be finely tuned to an extent that a 2 minute slide on the development scale results in significant difference to embryonic survival. We proved that this effect on survival is due to the perturbation of nuclear envelope-centrosome interaction, nuclear envelope coalescence and centriole duplication events during the time points at which embryos survive, in comparison to perturbations in pronuclear fusion events during the time points at which embryos do not survive. Thus it appears that embryonic survival is intricately linked to early cell biological events, some of which are more resilient to perturbations. This work is currently in the process of submission for peer-review. [Triveni Menon].

2. UV irradiated spermatozoa is routinely used for invitro fertilization experiments to generate haploid zebrafish embryos. Our experiments done by UV irradiating zebrafish spermatozoa for varying durations from 30 secs to 2.5 minutes show that all UV treatments result in haploid embryos, but shorter UV duration of 1 minute exposure result in better embryonic survival. This work is currently in the process of submission for peer-review. [Triveni Menon]

Conserved roles for eomesodermin transcription factors in the vertebrate central nervous system

Our attempts to understand the functional roles of two T-box transcription factors in zebrafish development revealed that both paralogs, eomesoderminA and eomesoderminB, are expressed at all stages of development from egg to 4 days post-fertilization. Additionally, loss of eomesoderminB causes cranial edema, mild cyclopia and perturbs brain ventricle formation. Loss of eomesodermin in humans causes a congenital microcephaly syndrome. We are attempting to build a zebrafish model of this disease by generating zebrafish CRISPR-CAS9 mutants for eomesoderminA and eomesoderminB. [Antara Ghosh]

Motor Biology

A mechanism for controlling Lipoprotein secretion from the Liver across Feeding-Fasting cycles

The mammalian liver is a key organ for establishing lipid homeostasis in the body and a protector against lipotoxicity. In fed state, the liver efficiently mobilizes triglyceride from a small pool of cytosolic lipid droplets to provide for lipoprotein secretion. However, fasting increases liver triglyceride massively (~10 fold) because adipose-derived fatty acids are delivered to the liver and stored as triglyceride in hepatic lipid droplets. A mechanism must exist to limit mobilization from this substantially increased triglyceride pool, so that dangerous overproduction of lipoproteins can be prevented. However, this issue has not been discussed or addressed in the existing literature. In this work we find a molecular pathway that recruits kinesin motors to lipid droplets. This recruitment is controlled by insulin, and therefore responds to the feeding-fasting cycle. In fed state kinesin facilitates transport and physical tethering of droplets to the ER, thereby promoting triglyceride mobilization from droplets. Fasting inactivates kinesin, thereby downregulating droplet-ER contacts and

triglyceride mobilization. This strategy could help maintain plasma triglyceride homeostasis by controlling lipoprotein secretion from hepatocytes, while still allowing the liver to protectively sequester away substantial amounts of triglyceride released from adipose tissue after fasting. [Priyanka Rai, Mukesh Kumar, Pradeep Barak and Roop Mallik]

Feeding-Fasting dependent recruitment of Membrane Microdomain proteins to Lipid Droplets in the Liver

Lipid droplets (LDs) are stores of neutral fat that facilitate lipid and protein trafficking in response to metabolic cues. Unlike most vesicles, the LD membrane is monolayer in nature. Interestingly, this membrane contains free cholesterol. LDs may therefore contain membrane microdomains that serve as a platform for assembling proteins involved in signal transduction, cell polarity, pathogen entry etc. In support of this, cell culture studies have detected microdomain-associated "raftophilic" proteins on LDs. However, the physiological significance of this observation is unclear. In this work we show that two well-known

membrane microdomain binding proteins associate differently with LDs purified from rat liver, depending on feeding/fasting state of the animal. The metabolically regulated trafficking of lipid-raft associated proteins to LDs observed here may provide insight into mechanisms by which the liver controls lipid homeostasis across feeding-fasting cycles. These observations are also directly relevant to the replication of Hepatitis-C virus in hepatocytes, a direction which will be pursued imminently in our Laboratory. [Kritika Sadh, Priyanka Rai and Roop Mallik]

Axonal Transport of soluble and membrane associated proteins in *Drosophila*

Kinesin-2, a heterotrimeric protein involved in multiple different intra-cellular transports, was shown to transport the soluble pre-synaptic enzyme choline acetyltransferase towards the synapse. We further established that the motor is also involved in transporting presynaptic vesicles containing rab4 and acetylcholinesterase in collaboration with other kinesins [Swagata Dey and Anuttama Kulkarni, Dipti Rai]

Molecular Cell Biology of Spermatogenesis in *Drosophila*

Sperm development and differentiation occurs within somatic cell enclosure. Once matured, the

spermatids are released into the seminal vesicle for utilization. It is a carefully regulated quality control filter, which maintains male fecundity. We found that signaling based on phospho-inositol-3-kinase activity in the somatic cyst cells controls the transition to meiosis of germline cells [S. Gupta, S. Chattarjee, C. Joshi, P. Gadre]

In a separate study we showed that WASp-Arp2/3 dependent local F-actin dynamics induced by the indentation of somatic cells by spermatid heads prevents premature and abnormal penetration of the cells. Also, the somatic activity of Orco, an odorant receptor co-receptor, is found to be essential for a proper sperm release [P. Dubey, T. Kapoor, S. Shirolikar]

A third independent project is initiated to study the roles of septate junctions and other cell adhesion molecules in spermatid coiling preceding the release [P. Dubey, T. Kapoor, S. Shirolikar]

Cryo-Electron Microscopy Facility

This facility was established in 2007 with a Zeiss Libra 120 EFTEM and two ultracut sectioning machines. It is now running at optimum and several members from the institute and from outside has availed it for their research. [S. Shirolikar, L. Borde]

Academic

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Administration

Veera Unhavana

National and International Involvement

Shobhona Sharma: 1. Fellow, Indian Academy of Sciences, Bangalore. 2. Fellow, Indian National Science Academy, New Delhi. 3. Advisory Member, Malaria Foundation, New York, USA. 4. Member, Editorial board of Journal of Vector Borne Diseases, Delhi. 5. Member, Scientific Advisory Committee of National Institute of Malaria Research, Delhi. 6. Member, Scientific Advisory Committee of Institute of Life Sciences, Bhubaneswar. 7. Member Review Committee Wellcome Trust- DBT India Alliance fellowships. 8. Member of SERB Empowered Expert Committee, DST. *Roop Mallik*: 1. Editorial Board Member, Nature Scientific reports. 2. Member, American Society of Cell Biology. 3. Member, Biophysical Society. 4. Member, Guha Research Conferences. *Vidita Vaidya*: 1. Fellow, Indian National Science Academy (INSA), New Delhi, 2. Editorial Boards of Neuropharmacology, Current Science, Neuronal Signaling, Scientific Reports, Journal of Neurochemistry, Progress in Neuropsychopharmacology and Biological Psychiatry, 3. Scientific Advisory Positions: Member, Management Board, National Centre for Biological Sciences, Bengaluru; Member, Scientific Advisory Committee (SAC) for Division of Biological Sciences (DBS), IISc., Bengaluru, Member, Dept of Biotechnology, Govt. of India, Neuroscience Task Force

Visits

Shobhona Sharma: Visited ILS, Bhubaneswar and National Institute of Malaria Research in July and December 2015, respectively to give invited talks. *Swagata Dey*: visited Prof. Gary Banker's laboratory at the Oregon Health & Science University, Portland, on Fulbright fellowship (August 2015 – May 2015). *Krishanu Ray*: 1. visited CBG, Max-Planck Institute, Dresden, Germany to present an invited seminar on Drosophila spermiation, March 11-12, 2015. 2. visited Nirma University, Gandhinagar, Gujarat, on the occasion of the Post-graduate student orientation program 2015, and delivered the keynote address to the faculty and students on July 6, 2015. 3. School of Life Sciences, University of Hyderabad to deliver a lecture on the mechanism of sperm release in Drosophila testis on July 20, 2015. 4. visited IISER-TVM, Thiruvananthapuram, Kerala, to deliver a lecture titled, "what happens when you poke a cell: evidences of localized and reactive F-actin dynamics in Drosophila," October 6, 2015. *Samir Gupta* visited 1. EMBL, Heidelberg, Germany to attend the Frontiers in Stem Cells & Cancer conference and presented a poster titled, "Somatic regulation of germ-cell proliferation in Drosophila testis: Roles of EGFR downstream signaling", during March 29-31, 2015. 2. *Samir Gupta, S. Chatterjee, C. Joshi and P. Gadre* attended the Biennial meeting of the Indian Society of Developmental Biologists at CCMB, Hyderabad during July 15-18, 2015 and presented posters. *Pankaj Dubey* attended the conference titled "Actin and Microtubule Cytoskeleton in Cell Motility Morphogenesis: An Integrated View" 26-30 May, 2015, in Roscoff, France and presented a poster titled, "Localized, Reactive F-actin Dynamics Prevents Abnormal Sperm Release in Drosophila". *Mithilesh Mishra*: visited Mechanobiology institute, National University of Singapore, April 2016.

Invited Talks*Roop Mallik*

1. Geometry, Cholesterol and Kala-azar. NISER Bhubaneswar. 19 May 2016.
2. Tiny Machines, Big Tasks. DST-INSPIRE camp, Pandit Ravishankar Shukla Univ, Raipur. 13-14 Aug, 2016.
3. Phagosome Maturation and Cholesterol : Kaleidoscope meeting of Chemists, June 2016, Goa
4. The journey of the Phagosome. NCBS Monsoon school, June 16th, 2016.
5. Geometry, Cholesterol and Kala-azar. TIFR Natural Sciences Colloquium. 11 May 2016.
6. Cholesterol, Geometry and Kala-azar. IIT Kanpur, BSBE department, 15 April 2016
7. Cholesterol, Geometry and Kala-azar. IISER Pune, 8 April 2016
8. Lipid Rafts and Dynein Assemblies. OWLS-2016 meeting, 19 March 2016, IIT-TIFR, Mumbai
9. Lipid rafts as Force generating platforms for Motor Proteins on Phagosomes. Mumbai University Physics Department Seminar. 21 January 2016.
10. Lipid rafts as Force generating platforms for Motor Proteins on Phagosomes. IACS Biology seminar, Indian Association for the Cultivation of Science, Kolkata. 18 January 2016.
11. Tiny Machines, Big Tasks. Inaugural S S Bhatnagar lecture series, Charotar University of Science & Technology (CHARUSAT), 9 January 2016
12. Motors, Lipids and the COP-I pathway : A New connection ? Frontiers in Cytoskeleton research: coordination, adaptation, fine tuning. Indo-French Discussion meeting, IISER Pune, 27 Oct 2015.
13. Motors, Lipids and the COP-I pathway : A New connection ? Wellcome Trust -DBT Alliance Annual Fellows meeting. Hyderabad, Nov 6, 2015
14. Geometrical clustering of Motor Proteins helps kill bacteria, IISc Bangalore: Bioengineering seminar series, Sep 28, 2015
15. The journey of the Phagosome. Research Talk, Bangalore Microscopy Course 2015, National Centre for Biological Sciences, Bangalore, Sep 26, 2015
16. Optical Manipulation. Didactic Talk, Bangalore Microscopy Course 2015, National Centre for Biological Sciences, Bangalore, Sep 24, 2015
17. Geometrical clustering of Motor Proteins helps kill bacteria, Colloquium, Dept of Physics, Indian Institute of Technology Madras (IIT-M). 26 August 2015.
18. Geometrical reorganization of Motor proteins and its relevance to Transport of cellular cargoes. The Institute of Mathematical Sciences, 25 August 2015
19. Lipid, Motors and the COPI pathway: A new connection? Society of Biological Chemistry Meeting, NIRRH Mumbai, 22 Aug 2015.
20. Intracellular Transport and Collective force generation by Motor Proteins. Theoretical Physics Colloquium, TIFR Mumbai. 18th August 2015.
21. Tiny Machines, Big Tasks. Dr. R.A. Mashelkar Endowment Lecture on Advanced Materials, National Chemical Laboratories, Pune, India. 10th July 2015

22. Leading bacteria to the death chamber: A Kinder face of Cholesterol. TCIS -Tata Institute of Fundamental Research Hyderabad, 16 June 2015
23. Optical Trapping. Mechanical manipulations and responses at the scale of the cell and beyond, NCBS Bangalore. 30th April 2014
24. The journey of the Phagosome. Mechanical manipulations and responses at the scale of the cell and beyond (discussion meeting), Raman Research Institute Bangalore. April 2015

Krishanu Ray:

1. 'Axonal transport of soluble and membrane associated proteins', Health Science Innovation, H3C organized by the Ohio State University, USA and All Indian Institute of Medical Sciences, India, at the Taj Mahal palace Hotel, Mumbai, January 15 to 17, 2015.
2. "Intracellular Transport by Kinesin-2: One motor many destinations", Frontiers in Cytoskeleton Research, IISER, Pune, October 25-27, 2015.
3. "Intracellular Transport by Kinesin-2: One motor many destinations", 2nd Biennial Indian Drosophila Research Conference, IIT-Kanpur, Pune, December 21-23, 2015.

Mithilesh Mishra:

1. "Molecular control of cytokinesis in fission yeast, *Schizosaccharomyces pombe*." 9th International conference in yeast biology, Kolkata, December 2015
2. "Taking cell division out of the cell- in vitro study of yeast cytokinesis." Optics Within Life Sciences, International meeting, Mumbai, March 2016
3. "Cellular geometry and cell division: effect of cell shape on actomyosin ring stability in fission

yeast *Schizosaccharomyces pombe*." MBI, National University of Singapore, April 2016

Shubha Tole

1. "The effect of position on cell fate", Infosys Foundation Lecture, IIT Kanpur, August 17th, 2015
2. "Early patterning interactions in the cortical primordium", Tohoku Forum for Creativity, Tohoku University, Sendai Japan, August 24-26, 2015
3. "Sensational barrels in the brain", IAS annual meeting, IISER-Pune, November 6th-8th 2016
4. "Towards a blueprint for building the brain: early patterning interactions", FAOBMB, BITS Pilani (Hyderabad campus), November 27th-30th 2016
5. "Towards a blueprint for building the brain", INSA Brain and Eye Symposium, LVPEI, Hyderabad, Jan 31st -Feb 3rd
6. "Cell fate specification in the developing brain", Volga Neuroscience conference, St. Petersburg-Nizhni Novogorod, Russia, July 24th-30th, 2016

Vidita Vaidya:

1. IPSCON Symposium, Antidepressants and making new neurons in the adult brain, Saurashtra University, Rajkot, Dec 2015
2. Third Obaid Siddiqui Oration Lecture, Early Experiences shape Behavior, NIBMG, Kalyani, Jan 2016
3. INSA-Leopoldina Academy Brain and Eye Symposium, Early life experience and psychiatric vulnerability, LVPEI, Hyderabad, Feb 2016
4. The Emotional Brain, Imprints of Life History, CBS Colloquium, Mumbai March 2016
5. Adult Neurogenesis, trophic factors and Rapid Action Antidepressants, Indo-Irish Meeting, Trinity College, Dublin, Ireland, April 2016

Conferences Organized by the Department

Infections and Molecular Epidemiology, Udaipur, October 29-31, 2015. Convenors: Shobhona Sharma and Gotam K. Jarori. Conference dwelt on various infectious diseases such as malaria, Leishmaniasis, filaria and viral diseases, and emphasized the need to set up appropriate databases for the same, in particular for human epidemiology.

Non-DAE Research Projects

Mabendra Sonawane:

Title: Identification of a regulatory gene network essential for the maintenance of epidermal architecture and integrity

Senior research fellowship from the Wellcome trust-DBT India alliance- April 2011- March 2017

Dr. Mabendra Sonawane and Prof. Elisabeth Knust

Title: Crumbs paralogues and their functional significance in zebrafish epithelia

DST-DAAD grant, April 2016 – March 2017

R. Mallik

Wellcome Trust-DBT Senior Research Fellowship (2013-18)

Priyanka Rai

Wellcome Trust – DBT India alliance Intermediate Fellowship (2012-2016)

Paulomi Sanghavi

Wellcome Trust – DBT India alliance Intermediate Fellowship (2016-2021)

Shobhona Sharma

1.ICMR "Effect of mild malaria on neural cells in a rodent model. Correlation with specific immune responses"; 2013-2016.

2.DBT-SIGID grant: "International associated laboratory in the area of systems immunology and genetics infectious diseases" 2014-2018.



Department of Chemical Sciences

Chemical Dynamics Supersonic Jet spectroscopy

Spectroscopic investigation and characterization of unconventional hydrogen bonds

Investigations of novel hydrogen bonds have been the primary area of focus of our research group in recent times. Some of these H-bonds involving **CH** and **SH** groups are very important as these form a large fraction of the non-covalent contacts in protein structures. However, these are much weaker than conventional H-bonds. Their typical binding energies are thought to be of the order of less than 4 kcal mole⁻¹ and they show very small shifts in stretching frequency upon formation of hydrogen bond. These bonds not only differ from conventional hydrogen bonds in their strength but also in their nature, directionality and frequency shifts. Experimentally, the hydrogen bonded complexes were formed using supersonic jet expansion technique and they were investigated using a variety of laser spectroscopic techniques. Ab initio and DFT calculations have been used to support the experimental findings.

C-H---Y (Y = N, O) H-bonding interactions

The role of C-H---Y (Y=O, N) H-bond (HB) interactions in the formation of clusters were investigated using various gas phase supersonic jet spectroscopic techniques. 1,2,4,5-tetracyanobenzene (TCNB) was chosen as HB donor and various O, N containing solvents were taken as HB acceptor. In TCNB, the four -CN groups present in the benzene ring make two C-H bonds more polar which facilitates formation of CH---Y

H-bond. The clusters were formed in supersonic jet expansion method and probed using Laser Induced Fluorescence (LIF) and Fluorescence Dip Infra-Red (FDIR) spectroscopy. Former one is used to characterize excited state electronic spectrum and the later one helps to get structural information of those complexes in the ground electronic state.

a) TCNB and its water clusters

LIF spectrum of jet cooled TCNB co-expanded with H₂O vapor showed three new peaks on the red side of the S₁-S₀ band origin (BO) of TCNB monomer. FDIR spectra by probing these peaks indicated that they were coming from 1:n (n=1,2, and 3) clusters of TCNB with water. All the three water clusters showed red shifts in the C-H stretching transition frequency with respect to that of bare TCNB monomer suggesting the formation of C-H---O H-bond. By comparing the experimental IR spectra with the computed ones, it was found that in 1:2 and 1:3 clusters, TCNB forms water chain structures where C-H acts as H-Bond donor and N atom of -CN group acts as H-Bond acceptor. Figure 1 shows the water clusters of TCNB where all the complexes are stabilized by C-H---O H-bond. The water chain connecting H-bond donor to an acceptor is known to play an important role in proton shuttling reactions between donor and acceptor in case of N and O containing donors and acceptors. C-H---O assisted water chain formation is therefore an important finding which might possibly lead to proton transfer even from the C-H moiety in some exotic condition. (Sanat Ghosh and S. Wategaonkar)

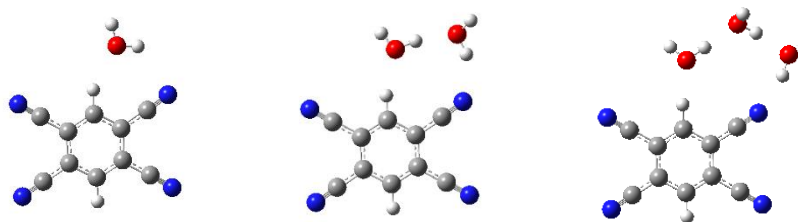


Figure 1: Ab initio computed global minimum energy structures of TCNB-(water)_n (n=1, 2 & 3) clusters.

b) TCNB with other O containing solvents

Formation of C-H---O H-bonding is also verified in other protic and aprotic solvents like methanol (MeOH), ethanol (EtOH), dimethylether (DME), and diethylether (DEE). In all the cases, these O-containing solvents form C-H---O H-bonded

complexes. Like water clusters, 1:2 clusters of MeOH and EtOH also form H-bonded chain, anchored between C-H and CN group in TCNB. Since DME and DEE cannot behave as H-bond donor therefore they cannot form H-bonded chain like H₂O and alcohol, instead they form symmetric

CH---O bound 1:2 clusters where two solvent molecules attached in two opposite C-H ends of TCNB. (Sanat Ghosh and S. Wategaonkar)

c) C-H---N interaction in TCNB-NH₃ clusters

Since NH₃ is a better base than water it is expected that it will form a stronger H-bond with TCNB than water and thereby greater red shift in C-H stretching frequency. LIF spectrum of TCNB with NH₃ shows a few new peaks which could be due to a single cluster or multiple clusters. Since mass detection of TCNB clusters is not possible at wavelengths accessible in the laboratory due to very high ionization potential (IP) of TCNB, it is difficult to comment on the size of the clusters in this situation. However IR spectra of these clusters were useful in identifying their sizes as well as their structures. FDIR spectrum of 1:1 cluster of NH₃ with TCNB shows a greater red shift in CH stretching frequency than that of in 1:1 cluster of water with TCNB which suggests that C-H---N H-bond is stronger than C-H---O H-bond. FDIR spectra of higher clusters suggested that NH₃ molecules can form chain like H-bonded clusters flanked by the C-H and CN moieties as well as they can be situated in two opposite ends of TCNB

molecule via C-H---N H-bonding (Figure 2) (Sanat Ghosh and S. Wategaonkar).

In order to study a few more CH---N bound clusters, LIF spectra of TCNB with trimethylamine (TMA) and trimethylamine were carried out. However, both of them did not show any LIF signature although binding energy calculation suggested that they are stable in the ground state. The reason for not observing sharp transitions in the LIF spectrum was attributed to dissociative excited state. In order to check this hypothesis, quantum chemical excited state calculations were carried out, which suggested that C-H---N bound conformers were not stable in the excited state. Excited state equilibrium geometry changes over to the pi bound structure. Therefore, it is difficult to see a sharp BO transition in the LIF spectrum as this transition may not be Franck-Condon active. (Sanat Ghosh and S. Wategaonkar)

In summary, using LIF and FDIR spectroscopy, we have shown that C-H can actively participate in H-bonding interactions. It can stabilize higher solvent clusters either via a chain like co-operative H-bonding interaction or via symmetric C-H---O H-bond bound structures.



Figure 2: Conformers of 1:2 complex of TCNB with NH₃

Proton transfer in complexes of Indole/Imidazole derivatives with NR₃ (R=H, alkyl groups)

As a part of the N atom acceptor solvents, earlier we had reported the optimized structures of the complexes of the title compounds in the ground state, excited state as well as cationic state. The computations suggested that proton transfer in these complexes occurs in the cationic state. Some evidence of this process was obtained in the hydrogen bonded complexes of benzimidazole (BIM) with Me₃N (trimethylamine; TMA) and Et₃N (trimethylamine; TEA). In addition the unprotonated amines were also observed in small quantities. Hence two processes namely the charge transfer as well as proton transfer seems to be operational in this system. In view of this, further

experiments were carried out to identify the proton transfer channel. The bigger question that we ask is, how the probability/efficiency of the charge/proton transfers change with the change in the relative ionization potentials/basicities, and are there any barriers for the two processes. For this study a range of aliphatic amines differing in their ionization potentials and proton affinities have been chosen as acceptors and aromatic heterocyclic compounds having an N-H group as the donor.

During the last year the ground state and the cationic state properties and potential energy surfaces of the N-H...X bound complexes were investigated towards this end. The systems studied were Indole (IND) and Benzimidazole (BIM) as

H-bond donors and their respective H-bonded complexes with Ammonia (Am).

Indole-Ammonia complex

The LIF and REMPI spectra of IND and its complex with ammonia were recorded. The band origins of the monomer and the H-bonded complex were confirmed by comparing the LIF and REMPI data. The FDIR spectra were recorded for both the systems. For the monomer, besides the phenyl and the pyrrole CH stretching vibrations, the N-H stretch was observed at 3530 cm^{-1} . The IR spectra of the complex showed two new enhanced peaks are in the $\sim 3315 \text{ cm}^{-1}$ region. From frequency calculations done at the B3LYP/aug-cc-pVDZ level, it could be deduced that the shifted N-H stretch and the symmetric stretch of ammonia are expected in that range. However, to determine the bound N-H stretch of Indole categorially, experiments were carried out on the IND- ND_3 complex. In the IND- ND_3 complex the N-H stretch of indole was found at 3306 cm^{-1} , i.e., red shifted by 224 cm^{-1} . Therefore, the 3310 cm^{-1} transition in the IND- NH_3 complex was assigned to the bound NH group. The slight difference of 4 cm^{-1} compared to that in the IND- ND_3 was attributed to the mixing with the symmetric stretch of NH_3 (3337 cm^{-1}). This mixing also leads to the enhancement of the ammonia stretch. In a previous FDIR study on BIM-Am, the shift was found to be around 270 cm^{-1} . The extent of red shift in N-H stretch seems to be proportional to the acidity of the donor [pKa of IND (16.97) while that of BIM (12.75)]. (Viola D'Mello and S. Wategaonkar)

ZEKE Spectroscopy of BIM and its Hydrogen Bonded clusters with NH_3 and H_2O

Complexes of Benzimidazole and its hydrogen bonded clusters with NH_3 and H_2O were investigated in the cationic state using Zero Kinetic Energy (ZEKE) photoelectron spectroscopy. ZEKE gives information about the accurate Ionization Potential of the molecule/complex and vibrational levels in the cationic state.

The ionization potentials (I.P.) of BIM was determined as 67546 cm^{-1} and that of its NH_3 and H_2O complexes as 63620 cm^{-1} and 64410 cm^{-1} , respectively. The spectral features in the individual spectra were assigned as follows with the help of calculated frequencies for the BIM cation. The prominent peak at 378 cm^{-1} was assigned to the 2nd harmonic of the butterfly mode of BIM monomer. This peak was also observed for the complexes too indicating that the butterfly mode was highly Franck-Condon (F-C) active mode upon ionization. (Viola D'Mello and S. Wategaonkar)

The ZEKE spectrum BIM-Am showed a major progression in 209 cm^{-1} transition which was assigned to the intermolecular NH...N stretching mode. Since electrostatic force is a major contributor to the formation of a hydrogen bond, the ionization of the complex would lead to a change along the hydrogen bond coordinate and hence the F-C activity is observed in this mode. The intermolecular bend and its overtone were also observed in combination with every member of the intermolecular stretch progression. (Viola D'Mello and S. Wategaonkar)

The ZEKE spectrum of BIM- H_2O also showed a progression in the intermolecular NH...O stretch. The butterfly intramolecular mode that was seen in (BIM)⁺ and (BIM-Am)⁺ was observed in (BIM- H_2O)⁺ spectrum as well. As in the case of (BIM-Am)⁺, the butterfly mode observed in combination with the intermolecular stretch progression. The N-H...O bound complex was different from the N-H...N counterpart in this that the intermolecular bend was not affected on ionization. (Viola D'Mello and S. Wategaonkar)

In summary, using the ZEKE study of BIM, BIM-Am and BIM- W_1 , we have determined the accurate ionization potential of these species which is an important parameter for the determination of the binding energy of the complexes and also identified the intermolecular stretching frequencies in these complexes.

Developmental work

IR-OPO DAQ Program

Existing communication software "Main Menu" of the IR-OPO laser was upgraded to another software called "Opilot". Once the communication with the IR-OPO laser using the new software Opilot was established, it was decided to include it in the home made Data Acquisition Program so that laser can be controlled using the DAQ program. So the existing DAQ program was modified to control IR-OPO using new software Opilot. Main Menu and its sub vi's in the DAQ program are replaced by the Opilot and the respective sub vi's. The modified DAQ program was then tested with the IR-OPO. (Ajay Patil)

Microchannel Plate ion detector

For the proton transfer experiments higher mass resolution (200 amu) was required in the TOF mass spectrometer. For the purpose the existing single channeltron detector was replaced by Hamamatsu 35 mm Microchannel plate detector by making suitable hardware changes. (Ajay Patil and Sachin Temkar)

Electron spin polarization and relaxation

Photochemistry and electron spin polarisation mechanism

With a view to understanding the photophysical quenching process of excited states by a stable free radical, when the diffusion between them is severely quenched, we have been investigating molecular systems consisting of a naphthalene moiety covalently linked to a TEMPO radical through a spacer group of different lengths. As the triplet excited state of naphthalene has much longer lifetime than its singlet excited state, the triplet state plays a dominant role in the photophysical quenching of the radical and generation of electron spin polarisation. With a view to extending our studies to molecular systems of long-lived singlet excited states, we have chosen a pyrene (Py) moiety as the chromophore, and synthesized two linked molecules of the type Py-Spacer-TEMPO, with different lengths of the spacer group. Preliminary results showed efficient quenching of pyrene fluorescence. TREPR studies of Py-CH₂-O-TEMPO showed sequential quenching of excited singlet and triplet states of the pyrene moiety and generation of electron spin polarisation of opposite signs in the TEMPO radical. (Sushma Kundu, Ranjan Das and Tinku Kumar of CBS, Mumbai)

Biophotonics

Manipulating the folding of amyloid beta: The hairpin shape adopted by amyloid beta peptide in the aggregated form, appears to be essential for membrane binding and toxicity. However, if the toxicity aspect can be avoided, then the in-register assembly of amyloid beta can potentially be used to make useful peptide complexes. We designed particular single mutations which would lead to steric crowding in the turn region and would inhibit folding. We indeed found that the resultant peptide aggregates very similar to Amyloid beta, but without the fold. Interestingly, it still preserves a specific inter-residue interaction which is observed in the wild type peptide, implying that this can be critical for the assembly process. [with M. Chandrakesan, D. Bhowmik, B. Sarkar, R. Abhyankar, M. Kallianpur, S. Dandekar, and the labs of P. K. Madhu and V. S. Mithu]

Origin of the membrane affinity of Amylin: Amylin is a 37 residue peptide whose aggregation is implicated in Type II diabetes. We have found that the amylin oligomers have much higher membrane affinity than the monomers, a result that is intriguingly similar to another disease causing peptide: amyloid beta. We have now attempted to understand the origin of this enhanced affinity. It appears that it undergoes an alpha-helical to a beta sheet transition as the oligomers evolve. This shows

that the same enhanced membrane affinity (like amyloid beta) do not necessarily imply similar conformational transitions. [with Anoop Rawat, Bappaditya Chandra]

Construction of a “line-confocal” Raman spectrometer: A confocal Raman spectrometer gives spatially resolved Raman spectra. High optical power densities are frequently required to get enough signal, but such high densities can destroy proteins and other delicate samples. We have now constructed a “Line-confocal” spectrometer, which distributes the power along a line. This maintains the spatial resolution but uses much lower power densities for obtaining the same signal. The result is a Raman instrument especially suited for biological samples. [with Barun Maity]

Fluorogenic detection of neurotransmitters: We have achieved a modification of the celebrated Falck-Hillarp method of labeling monoamine neurotransmitters in neurons. In this method, we demonstrated the use of Ortho-phthalaldehyde to label serotonin and dopamine in neurons. The advantage over the F-H method is that our method can label cells and organisms in water, and has much less toxicity. [with Kallol Bera, A. Rakshit, B. Sarkar]

Single Molecule Protein Mechancis

Single-Molecule Biophysics

Single-molecule force spectroscopy of *Plasmodium falciparum* circumsporozoite

protein domains reveals weakly folded structures : The most effective vaccine candidate of malaria is based on the *Plasmodium falciparum* circumsporozoite protein (CSP). This is a major surface protein of the infective sporozoites and has

been implicated in the structural strength, motility and immune evasion properties of the sporozoites. Although reversible conformational changes of the protein have been implicated for its mammalian host-infection, the detailed structure and dynamic properties of CSP remain incompletely understood, especially at a single molecule level. Here, we have studied the structural and mechanical properties of the CSP, NANP repeat region (CSP_{rep}), as also the near full length CSP, without the signal and anchor hydrophobic domains (CSP_{ΔHP}), using single-molecule force spectroscopy. Our results show that the CSP_{rep} possess heterogeneous conformations. About 40% molecules required virtually no mechanical force to unfold (<10 pN), and hence were mechanically compliant and perhaps acting as entropic springs. The remaining 60% were partially structured with low mechanical resistance (~70 pN). CSP_{ΔHP} exhibited multiple force peaks indicating specifically folded domains, with two major populations possibly indicating the open and collapsed forms. Our findings suggest that the overall low mechanical resistance of the repeat region, exposed on the outer surface of the protein on the sporozoites, and flexible full-length conformations of CSP, may provide the sporozoites not only with immune evasion properties, but also with “mechanical buffering” capacity required during its navigation through the

mosquito and vertebrate host tissues. [Aditya Patra, Shobhona Sharma, A. Sri Rama Koti]

Significance of 1B and 2B domains in modulating elastic properties of lamin A

Nuclear lamins are type V intermediate filament proteins which form an elastic meshwork underlying the inner nuclear membrane. Lamins directly contribute to maintain the nuclear shape and elasticity. More than 400 mutations have been reported in lamin A that are involved in diseases known as laminopathies. These mutations are scattered mainly in the lamin rod domain along with some in its C-terminal domain. The contribution of the rod domain towards the elasticity of lamin A molecule was hitherto unknown. Here, we have elucidated the significance of the 1B and 2B domains of the rod in modulating the elastic behavior of lamin A by single-molecule force spectroscopy. In addition, we have also studied the network forming capacity of these domains and their corresponding viscoelastic behavior. We have shown that the 1B domain has the ability to form a lamin-like network and resists larger deformation. However at the single-molecular level, both the domains have comparable mechanical properties. The elasticity of the lamin network originates from the self-assembly of the 1B domain. [Monindra Bera and Kausik Sengupta from SINP (Kolkata) and A. Sri Rama Koti]

Reaction Dynamics

We provided the first experimental evidence for the existence of a soluble *polymer:fullerene:solvent* ternary seed phase which dictates the eventual film morphology of the photoactive layer in organic bulk heterojunction (BHJ) solar cells. By carefully measuring the timescale for rise of the photo-

generated charges in *polymer:fullerene* complexes in solution, we could estimate the lengthscale of the pre-formed nanometric polymer domains and demonstrate a size correlation of it in the dried films. This paper is published in the journal *Nanoscale*.

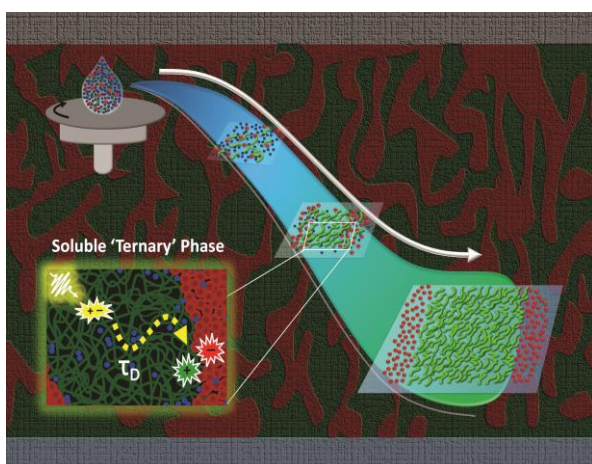


Fig 1: The conceptual representation of bulk heterojunction film formation is schematically shown. A solution containing conjugated polymers (in green) and fullerenes (in red) are usually mixed and dried to make a BHJ film with interpenetrating polymer:fullerene domains. Using conventional transient absorption spectroscopy which measures the rise of charges after exciton diffusion, we provide the lengthscale of pre-formed soluble polymer:fullerene:solvent ternary complex in solution. See Palas Roy et al. *Nanoscale*, **2016**, *8*, 2768-2777.

The group utilizes contemporary ultrafast optical spectroscopy techniques to establish a causal link between structural dynamics and reaction efficiencies in macromolecular systems. We have used ultrafast optical spectroscopy techniques to not only track reaction trajectories but also to

generate synthetic strategies for stabilizing reactive intermediates within supramolecular architectures.

Probing the lengthscale of soluble aggregates through charge transfer rates

Optimizing the light trapping process and subsequent charge separation chemistry is at the heart of engineering efficient photon-conversion devices. Organic solar cells have appeared as a viable alternative for cheap solar cell technology. However, the fundamental issues associated with robustness and low-efficiency has caused delay in technology transfer. One of the popular varieties of solar cells is the bulk heterojunction (BHJ) solar cell which incorporates a mix of donor polymer with organic fullerene acceptor. The instability of the nanometric domain size in the film does cause inaccuracies in data reporting and affects the optimization of device performance. In order to fundamentally understand the domain size dependence with solvent that is used for spin casting, we devised a unique approach to score for lengthscale of the soluble polymer:fullerene aggregates. We precisely measured the timescale for the rise of the charges after exciton generation in the bulk of the polymer domain. Through the analysis of the CT reaction rates along with exciton diffusion coefficient we demonstrated the existence of a *polymer:fullerene:solvent* ternary complex in solution. Our work shows that the donor-acceptor interfaces can be tailored in the solution state itself for device optimization of organic solar cells. [Palas Roy, Ajay Jha, and Jyotishman Dasgupta].

Femtosecond Stimulated Raman spectroscopy on Conjugated Polymers

The group has set up a home-built femtosecond stimulated Raman spectrometer (FSRS), only the second of its kind in India, which can record Raman snapshots of excited states with a temporal precision of ~ 70 fs and spectral resolution of 10 cm^{-1} . Using this unique tool we have explored the exciton dynamics in low bandgap polymers. We have probed the ultrafast planarization of the bridge thiophene during the process of exciton localization in a donor-bridge-acceptor based conjugated polymer. The FSRS data provided unequivocal evidence for excited state red-shift of the delocalized C=C stretching mode of the thiophene ring along with intensity increase upon planarization. Our work thus provides detailed structural information which is required for designing novel low bandgap polymers with long exciton lifetime or long-lived charges. [Palas Roy and Jyotishman Dasgupta.]

Biosynthetic pathway of carotenoids: Biological regulation of *all-trans* carotenoids

Enzymes can remodel the ground state reactivity of large conjugated organic substrates via local protein-substrate interactions and slow conformational fluctuations. Carotenoids are an important class of polyene pigments that are taken up by the photosynthetic apparatus to form protein-pigment complexes. We are currently working to understand the metabolic regulation of carotenoid lycopene in photosynthetic organisms by enzyme CRTISO. Although, the mechanism of isomerization of prolycopene by CRTISO is not fully understood especially the requirement of electrons, it has been reported that light can rescue the impaired CRTISO activity in the chloroplasts. The efficiency of the light induced pathway therefore becomes important to quantify especially since the kinetic implications of photo-reaction quantum yields inside the chloroplasts remain unexplored. We recently demonstrated the existence of a competing pathway for efficient generation of lycopene through triplet state sensitization. In addition, we have investigated the conformational propensities of the FAD molecule in a confined environment to appreciate the spectroscopic signatures of the protein bound FAD. Our work should enable a molecular understanding of the events leading to isomerization of prolycopene by the enzyme CRTISO. [Vijaya Lakshmi, Joel Cornelio, and Jyotishman Dasgupta; external collaborator: Partha Sarthi Mukherjee, IISc Bangalore]

Visible Light Photochemistry inside Molecular Nanocages

Combining the idea of generating optically allowed *delocalized* host-guest CT states with reactive confinement provided by molecular cages, a new visible light photochemistry strategy has been pioneered by our group. Using a well-defined metal-organic nanocage as a delocalized electron acceptor, we have formulated an efficient chemical scheme to carry out ultrafast hydrogen abstraction reactions from organic substrates in water. The method highlights the first use of singlet excited states to trigger efficient atom transfer reactions. Using transient absorption spectroscopy tools we recently identified all the timescales of water dynamics around the nanocage. Future goals include construction of a light harvesting system which can carry out multiple redox reactions which would lead to catalytic reactions in free solution. [Rahul Gera, Ankita Das, Swagata Halder, Bijon Sarkar and Jyotishman Dasgupta]

Theoretical and Computational Molecular Biophysics, Biochemistry, and Physical Chemistry

Single Molecular Breadboard Circuits

In collaboration with experimental researchers from Switzerland and France, we have demonstrated that single organic molecules can function as scaffolds to efficiently build and rewire a multitude of microscopic circuits with distinct conductance features. Through a joint experimental and theoretical study of the conductance of a bis-terpyridine p-phenyl (**TP1**) molecular junction we translate the concept of a breadboard circuit (well-known in conventional macroscopic electronics) to the molecular scale.

Single molecule break junction techniques measure molecular conductance and offer the potential to develop molecules as electronic circuit elements (e.g wires or switches or diodes). To achieve this potential, it is important to understand how molecular components behave within a big macromolecular circuit. This is an unsolved fundamental challenge in field of molecular electronics. As such, previous studies have only been able to create and study 2-3 circuits within a single molecular scaffold. In comparison, the **TP1** molecular scaffold in our present manuscript offers 61 distinct single and multi-terminal circuits! The **TP1** scaffold allows us to rigorously introduce the concept of a molecular breadboard circuit with a large number of constituent sub-circuits for the first time. The TP1 molecular junction is easily one of the most complex molecular junctions studied to date offering upto 61 distinct circuits and tremendous flexibility in terms rotations of seven aromatic rings. To enumerate the conductance of such a complex junction, we have introduced a new theoretical and analytical framework that is easily transferable, takes into account all possible sub-circuits along with their conformational flexibility, and rigorously captures all experimentally observed conductance states. Our analysis pushes the limits of theory, analysing the conductance of over 1000 circuits to rigorously map the current flow pathways through the TP1 molecular breadboard. [Veerabhadrarao Kaliginedi (University of Bern, Switzerland), Guy Royal (Université Grenoble Alpes, Département de Chimie Moléculaire, France), Ravindra Venkatramani, (IIFR)]

A New Spectral Band for Probing Biomolecular Structure and Dynamics

In the course of our studies over the last year, we have found theoretical evidence for distinctive charge transfer transitions in proteins in the 300-800 nm region. Through excited state electronic structure calculations on charged amino acid

residues sampled from classical atomistic molecular dynamics simulations of α_{3C} (a synthetic protein devoid of aromatic amino acids), we have showed unique spectral signatures of interactions between charged lysine/glutamate amino acids beyond 300 nm. The distinctive near UV spectral band was assigned to charge transfer transitions involving the amino (NH_3^+)/carboxylate (COO^-) head-groups of lysine/glutamate and the peptide backbone. The positions and intensities of the charge transfer transitions were found to be sensitive to the amino acid conformations, interaction between charged amino acids, and the solvation environment. Our results are supported by experimental studies in the lab of collaborators at IIT-Guwahati on non-aromatic amino acids in monomer/peptide forms and on the α_{3C} protein. Taken together, the joint experimental and theoretical investigation adds a new spectral window (between 300-500 nm) for optical probes of biomolecular structure, and dynamics. [Rajaram Swaminathan (IIT-Guwahati), Ravindra Venkatramani (IIFR)]

A Computational Framework for Determination of Coordination Chemistry in the Interaction of Small Peptides with Metals

We have investigated the binding modes of a small penta-peptide fragment (N-H-S-F-M) to Cu^{2+} metal ions. Experimental (visible) absorption spectra for the complex and associated pH dependent shifts were available from the lab of Prof. Shyamalava Mazumdar but the underlying metal coordination sphere was unknown. We examined different possibilities for Cu^{2+} coordinating ligands through electronic structure calculations and obtained optimized ground state geometries and TDDFT based excitation spectra for the complexes. We further carried out molecular dynamics studies of the penta-peptide complex bound with Cu^{2+} bound the ligands suggested by electronic structure calculations. We were able to propose a tetra-coordinated distorted tetrahedral geometry for the complex with one sulphur (M sidechain), two nitrogens (H sidechain and N amino terminus), and one oxygen (N sidechain) ligands coordinating the copper. We were further able to propose the possibility of a hexa-coordinated complex with two additional water oxygen ligands. Our studies show that the broad absorption profile for the copper complexes observed in experiments arises from Metal-to-Ligand charge transfer transitions. The computational framework setup in this study is easily transferrable to study metal-peptide interactions broadly within the context of biological

processes and should also be useful to design small molecules which sense the presence of metal ions. [Shyamalava Mazumdar (TIFR), Ravindra Venkatramani (TIFR)]

Effect of Metal Ion Ligand on the Stability of Metalloproteins

Metalloproteins catalyze important biological processes such as photosynthesis, respiration, nitrogen fixation, and drug metabolism. During the last year we have studied the effect of the metal ligand on the stability of metalloproteins using Azurin, a small protein from the cupredoxin family as a model system. We have employed Steered

Molecular Dynamics (SMD) simulation techniques to get the molecular insight of the unfolding pathways of apo (copper free) and holo (copper-bound) forms of azurin under the action of mechanical force. Our simulations provide a high resolution structural model of the sequence of unfolding events for the holo and apo systems in atomistic detail and reveal that the presence of metal ion changes the sequence of unfolding events. These models support experimental investigations of Azurin unfolding under mechanical pulling forces in the lab of our collaborators at TIFR. [A.S.R. Koti (TIFR), Ravindra Venkatramani (TIFR)]

Biomolecular Structure, Dynamics and Interaction

NMR pulse sequences

Non uniform sampling in combination with homonuclear broadband decoupling along indirect dimension, and indirect covariance processing has been used to record ultra-high resolution two-dimensional TOCSY spectra in less than half an hour, for typical sample concentrations in mM range. TOCSY correlations belonging to protons separated by as little as ~ 2 Hz could be distinctly discerned. Utility of the technique for very low concentrations has been demonstrated (Veerra Mohan Rao Kakita and R. V. Hosur).

Solution Structure of CPR3

Cyclophilins regulate protein folding, transport and signalling through catalysis of proline isomerization, and are ubiquitously expressed in both prokaryotes and eukaryotes. Cpr3 is the yeast mitochondrial cyclophilin and it is structurally and biophysically uncharacterized so far. Yeast cyclophilin gene cpr3 is essential for the lactate metabolism. Here, we report ^1H , ^{13}C , and ^{15}N chemical shift assignments of Cpr3 protein determined by various 2D and 3D heteronuclear NMR experiments at pH 6.5, and temperature 298 K. The structural fold of Cpr3 is seen to be comprised of eight β strands corresponding to stretches of residues, K23-V30 ($\beta 1$), G36-L42 ($\beta 2$), R73-I75 ($\beta 3$), M79-Q81 ($\beta 4$), G114-S118 ($\beta 5$), F130-I132 ($\beta 6$), H144-V150 ($\beta 7$) and E173-E181 ($\beta 8$) and three helical regions corresponding to residues K49-T59 ($\alpha 1$), P138-L140 ($\alpha 2$), and M154-S162 ($\alpha 3$) (Vaibhav Kumar Shukla, Jai Shankar Singh, Dipesh Trivedi, Ramakrishna V. Hosur, Ashutosh Kumar).

Kinetics of Protein Aggregation

We have studied here using a number of biophysical tools the effects of osmolytes, betaine, citrulline, proline and sorbitol which differ significantly in terms of their physical

characteristics such as, charge distribution, polarity, H-bonding abilities etc, on the fibrillation of insulin. Among these, betaine, citrulline, and proline are very effective in decreasing the extent of fibrillation. Proline also causes a substantial delay in the onset of fibrillation in the concentration range (50-250 mM) whereas such an effect is seen for citrulline only at 250 mM, and in case of betaine this effect is not seen at all in the whole concentration range. The enthalpies of interaction at various stages of fibrillation process have suggested that the preferential exclusion of the osmolyte and its polar interaction with the protein are important in inhibition. The results indicate that the osmolytes are most effective when added prior to the elongation stage of fibrillation. These observations have significant biological implications, since insulin fibrillation is known to cause injection amyloidosis and our data may help in designing lead drug molecules and development of potential therapeutic strategies (Sinjan Choudhary, Nand Kishore and R. V. Hosur).

Structure, dynamics and interaction of Ca^{2+} -binding proteins

The protozoan parasite *E. histolytica* encodes twenty-seven Ca^{2+} -binding proteins (CaBPs) suggesting that the organism has an intricate and extensive Ca^{2+} -signaling system. The structural and functional characterization of some of these CaBPs studied so far reveals their predominant role in phagocytosis and endocytosis. However, not all amoebic CaBPs are involved in phagocytosis and endocytosis. An unusual calcium binding protein from *E. Histolytica* that binds and hydrolyzes adenosine and guanosine triphosphates: A calcium binding protein (abbreviated as EhCaBP6) is mainly localized in the nucleus and present at the microtubule end and at the intercellular bridge with the microtubules during cytokinesis. Hence, it is

supposed to be involved in cell division. In other organisms, calmodulin (CaM) plays a role of a major signal-transducing factor, through which Ca^{2+} concentrations are regulated during the cell cycles. In an attempt to understand the structural and functional similarity of EhCaBP6 with CaM, we have determined the 3D solution structure of EhCaBP6 using NMR. The protein EhCaBP6 has one unusual (EF-I), one canonical (EF-III) and two non-canonical (cryptic) (EF-II and EF-IV), EF-hands. The cryptic EF-II and EF-IV pair with Ca^{2+} -binding EF-I and EF-III, respectively, to form a two-domain structure similar to CaM. The structural similarity between EhCaBP6 and CaM, despite their low sequence similarity, suggests towards their similar functions during the cell cycle. Intriguingly, the EhCaBP6 binds and hydrolyzes adenosine triphosphate. This is the first known instance of a CaBP that hydrolyzes guanosine triphosphate. (Deepshikha Verma, and A. Bhattacharya (JNU, New Delhi))

Biomolecular Interaction

Structure and Dynamics of a putative UV inducible protein (UVI31+) from *C. reinhardtii* that exhibits RNA and DNA endonuclease activity: *C. reinhardtii* is a single celled alga, which undergoes apoptosis in response to UV-irradiation. UVI31+ in *C. reinhardtii* exhibits DNA and RNA endonuclease activity, induced upon UV-stress. UVI31+ that normally localizes to cell wall and pyrenoid regions gets redistributed into punctate foci within the whole chloroplast, away from the pyrenoid, upon UV-stress. The structure, dynamics and the putative function of UVI31+ have been studied. The 3D structure of UVI31+ has $\alpha_1\beta_1\beta_2\alpha_2\alpha_3\beta_3$ fold very similar to BolA family of proteins, which in turn is similar to the well-described K-Homology Class-II (KH) domain that contains RNA and DNA binding motif. KH domains bind RNA or ssDNA, and are found in proteins associated with transcriptional and translational regulation, along with other cellular processes. Further, UVI31+ is found to recognize DNA primarily by its β -sheet domain with a dissociation constant of 52 nM. Point mutation at S114 of UVI31+ to Ala residue (S114A) reduced the endonuclease activity 10 fold. (Himanshu Singh, Sunita Patel, B.J. Rao (DBS))

Towards Tailoring Plant Protease Inhibitors for Control of the Crop Pest *Helicoverpa armigera*

Developing a peptide based eco-friendly insecticidal agents to control insect pests that adversely affect the agricultural production by destroying the crops or infesting the livestock is a major challenge. The

most common Lepidoptera species that cause damage to agriculture sector is *Helicoverpa*. Recently, it has been reported that peptide based protease inhibitors (PIs) from *Capsicum annuum* potentially inhibit *H. armigera* gut proteases and also show a significant effect on its larval growth. However, very little information is currently available about the three-dimensional (3D) structure of these PIs or information about the residues that mediate their interaction with insect gut proteases. Recently, three recombinant PIs (IRD7, IRD9, IRD12) have been found to be very potent inhibitors with specific reference to their (i) stability in proteolytic environment (ii) proteinase inhibition specificities and (iii) inhibitory activity against insect proteinases. Thus, we set out to overexpress these three recombinant PIs, compare their activity *in-vitro* and *in-vivo*, and determine their 3D structure with a view to selecting the best candidate for future development as bioinsecticide proteases. As a prelude to the determination of 3D structures, we have carried out complete sequence specific ^1H , ^{13}C and ^{15}N resonance assignments for IRD7 and IRD12 and studied their dynamics using ^{15}N -relaxation data. The chemical shift index and the relaxation data show that ITD7 and IRD12 are well folded and highly stabilized with four disulphide bridges. (This project is being undertaken under DST-DIISRTE joint research project (*Australia-India Strategic Research Fund (AISRF)*)). (Janeka Gartia, Glenn King, The Queen'sland University, Brisbane, Australia and Dr. Ashok Giri, NCL Pune)

Differential accumulation and mobilization of starch and lipid in *Chlamydomonas reinhardtii*

Chlamydomonas reinhardtii has recently emerged as a viable alternative source of fossil fuel. However, the metabolic flow of carbon in *C. reinhardtii* for making the carbon reserve is not yet understood. In addressing this issue, we have grown the wild-type (cw15) and the starch deficient (sta6) strains of *C. reinhardtii* with a singly or doubly ^{13}C -labelled acetate as the sole source of carbon to monitor its assimilation by ^{13}C -NMR under nitrogen starvation and study the dynamics of starch and lipid reserves formed as dominant sinks of carbon. During such growth condition, the starch was found to accumulate and mobilize faster than TAG. This study describes different growth conditions for acetate carbon flow into formation of either starch or/and TAG and their remobilization during nitrogen replenishment condition, thus establishing a system for probing the cellular nitrogen sensing, uptake mediated changes in carbon flux. (Himanshu Singh, Manish Shukla, B.J. Rao (DBS)).

Functional manipulation of a putative UV inducible protein (UVI31+) from *Chlamydomonas reinhardtii*

Chlamydomonas reinhardtii is a single celled alga that undergoes apoptosis in response to UV-irradiation. UVI31+ in *C. reinhardtii* exhibits DNA and RNA endonuclease activity, which is induced upon UV-stress. UVI31+ that normally localizes near cell wall and pyrenoid regions gets redistributed into punctate foci within the whole chloroplast, away from the pyrenoid, upon UV-stress. The 3D solution state NMR structure of the putative UV inducible protein UVI31+ from *C. reinhardtii* revealed $\alpha_1\beta_1\beta_2\alpha_2\alpha_3\beta_3$ fold similar to that of BoLA and KH-domain type II protein families. Three α -helices of UVI31+ form one side of the protein surface while three-stranded β -sheet forms other

side. A strong hydrophobic core, providing a compact 3D protein structure, glues these secondary structural elements. Twenty-three residues (D54-H76) long polypeptide stretch connecting β_1 and β_2 strands is found to be highly flexible as confirmed by ^{15}N -relaxation NMR study. UVI31+ is found to recognize the DNA primarily by its β -sheet. The search for the catalytic triad in UVI31+ revealed the involvement of following residues: Ser 114, His 95 and Thr 116. Further, the S114A mutant of UVI31+, chosen for mutational study as Ser hydroxyl group is implicated as nucleophile in the catalysis of nucleases action, intriguingly showed significant loss of DNA endonuclease activity. (Himanshu Singh & K.V.R. Chary)

Materials Chemistry

Synthesis of new molecules/materials

Inorganic Vanadates as viable electrodes for supercapacitor applications

The ever-increasing global energy demands have spurred increased research into energy harvesting and storage systems. The development of effective energy storage systems with high energy density as well as high power density is becoming increasingly important. Electrochemical capacitors, also termed as supercapacitors, have attracted significant interest as these devices bridge energy density gap between conventional capacitors and batteries. To this effect, we have reported the optimized synthesis and electrochemical characterization of a composite of few-layered nanostructured MoS_2 along with an electroactive metal oxide BiVO_4 . In comparison to pristine BiVO_4 , and a composite of graphene/ BiVO_4 , the $\text{MoS}_2/\text{BiVO}_4$ nanocomposite provides impressive values of charge storage with longer discharge times and improved cycling stability. Specific capacitance values of 610 Fg^{-1} at 1 Ag^{-1} and 166 Fg^{-1} at 10 Ag^{-1} were obtained for just 2.5 wt% MoS_2 loaded BiVO_4 . The results suggest that the explicitly synthesized small lateral-dimensioned MoS_2 particles act as notable capacitive component that help augment the specific capacitance. Over the past year, the optimized synthesis of monoclinic BiVO_4 , and few-layered nanostructured MoS_2 has been finalized and also the discharge capacities and cycling performance of the $\text{MoS}_2/\text{BiVO}_4$ nanocomposite using an aqueous electrolyte have been obtained. The data obtained shows the $\text{MoS}_2/\text{BiVO}_4$ nanocomposite to be a promising candidate for supercapacitor energy storage applications. (Y. Arora & D. Khushalani)

Enhancement in Rate of Photocatalysis Upon Catalyst Recycling

Recyclability is an important aspect for heterogeneous photo-catalysts. Ease of recovery and stability of the photo-catalyst in terms of efficiency over the number of cycles are highly desired and in fact is ideal if the efficiency is constant and not decrease marginally with each cycle. Over the past year we have been able to observe a seminal observation in which the photocatalytic activity is shown to in fact improve with increasing number of catalytic cycles (1.7 better after the 1st cycle and 3.1 times better after the 2nd cycle). Specifically, nanorods of pure TiO_2 and TiO_2 doped with controlled amount of tungsten have been used to degrade two model pollutants: Phenol and Rhodamine B under exclusive visible light illumination. It was found that, in case of 1 mol.% W incorporation, rate of photocatalysis and also the range of visible light absorption of the photocatalyst increased after the photocatalysis as compared to before photocatalysis. This aspect is unique for doped TiO_2 and hence provides an intriguing way to mitigate low photoactivity. (K. Patel & D. Khushalani)

Novel luminescent Carbon Nanodots

Our research group has recently embarked upon the evaluation of carbon nanodots. Fluorescent carbon dots are a new class of nanomaterials that have emerged recently and they have incited a lot of interest because of their optical properties, low toxicity and simple synthetic routes. In this work, fluorescent carbon dots have been prepared by a unique simple, one step route involving microwave

assisted pyrolysis. An important feature of the method used is that no surface passivating reagent or harsh pH conditions are used. Six different precursors have been evaluated (glucose, sucrose, maltose, cyclodextrin, amine-, and thiol-functionalized cyclodextrin) to gain insight into the nature and origin of fluorescence. The synthesized carbon dots have been characterized by TEM, UV-Vis, FTIR, NMR, MALDI and fluorescence measurements. It has been showcased that amine functionalities on the surface of these structures greatly enhance the emissive properties whereas thiol based groups tend to quench the fluorescence. (D. Sasi & D. Khushalani)

Evaluation of novel Perovskite based light absorbers for use in heterojunction solar cells

Over the last 2-3 years there has been an exponential increase in the interest shown on novel light absorbing materials being referred to as “perovskites”. These are compounds with ABX₃ stoichiometry and these are all coordination compounds of lead: CH₃NH₃PbI₃, CH₃NH₃PbCl_xI_{3-x}, CH₃NH₃PbBr_xI_{3-x}, etc. These compounds have gained such popularity because the solar cells that have been fabricated using this light absorbing materials are found to routinely give efficiencies in the range of 10-20%. In our work, CH₃NH₃PbI₃, has been deposited, using a two-step deposition technique, on three different substrates: Bare FTO and two different types of TiO₂ electron transport layers. These structures have then been monitored, using XRD, for degradation under exclusively UV and visible light. It has been observed that the topography of the underlying substrate is shown to impose a substantial effect on the particle size of the HOIP phase that gets deposited on top. Furthermore, subsequently it has been observed that the particle size, the level of crystallinity and also type of irradiation (UV vs. Visible light) all are important parameters that substantially influence the rate and manner of degradation of HOIPs. These are in addition to the oft-cited parameters such as moisture, O₂ and temperature. Moreover, depending on the level of degradation, it has been intriguingly observed that the HOIP phase can be regenerated upon a simple treatment involving I₂ deposition. This latter aspect has potential to circumvent the deleterious degradation that is

hindering further progress on this highly promising material. (C. Seth & D Khushalani)

Nanotubes vs Spheres: Optimizing Drug Delivery Vehicles

Functional biomaterials can be used as drug loading devices, components for tissue engineering or as biological probes. Over the last year the synthesis of stoichiometrically pure, porous hollow hydroxyapatite nanotubes and their subsequent evaluation as potential drug delivery vehicles in comparison with nanospheres has been undertaken. These are new structures that are allowing us to investigate how morphology of nanostructures dictates the rate and manner of in vitro and in vivo cell encapsulation of drug delivery vehicles. Previously, only spherical capsules have been evaluated, however now with these unique 1D structures, we are observing how the efficacy of the drug delivery vehicles can be improved while maintaining biocompatibility. Single-particle analysis has been extensively performed to successfully prove the sole formation of HAP phase. The facile synthesis involves a sol-gel process under neutral conditions in the presence of a sacrificial anodic alumina template. The structures formed have been characterized by XRD, SEM, TEM, SAED, EELS, EDS and BET measurements. The diameter of the resulting tubes is in the range of 140-350 nm, length is on the order of a few microns and the wall thickness of the tubes is ca. 30 nm. The synthesis has been extended to form luminescent HAP nanotubes by incorporating Tb³⁺ ions into the structure which allowed facile direct imaging of the tubes and the tubes were tested for biocompatibility using MTT assay. Furthermore, direct imaging in the presence of fibroblast cells was also performed using a FRET pair composed of fluorescent proteins: SYFP-TQ. Structural changes were extensively studied using confocal microscopy to study the capability of the HAP nanotubes to be readily endocytosed in the cell without deleterious effects. Finally, these HAP nanotubes were evaluated for encapsulation capability using a variety of “cargo” molecules whose composition was varied from being hydrophilic to hydrophobic and also, molecular weights of the cargo molecules were varied up to 70kDa. (B. Chandanshive & D. Khushalani)

Chemical Biology

The group has reported novel ratiometric fluorescent sensors for detecting signaling phospholipids, phosphoinositides, in live cells using confocal microscopy. The importance of this class

of phospholipids is underscored by the fact that disturbances in the metabolism of these phospholipids have been linked to multiple diseases including cancer, bipolar disorder, and type 2

diabetes. Therefore chemical tools for detecting these phospholipids in biological systems can provide vital insights in to understanding the basis of cell signaling and the changes that occur under pathological conditions. This work was reported in ACS Chemical Biology, 2016. 'Cell Permeable Ratiometric Fluorescent Sensors for Imaging Phosphoinositides' [Samsuzzoha Mondal, Ananya Rakshit, Suranjana Pal, and Ankona Datta]

The group has developed a sensitive fluorescent and colorimetric sensor for detecting mercury ions in aqueous medium as well as in living cells. The probe can detect low nano-molar (ppb) levels of mercury selectively in the presence of other metal ions and can therefore be applied for detecting mercury contamination in drinking water. The group has also designed and synthesized several novel ligands for binding and chelating toxic metal ions.

Ratiometric Fluorescent Probes for Imaging Phosphoinositides

Phosphoinositides are membrane phospholipids that participate in cellular signal transduction. Crucial cellular and sub-cellular processes including membrane trafficking, cytoskeletal rearrangement and nuclear events are mediated via phosphoinositide signaling, making this class of phospholipids the singularly most important signaling lipids on the membrane. Dynamic changes in phosphoinositide locations on the membrane in conjunction with binding of phospholipid headgroups to cytosolic and membrane proteins execute these essential cellular events. Hence, visualizing phosphoinositide dynamics is key to discovering mechanistic principles underlying signal transduction. Fluorescence imaging is ideal for tracking and quantifying phosphoinositides in live cells because of its high spatial and temporal resolution. *Major challenges in phosphoinositide detection are linked to their cellular location and low concentrations.* Briefly, phosphoinositides are present in the inner leaflet of the plasma membrane and in the membrane of intracellular organelles. Also, these phospholipids constitute less than 5% of the total cellular phospholipid content. To add to the chemical complexity, differential phosphorylation of the inositol head group in phosphoinositides affords seven structurally distinct variants each regulating different cellular events. Therefore, the requirement for phosphoinositide imaging is: cell-permeable sensitive fluorescent probes that can selectively detect specific phosphoinositides. We have

modified short 13 and 20 amino acid peptides derived from the phosphoinositide binding site of a protein gelsolin to develop ratiometric fluorescent sensors for phosphoinositides. The sensors respond selectively to two crucial signaling phosphoinositides, phosphatidylinositol-4, 5-bisphosphate and phosphatidylinositol-4-phosphate, over other membrane phospholipids and soluble inositol phosphates. More importantly, the probes are cell permeable and light up signaling phosphoinositides both in the plasma membrane and in the perinuclear region as observed through multi-photon excitation confocal microscopy of live cells (Fig1). (Ankona Datta, Samsuzzoha Mondal and Ananya Rakshit)

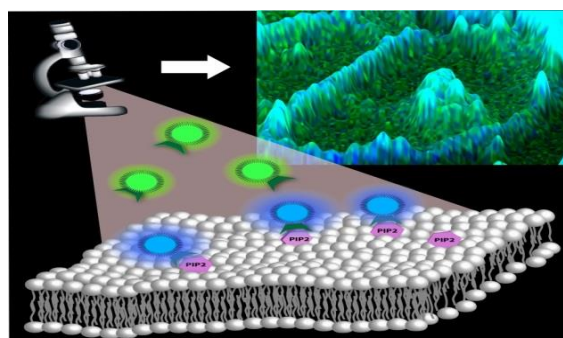
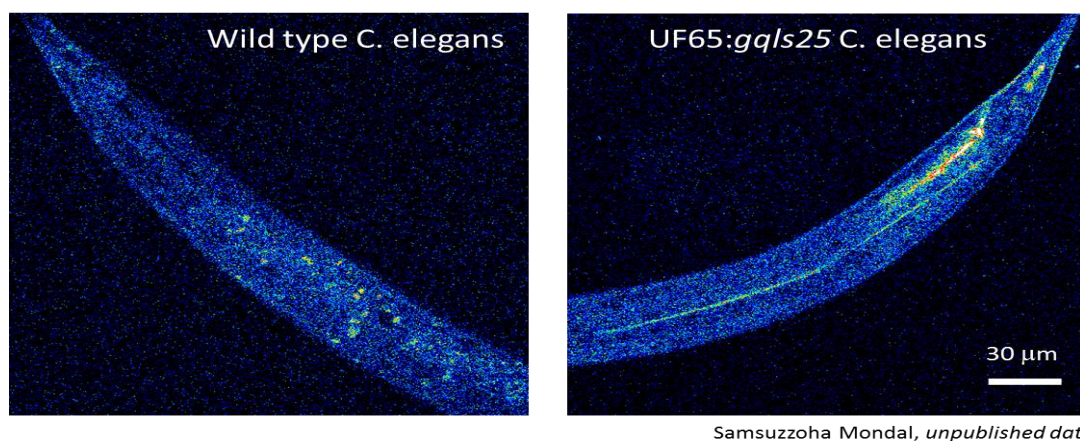


Fig 1: Ratiometric molecular probes for sensing signaling phospholipids. Probe molecules that do not interact with the phospholipids emit in the green, and the probe molecules that interact with the signaling lipids emit in the blue. Inset top right: Confocal image of live cells with the probe highlighting phosphoinositides in blue. The green emission is from unbound probe molecules. Thus, the probe changes color selectively in the presence of cellular phosphoinositides and is able to detect these signaling lipids.

Imaging Phosphoinositides *In vivo*

In collaboration with Prof. Sandhya Koushika (DBS, TIFR), we have tested our probes in an optically transparent multi-cellular model systems, *C.elegans*. Mutant (UF65:*gqls25*) worms, which overexpress PI4P-5-kinase were used for the studies. PI4P-5-kinase converts phosphatidylinositol 4-phosphate (PI4P) to phosphatidylinositol 4,5-bisphosphate (PI(4,5)P2). Hence, the neurons in the mutant worms have high concentration of PI(4,5)P2. We observed high fluorescence intensity in the mutant worms highlighting a few neurons, whereas the wild type worms showed uniform intensity (Fig 2). This result indicated the possible application of the probes for *in vivo* imaging of phosphoinositides. (Ankona Datta, Sandhya Koushika, Samsuzzoha Mondal)



Samsuzzoha Mondal, unpublished data

Fig 2: Application of ratiometric phosphoinositide probes for in vivo imaging in C.elegans. Right: Wild type C.elegans showing uniform intensity in the blue channel; Left: Mutant C.elegans highlighting over-production of PI(4,5)P2 in a neuron.

Design and Development of Selective Fluorescent Sensors for Detecting Metal Ions

Metal ions play essential roles as cofactors for enzymes and are present in the catalytic sites of 41 % of all enzymes with known three-dimensional structures. The labile metal ion pool that is coordinated to ions like chloride, citrate, and phosphate also plays significant roles in regulatory and signaling processes. Because of their unique role in biological function, dysregulation of metal ion homeostasis leads to severe pathological conditions including neurodegeneration. Insight into metal ion dynamics in the living systems is therefore necessary for achieving a mechanistic understanding of the biology of metals, especially regulation. Such endeavors will also provide therapeutic routes for metal-ion related maladies. In this respect, metal ion sensors are important chemical tools that enable monitoring *in vivo* metal ion concentrations and dynamics.

In our group, we are particularly interested in developing sensors for the transition metal ion manganese (Mn). Mn is a cofactor for enzymes like superoxide dismutase and glutamine synthetase that are essential for brain function. Weakly bound or labile manganese exists mostly in the +2 oxidation state and has been implicated in detoxification of reactive oxygen species. While essential, overexposure to Mn through occupational and environmental sources has been reported to cause Mn accumulation in the basal ganglionic regions of the brain. Excess Mn in the brain has been associated to a human neurological disorder, manganism which displays symptoms similar to Parkinson's disease. A recent study has indicated that the groundwater of several states in India including West Bengal, Assam, Meghalaya, and Tripura have unsafe levels of Mn. Mn exposure

has been reported to cause cognitive disorders in children exposed to Mn^{2+} through drinking water. The subtle balance between the essentiality and toxicity of Mn implies the existence of a sensitive regulatory pathway that maintains Mn homeostasis in vertebrate systems. *However, many of the Mn regulatory pathways are yet to be elucidated due to lack of tools that can help visualize Mn dynamics in vivo.* Chemical tools that can visualize and quantify Mn concentrations and fluxes in biological systems will be ultimately useful in deciphering Mn transport and regulation in living systems and provide mechanisms underlying Mn toxicity. Apart from *in vivo* Mn imaging, these chemical tools can also be specifically modified and optimized for detecting potentially toxic levels of Mn in drinking water. Towards this goal we have worked on the development of a water-soluble ratiometric fluorescent sensor for manganese. We have been able to synthesize several precursors for the desired sensor and are currently working on the final stages of the synthesis. We have also designed and synthesized metal ion specific chelators that can be used to treat metal ion induced oxidative stress.

In parallel to the work on developing sensors for essential metal ions like manganese, we have also worked on developing sensors for other environmentally toxic metal ions (Figure 3). The aim was to design sensitive detection schemes that could quantify low ppm to ppb levels of toxic metal ions in drinking water. We have developed a dual fluorescent and colorimetric sensor that can detect nano molar (ppb) levels of mercury (II) ions (*manuscript in preparation*). (Ankona Datta, Anindita Sarkar, Ananya Rakshit, and Sayani Das)

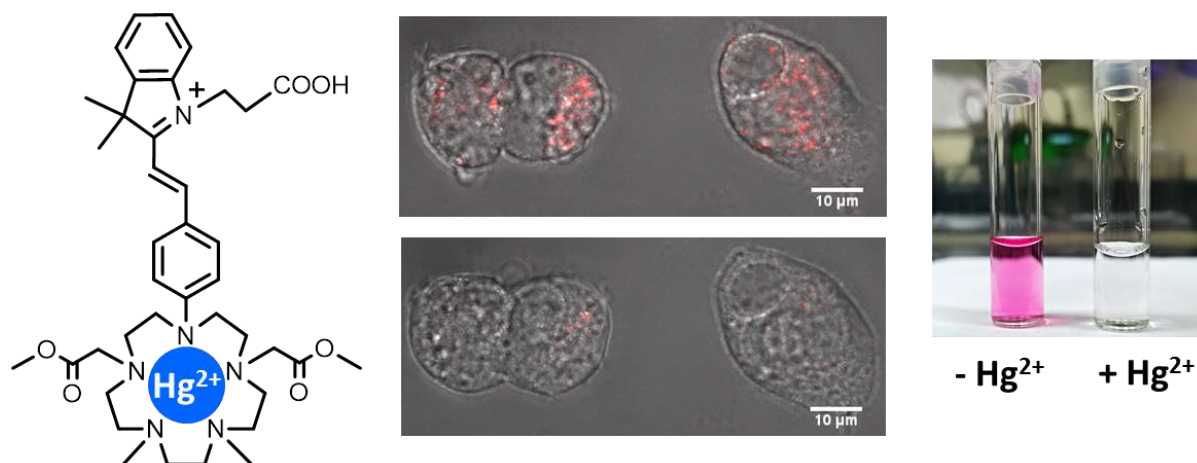


Figure 3: Left: Structure of a novel fluorescent quenching-based sensor for Mercury (II) ions; Middle: Internalization of the probe in live cells (top panel) and probe quenching in cells treated with Mercury (II) ions (bottom panel); Right: Colorimetric response of the probe in the presence of mercury ions.

Development of Magnetic Resonance Imaging Based Probes for Detecting Manganese Ions

Manganese being paramagnetic, can affect the relaxation properties of protons within biological tissue. This affords a contrast enhancement in magnetic resonance imaging, which can be mapped to locate excess manganese pools. However, the contrast enhancement is not enough to detect physiologically relevant levels of manganese. We have developed ^{19}F -based probes for manganese detection, which can exhibit higher sensitivity due to the low abundance of ^{19}F -containing molecules in biological systems (Figure 4).

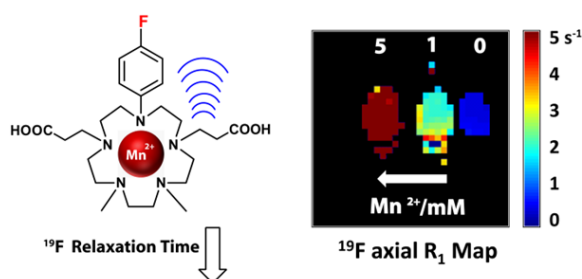


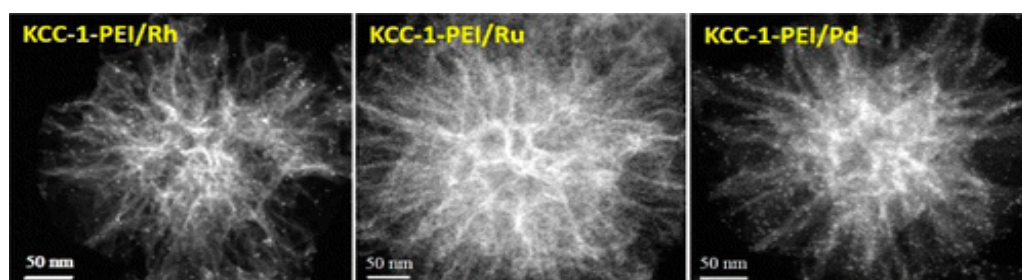
Figure 4: A novel fluorinated macrocyclic molecule that can be used for selectively detecting Mn^{2+} ions using ^{19}F magnetic resonance imaging. (Ankona Datta, Anindita Sarkar; Michal Neeman and Inbal Biton (WIS, Israel))

Nanocatalysis

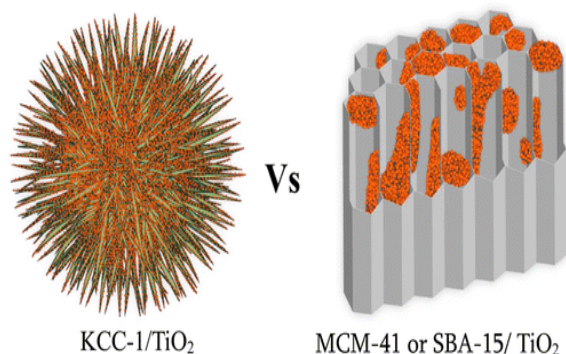
We have developed a facile protocol for the synthesis of fibrous nanosilica (KCC-1) with controllable size and fiber density. We are able to tune the particle size and now, one can synthesize KCC-1 with a particle size as small as 40 nm or as large as 1200 nm, with varying fiber density. Interestingly, we could double the surface area of KCC-1 to $1244 \text{ m}^2/\text{g}$ and achieve a pore volume of $2.18 \text{ cm}^3/\text{g}$, which are the highest values reported

to date for KCC-1. (Nisha Bayal, Baljeet Singh, Vivek Polshettiwar)

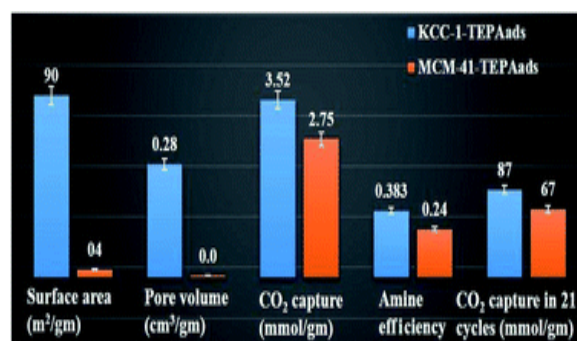
We have developed a simple and sustainable protocol for the synthesis of monodisperse metal nanoparticles supported on KCC-1. Use of expensive dendrimer was replaced by inexpensive polyethylenimine to produce highly monodispersed supported metal nanocatalysts. (Mahak Dhiman, Vivek Polshettiwar)



The design and synthesis of high surface area photocatalysts by coating TiO₂ on the fibrous nano-silica (KCC-1) using atomic layer deposition (ALD) was achieved. Our developed catalyst showed enhanced photo-catalytic activity, better than well-known MCM-41 and SBA-15 supported TiO₂ catalysts as well as other silica supported TiO₂ catalysts reported in the literature till date. (Rustam Singh, Vivek Polshettiwar)



Hybrid materials by functionalization of KCC-1 were synthesized for efficient CO₂ capture. KCC-1 based sorbents were found far better in terms of CO₂ capture capacity, rate of adsorption and stability. (Baljeet Singh, Vivek Polshettiwar)



Bioinorganic Chemistry

Copper binding peptides as models for intermediates of the CuA centre of cytochrome oxidase

We have designed several novel peptides derived from the metal-ion binding sequence of the CuA center of cytochrome oxidase of *Thermus thermophilus* and of human. These peptides were found to bind to single copper ion with characteristic type-2 EPR signal supporting a planar geometry around the metal ion. The results suggested that a nine amino acid peptide sequence could stabilise a red colored copper complex, while a 12 amino acid peptide stabilised green or blue copper complexes analogous to those detected earlier as kinetic intermediates during assembly of the purple dinuclear Cu₂S₂ core of the CuA center of the subunit II or cytochrome oxidase (Dwaipayan Dutta Gupta and S Mazumdar).

Enzymatic mono-oxygenation of unsaturated fatty acids by thermostable cytochrome P450 enzyme

CYP175A1 is a thermophilic P450 with high potential to invoke as an industrially viable biocatalyst. However, very little is known about the natural substrate that can undergo biotransformation in the enzyme pocket. The crystal structure of CYP175A1 was found to be closely related to its mesophilic analogue P450 BM-3, which is a fatty acid metabolizing enzyme. Our studies had revealed that CYP175A1 catalyzes regioselective mono-oxygenation of different monounsaturated fatty acids depending upon the position and stereochemistry of the double bond in

the substrate. We showed that polyunsaturated fatty acids (arachidonic acid, linoleic acid, α -linolenic acid & γ -linolenic acid) can also be oxygenated by the enzymatic action of CYP175A1 although the enzyme did not show any detectable activity on the corresponding saturated analogues (arachidic acid and stearic acid). The product analyses show that unlike monounsaturated fatty acids, polyunsaturated fatty acids undergo mono- as well as di-oxygenation reactions. Further, with the increase in unsaturation of the fatty acid the yield of mono-oxygenated product improved. The product analyses show that the regioselectivity of these oxygenation reaction is tightly regulated by the number and position of the double bonds in the fatty acids. Molecular docking calculations suggested that "U"-type conformations of the polyunsaturated fatty acids are particularly responsible for their binding at the enzyme pocket, and that is also consistent with the observed regioselectivity in the oxygenation reaction (Shibdas Banerjee, Dwaipayan Dutta Gupta and S Mazumdar).

Role of Substituents on the Reactivity and Product Selectivity in Reactions of Naphthalene Derivatives Catalyzed by CYP175A1

The thermostable nature of CYP175A1 enzyme is of potential interest for the biocatalysis at ambient temperature or at elevated temperature under environmentally benign conditions. Although little is known about the substrate selectivity of this enzyme, the biocatalytic activities of CYP175A1 on

different substituted naphthalenes have been studied in oxidative pathway, and the effect of the substituent on the reaction has been determined. The enzyme first acts as a peroxygenase to convert substituted naphthalenes to the corresponding naphthols, which subsequently undergo in-situ oxidative dimerization to form dyes of different colors possibly by the peroxidase-type activity of CYP175A1. The product analyses and kinetic measurements suggested that the presence of electron releasing substituent (ERS) in the substrate enhanced the substrate conversion, whereas the presence of electron withdrawing substituent (EWS) in the substrate drastically reduced the substrate conversion. The position of the ERS in the substrate was also found to play an important role in the transformation of the substrate. The results further demonstrate that mutation of the Leu80 residue to Phe enhances the reactivity of the enzyme by favoring the substrate association in the active site. The observed rates of the enzymatic oxygenation reaction of the substituted naphthalenes followed the Hammett correlation of substituent effect, supporting aromatic electrophilic substitution mechanism catalyzed by the cytochrome P450 enzyme (Shibdas Banerjee, Sandeep Goyal, and S Mazumdar).

The Protein Inhibitor of nNOS (PIN/DLC1/LC8) binding does not inhibit the NADPH-dependent heme reduction in nNOS, a key step in NO synthesis.

The neuronal nitric oxide synthase (nNOS) is an essential enzyme involved in the synthesis of nitric oxide (NO), a potent neurotransmitter. Although previous studies have indicated that the dynein light chain 1 (DLC1) binding to nNOS could inhibit the NO synthesis, the claim is challenged by contradicting reports, and the mechanism of nNOS regulation remained unclear. nNOS has a heme-bearing, Cytochrome P450 core, and the functional enzyme is a dimer. The electron flow from NADPH to Flavin, and finally to the heme of the paired nNOS subunit within a dimer, is facilitated upon calmodulin (CaM) binding. We showed that DLC1 binding to nNOS-CaM complex does not affect the electron transport from the reductase to the oxygenase domain. Therefore, it cannot inhibit the rate of NADPH-dependent heme reduction in nNOS, which results in L-Arginine oxidation. Also, the NO release activity does not decrease with increasing DLC1 concentration in the reaction mix, which further confirmed that DLC1 does not inhibit nNOS activity. These findings suggest that the DLC1 binding may have other implications for the nNOS function in the cell (Swapnil S. Parhad, Deepa Jaiswal, Krishanu Ray, S Mazumdar).

Members

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P. Arumugam, D.P. Avhad, B.B. Chandanshive, Gitanjali A. Dhotre, Sushma Kundu, B.T. Kansara, M.V.Kallianpur, A.N. Patil, Satyanarayan, S.G. Temkar

Research Scholars

Yukti Arora, Shrabasti Bhattacharya, Mandar Bopardikar, Anustup Chakraborty, Amitava Chandra, Bappaditya Chandra, Anirban Das, Ankita Das, Sayani Das, Simli Dey, Dwaipayana Datta Gupta, Deepshikha, Mahek Dhiman, Viole D'Mello, Rahul Gera, Nita Ghosh, Sanat Ghosh, Mona Gupta, Swagata Haldar, Ajay Jha, Barun K. Maity, Ayan Maity, Soumyajit Mitra, Abhijit Mondal, Imon Mondal, Samsuzzoha Mondal, Sanjoy Paul, Ananya Rakshit, Palas Roy, Anindita Sarkar, Bijon Sarkar, Charu Seth, Baljeet Singh, Himanshu Singh, Rustam Singh, Subha B., K. Vijaya Lakshmi, Anju Yadav

Visiting Fellows

Nisha Bayal, Shreetama Karmakar, Anoop Rawat, Manish Shandilya, Priyanka Shinde

Senior/Junior Research Fellows/Research Associates

Mayank Boob, Joel Corneilo, Ramiz Sheikh, Manisha Yadav

NMR Facility Staff

M.C. Dabholkar, D.A. Jadhav, M.V. Joshi, M.V. Naik

Administrative Staff

Shashikant K. Kadam, Jayesh Malkan

National and International Involvement

Sanjay Wategaonkar 1. Associate Editor, Journal of Chemical Sciences (Springer), Indian Academy of Sciences, Bangalore (May 2015 to date); 2. Member, Editorial board of "Physics Teacher", Indian Physical Society (2011 to date); 3. Vice President (2014

onwards) and Executive Council member of the Indian Society for Radiation and Photochemical Sciences, BARC, Mumbai (2010 to date); 4. Member, International Steering Committee, Asian Spectroscopy Conference, since 2012; 5. Member of the DAE Specialist Group, Chemistry (SG-13) for the XIIth plan. *S. Maiti* 1. Member, Working Group on Photonics, Dept. of Information Technology, Govt. of India; 2. Member, Editorial Board, Journal of Optics, Springer; Member, Editorial Board, Frontiers in Physiology and Biophysics (Nature Publication Group); 3. President and Founding Member, Fluorescence Society (www.fluorescenceindia.org), March 2016 – present. *J. Dasgupta* 1. Editorial Board Member of Scientific Reports, a journal carried by Nature Publishing Group; 2. Member of the American Chemical Society; 3. Secretary of the Fluorescence Society, a national organization that convenes scientific meetings annually for all chemists and biologists in the country; 4. Represented India in the 7th Indo-German Frontiers of Engineering meeting at Potsdam, Germany. *R. Venkatramani* 1. Life Member Indian Biophysical Society; 2. Fellow of the Royal Society of Chemistry; 3. Secretary, Royal Society of Chemistry, West India Section; 4. Editorial Board of Scientific Reports (Nature publishing group); 5. Reviewer (Physical Chemistry Chemical Physics, Journal of Physical Chemistry Journal of Chemical Sciences, Scientific Reports). *R. V. Hosur* Director: 1. UM-DAE Centre for Excellence in Basic Sciences, University of Mumbai, Kalina campus, Mumbai-400098; 2. Chairperson, INSPIRE Faculty selection committees; 3. Council, UoM-DAE CBS, Mumbai, 2009- 4. Academic Board, UoM-DAE CBS, 2009- 5. Member, DBT-IISc review committee, 2014-; 6. Member DAE-SRC young scientist award committee; 7. Member, NASI young scientist award selection committee; 8. Member, NASI Fellowship Scrutiny Committee; 9. Member, Editorial Board, The Scientific World Journal (2013-); 10. Member, Editorial Board, International Journal of Chemistry (2014-); 11. Member, Council, International Society of Magnetic Resonance (ISMAR), 2014-; 12. Member, Scientific Advisory Committee of ISMAR, 2014-; 13. Member, DBT Task Force on Modern Biology, 2014-. *K.V.R. Chary* 1. Elected Council Member of The National Academy of Sciences, India (2016-2018) 2. Member of Fellowship Scrutinizing Group of The National Academy of Sciences, India (2016-) 3. Elected Fellow of The World Academy of Sciences (FTWAS; 2014) 4. Elected as Treasurer and Steering Committee Member, Asian Biophysics Association (2013-present) 5. Elected as Member, International Advisory Board, International Council on Magnetic Resonance in Biological Systems (ICMRBS), (2014-2016) 6. Elected Chairperson, International Council on Magnetic Resonance in Biological Systems (ICMRBS), (2012-2014) 7. Member, IUPAB National Committee of INSA (2012-16) 8. Council Member, International Council on Magnetic Resonance in Biological Systems (ICMRBS), 2005-2014 9. Executive Council Member (2008-present) and Advisor (2012-present), Royal Society of Chemistry, West India Section 10. Member, Editorial Advisory Board, of the Journal Current Bioinformatics, launched by Bentham Science Publishers, The Netherlands and U.S.A. (2005-present); Member, Editorial Board, of “The Open Magnetic Resonance Journal”, launched by Bentham Science Publishers, The Netherlands and U.S.A., (2007- Present) 11. Fellow of Royal Society in Chemistry (FRSC) (2004-present) 12. Convenor, Indian Science Congress Association, Mumbai Chapter, Mumbai (2010-2015) 13. Member, J.N. Tata Endowment Selection Committee, Mumbai (2005-Present) 14. Member, Management Advisory Committee for the “National Facility for High Field NMR”, TIFR 15. Member, National Magnetic Resonance Society, India; Chemical Research Society of India, India; Indian Biophysical Society, India; Indian Chemical Society, India and Member, Society of Biological Chemists. *P. K. Madhu* 1. Convenor, MagRes Academic Advisory body (MRAAB) TIFR, Hyderabad 2. Member: Editorial Board, Journal of Magnetic Resonance, Journal of Biomolecular NMR, Solid State NMR 3. International Advisor, European School on Solid-state NMR 4. Member: Board of Trustees of EUROMAR, European Magnetic Resonance Meeting 5. Scientific Committee Member: ISMAR 2017. *Deepa Khushalani* 1. Member, Chemical Research Society of India 2. Member, Materials Research Society (USA and India) 3. Fellow of Royal Society of Chemistry. *Ankona Datta* 1. Member of the Fluorescence Society; 2. Member of the Indian Biophysical Society; 3. Member of the American Chemical Society; 4. Council member of the Materials Research Society of India, Mumbai Chapter; 5. Member of the Society of Biological Inorganic Chemistry. *Vivek Polshettimar* 1. Session Chair in 8th Int. Conf. on Mater. for Adv. Technologies (ICMAT2015), Singapore, 28 June to 03 July, 2015. 2. Sector Expert Jury for Parivartan Awards 2015. 3. Member of Advisory Committee for Functional Nanomaterials in Industrial Applications: Academic-Industry Meet (29-31st March 2016), UCLan, Preston, UK. 4. Thesis examiner and thesis vivvo-vice external examiner of students of various IITs, CSIR laboratories and universities. 5. Member of Executive Committee of Society for Materials Chemistry (SMC). 6. Member of Executive Committee of RSC Chemical Nanosciences and Nanotechnology. *Shyamalava Mazumdar* Life member, Chemical Research Society of India; Life member, Indian Biophysical Society; Steering Committee Member, Asian Biological Inorganic Chemistry; Member, National Organising Committee, Modern Trends in Inorganic Chemistry; Member, Society of Biological Inorganic Chemistry; Member Syllabus Committee, University of Mumbai; Member, DBT Task force on NanoBiotechnology.

Visits

Sanat Ghosh: Global Young Scientist Summit @one-north 2016, 17-22 January 2016, Singapore University of Technology and Design, Singapore; *Sudipta Maiti*: Invited visiting faculty to Leipzig university (June, 2016); *A.S.R. Koti*: Attended EMBO conference on “Ubiquitin and ubiquitin-like modifiers: From molecular mechanisms to human diseases”, September 18-22, 2015, Cavtat, Croatia; *Dr. Jyotishman Dasgupta*: visited Physics Department at Freie University, Berlin, Germany in October 2015. He delivered a colloquium during that time; *R.V. Hosur*: visited USA for attending international conference on Biomolecular Stereodynamics, June 9-13, 2015; visited USA for giving lecture at Stanford, Berkeley, Washington, New York, San Diego, June 18-30, 2015; *K.V.R. Chary*: SP Pune University, Pune held on February 26, 2015 to deliver an invited talk; State Key Laboratory of Bio-organic and Natural Product Chemistry, Shanghai Institute of Organic Chemistry, Chinese Academy of Science on Friday, May 8, 2015 to deliver an invited talk; Hongzhou, China, from May 9-12, 2015 to attend Asian Biophysics Association Conference to deliver a talk and Chair a session; SGP GIMS, Lucknow, on June 23, 2015 to attend National Workshop on “NMR in Biological Systems”; University of Wisconsin, on August 4, 2015 to deliver an invited talk; Structural Biology Initiative CUNY Advanced Science Research Center (ASRC) Monday, August 10, 2015 to deliver an invited talk; National Institutes of Health, National Heart, Lung, and Blood Institute, Bethesda, Maryland, USA, on August 17, 2015 to deliver an invited talk; Nano Cell, University of Linz, Austria, on November 23, 2015 to deliver an invited talk.

Invited Talks

S. Wategaonkar

1. “CH•••O Hydrogen bond mediated microsolvation of imidazole derivatives”, 5th Asian Spectroscopy Conference

(ASC5), University of Sydney, Australia, September 29–October 2, 2015.

2. "NH--S Interaction perspective", 21st International Conference on Horizons in Hydrogen Bond Research, Wroclaw, Poland, September 13–18, 2015.

Sudipta Maiti

1. Achilles Heel of Amyloid Beta, Institute of Chemical Technology, Mumbai, April 7, 2015
2. Understanding the Enhanced Membrane Affinity of Amyloid Beta oligomers, Asian Biophysic Association Annual Meeting, Hangzhou, China, May 10, 2015
3. "Amyloid Oligomers: The Universal Culprit", Biophysics Pashchim IX, Pune, Oct. 3, 2015
4. "Photonics for Brain Diseases", WRAP 2015, IISc Bangalore, Dec. 17, 2015
5. "Amyloids: A new twist", Optics Within Life Sciences, TIFR, March 2016

A.S.R. Koti

1. 24th April 2015: "Quantification of Protein Dynamics interms of Flexibility/Rigidity by Single-Molecule Force Spectroscopy Experiments", Indian Cell Mechanics Meeting, April 24-26, 2015, RRI Bangalore, India
2. 29th April 2015: "AFM based Dynamic Force Spectroscopy", Cell Mechanics Workshop, April 27- May 2, 2015 NCBS Bangalore, India
3. 23rd May 2015: "Can we quantify Protein dynamics in terms of protein stiffness?", Structure and Dynamics of Biomolecular Complexes, May 23, 2015, TIFR Mumbai, India
4. 10th July 2015: "Quantification of Protein Dynamics using Atomic Force Microscopy", International Conference on Electron Microscopy and 36th Annual Meeting of the Electron Microscope Society of India (EMSI-2015), July 8-10, 2015, Navi Mumbai, India
5. 7th January 2016: "Quantification of Protein Dynamics in terms of Flexibility/Rigidity by Single-Molecule Force Spectroscopy Experiments", 13th DAE-BRNS Biennial Trombay Symposium on Radiation & Photochemistry (TSRP-2016) and Asia Pacific Symposium on Radiation Chemistry (APSRC-2016), January 5-9, 2016, BARC, Mumbai, India
6. 13th March 2016: "Atomic force microscopy (AFM)", Fluorescence Correlation Spectroscopy (FCS-2016) Workshop, March 13-15, 2016, TIFR, Mumbai, India
7. 13th March 2016: "Dynamic Force Spectroscopy (DFS) on Proteins", Fluorescence Correlation Spectroscopy (FCS-2016) Workshop, March 13-15, 2016, TIFR, Mumbai, India
8. 18th March 2016: "Protein Stiffness and Dynamics Probed by Force Spectroscopy and Fluorescence Spectroscopy", Optics Within Life Sciences (OWLS-2016), March 16-19, 2016, TIFR, Mumbai, India

Jyotishman Dasgupta

1. "Photoinduced Charge Transfer States: Elicit, Engineer, Enhance!" at Shiv Nadar University, Noida, April 2016.
2. "Probing Ultrafast Photo-isomerization Reactions that Regulate Photosynthetic Acitivity" in the Optics within Life Sciences (OWLS) meeting at TIFR, Mumbai, March 2016
3. "Charge Transfer Rates in Soluble P3HT:PCBM Nano-aggregates Predict the Solvent Dependent BHJ Film Morphology" in Discussion Meeting on Electron Transfer in Chemistry at ICTS, Bangalore, January 2016.
4. "Photoregulation of Photosynthetic Apparatus by Isomerization Chemistry of Conjugated Chromophores: Insights from Time-resolved Spectroscopy" in the Physics Department at Freie University, Berlin, Germany, October 2015
5. "Femtosecond Raman snapshots on Phytochrome" in the Photoreceptors Roundtable at Fruaenchimsee, Bavaria, Germany, October 2015
6. "Photoinduced charge transfer rates as a probe for characterizing donor-acceptor interfaces in polymer-based

solar cells" in the 250th ACS National Meeting at Boston, Massachusetts, USA, August 2015.

7. "Photoinduced Charge Generation: Elicit, Engineer, Enhance!" in CRSI Mid-Year Meeting at NIT Trichy, August 2015.
8. "Chemistry with a non-local perspective" in Discussion Meeting on Emerging Themes in Nanophotonics, Goa, December 2015.

Ravindra Venkatramani

1. Sequence and Complexation Dependent Modulation of Stiffness in Ubiquitin Family Proteins, National Network for Mathematical and Computational Biology (NNMCB) National Meeting, Pune, December 27-30, 2015.
2. Describing rates and mechanisms of electronic charge flow through molecules, Kaleidoscope: A Discussion Meeting in Chemistry, July 2-5, 2015.

R. V. Hosur

1. June 12, 2015; 'Molten Globule nature of P2 from Plasmodium falciparum and toxoplasma gondii, 19th conversation on Biomolecular Stereodynamics, Albany, USA
2. July 16, 2015; 'Moving the Frontiers of Protein NMR' IISc, Bangalore
3. July 22, 2015; 'UM-DAE CEBS: A new Model for Basic Sciences Education and Research in India', IISER, Pune
4. Aug 1, 2015; 'Evolution of NMR based Structural Biology', IIT-Bombay, Mumbai
5. October 11, 2015; 'Science, Innovation and Development at Maker Mela, Somaiya college, Vidyavihar, Mumbai
6. November 5, 2015; Enhancing speed, Enhancing Resolution, Controlling Protein
7. January 27, 2016; Structure, Dynamics, folding/unfolding of SUMO proteins, NCBS Bangalore, International symposium on sumo proteins.
8. February 18, 2016; Some Recent Developments in Protein NMR; NMRS 2016 at IIT-Kharagpur

K.V.R. Chary

1. Invited talk on, "Structure and Dynamics of Intrinsically Ordered and Disordered Proteins by NMR: The state-of-the-art." at Indian Science Congress 2015, Kalina Campus, Mumbai University, on Monday, January 5, 2015
2. Key-note address on, "Bioinformatics and NMR Spectroscopy", at Lecture-Cum-Workshop on "Application of Bioinformatics in Drug Designing", held at DY Patil University, on Thursday, January 22, 2015.
3. Invited talk on, "NMR At The Interface Of Physics, Chemistry And Biology/Biotechnology", at Bio-Integration 2015 "Integrating Chemistry and Physics in Rediscovering Biotechnology" A National Seminar under Faculty QIP programme of SPPU, Pune held on Thursday, February 26, 2015.
4. Invited talk on, "Structure and Dynamics of UV inducible protein (UVI31+) from Chlamydomonas reinhardtii that exhibits RNA and DNA endonuclease activity", during the Asian Biophysics Association Conference, held at the Hongzhou, China, from May 9-12, 2015.
5. Invited talk on, "Echoes in NMR", at National Workshop on "NMR in Biological Systems", held at SGPGIMS, Lucknow, on June 23, 2015.
6. Invited talk on, "NMR of Nucleic Acids", at National Workshop on "NMR in Biological Systems", held at SGPGIMS, Lucknow, on June 25, 2015.
7. Invited talk on, "Evolution through Structure", at National Workshop on "NMR in Biological Systems", held at SGPGIMS, Lucknow, on June 25, 2015
8. Invited talk on, "An unusual calcium binding protein from Entamoeba histolytica", DCS Annual Talks, held at TIFR, on November 4, 2015.

9. Invited talk on, “ β -crystallins: Intrinsic Order & Disorder”, at the International Conference of FAOBAB, on Sunday, November 29, 2015.

Deepa Khushalani

1. ICONSAT 2016, March 2016, IISer Pune: “Hollow Nanotubes for Drug Delivery Applications.”
2. National Conference on Recent Trends in Science of Materials, December 2015, MSU Baroda: “Formation of Functional Oxides: Their Use in Energy Capture and Storage”
3. African – MRS 2015, December 2015, Ghana: “Formation of Functional Oxides: Their Use in Energy Capture and Storage”
4. ICMAT – IUMRS-ICA 2015 (International Conference on Materials for Advanced Technologies) June 2015, Singapore: “Unique Biodegradable Hollow Nanotubes for Drug Delivery Applications”

Ankona Datta

1. ‘Chemical Tools for Imaging Signaling Phospholipids’ Invited Talk, Optics Within Life Sciences, March 2016, TIFR, Mumbai, India.
2. ‘Tracking Manganese in Living Systems’, Invited Talk, 6th International Conference on Metals in Genetics, Chemical Biology, and Therapeutics, February 2016, Indian Institute of Science, Bangalore, India.
3. ‘Probes for Sensing Manganese in Live Cells’, Invited Talk, Cell Biology of Metals Gordon Research Conference, July 2015, Vermont, USA
4. ‘Turn-on Fluorescence Sensors for Detecting Mn(II) in Living Systems’, Contributed Talk, 17th International Conference on Biological Inorganic Chemistry, July 2015, Beijing, China.
5. ‘A Chemical Dialect for Sensing Bio-Molecules’, Contributed Talk, Department of Chemical Sciences, Annual Meeting, November 2015, Mumbai, India.
6. ‘Chemical Tools for Sensing Biomolecules’, Invited Talk, Complex Chemical System, November 2015, I.I.T. Kanpur, India
7. ‘Fluorescent Probes for Tracking Small Molecules and Ions in Live Cells’, Invited Talk, 5th National Symposium on Functional Applications of Colorants, October 2015, ICT, Mumbai, India.
8. ‘Fluorescent Sensors for Tracking Biomolecules in Live Cells’, Invited Talk, National Seminar on Recent Advances in Spectroscopy and Analytical Techniques, October 2015, NMIMS, Mumbai, India.
9. ‘Turn-on Fluorescent Sensors for Tracking Biologically Essential Small Molecules’, Invited Talk, Tezpur University, September 2015, Assam, India.
10. ‘Chemical Tools for Probing Biology’, Poster Presentation, Kaleidoscope a meeting for young Indian scientists organized by I. I. T. Bombay, July 2015, Goa, India.
11. ‘Turn-on Fluorescent Sensors for Visualizing Small Molecules *in vivo*’, Invited Talk, Ankona Datta, Recent Trends in Chemical Sciences, February 2015, St. Aloysius College, Mangalore, India.
12. ‘Imaging the Chemistry of Life: Techniques and Tools’, Invited Talk, Ankona Datta, Recent Trends in Chemical Sciences, February 2015, St. Aloysius College, Mangalore, India.

Vineek Polshettinvar

1. “Magnetically Recoverable Fibrous Nanosilica (KCC-1)”, in special symposium on Magnetic Materials in 250th ACS National Meeting & Exposition, Boston, USA, August 16-20, 2015.
2. “KCC-1 based Nanocatalysis”, in special symposium on Nanocatalysis 250th ACS National Meeting & Exposition, Boston, USA, August 16-20, 2015.

3. “Fibrous Nanosilica (KCC-1) based Catalysts for Green Environment and Sustainable Energy”, in 8th International Conference on Materials for Advanced Technologies (ICMAT2015), Singapore, 28 June to 03 July, 2015.
4. “Functionalized Fibrous Nanosilica (KCC-1) based Materials for Catalysis, Photocatalysis and CO₂ Capture”, Energy, Functional Materials and Nanotechnology (ICEFN 2016), at Department of Chemistry, D.S.B. Campus, Kumaun University, Nainital, Uttarakhand, 27-29th March, 2016.
5. “Functionalized Fibrous Nanosilica (KCC-1) for Energy and Environment”, International Conference on Nanoscience and Technology (ICONST-2016) on February 29 to March 2, 2016, at Indian Institute of Science Education and Research (IISER), Pune.
6. “Morphology controlled Nanomaterials for energy, environment and health”, Maharashtra Institute of Pharmacy, Pune during 12-13 Feb 2016.
7. “Functionalized Fibrous Nanosilica (KCC-1) for Catalysis and CO₂ Capture”, Indo-Japan DU-JAIST symposium on functional molecules/materials” at the Department of Chemistry, University of Delhi during 26-27 February, 2016.
8. “Morphology Controlled Nanomaterials for Catalysis and CO₂ Capture”, National Conference on “Chemical Sciences: Emerging Scenario & Challenges (NCCS-2016)”, on 29-30 Jan 2016, at Amravati University, Amravati.
9. “Nano-Catalysis: Morphological Controlled Synthesis of Nanomaterials and Their applications as Catalysts”, National Seminar on "Advances in Materials Chemistry and Applications", on 21-22 December 2015, at Changu Kana Thakur College, New Panvel.
10. “Green Organic Transformation using Nanocatalysis”, Symposium on "Advances in Green Chemistry", on 18th December 2015, at St. John Institute of Pharmacy and Research, Palghar.
11. “Morphology controlled Nanomaterials for Catalysis and CO₂ Capture”, 4th International Conference on Advanced Nanomaterials and Nanotechnology (ICANN2015), on 08-11 December 2015, in Guwahati-Assam, India at the Indian Institute of Technology Guwahati Campus.
12. “Green Chemistry by Nanocatalysis”, 4th Industrial Green Chemistry World (ICGW-2015), Mumbai, on 5th December 2015, at Hotel Courtyard Marriott International, Mumbai, INDIA.
13. “Fibrous Nanosilica (KCC-1) based Hybrid Materials for Catalysis and CO₂ Capture”, at R & D Center, Reliance Industry Ltd. (RIL), Mumbai, 18 September 2015.
14. “Shape and Morphology Controlled Nanomaterials for Sustainable Energy & Green Environment”, at UM-DAE Center for Excellence in Basic Sciences (CBS), Mumbai, 15 September 2015.
15. “Shape and Morphology Controlled Nanomaterials for Sustainable & Green Catalysis”, at Department of Physics, Mumbai University, Mumbai, 27 August 2015.

S. Mazumdar

1. Understanding the active site properties of an orphan Cytochrome P450, 17th International Conference on Biological Inorganic Chemistry (ICBIC17), Beijing, China, July 20-24, 2015
2. Recent developments of Electrospray Ionization Mass Spectrometry in the study of sequence and structures of biological macromolecules, Workshop on Advanced Techniques & Applications of Mass Spectrometry, Mumbai, 19-20 November, 2015
3. Cytochrome P450 enzymes for Nano-bio Catalysis in Environmental Detoxification, Conference on Chemical Sciences: Emerging Scenario & Challenges (NCCS-2016), SGB Amravati University, 29th – 30th January, 2016

Conferences Organized by the Department

6th International Conference on Metals in Genetics, Chemical Biology, and Therapeutics, Indian Institute of Science, Bangalore, India, February 2016

Electron Transfer workshop at ICTS, Bangalore, January 2016

This meeting will be expanded to a full blown 5-day discussion meeting and workshop to help raise awareness amongst country's best students about the latest trends in contemporary electron Transfer research.

School on Plasmonics and Nano-optics at TCIS Hyderabad, December 2015

The school catered to students and scientists interested in learning fundamentals of plasmonics especially molecule-metal interfaces using both near-field and far-field optical techniques.

National Poster Symposium on Advances in Chemical Sciences, jointly Organized by Royal Society of Chemistry, December 12, 2015

India Deccan Local Section, India & Tata Institute of Fundamental Research, Centre for Interdisciplinary Sciences, Hyderabad.

Kaleidoscope: A Discussion Meeting, Goa, July 13-17 2016

Kaleidoscope is an annual meeting series aimed at young investigators working in various fields of chemistry and its allied area in biology and physics.

Modern Trends in Electron Transfer Chemistry: From Molecular Electronics to Devices, ICTS, Bangalore, Jan 29-30 2016

The meeting introduced students, young researchers, and the public to exciting problems and directions in contemporary ET research which spans multiple disciplines across physics, chemistry, and biology. The format of the program included research talks and poster sessions with 25 students and researchers from India. The topics covered both experimental and theoretical

aspects of molecular electronics and devices. The meeting included a public lecture by Prof. Latha Venkatraman (Columbia University) on the exciting field of Molecular Electronics.

International Conference of Optics Within Life Sciences (OWLS-2016), TIFR, Mumbai, March 16-19, 2016

The OWLS conference series highlights advances in optical imaging/spectroscopic techniques and their applications to study biological systems across molecular, cellular, and organism scales. The 14th edition of OWLS brought this important meeting to India for the first time. OWLS-2016 had nine thematic sessions: Fluorescence Spectroscopy, Super-resolution Imaging, Single Molecule spectroscopy, Nanoscale Biophysics, Ultrafast Phenomena in Biology, Bio-imaging in Live Cells, SERS Platforms in Biology, Probes for Imaging, Spectroscopy, and Sensing, and Theoretical Optical Spectroscopy. The conference featured invited lectures, contributed lectures, and poster sessions. Nearly 400 students and researchers from India and all over the world attended.

FCS Workshop An annual National Workshop, organized preceding the OWLS meeting

NMR Meets Biology: An Interaction Week: January 14-19, 2016, Kerala, India

The interaction meeting focused on the state-of-the-art solid- and solution-state NMR methods to tackle challenging issues in biology. The workshop sessions consisted of tutorials on methods and applications of NMR to biological problems and hands-on-sessions on structure solving and spin systems simulations. The progress made with NMR on biological system, like membrane proteins, was highlighted. The meeting also had several brain-storming sessions on the future prospects in this field, with respect to the methods and systems. There were only oral presentations at the meeting. The number of participants was limited to 50.

Non-DAE Research Projects

K.V.R. Chary

The DST-DIIRTE joint research project (Australia-India Strategic Research Fund (AISRF)), DST, 2015-17

P.K. Madhu

1. Indo-Swiss PEP entitled "Heteronuclear decoupling under homonuclear recoupling sequences" with Matthias Ernst, ETH, Zurich, Switzerland

2. Danish-Indian collaboration programme entitled "Solid-state NMR methods and applications" (with Niels Nielsen, University of Aarhus, Denmark).



Department of Condensed Matter Physics and Materials Science

Magnetism, Superconductivity, Intermetallics, Oxides

Oxides

Magnetic and magnetodielectric coupling anomalies in the Haldane Spin-chain System $\text{Nd}_2\text{BaNiO}_5$

During previous years, we reported interesting magnetoelectric coupling effects in the heavy rare-earth members (R= Gd, Dy, and Er) of the Haldane spin-chain family R_2BaNiO_5 . We wanted to compare and contrast with the behavior in light rare-earth members to explore possible influence partial delocalization of 4f orbital in the latter and therefore studied Nd member. We find a magnetic anomaly at low T (<10 K) of a glassy type, in addition to the one at T_N (48 K), in $\text{Nd}_2\text{BaNiO}_5$, thereby suggesting 're-entrant' magnetic behavior of this compound. The presence of magnetodielectric coupling in this compound is also established. This study thus establishes that these two observations are not restricted to heavy rare-earth members, but appear to a characteristic property of this family of oxides. However, our attempts to find ferroelectricity, characteristic of heavy rare-earth members, are not successful till now. The dielectric constant interestingly tracks the magnetic feature due to the depopulation of exchange-interaction-split Kramers doublet and its frequency-dependence suggests an interesting slow dynamics of this phenomenon. A comparison of frequency dependence of ac susceptibility and dielectric constants in the presence of external magnetic fields supports our earlier proposals that the dynamics of electric and magnetic dipoles appear different, despite existence of magnetodielectric coupling, warranting theoretical studies on this aspect in this area of great current interest and also emphasizes possible role of 4f hybridization for Nd. (Tathamay Basu, Niharika Mohapatra, Kartik K. Iyer, Kiran Singh and E. V. Sampathkumar).

Enhanced Magnetic Ordering temperature and Dielectric Behavior in off-stoichiometric $\text{Ca}_3\text{Cu}_{1-x}\text{Mn}_{1+x}\text{O}_6$ (x = 0.07)

A marginally Cu deficient compound $\text{Ca}_3\text{Cu}_{0.93}\text{Mn}_{1.07}\text{O}_6$, derived from $\text{Ca}_3\text{CuMnO}_6$ was studied for its structural and magnetic properties using magnetization, heat capacity, and dielectric studies as well as neutron diffraction. Interestingly enough, this off-stoichiometry leads to long-range magnetic order at a much higher temperature of ~ 23 K, compared to that reported (5.3 K) for the stoichiometric compound, thereby strengthening our earlier proposal that this system is an example for 'order by disorder' phenomenon. It is also intriguing to note that another anomaly is observed in ac susceptibility and dielectric measurements around 110 K, which has not been observed in the stoichiometric compound and we attribute to intrachain interactions (reinforcing our assertions on novel roles spin-chain behavior in recent years). The magnetic structure of $\text{Ca}_3\text{Cu}_{0.93}\text{Mn}_{1.07}\text{O}_6$ obtained from the analysis of temperature-dependent neutron diffraction data, is found to be of a ferrimagnetic type. $\text{Ca}_3\text{Cu}_{0.93}\text{Mn}_{1.07}\text{O}_6$ also exhibits dielectric anomalies in the vicinity of the two magnetic ordering temperatures. Overall, this off-stoichiometric composition presents an interesting situation in comparison with the literature results on stoichiometric composition. (S. Rayaprol, S. D. Kaushik, K. K. Iyer and E. V. Sampathkumar).

Magnetic and magnetodielectric behavior of GdCrTiO_5 and its implications

We have investigated magnetic and magnetodielectric behaviour of a new member in the family RCrTiO_5 that belongs to the same structure as well-known magnetoelectric system, RMn_2O_5 , in which geometrical frustration plays a role on multiferrocity. We have made many interesting observations. The results suggest that there is no clear-cut evidence for long range magnetic ordering in GdCrTiO_5 down to 2 K. Though there are some observations near about 11 K that could be attributable to weak Cr magnetic ordering, this requires further confirmation.

Nevertheless, the results unequivocally establish that the magnetic ordering from Cr in this compound is suppressed with respect to that in the Nd analogue. T_N value for the Nd analogue is known to be high (21 K), despite the fact that, as well-known, the magnetic moment on Nd is much smaller compared to that on Gd. We believe that the enhanced T_N value for the Nd case arises from the competing role of 4f-radial extension, which is known in the rare-earth literature to increase as one moves away from Gd towards lighter rare-earths, thereby resulting in enhanced hybridization. We therefore tend to argue that Nd 4f (by way of hybridization) has a role to determine the magnetism of Cr, in contrast to original belief proposed long ago. This compound is characterized by magnetodielectric coupling, interestingly without any feature in the absence of magnetic-field. Additional dielectric data at higher temperatures (well above ~ 50 K) suggest the existence of short range electric ordering; this could be associated with an interplay between crystallographic disorder and short-range magnetic order, even at temperatures as high as about 150 K, as inferred from the presence of a broad asymmetric Raman spectral feature as well. There is a possibility of antisite disorder between Cr and Ti crystallographic positions and this high temperature feature may arise because of hopping conductivity between these two sites. It is hoped that this work motivates further studies to explore the role of geometrically frustrated magnetism (as in the case of RMn_2O_5) in this family as well. (Tathamay Basu, Kiran Singh, Smita Gohil, Shankar Ghosh, and E.V. Sampathkumaran).

Complex dielectric and impedance behavior of Fe_2TiO_5

We have investigated the complex dielectric and impedance properties of polycrystalline Fe_2TiO_5 (FTO), on which we reported some interesting results last year, as a function of temperature. to understand the grain (G) and grain boundary (G_b) contributions to its dielectric properties. The temperature and frequency (ν) dependent dielectric data show sharp increase in ϵ' above 175K accompanied with a frequency dependent peak in $\tan\delta$. At low temperatures ($T < 175\text{K}$), the grain contribution is responsible for the observed dielectric behavior even at low frequencies. Our analysis illustrates that above 175K, G_b contribution starts appearing at very low frequencies ($f < 175\text{Hz}$), whereas G contribution dominates at higher frequencies. The critical frequency which distinguishes these two contributions increases with increasing temperature. The frequency dependence of ac conductivity follows the Jonscher's power-law

and is found to be consistent with correlated barrier hopping. The observed dielectric relaxation follows thermally activated process and shows non-Debye type behavior which is associated with polaron hopping. (Shivani Sharma, Tathamay Basu, Aga Shahee, K. Singh, N. P. Lalla and E. V. Sampathkumaran).

Intermetallics

Observation of 're-entrant inverse-magnetocaloric phenomenon' and asymmetric magnetoresistance behavior in RFe_5Al_7 (R= Gd and Dy)

The magnetocaloric effect (MCE) of a few rare-earth based ferrimagnets containing two magnetic sublattices, attracted some attention a few decades ago, as there is a sign cross-over at the magnetic compensation point. We consider it important to further expand our knowledge on MCE phenomenon in this respect by focusing on other multi-sublattice magnetic systems. We have noted that the rare-earth intermetallics of the type, RFe_5Al_7 , crystallizing in ThMn_{12} -type tetragonal ($I4/mmm$) structure, provide an ideal opportunity for the same. After initial investigations in 1982, the interest in this family got revived only very recently. With the primary motivation of understanding of MCE behavior of such a complex ferrimagnet, we have undertaken a magnetic study of two members, namely R= Gd and Dy, of this family. These two members order ferrimagnetically at 250 and 223 K respectively. Primary conclusions are: (i) There are (*unusually*) multiple sign-crossovers in the temperature (T) dependence of isothermal entropy change (ΔS) in the case of Dy compound; in addition to nil ΔS at the magnetic compensation point known for two-magnetic-sublattice systems, there is an additional sign-crossover at low temperatures, as though there is a need to invoke a new concept called 're-entrant inverse magnetocaloric effect'. Corresponding sign reversals could also be observed in the magnetoresistance data, however without sign reversal at the normal to inverse MCE transition point. (ii) The plots of magnetoresistance versus magnetic field are found to be unusually asymmetric with the reversal of the direction of magnetic-field (H) well below T_N for both compounds, comparable to that reported recently for antiferromagnetic tunnel junctions. We attribute these to subtle changes in spin orientations of R and Fe moments induced by T and H . Thus, we observed conceptually novel features in these materials. (Venkatesh Chandragiri, Kartik K Iyer and E.V. Sampathkumaran)

Multiband superconductivity in $\text{Lu}_3\text{Os}_4\text{Ge}_{13}$

As we have shown before, intermetallic $\text{R}_3\text{T}_4\text{X}_{13}$ series consist of a cage-like structure and have attracted attention due to their unconventional electronic ground states. In this work, we report the normal and superconducting state properties of a high-quality single crystal of $\text{Lu}_3\text{Os}_4\text{Ge}_{13}$ belongs to the above-mentioned series and crystallizes in a cubic crystal structure with the space group $\text{Pm}\bar{3}$ (3) over barn. Using electrical transport, magnetization and heat capacity measurements, we show that $\text{Lu}_3\text{Os}_4\text{Ge}_{13}$ is a type-II multi-band superconductor ($T_c = 3.1$ K) with unusual superconducting properties. The analysis of the low-temperature heat capacity data suggests that $\text{Lu}_3\text{Os}_4\text{Ge}_{13}$ is a moderately coupled multi-band BCS superconductor with two gaps ($2D/k_B T_c = 3.68 \pm 0.04$ & 0.34 ± 0.02) in the superconducting state. The dc-magnetization (M-H) shows a large reversible region in the superconducting state similar to the vortex liquid phase observed in high- T_c superconductors. The value of the Ginzburg number G_i suggests that the thermal fluctuations, though small compared to those in high- T_c cuprates, may play an important role in the unpinning of the vortices in this compound. The electronic band structure calculations show that three bands cross the Fermi level and constitute a complex Fermi surface in $\text{Lu}_3\text{Os}_4\text{Ge}_{13}$. [S. Ramakrishnan, Om Prakash and A. Thamizhavel and A.K. Nigam]

Ferromagnetic ordering of minority Ce^{3+} spins in a quasi-skutterudite cubic single crystal of $\text{Ce}_3\text{Os}_4\text{Ge}_{13}$

Intermetallic $\text{R}_3\text{T}_4\text{X}_{13}$ series consists of cage like structure and have been in focus due to their unconventional electronic ground states. After establishing superconductivity in $\text{Y}_3\text{Os}_4\text{Ge}_{13}$ and $\text{Lu}_3\text{Os}_4\text{Ge}_{13}$, we began to work with magnetic rare earth atom in the same structure. Here, we report site-disorder driven ferromagnetic ordering of nearly 8% Ce atoms in single crystalline $\text{Ce}_3\text{Os}_4\text{Ge}_{13}$ below 0.5 K. $\text{Ce}_3\text{Os}_4\text{Ge}_{13}$ crystallizes in a cubic structure with space group $\text{Pm}\bar{3}n$. The ordered structure should have Ce atoms in the 6(d), Os atoms in the 8(e), Ge atoms in 24(k), 2(a) positions. However, the structural analysis shows that the 2(a) Ge site is partially occupied by Ce atoms and the 6(d) site is partially occupied by Ge. We find that approximately 8% of the total Ce ions are present on the 2(a) site. While the Ce ions on the 2(a) site are in Ce^{3+} magnetic state, those on the 6(d) site are in the Ce (nonmagnetic) state. This is due to the fact that the Ce at 2(a) site is loosely bound within the cage, hence is weakly hybridized with other atoms as compared to the Ce at 6(d) position. Weak Ce 4f-ligand hybridization leads to Ce atoms in the Ce^{3+}

(magnetic) state in 2(a) position while rest of the Ce atoms in the unit cell (6(d) position) are in Ce^{4+} (non-magnetic) state. The heat capacity study shows a peak below 0.5 K corresponding to the ferromagnetic ordering of the 8% Ce^{3+} moments. The ferromagnetic ordering below 0.5 K is also seen in the ac-susceptibility data. At low temperatures ($1.8 \text{ K} < T < 6 \text{ K}$), the magnetization shows $\log(T)$ dependence, whereas the resistivity shows power law ($T^{1.1}$) temperature dependence indicating the non-Fermi liquid behavior of the quasiparticles. Our detailed investigations establish that $\text{Ce}_3\text{Os}_4\text{Ge}_{13}$ is a moderate heavy fermion system that exhibits ferromagnetic ordering of minority Ce^{3+} spins (in 2(a) site) below 0.5 K. The existence of two different Ce valence states is a rare occurrence for a metallic system. It is even rather unusual for small concentration of Ce spins to undergo bulk magnetic ordering in a site-disordered crystal lattice giving rise to non-Fermi liquid behaviour. [S. Ramakrishnan, Om Prakash and A. Thamizhavel]

Charge density wave(CDW) ordering in $\text{Dy}_2\text{Ir}_3\text{Si}_5$ single crystal

Charge-density-wave (CDW) transitions occur in low dimensional solids where it is possible to achieve nesting of Fermi surfaces that leads to the appearance of a periodic lattice distortion with an accompanying energy gap. This instability is possible to achieve only in low dimensional solids as was demonstrated by Peierls. This is very well documented from the early works of many research groups performed on a wide range of quasi-low-dimensional systems includes transition-metal dichalcogenides and trichalcogenides. Even though in 3D compounds it is not possible to get a perfect nesting but CDW ordering has also been established in 3D materials such as $\text{R}_5\text{Ir}_4\text{Si}_{10}$ (R = rare-earth elements). So it appears that even in imperfect nesting there remains a possibility for the appearance of CDW. In order to probe the theory further and search for novel CDW behaviors, new classes of materials are needed. One such system is the rare earth ternary silicides, $\text{R}_2\text{Ir}_3\text{Si}_5$ which has received current research attention owing to its complex 3D crystal structure and the unusual ground states that they exhibit such as: superconductivity, CDW, Kondo behavior, coexistence of CDW and superconductivity or magnetism, etc. Earlier we established that $\text{Lu}_2\text{Ir}_3\text{Si}_5$ exhibits superconductivity at 3.5 K and shows strongly coupled(electron phonon) first order CDW transition between 150 and 200 K. We have now successfully grown high quality single crystals of $\text{Dy}_2\text{Ir}_3\text{Si}_5$ by Czochralski method. The physical properties of the single-crystalline samples of $\text{Dy}_2\text{Ir}_3\text{Si}_5$, have been investigated by magnetic susceptibility, resistivity and heat capacity studies.

We observed multiple charge density wave transitions in all the measurements. We definitely see a strong coupling of the Dy^{3+} moment to the underlying CDW transition as established by strong hysteresis in the high temperature (150 to 200 K) magnetization. This could be due to the change in the moment of Dy^{3+} spins or due to the modification in the energy states split by the crystalline electric field (CEF). Synchrotron studies to determine the q vectors responsible for the CDW ordering and neutron scattering studies to probe CEF split states are in progress. [S. Ramakrishnan, A. Thamizhavel in collaboration with P. Lal and D. Pal, I.I.T Guwahatti]

Superconductivity of single crystalline Bismuth below 0.53 mK

The unusual physical properties of semi-metal Bismuth (Bi) warrant a special place in the periodic table of elements. In fact, physical properties of Bi have been extensively studied for more than a century and they are even continued today. Bi was in fact the first element whose Fermi surface was experimentally identified and provided the basis to determine that of other metals. Many of the outstanding properties of bulk Bi are linked to its peculiar electronic structure. It has tiny electron and hole pockets and a very small density of states (DOS) at the Fermi level. Since the carrier density is so low, metallic screening is therefore much weaker than in typical metals, and the inter-atomic bonding has a stronger directional component. This connects with the layered crystal structure with alternating weak and strong inter-layer bonds, which can be described as a stacking of bilayers. Such a structure leads to many unusual features of Bi. Small Fermi surface (FS) (just 10^{-5} of the Brillouin zone), low carrier density ($3 \times 10^{17}/\text{cm}^3$ at 2 K), low Fermi energy (~ 25 meV), and small effective carrier mass ($m_e^* < 0.003 m_0$ along the trigonal axis) distinguish Bi from other elements. Since low Fermi energy results in small electron-phonon scattering, it is why Bi has large electron mean free path (exceeding $2 \mu\text{m}$ at 300 K). All of these properties make Bi particularly suitable for studying quantum phenomena. However, superconductivity, a macroscopic quantum phenomenon has never been observed in bulk Bi under ambient conditions till now.

We now report first ever observation of bulk superconductivity of a high pure (99.9999%) single crystal of Bi at 0.53 mK under ambient conditions with a critical field ($B_c(0)$) of $5 \mu\text{T}$ using DC Squid magnetization measurements. The Bi crystal was grown using modified Bridgeman technique.

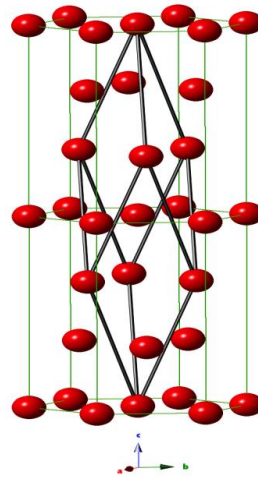


Fig. 1. Crystal Structure of Bismuth

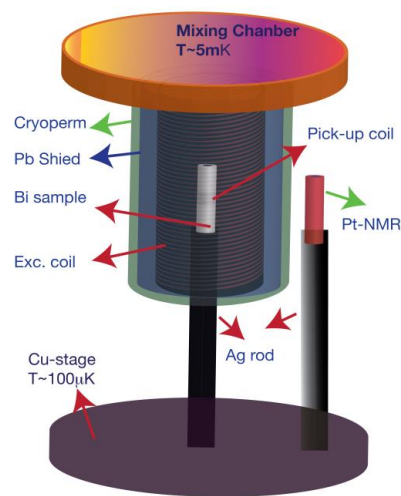


Fig. 2 DC Squid seup at μK stage

The crystal structure of Bi (Fig. 1) shows that the inter-atomic bonding in Bi has a strong directional component leading to a layered crystal structure with alternating weak and strong inter-layer bonds. Such a structure is a crucial factor to observe many quantum phenomena rather easily in Bi. A cylindrical crystal of the length 8mm and diameter 4 mm of Bi was attached to an annealed high purity silver rod (99.999%) which is threaded to the copper nuclear stage. The detection of superconductivity was made using a DC squid (see Fig. 2) magnetometer. A primary coil was directly wound on the former made from stycast which is attached to the mixing chamber of the dilution refrigerator (Leiden, Cryogenics, The Netherlands). The chamber was shielded with a cryoperm and superconducting lead shields so that the ambient field inside the chamber is less than 4 nT when there is no current in the primary coil. The secondary coil was wound directly on the sample and it is connected to a DC squid, which in turn is connected to the RF amplifier fixed at the head of the cryostat. The DC magnetometer assembly is kept at the compensated magnetic field region (< 10

nT) of the copper nuclear stage (see Fig. 2). The RF head is connected to the squid control unit which directly reads output in volts. The dc magnetometer was calibrated at 4.2 K by measuring the diamagnetic signal from superconductors such as Nb and Pb. The temperature was measured using a squid based noise thermometry (PTB, Germany) and ^{195}Pt NMR thermometer (PLM 5, Finland) down to 0.1 mK.

Recent studies have shown that reduced (oxygen deficient) SrTiO_3 exhibited superconductivity around 50 mK for the lowest carrier density of $5 \times 10^{17}/\text{cm}^3$. From this result, they claimed that the T_c cannot be estimated from the BCS model and their results posed new constraints for microscopic pairing scenarios. This makes the superconductivity in Bi even more puzzling since its carrier density is even lower than that of oxygen deficient SrTiO_3 . It is possible that multivalley electronic structures, intra-valley electron-phonon interaction could lead to net attractive potential which could lead to superconductivity in Bi.

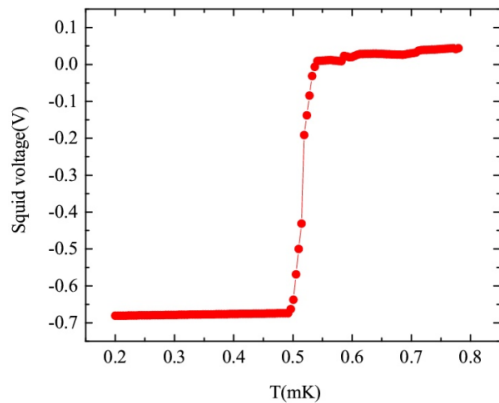


Fig. 3 Diamagnetic signal at 40 nT

One can see the Meissner signal (see the Fig. 3) whose magnitude is comparable to the diamagnetic signal observed for superconducting Pb calibrated at higher temperature. It also agrees favorably with the signal size observed for pure Rh in our earlier run. The temperature dependence of the critical field is shown in Fig. 4. The extrapolated value of the critical field at 0 K ($B_c(0)$) is found to be $5 \mu\text{T}$ which is similar to that of Rh. But the carrier concentration in Bi is more than five orders of magnitude less than that of Rh. The conventional theoretical approach to explain superconductivity in Bi fails due to that fact that the phonon energy and Fermi energy are comparable in this material.

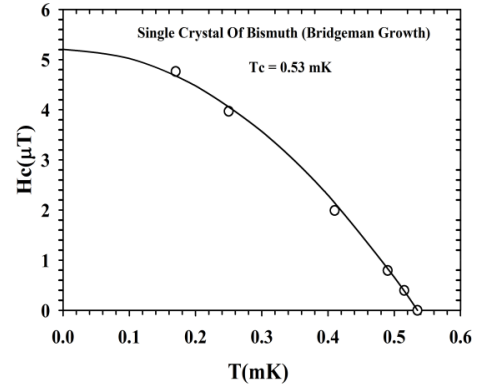


Fig. 4 Critical field dependence on Temperature

Discovery of superconductivity in Bi also makes Bi as the superconductor with the lowest carrier density thus, breaking the record held by doped SrTiO_3 for nearly 50 years. We believe that superconductivity of Bismuth under ambient pressure will stimulate new theoretical ideas to understand superconductivity in extremely low carrier density materials. [S. Ramakrishnan, Om Prakash and A. Thamizhavel]

Coexistence of superconductivity and a charge density wave in $\text{LaPt}_2(\text{Si}_{1-x}\text{Ge}_x)_2$ ($0 < x \leq 0.5$)

As mentioned before, CDW is a periodic modulation of electronic charge density and is the ground state in quasi-low-dimensional materials (QLDM) at low temperatures because the elastic energy required by the lattice to vary the position of atoms is lower than the gain in conduction electron energy. Recent studies show that LaPt_2Si_2 shows a CDW transition at around 112 K and superconducting transition at 1.8 K. It has also been established that superconductivity and CDW modulation coexist in the (Si(2)-Pt(1)-Si(2)) layer in the structure with Pt(1) site responsible for the CDW effect. LaPt_2Si_2 is a promising system for further investigations due to its stability in a low-dimensional structure and coexistence of superconductivity and a CDW in the same layer. Motivated by these considerations we carried out a detailed investigation of the effect of chemical pressure on the CDW and superconductivity in LaPt_2Si_2 . Interplay between a charge density wave (CDW) and superconductivity in $\text{LaPt}_2(\text{Si}_{1-x}\text{Ge}_x)_2$ has been studied by electrical transport and magnetic measurements. LaPt_2Si_2 crystallizes in CaBe_2Ge_2 type structure which shows a first order structural phase transition from tetragonal to orthorhombic accompanied by a CDW transition at 112 K and superconducting transition at around 1.22 K as confirmed by temperature dependence of resistivity and magnetic measurements. For 2% doping of germanium, while the CDW temperature T_{CDW} decreases, the superconducting transition

temperature T_C shows an increase. T_{CDW} increases for 5% doping of germanium and the superconducting transition decreases. These findings demonstrate the competing nature of a CDW and superconductivity. These results reflect the competitive nature of the CDW and superconductivity in this system. Dependence of T_{CDW} and T_C on x is unusual. More measurements on well controlled samples with intermediate concentrations are required to establish this unusual feature. [R. Gupta, U.B Paramanik, S. Ramakrishnan, K.P. Rajeev and Z.Hossain].

Switching effect in the magnetization response in a superconducting specimen of $Ca_3Rh_4Sn_{13}$

The classical Meissner effect (diamagnetic effect or DME) is the quintessential phenomenon of the complete expulsion of magnetic flux from a superconductor during its transition from normal to the superconducting state. In contrast to the DME, another phenomenon often designated as the paramagnetic Meissner effect (PME), or Wohleben effect, in which the field-cooled (FC) magnetization of some of the high and low temperature superconducting samples is observed to be paramagnetic below the transition temperature T_C , has been reported several times in the literature.

This anomalous paramagnetic response in low T_C superconductors has been interpreted as due to the absence of complete flux expulsion and partial flux trapping in the interior of the sample due to inhomogeneous manner of cooling in the presence of a field, and the subsequent compression of the trapped field. An earlier study in a weakly pinned single crystal specimen of $Ca_3Rh_4Sn_{13}$ had revealed the presence of positive magnetization on field cooling (PMFC) in low applied fields. Present investigations show that the isofield magnetization measurements in a superconducting single crystal of $Ca_3Rh_4Sn_{13}$ exhibit the PME response in a specific region of the magnetization curve while field cooling under various experimental conditions. Such a response in the specific region is found to be multivalued/metastable, which can be manipulated in a characteristics manner by altering the experimental conditions. The controlled switching of magnetization between widely differing values including the change in sign of magnetization, has application potential in magnetic switching and binary memory devices thus making use of the presence of metastable states in this system. [Suresh Babu; Thamizhavel, A.; S. Ramakrishnan and D. Pal]

Magnetic properties of the tetragonal $RCuGa_3$ ($R = Pr, Nd$ and Gd) single crystals

Using Ga as flux, we have grown the single crystals of $RCuGa_3$ ($R = La, Pr, Nd$ and Gd) compounds, which have tetragonal structure (space group $I4mm$). The magnetic properties were probed by heat capacity, magnetization and electrical resistivity. $PrCuGa_3$ and $NdCuGa_3$ order magnetically below 6 K, the ground state being a doublet. The magnetization data on $GdCuGa_3$ show combined characteristics of spin glass and antiferromagnetic behavior at low temperatures. We have further determined the crystal electric field (CEF) level energy spectra from the Schottky heat capacity data. The magnetic properties of Pr and Nd analogs are anisotropic due to the magnetocrystalline anisotropy arising from the CEF splitting of the Hund's rule derived ground state multiplet and the anisotropic Fermi surface. ESR data on $GdCuGa_3$ between 11K and room temperature indicate an enhancement of magnetic fluctuations associated with spin reorientation and both homogeneous and inhomogeneous thermal broadening of the line width, which may be due to atomic disorder. [R. Nagalakshmi and S. Nallamuthu, Department of Physics, NIIT, Tiruchirappalli, India; Ruta Kulkarni, S. K. Dhar and A. Thamizhavel, T.I.F.R.; V. Krishnakumar, Department of Physics, Periyar University, Salem; Marian Reiffers and Ivan Ćirklić, Department of Experimental Physics, Watsonova

47, SK-040 01 Kosice, Slovakia; Hans Hagemann and Dominique Lovy, Department of Physical Chemistry, University of Geneva, Switzerland].

Anisotropic magnetic properties of $EuAl_2Si_2$

We have grown a single crystal of hexagonal $EuAl_2Si_2$ for the first time in literature using Al-Si eutectic flux. We observed an antiferromagnetic transition at $T_N = 33.3$ K, in agreement with the previously reported value on polycrystalline sample. The isothermal magnetization at 2 K measured along and perpendicular to the c -axis shows anisotropic behavior, which is rather unexpected as Eu^{2+} is an S-state ion. The electrical resistivity shows an upturn between T_N and 60 K as the temperature is lowered below ~ 60 K, suggesting the presence of antiferromagnetic correlations in the paramagnetic state. Magnetoresistivity at 2 K at 14 T for $H // [0001]$ is huge, nearly 1070 %. The thermal variation of the hyperfine field, inferred from ^{151}Eu Mössbauer spectroscopy, follows an $S = 7/2$ mean field curve, and consistent with a second order magnetic transition. [Arvind Maurya, Ruta Kulkarni, A. Thamizhavel and S.K. Dhar, T.I.F.R.; P. Bonville, SPEC, CNRS, Université Paris-Saclay, CEA-Saclay, France].

Enhanced electronic band density of states in intermetallic EuTSi_3 ($T = \text{Rh, Ir}$)

Magnetic properties of single crystalline EuRhSi_3 and polycrystalline EuIrSi_3 were probed by thermodynamic, transport and ^{151}Eu Mössbauer spectroscopy measurements. The single crystal magnetization in EuRhSi_3 has a strongly anisotropic behavior at 2 K with a spin-flop field of 13 T along the easy axis of magnetisation, and we present a model of these magnetic properties which allows the exchange constants to be determined. In both compounds, specific heat showed the presence of two closely spaced magnetic transitions near 50 K, and the ^{151}Eu Mössbauer spectra demonstrate that the intermediate phase has an incommensurate amplitude modulated structure. We find anomalously large values, compared to other members of the iso-structural EuTX_3 ($X = \text{Si}$ and Ge) series, for the RKKY Néel temperature, the spin flop field (13 T) and the spin wave gap ($\approx 20\text{-}25$ K), the spin disorder resistivity in EuIrSi_3 ($\approx 240 \mu\Omega\text{cm}$) and for the saturated hyperfine field (52 T). A coherent and qualitative interpretation of these results was provided by assuming a high density of electronic band states $N(E_F)$ at the Fermi energy. [Arvind Maurya, A. Thamizhavel, S.K. Dhar, T.I.F.R.; P. Bonville, SPEC, CNRS, Université Paris-Saclay, CEA-Saclay, France].

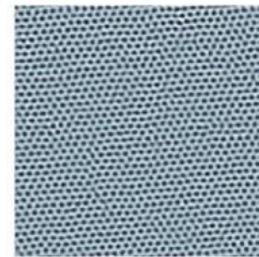
Magnetic properties and complex magnetic phase diagram in non-centrosymmetric EuRhGe_3 and EuIrGe_3 single crystals

Using In flux we grew the single crystals of EuRhGe_3 and EuIrGe_3 , which crystallise in the tetragonal, non-centrosymmetric BaNiSn_3 -type structure (space group $I4mm$). EuIrGe_3 exhibits two magnetic transitions at $T_{N1} = 12.4$ K and $T_{N2} = 7.3$ K; on the other hand EuRhGe_3 undergoes a single antiferromagnetic transition at $T_N = 12$ K. ^{151}Eu Mössbauer spectra show evidence for a cascade of transitions from paramagnetic to incommensurate amplitude modulated followed by an equal moment phase at lower temperatures in EuIrGe_3 . This latter phase alone occurs in EuRhGe_3 . In both compounds, the magnetization measured up to 14 T suggests that the equal moment phase has a spiral spin arrangement. A superzone gap is observed for the current density $J // [001]$, which is enhanced by a transverse magnetic field. The magnetic phase diagram constructed from magnetization and magnetoresistivity data is complex in both compounds, revealing the presence of many phases in the H-T space. [Arvind Maurya, R. Kulkarni, A. Thamizhavel and S.K. Dhar, T.I.F.R.; P. Bonville, SPEC, CNRS, Université Paris-Saclay, CEA-Saclay, France].

Exploring metamagnetism of single crystalline EuNiGe_3 by neutron scattering

We have extended our previous work on EuNiGe_3 by investigating its magnetic order versus temperature and magnetic field by single crystal neutron diffraction. Despite the strong absorption of neutrons by Eu, the (B, T) phase diagram in the low temperature phase was extracted. The zero field magnetic structure was found to be an equal moment helicoidal phase, with an incommensurate wave vector $\mathbf{k} = (1/4, \delta, 0)$, with $\delta \approx 0.05$. Applying the field along the tetragonal axis, we found a peculiar behavior of δ , which changes from 0.05 to 0.072 at 2 T, where the first spin-flop transition was observed in our previous work, and vanishes at 3 T, where the second magnetization jump takes place in the isothermal magnetization at 2 K. The results obtained from neutron diffraction are in perfect agreement with previous macroscopic measurements of magnetization and magnetoresistivity. Most of these features were well reproduced by a self-consistent mean-field calculation. [X. Fabrèges and A. Gukasov, Laboratoire Léon Brillouin, CEA, CNRS, Université Paris-Saclay, CEA-Saclay, France; P. Bonville, SPEC, CNRS, Université Paris-Saclay, CEA-Saclay, France; A. Maurya, A. Thamizhavel and S.K. Dhar, T.I.F.R.].

Real space investigations of the vortex lattice in weakly pinned Type II superconductor NbSe_2



The vortex lattice in an NbSe_2 single crystal imaged at 450 mK and 15 kOe.

The focus of our research is on real space investigation of the order disorder transition of the vortex lattice in a weakly pinned superconductor. These experiments were performed on Co-intercalated NbSe_2 single crystals using the high field milli-Kelvin scanning tunneling microscope developed in TIFR. Tracking the evolution of vortex lattice with temperature and magnetic field, we showed that in the presence of a weak random pinning potential, the vortex lattice disorders through two successive first order phase transitions where the positional order and the orientational order are destroyed. We also demonstrated that the vortex phase diagram is strongly influenced by the orientational coupling between the vortex lattice and the crystalline lattice. [Indranil Roy, Somesh

Chandra Ganguli, Harkirat Singh, Rini Ganguly, A. Thamizhavel, Vivas Bagwe]

Gold-rich $R_3Au_7Sn_3$: establishing the interdependence between electronic features and physical properties

We have discovered two new polar intermetallic compounds $Y_3Au_7Sn_3$ and $Gd_3Au_7Sn_3$, which crystallise in the hexagonal, $P6_3/m$ - type structure. Chemical bonding analyses of both compounds indicate that the majority of bonding originates from the heteroatomic Au-Gd and Au-Sn interactions, while homoatomic Au-Au bonding is evident within the $Au@Au_6$ clusters. $Gd_3Au_7Sn_3$ is an antiferromagnet with $T_N = 13$ K, while $Y_3Au_7Sn_3$ is a Pauli paramagnet which presumably is superconducting at low temperatures as suggested by a strong downward curvature in its electrical resistivity at about 1.9 K. DFT-based band structure calculations on $R_3Au_7Sn_3$ account for the results of conductivity measurements and provide conclusive hints about the magnetic structure of $Gd_3Au_7Sn_3$. [Alessia Provino*, Simon Steinberg, Volodymyr Smetana, Pietro Manfrinetti* and Anja-Verena Mudring. The Ames Laboratory, Iowa State University, Ames, USA; Ruta Kulkarni and Sudesh K. Dhar, T.I.F.R.; *Department of Chemistry, Univ. of Genova, Italy].

Critical behavior of magnetic phase transitions in R_2CoGa_8 ($R = Gd, Tb$) by means of photopyroelectric calorimetry

From thermal diffusivity and specific heat measurements, we have analysed the critical state data close to the respective Néel temperatures of Gd_2CoGa_8 and Tb_2CoGa_8 . In the case of Gd_2CoGa_8 , the data suggest that the compound belongs to the Heisenberg universality class, in agreement with its magnetic structure. For Tb_2CoGa_8 , the shape of the magnetic transition is affected by the presence of two small anomalies, which do not allow extraction of the corresponding critical parameters. [A. Oleaga and A. Salazar, Departamento de Física Aplicada I, Universidad del País Vasco UPV/EHU, Bilbao, Spain; A. Thamizhavel and S.K. Dhar, T.I.F.R.].

The nano-microfibrous $R_{11}Ni_4In_9$ intermetallics: New compounds and extraordinary anisotropy in $Tb_{11}Ni_4In_9$ and $Dy_{11}Ni_4In_9$

We have discovered the existence of new members in the $R_{11}Ni_4In_9$ family of fibrous compounds for $R = Dy, Ho, Er, Tm$ and Lu . These compounds crystallise from their molten state in the arc furnace in self-assembled nano/microfibres, translating into a macroscopic microwire morphology of the alloys, which is responsible for the strong anisotropy observed in their physical properties. Multiple

magnetic transitions are obtained in $Tb_{11}Ni_4In_9$ and $Dy_{11}Ni_4In_9$ with the highest ordering temperature, T_C , of 112 and 88 K, respectively. Ferrimagnetic behavior with extremely high coercive fields ($H_C = 6.6$ T for $Tb_{11}Ni_4In_9$ and 5.7 T for $Dy_{11}Ni_4In_9$ at 2 K) is found when the fibres (and the c -axis) are oriented parallel to the magnetic field. First principles calculations were performed for several representative compounds to explain the underlying phase stability and their magnetism. [A. Provino*, K.A. Gschneidner, Jr, Y. Mudryk, P. Manfrinetti*, D. Paudyal and V.K. Pecharsky, The Ames Laboratory, Iowa State University, USA; S.K. Dhar, T.I.F.R.; C. Ferdeghini, *Department of Chemistry, University of Genova, Italy].

Magnetic structure of $R_5Ni_2In_4$ and $R_{11}Ni_4In_9$ ($R = Tb$ and Ho): strong hierarchy in the temperature dependence of the magnetic ordering in the multiple rare-earth sublattices

We have shown that $R_5Ni_2In_4$ and $R_{11}Ni_4In_9$ with $R = Ho, Tb$ display a multitude of transitions as function of temperature as revealed by specific heat, magnetization and neutron diffraction data. These transitions are of magnetic origin and are connected to the appearance of magnetic order on the different sublattices of the rare earth in the crystallographic structure. There are three R-sublattices in $R_5Ni_2In_4$ which order at different temperatures in a sequence $R1(2a)$ and $R3(4g)$ together, and then $R2(4g)$ with magnetic propagation vectors $\kappa_1 = (0,0,0)$ and $\kappa_2 = (0, \delta, 1/2)$, where the second propagation vector acts mostly on the R2 site. In $R_{11}Ni_4In_9$ there are five R-sublattices and the sequence of ordering with decreasing temperature is $R2(4i)$ and $R5(2a)$, then $R1(\delta\beta)$ followed by $R3(4i)$ and lastly $R4(4g)$. Three or four different magnetic propagation vectors, acting within different temperature ranges and on different R-sublattices are present in $Tb_{11}Ni_4In_9$ and $Ho_{11}Ni_4In_9$, respectively. The strength of the magnetic interactions of the different sublattices can be linked to structural details for both $R_5Ni_2In_4$ and $R_{11}Ni_4In_9$ compounds. [C. Ritter, Institut Laue-Langevin, Grenoble, France; A. Provino and P. Manfrinetti, Department of Chemistry, University of Genova, Italy; V.K. Pecharsky and K.A. Gschneidner, Jr., The Ames Laboratory, Iowa State University, USA; S.K. Dhar, T.I.F.R.].

Ti_3CrCu_4 : A possible 2-D ferromagnetic spin fluctuating system

Ti_3CrCu_4 is a new ternary compound which crystallises in the tetragonal Ti_3Pd_5 -type structure. The Cr ions placed in the tetragonal a - b plane form square nets ($a = 3.124$ Å), which are separated by an unusually large distance $c = 11.228$ Å along the tetragonal axis, thus forming a 2-D Cr sublattice.

The zero field heat capacity C/T shows an upturn below 7 K (~ 190 mJ/mol K² at ~ 0.1 K) which is suppressed in applied magnetic fields and interpreted as suggesting the presence of spin fluctuations. The resistivity at low temperatures shows non-Fermi liquid behavior. Low temperature measurements thus reveal an unusual magnetic state in Ti_3CrCu_4 characterised by the presence of ferromagnetic spin fluctuations with a possible 2-D character due to the 2-D nature of Cr-sublattice. Electronic structure calculations employing LSDA reveal a sharp Cr-density of states peak close to the Fermi level, therefore suggesting proximity to a magnetic instability. [S.K. Dhar, R. Kulkarni and Neeraj Goyal*, T.I.F.R.; A. Provino and P. Manfrinetti, Department of Chemistry, University of Genova, Italy; D. Paudyal, The Ames Laboratory, Iowa State University, Ames, USA, *Department of Cognitive and Spintronic Technologies, Max Planck Institute for Microstructure Physics, Weinberg 2, D-06120 Halle, Sachsen-Anhalt, Germany].

Kondo lattice and antiferromagnetic behavior in quaternary $\text{CeTAl}_4\text{Si}_2$ ($T = \text{Rh, Ir}$) single crystals

Single crystals of $\text{CeTAl}_4\text{Si}_2$ ($T = \text{Rh, Ir}$) were grown using Al-Si binary eutectic composition as flux. We have explored in detail the anisotropic properties of $\text{CeRhAl}_4\text{Si}_2$ and $\text{CeIrAl}_4\text{Si}_2$, which undergo two antiferromagnetic transitions, at $T_{N1} = 12.6$ and 15.5 K, followed by a second transition at $T_{N2} = 9.4$ and 13.8 K, respectively, with the [001]-axis as the relatively easy axis of magnetisation. The electrical resistivity at ambient and applied pressure provides evidence of Kondo interaction in both compounds, further supported by a reduced value of the entropy associated with the magnetic ordering, and the large Sommerfeld coefficient, γ , 195.6 and 49.4 mJ/mol K² for $\text{CeRhAl}_4\text{Si}_2$ and $\text{CeIrAl}_4\text{Si}_2$, respectively, classifying these compounds as moderate heavy fermions. The crystal electric field energy levels are derived from the peak seen in the Schottky heat capacity. Electronic structure calculations using the local spin density approximation+U [LSDA+U] provide physical insights on the observed magnetic behavior of these two compounds. [Arvind Maurya, Ruta Kulkarni, A. Thamizhavel and S.K. Dhar, T.I.F.R.; D. Paudyal, The Ames Laboratory, Iowa State University, USA].

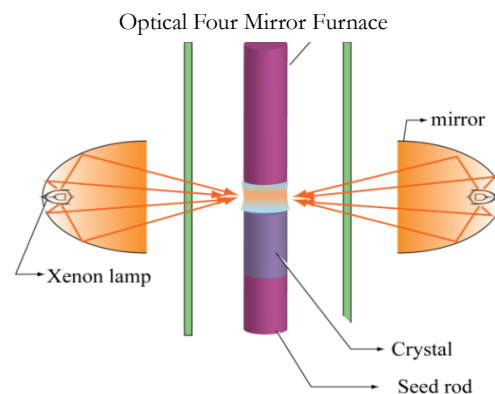
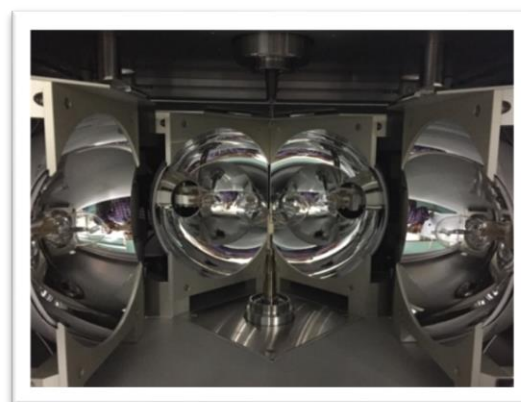
Electronic nature of the lock-in magnetic transition in $\text{CeXAl}_4\text{Si}_2$

We have extended our previous work on Kondo lattice antiferromagnets $\text{CeRhAl}_4\text{Si}_2$ and $\text{CeIrAl}_4\text{Si}_2$ by performing detailed neutron scattering measurements on their single crystals. Both compounds exhibit sharp magnetic transition from an incommensurate phase, at intermediate

temperatures, to the lock-in commensurate phase at low temperatures. The spin structures in these two phases are manifested by spin density wave and long-range antiferromagnetic configurations of correlated Ce ions, respectively. The analysis of the experimental data, combined with the calculation of the Fermi surfaces, suggests that the incommensurate phase can be arising due to the Fermi surface nesting. [J. Gunasekera, A. Dahal, D.J. Singh and D.K. Singh, Department of Physics and Astronomy, University of Missouri, Columbia, USA; L. Harriger and S.M. Disseler, NIST Center for Neutron Research, Gaithersburg, Maryland, USA; A. Maurya, A. Thamizhavel and S.K. Dhar, T.I.F.R.; T. Heitmann, University of Missouri Research Reactor, Columbia, USA].

Crystal growth of rare-earth intermetallics, anisotropic magnetic properties

A four mirror optical floating zone furnace was successfully installed. This new floating zone furnace adds up to our existing crystal growth facilities, to grow oxide single crystals in particular. Since this is a crucible-less technique high quality single crystals of both oxides and intermetallic compounds can be grown. The mirror arrangements and the lamps together with a schematic are shown in the figure below.



Schematic representation of the mirror furnace
A variety of single crystals of both oxide and

intermetallic compounds have been grown using this furnace.

Single crystals of $\text{Gd}_2\text{Ti}_2\text{O}_7$ and NiFeGa are shown below:



As grown NiFeGa single crystal



$\text{Gd}_2\text{Ti}_2\text{O}_7$ Single crystal

Study on Magnetic Antiperovskite

Further studies on Mn_3GaC antiperovskite compound with Sn substitution have been carried out to study the magnetocaloric effect (MCE). These compounds are also categorized as functional materials. The study reveals that the nature of the magnetocaloric effect (MCE) has a strong dependence on the nature of the magnetic ordering. For small amounts of Sn, an inverse MCE is observed, wherein an increase in the applied field beyond 5 T leads to a table like temperature dependence of the entropy due to a coupling between the first order ferromagnetic (FM)–antiferromagnetic (AFM) transition and the field induced AFM–FM transition. For the Sn-rich compounds, conventional MCE behaviour is observed, which could be explained as due to the introduction of local strain by A site ions (Ga/Sn), which affect the magnetostructural coupling in these compounds. [A.K. Nigam in collaboration with K.R. Priolkar and Elaine Dias of Goa University, Goa under a joint BRNS project]

Study on magnetic perovskite (RCrO_3)

In order to study the transition metal doping induced structural and magnetic changes in RCrO_3 , polycrystalline $\text{RCr}_{1-x}\text{Mn}_x\text{O}_3$ samples (where R = Tb, Tm, $x = 0, 0.05$ and 0.1) were prepared using Ball Milling technique. The magnetic measurements have been performed in the temperature range 2 – 300K and magnetic fields upto 7 Tesla. Temperature and magnetic field dependent powder neutron diffraction measurements have also been carried out at high resolution ECHIDNA beamline at Bragg user facility, ANSTO, Sydney. The data is being analysed to determine the magnetic state of the samples. [Megha Vagadia and A. K. Nigam]

Magnetic state of Multiferroic compound $\text{CdCr}_2\text{Se}_{4-x}\text{S}_x$

Interplay between structural disorder and magnetic interaction is investigated for a multiferroic candidate material, CdCr_2Se_4 . Ferromagnetic order in CdCr_2Se_4 sets in below $T_C \sim 130$ K as a result of competition between the direct Cr-Cr spin coupling and the near neighbor Cr-Se-Cr exchange interactions. Hence, a small change in the crystal structure is expected to drastically affect its magnetic order. Local lattice distortions within the overall cubic symmetry were brought about by replacing a small percentage of Se by isovalent S. Detailed crystal structure study using EXAFS and Raman Spectroscopy reflects the presence of local distortions within the overall cubic symmetry. Contrary to the expectation, magnetic properties of the substituted compositions do not show any drastic changes. [in collaboration with Preeti Bhobe and her group at IIT Indore]

Studies on Heusler alloys

A study on pseudo quaternary $\text{Fe}_{2-x}\text{Co}_x\text{MnSi}$ alloys has been carried out in detail through structural, magnetic, transport and spin polarization measurements. A fully ordered $L2_1$ structure is observed for $x = 0.4$ from the x-ray diffraction and Mossbauer data. For this composition, anomalous non-metallic like behaviour has been observed along with a high spin polarization (~ 0.66) that was measured using Point Contact Andreev reflection spectroscopy. Substitution of Co in place of Fe is found to suppress the antiferromagnetic phase and stabilizes the ferromagnetic phase as evident from magnetization and resistivity data. The Curie temperature and saturation magnetization values increase with increase in the Co concentration. Recently, a new class of materials called spin gapless semiconductors (SGSs) has emerged showing a promise for spintronic applications. The band structure of SGS has one spin-polarized subband resembling to that of a semiconductor, while the other subband has a zero band gap at the Fermi level. Therefore, they combine the band structures of a ferromagnet and a semiconductor. Because of this unique property, these are being considered as substitutes for diluted magnetic semiconductors (DMS), which have a drawback of low Curie temperature. A study of equiatomic quaternary Heusler alloy CoFeMnSi and CoFeCrGa through electrical transport and spin polarization measurements strongly suggests spin gapless semiconductor nature of this alloy. [in collaboration with K.G. Suresh and his group at IIT Bombay.]

Comparative NMR studies on $\text{Ca}_3\text{LiRuO}_6$ and $\text{Ca}_3\text{NaRuO}_6$

We have carried out a comparative study of two rufinate compounds, $\text{Ca}_3\text{LiRuO}_6$ and $\text{Ca}_3\text{NaRuO}_6$, with $\text{A}_3\text{A}'\text{TO}_6$ -type ($\text{A} = \text{Ca}, \text{Sr}; \text{A}' = \text{Li}, \text{Na}, \text{TM}; \text{T} = \text{Transition Metal}$) of structure to understand the magnetic interactions. Both these systems display a high magnetic ordering for Ru based systems. $\text{Ca}_3\text{LiRuO}_6$ is a weak ferromagnet with a magnetic ordering temperature of 115 K. The ^7Li NMR linewidth of $\text{Ca}_3\text{LiRuO}_6$ displays a broad shoulder above the magnetic ordering temperature. Anomalous shoulder of this type is observed in the magnetic susceptibility data also. The origin of these phenomena is not clear but could possibly be attributed to low dimensional magnetism. A contrasting magnetic behavior is seen in $\text{Ca}_3\text{NaRuO}_6$, an antiferromagnet with a transition temperature at 87 K. The heat capacity of these compounds show a λ -type anomaly at respective magnetic transition temperatures. However, in both the systems the entropy change (ΔS) is much less than that of an ordered $S = 3/2$ system. The NMR study shows that the Knight shift is proportional to the magnetic susceptibility. One striking aspect is that NMR line-width remains constant for ^{23}Na spectra whereas it is strongly temperature-dependent for ^7Li spectra above the magnetic ordering temperature. This is quite unexpected since the structure is same and the magnetic ordering temperatures are not very different. The temperature dependent width suggests that short range magnetic interactions are playing a pivotal role in the case of $\text{Ca}_3\text{LiRuO}_6$ and notably ^7Li NMR linewidth is able to sense it. A careful look into the structural differences suggests that one of the exchange interaction path is shorter in $\text{Ca}_3\text{LiRuO}_6$ compared to $\text{Ca}_3\text{NaRuO}_6$ and could give rise to 1D type of magnetic correlations above the long range ordering temperature in $\text{Ca}_3\text{LiRuO}_6$. This difference in J_1 could also be the underlying cause for the difference in magnetic ground states of these two systems, weak ferromagnetism versus antiferromagnetism. [T. Chakrabarty and P. L. Paulose]

^{31}P NMR studies on $\text{SrCo}_2(\text{PO}_4)_2$ system

$\text{SrCo}_2(\text{PO}_4)_2$ is a strongly correlated system with Co^{2+} ions ($S=3/2$) ordering magnetically. The Co^{2+} ions form dimers among themselves, but they have a unique feature of not being isolated dimers. Instead the dimers make chain-like arrangement

with possible inter-chain interactions. There are two structurally different cobalt and phosphorus ions present in this compound. Since the chain-like arrangement between the cobalt dimers are mediated through phosphorus, we have carried out ^{31}P -NMR studies to gain microscopic understanding of the magnetic structure. We were able to separate out the difference between the two phosphorus environments from the Knight Shift measurements as they experience different local magnetic fields and show different kind temperature dependence of NMR spectra. Down to 80 K, the two phosphorus NMR resonances show similar kind of shift with temperature. We have also carried out spin-lattice relaxation (T_1) measurements of these two structurally different phosphorus nuclei down to 10 K below which detection of NMR signal is difficult because of magnetic ordering. [T. Chakrabarty, Arvind Yogi, A. Thamizhavel, S.K. Dhar and P. L. Paulose]

Versatile Nuclear Magnetic Resonance spectrometer for studies of strongly correlated electronic systems at low temperatures

A versatile solid state NMR spectrometer is set up, providing a new tool to study strongly correlated systems of current interest. Solid state NMR is very challenging from an experimental point of view because of fast nuclear relaxation in the strongly correlated systems unlike in standard organic/inorganic solid state systems. The faster nuclear relaxation leads to very broad spectral lines making it very difficult to detect the resonance. Even if one buys a basic commercial system costing more than several crores of rupees, expertise has to be acquired to develop specially designed probes for observing the weak signals. Extending the experiment further to low temperatures down to 1.5K is even more challenging. We have chosen a very low cost option to develop a versatile Nuclear Magnetic Resonance spectrometer for solid state studies. A commercial console with radio frequency (RF) transmitter and receiver was coupled to an RF amplifier with matching circuitry to carry out NMR studies using an old superconducting magnet system and specially constructed probes for low temperature studies down to 1.5K. We have carried out ^7Li , ^{23}Na , ^{31}P and ^{51}V NMR spectroscopic studies on oxide systems which show multiferroic or low-dimensional magnetic properties. [P. L. Paulose]

Electron Spectroscopy

Exceptional surface and bulk electronic structure in a topological insulator, Bi_2Se_3

In recent experiments, it was discovered that the spin-orbit coupling can lead to new phases of quantum matter with highly nontrivial collective quantum effects. Topological insulators are one such realization, where surface states of a bulk insulator exhibit Dirac point quite distinct from graphene. The surface states of a strong topological insulator are metallic with novel electromagnetic properties protected by the time reversal symmetry. While symmetry of the surface states in these materials exhibit behavior typical of topological insulators, the outstanding problem is the metallicity underneath topologically ordered surface states and the appearance of Dirac point far away from the Fermi energy. Enormous efforts are being devoted to get the Dirac point at the Fermi level via exposure to foreign materials so that these materials can be used in technology and realize novel fundamental physics. Ironically, the conclusion of bulk metallicity in the electronic structure is essentially based on the angle resolved photoemission spectroscopy, a highly surface sensitive technique. Here, we employed *state-of-the-art* hard x-ray photoemission spectroscopy with judiciously chosen experiment geometry to delineate the bulk electronic structure of a topological insulator and a potential thermoelectric material, Bi_2Se_3 . The results exhibit signature of insulating bulk electronic structure with tiny intensities at the Fermi level akin to defect or vacancy induced doped states in the semiconductors. The core level spectra exhibit intense Plasmon peak associated to core level excitations manifesting the signature of coupling of electrons to the collective excitations, a possible case of plasmon-phonon coupling. In addition, a new loss feature appear in the core level spectra indicating presence of additional collective excitations in the system.[Collaborators: Deepnarayan Biswas, Sangeeta Thakur, Geetha Balakrishnan (Univ. of Warwick, UK), and Kalobaran Maiti]

Anomalies in the surface electronic structure of Cr

Elemental Cr exhibits interesting magnetic properties that led to its wide ranging applications such as recording media, high density storage media, magnetic sensors, and giant magneto resistance based devices. Bulk Cr forms *bcc* structure and is a good example of the Fermi surface nesting driven antiferromagnet exhibiting in commensurate spin density wave (ISDW) state below the temperature,

311K. The spin density wave (SDW) phase becomes commensurate via a spin-flip transition around 150K. Various studies revealed many controversies in its electronic properties. For example, observation of antiferromagnetic and/or ferromagnetic surface order while the bulk is antiferromagnetic, complex surface-bulk differences in the electronic structure and properties, controversy on the existence of the orbital Kondo effect and/or the Shockley surface states, and proximity to quantum criticality. Contrasting scenario on the energy gap has been reported in the literature such as the signature of pseudo gap, and/or direct multiple gaps in the ISDW phase. We studied the electronic structure of high quality Cr(110) films grown on the W(110) surface employing angle resolved photo emission spectroscopy (ARPES). Experimental spectra from differently aged samples exhibit distinct signatures of the surface and bulk character of the features in the electronic structure. We observe that oxygen content on the surface gradually increases with aging and the hybridization of the adsorbed oxygen with the surface Cr atomic states is significantly strong at temperature around room temperature or higher while they remain almost unreacted at lower temperatures. The energy bands exhibit signature of band folding due to the spin density wave transition. The temperature variation down to 5 K exhibits emergence of an additional sharp (weakly dispersing) feature corresponding to the surface electronic structure presumably due to the correlation induced effects. These results reveal origin of the complex surface behavior of Cr, evolution of the surface states with aging and the importance of electron correlation induced effects in the electronic structure.[Collaborators: Khadiza Ali, Shyama R. Varier, Deepnarayan Biswas, Srinivas C. Kandukuri, and Kalobaran Maiti]

Doping of Graphene by Low-Energy Ion Beam Implantation: Structural, Electronic, and Transport Properties

Graphene, a single layer of sp^2 -bonded carbon atoms, has attracted much attention due to its potential application for post CMOS-devices and compatibility with existing fabrication processes. We discovered that tailoring of the electronic properties down to the nanometer scale can be achieved by doping of the graphene sheet via low energy irradiation. With an irradiation energy of 25 eV and a fluence of approximately $5 \times 10^{14} \text{ cm}^{-2}$ we achieve a nitrogen content of around 1 %. We showed that the dopants arrange preferably at lattice sites given

by the 6x6-reconstruction of the underlying substrate. This selective incorporation is most likely triggered by adsorbate layers present during the ion bombardment. The structural, electronic, and transport properties of substitutional defects in SiC-graphene are studied by means of scanning tunneling microscopy and magnetotransport experiments. Using ion incorporation via ultralow energy ion implantation as discussed above, the influence of different ion species (boron, nitrogen, and carbon) can directly be compared. While boron and nitrogen atoms lead to an effective doping of the graphene sheet and can reduce or raise the position of the Fermi level, respectively, $^{12}\text{C}^+$ carbon ions are used to study possible defect creation by the bombardment. For low-temperature transport, the implantation leads to an increase in resistance and a decrease in mobility in contrast to undoped samples. For undoped samples, we observe in high magnetic fields a positive magnetoresistance that changes to negative for the doped samples, especially for $^{11}\text{B}^+$ and $^{12}\text{C}^+$ ions. We conclude that the conductivity of the graphene sheet is lowered by impurity atoms and especially by lattice defects, because they result in weak localization effects at low temperatures. [Collaborators: P. Willke, J. A. Amani, Anna Sinterhauf (Univ. Goettingen, Germany), S. Thakur (TIFR), Thomas Kotzot, Thomas Druga, S. Weikert (Univ. Goettingen, Germany), K. Maiti (TIFR), H. Hofsaess, and M. Wenderoth (Univ. Goettingen, Germany)]

Bandwidth enhancement in Josephson Parametric Amplifiers

We have developed an impedance engineered Josephson parametric amplifier capable of providing bandwidth beyond the traditional gain-bandwidth product. It involves engineering the imaginary part of the environmental impedance. We experimentally demonstrate a nearly flat 20 dB gain over a 640 MHz band, along with a mean 1-dB compression point of -110 dBm and near quantum-limited noise. The results are in good agreement with our theoretical model. This device will be crucial for multi-qubit experiments which are planned for the near future. This work has also led to several collaborations with groups in USA, France and China for further improving device performance. [Tanay Roy, Suman Kundu, Madhavi Chand, Vadiraj A. M., A. Ranadive, N. Nehra, Meghan P. Patankar, R. Vijay]

Novel three qubit system: The Trimon

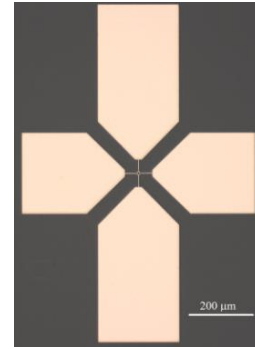


Fig.: Optical image of the new multi-mode quantum device, nicknamed trimon.

We have developed a new type of multi-mode qubit where a single superconducting circuit implements three coupled qubits. The circuit consists of a four junction ring with capacitances shunting each of the nodes with every other one. The three effective spin 1/2 systems have an always on longitudinal coupling which enables us to implement simple quantum gates. The symmetry of the three modes offers different couplings to the measurement cavity which protects two of the modes from decaying into the cavity mode while still being measurable via dispersive shift of the cavity frequency. Preliminary experiments look promising and we have identified and characterized the three modes. Our design offers a new paradigm for multi-qubit architecture and can be an important building block for quantum error correction and quantum simulation experiments. [Tanay Roy, Suman Kundu, Madhavi Chand, Sumeru Hazra, Naveen Nehra, Cosmic Raj, Arpit Ranadive, Meghan P. Patankar, Kedar Damle, R. Vijay]

Semiconductors

Understanding the growth mechanism of MOVPE-grown Ni-catalyzed GaN nanowires

While GaN nanowires have been extensively studied for several nanoscale photonic and electronic applications, there are however very few reports on the fundamental mechanism of the GaN nanowire growth process. In our work, we have grown nickel-catalyzed GaN nanowires by metal-organic vapor phase epitaxy (MOVPE), and performed comprehensive investigations to address two major aspects of the growth mechanism: (i) phase of the catalyst during growth (i.e. whether the growth was via a vapor-liquid-solid (VLS) or a vapor-solid-solid (VSS) route) and (ii) modes of reactant collection during growth.

We have grown GaN nanowires via MOVPE using a nickel catalyst, with trimethylgallium and ammonia

as precursors, on sapphire substrates of different orientations. We optimized the growth temperature, ambient gas environment and pressure, V/III ratio, and precursor flows to obtain thin nanowires. Nanowires grown on different substrates were compared using electron microscopy, X-ray diffraction, photoluminescence and Raman scattering. On c-plane and r-plane sapphire substrates the wires grew along $\langle 10\text{-}10 \rangle$, while on m-plane sapphire the wires grew along both the semipolar $\langle 10\text{-}11 \rangle$ and nonpolar $\langle 10\text{-}10 \rangle$ directions. The distribution of length and thickness of the nanowires was studied to understand how the reactants are collected by the catalyst i.e. by direct impingement on the catalyst or by adatoms diffusing along the nanowire surface or both. Using data from over hundred wires, we find that the envelope function of the length-diameter plot of the GaN nanowires initially increases due to the Gibbs-Thomson effect and then decreases due to diffusion-limited growth. This behavior has been observed and modelled earlier in other nanowires systems like InAs, GaAs and InP, but not in GaN. We also performed extensive post-growth compositional analysis of the catalyst tip using energy-dispersive X-ray spectroscopy and electron energy-loss spectroscopy and found that the catalyst particle is Ni_2Ga_3 . This alloy is expected to be a solid at the growth temperature even when size-dependent melting point depression is accounted for, hence indicating a VSS growth mode. [Carina B. Malaikkal, Nirupam Hatui, A. A. Rahman, R. D. Bapat, B. A. Chalke, and Arnab Bhattacharya]

Investigation of growth and light emission from GaP based nanowires

Gallium phosphide has a bandgap of 2.26 eV in the green region, but is indirect in the stable, bulk zinc-blende (ZB) crystal structure. There have been theoretical predictions that the wurtzite (WZ) phase of GaP can be stable in nanowires (NWs) and hence a better light emitter. Theoretical predictions on the band structure of wurtzite GaP are contradictory, and there have been very few experimental reports on the growth of wurtzite GaP and even fewer studying luminescence from wurtzite GaP-based NWs. We have grown GaP nanowires via MOVPE using a gold catalyst mediated vapour-liquid-solid method and trimethylgallium and phosphine as precursors. We optimized the growth parameters like temperature, pressure and reactant flow rates. Characterization of the GaP nanowires using scanning and transmission electron microscopy, photoluminescence, X-ray diffraction and Raman scattering studies allowed a comparison of NW growth on different substrates. On c-plane sapphire and silicon (111) substrates the GaP nanowires form in the wurtzite phase and without any defects. At

similar growth conditions we obtained zinc-blende wires on GaAs (111) and GaP (111). We have observed luminescence from GaP/AlGaP core shell structures, and will be using this to understand into the band-structure of these materials. [Carina B. Malaikkal, Nirupam Hatui, Mahesh R. Gokhale, and Arnab Bhattacharya]

Studies on ternary III-III/V (GaInP) and III/V-V (GaAsP) nanowires

While binary III/V nanowires like InAs or GaP are relatively easy to grow via the catalyst mediated vapour-liquid-solid (VLS) technique, the growth of ternary materials like InGaP (III-III/V) and GaAsP (III/V-V) is much more challenging due to the different incorporation efficiencies of elements within the same group. These materials are however of interest since their bandgap lies in the visible region of the spectrum. We have investigated the growth of ternary GaAsP and GaInP NWs on Si(111) substrates using the Au-catalyst mediated VLS growth technique in a MOVPE system using standard precursors. While the variation of PH_3 and TMIIn molar flux allows different In compositions to be obtained for GaInP NWs, with a linear behavior in the ratio of gas phase to solid phase composition of Indium, for GaAsP NWs, the very strong incorporation preference of As over P limits the accessible composition range. Without a double dilution arrangement, 6% P incorporation could be obtained. [Mahesh R. Gokhale, Carina B. Malaikkal, and Arnab Bhattacharya]

Synthesis and characterization of ReS_2 and ReSe_2 : layered semiconducting chalcogenide single crystals

We reported the synthesis of high-quality single crystals of ReS_2 and ReSe_2 transition metal dichalcogenides using a modified Bridgman method that avoids the use of a halogen transport agent. Comprehensive structural characterization using x-ray diffraction and electron microscopy confirmed a distorted triclinic $1T'$ structure for both crystals, and revealed a lack of Bernal stacking in ReS_2 . Photoluminescence measurements on ReS_2 showed a layer independent bandgap of 1.51 eV, with increased PL intensity from thicker flakes, confirming interlayer coupling to be negligible in this material. For ReSe_2 , the bandgap is weakly layer dependent and decreases from 1.31 eV for thin layers to 1.29 eV in thick flakes. Both chalcogenides showed feature-rich Raman spectra whose excitation energy dependence was studied. The lower background doping inherent to our crystal growth process resulted in high field effect mobility values of $79 \text{ cm}^2/\text{Vs}$ and $0.8 \text{ cm}^2/\text{Vs}$ for ReS_2 and ReSe_2 respectively, as extracted from FET structures fabricated from exfoliated flakes. These are a factor

5-8 times better than previously reported for thick flakes. Our work shows ReX_2 chalcogenides to be promising 2D materials candidates, especially for optoelectronic devices, without the requirement of having monolayer thin flakes to achieve a direct band gap. [Bhakti Parekh, A. Jindal, Sai Shradha, B.A. Chalke, R.D. Bapat, A. Thamizhavel, M.M. Deshmukh and Arnab Bhattacharya, TIFR, with collaborators from the Chhowalla group, Rutgers Univ.]

Temperature-dependent inductively-coupled-plasma reactive ion etching of polar, semi-polar and non-polar AlN and GaN

We worked on the dry etching of polar (0001), semi-polar (11-22) and non-polar (11-20) GaN and AlN using ICP-pre-treatment in BCl_3/Ar prior to main etching in Cl_2/Ar based ICP plasma in the temperature range 22-205°C. The aim was to study the effect of etching beyond sublimation temperatures of GaCl_3 (201°C) and AlCl_3 (183°C). For the samples etched with a pretreatment step, the etch-depths remain almost constant along the entire temperature range for both GaN and AlN. There is a small enhancement high temperature, which is related to the elimination of etch delay time required to remove surface oxides by pretreatment before the start of actual GaN and AlN etching in Cl_2/Ar plasma. The samples etched with pre-treatment show smooth morphology similar to or better than the as-grown surfaces. Thus, ICP-RIE etching of GaN and AlN at temperatures beyond the sublimation temperatures of GaCl_3 and AlCl_3 may be a useful route to achieve high etch-rates while maintaining a smooth surface morphology. [Amit P. Shah, A.A. Rahman, R.D. Bapat, B.A. Chalke, and Arnab Bhattacharya]

THz Spectroscopy

We continued our efforts towards in-house fabrication of THz radiation sources and detectors with different designs. We have simulated several new designs of the Antennas and currently we are trying to now fabricate these optimized structures. [Goutam Rana, S. Dattagupta IIT-B, S. S. Prabhu]

We made several simulations of the THz experimental data to extract n and k from it. Many programs were written and we have optimized the algorithms now. [Jaydeep Watve, C. S. Garde, VIIT-Pune; S.S.Prabhu TIFR]

Optical properties of Metallo-Dielectric structures

We had demonstrated design method for plasmonicquasicrystals for specific wavelength range. Broadband, omni directional and polarization

independent excitation of plasmon modes are demonstrated in plasmonicquasicrystals with 5-fold rotation symmetry. We extended the studies to their nonlinear optical response.

Broadband second harmonic generation that is phase matching independent is demonstrated. The nonlinearity of the metal film though is weak, the strong local field helps generate second harmonic. [A. V. Gopal, Sachin Kasture, Ajith P R, V J Yallapragada, A. Nagarajan]

A fully vectorial model to calculate the beam shifts is developed. In combination with the in-house developed RCWA code, the shifts are numerically calculated. It is shown that in addition to the well-known G-H shift, when a focused beam is used, one need to care of the angular shift. A novel direct measurement setup developed with 100nm resolution. It is used to measure giant plasmon mediated G-H shift as well as a small shift when reflected from a gold film. [A. V. Gopal, V. J. Yallapragada, G. Muly;G. S. Agarwal, Oklahoma State University, USA].

Optical spectroscopy of semiconductors

We have continued to work on MoS_2 which, unlike Graphene, has a finite bandgap which is important for conventional electronics and opto-electronics. We had previously identified for the first time exciton transitions at the H-point of the Brillouin zone, in the optical spectrum of bulk MoS_2 . Before our work the H-point spectral feature was wrongly identified as the excited state transition of the A exciton of MoS_2 and was used to estimate the exciton binding energy E_b which came to $\sim 50\text{meV}$. Our work therefore reopened the question of E_b in bulk MoS_2 . To address this we performed micro-transmission and micro-photocurrent spectroscopy measurements on thin uniform flakes of MoS_2 to estimate the absorption spectrum where clear excitonic resonances were seen.

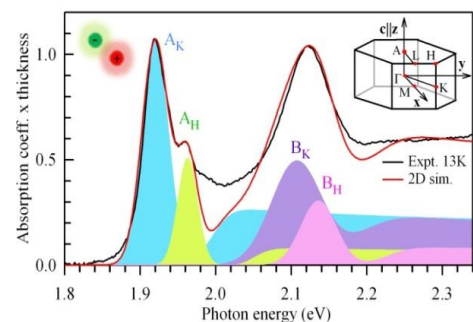


Fig: Absorption spectrum of bulk 2H- MoS_2 fitted to show the 2D exciton contributions, two each at K- and H-point of the Brillouin zone.

We showed that to understand the absorption spectrum of bulk MoS_2 around its direct gap within

the effective-mass hydrogenic model, one must consider four transitions, two at K- and also two at H-points. The other important finding was that excitons in bulk MoS₂ behave as if they are two-dimensional with their motion confined to a plane perpendicular to the c-axis, in agreement with recent density functional theory calculations. Our analysis gave a much larger effective $E_b \sim 84\text{meV}$ for A exciton in bulk MoS₂. Through scaling involving dielectric function and effective mass values we also estimated E_b for the A exciton in monolayer MoS₂ as $\sim 250\text{meV}$, which is close to 220meV measured using electron tunneling spectroscopy.

We also studied photoluminescence (PL) decay in monolayer MoS₂. Circular polarization resolved PL gives evidence for coupling of spin and valley degrees of freedom in monolayer MoS₂. For any spintronics application PL helicity will be an important tool for estimating spin polarized carrier population. Also understanding the luminescence mechanism and decay pathways is important for future flexible light emitting devices. Using our home built micro-PL spectroscopy setup we studied temperature dependence of PL from monolayer MoS₂ on SiO₂/Si substrate. We found that the low temperature PL peak attributed to the A exciton/trion emission is red shifted relative to its position in the absorption spectrum, the latter obtained from an analysis of reflectance contrast spectroscopy data. This indicated that the excitons are not completely free. At high temperatures the PL features associated with both A exciton/trion and defects (D), decay with increase in temperature in a seemingly activated fashion with similar activation energy $E_a \sim 50\text{meV}$, much smaller than E_b in monolayer MoS₂. The peak positions of A and D are well separated in energy by $\sim 90\text{meV}$ at low temperatures. It therefore rules out the usual mechanism for PL decay where electrons/holes are thermally excited to states having energy E_a higher than the emission peak, from where they more readily recombine non-radiatively. We suggested a new PL decay model that may be generic to 2-dimensional monolayer materials. The excitons in monolayer MoS₂ strongly couple with A_{1g} phonons, wherein S atoms vibrate perpendicular to the film plane. This can facilitate interaction of excitons with the substrate defects/traps and enhance the possibility of their non-radiative loss. In our phenomenological model we expressed the non-radiative lifetime as being inversely proportional to the average number of excited A_{1g} phonon modes obtained from Bose-Einstein statistics. Our formula fitted the temperature dependence of the PL intensity of all the features satisfactorily yielding a phonon energy $E_p \sim 47 \pm 3\text{meV}$, close to that of

A_{1g} (50meV) [Nihit Saigal, Vasam Sugunakar and Sandip Ghosh]

Soft Condensed Matter

Multiscale flow in an electro-hydrodynamically driven oil-in-oil emulsion

Efficient mixing strategies in a fluid involve generation of multi-scale flows which are strongly suppressed in highly viscous systems. In this work, we report a novel form of multi-scale flow, driven by an external electric field, in a highly viscous ($\eta \sim 1\text{ Pa s}$) oil-in-oil emulsion system consisting of micron-size droplets. This electro-hydrodynamic flow leads to dynamical organization at spatial scales much larger than that of the individual droplets. We have characterized the dynamics associated with these structures by probing the spectrum of stress fluctuations created by these flows. Our results display scale invariance in the energy spectra over three decades with a power law reminiscent of turbulent convection and demonstrate an efficient mixing strategy in micro-scale systems. [Atul Varshney, Smita Gohil, Mayur Sathe, Seshagiri Rao R V, J. B. Joshi, S. Bhattacharya, Anand Yethiraj and Shankar Ghosh]

Granular self-organization by auto-tuning of friction

Self-organization is ubiquitous in nature, although a complete understanding of the phenomena in specific cases is rare. Here we elucidate a route to self-organization in a model granular system. The local rules of motion are extracted from the experiment. When converted into an algorithm, they simulate the main aspects of the experimental results. From this, a key ingredient for achieving robustness emerges, namely, a continuously variable relative fraction of time the objects spend in two distinct motional degrees of freedom, rolling and sliding. In so doing, they access a large range of effective friction coefficients that allows self-tuning of the system to adjust its response to changing environments and guarantees a protocol-insensitive unique final state, a previously unidentified paradigm for self-organization. [Deepak Kumar, Nitin Nitsure, S. Bhattacharya and Shankar Ghosh]

Nanomaterials

Local structure, composition and crystallization mechanism of a model two-phase 'composite nanoglass'

Scientists have very recently proven – both experimentally and theoretically – the existence of a new class of materials called nanoglasses that consist of glassy, nanometer-sized grains connected by

lower-density interfacial regions. Such nanoglasses are essentially single-phase materials, often synthesized by consolidating nanometer-sized glassy particles. We suggest that another class of locally phase-separated, two-component, amorphous systems with several distinctive properties may be considered as ‘composite nanoglasses’. We have carried out a detailed study of the local composition and structure of a model, bi-phasic nanoglass with nominal stoichiometry $\text{Cu}_{55}\text{Nb}_{45}$. Three dimensional atom probe data (carried out at U. North Texas) suggest a nanoscale-phase-separated glassy structure having well defined Cu-rich and Nb-rich regions with a characteristic length scale of $\approx 3\text{nm}$. However, extended x-ray absorption fine structure analysis (carried out at the Advanced Photon Source, Argonne) indicates subtle differences in the local environments of Cu and Nb. While the Cu atoms displayed a strong tendency to cluster and negligible structural order beyond the first coordination shell, the Nb atoms had a larger fraction of *unlike* neighbors (higher chemical order) and a distinctly better-ordered structural environment (higher topological order). This provides the first experimental indication that metallic glass formation may occur due to frustration arising from the competition between chemical ordering and clustering. These observations are complemented by classical as well as *ab initio* molecular dynamics simulations. Our study indicates that these nanoscale phase-separated glasses are quite distinct from the single phase nanoglasses (established recently) in the following three respects: (i) they contain at least two structurally and compositionally distinct, nanodispersed, glassy phases, (ii) these phases are separated by comparatively sharp inter-phase boundaries, and (iii) thermally induced crystallization occurs *via* a complex, multi-step mechanism. Such materials therefore appear to constitute a new class of disordered systems that may be called a *composite nanoglass*. [P Ayyub, in collaboration with R. Banerjee at UNT and S. Chattopadhyay at APS]

Two-dimensional nanostrips of hydrophobic copper tetradecanoate for making self-cleaning glasses

We have found a simple, solution-based technique for coating arbitrary surfaces with thin layers of self-assembled copper tetradecanoate (CTD) nanostrips, resulting in an optically transparent, superhydrophobic coating. The nanostrip-coated surfaces show water contact angles close to 150° and roll-off angles as small as 2° - 3° . Importantly, CTD retains its hydrophobic nature even after annealing the self-assembled nano-strips at 200°C , which does not alter the crystal structure but ‘melts’ the surface microstructure. This clearly indicates

that the hydrophobicity in CTD is not induced by the surface microstructure (as has been suggested earlier). Strong-hydrophobicity in CTD over a relatively wide temperature range presumably results from the presence of the long aliphatic (tetradecanoate) chains in their structure. Importantly, the self-assembled copper tetradecanoate nano-strips can be dip-coated on glass to render it hydrophobic and at the same time retain a significant level of transparency over the entire visible region. Such nanostructured thin films may be expected to find applications not only as a self-cleaning glass, but also as a corrosion resistant coating, in gas storage (due to the layered structure), and as an active catalyst because of the visible absorbance. [Subhrangsu Sarkar, Smita Gohil and Pushan Ayyub with Sriparna Chatterjee at CSIR-IMMT, Bhubaneswar]

Nanoelectronics

Quantum Hall effect in tunable 1-D lateral superlattice in graphene--role of crossed electric and magnetic fields

In this work we probe quantum Hall effect in a tunable 1-D lateral superlattice (SL) in graphene created using electrostatic gates. Lack of equilibration is observed along edge states formed by electrostatic gates inside the superlattice. We create strong local electric field at the interface of regions of different charge densities. Crossed electric and magnetic fields modify the wavefunction of the Landau Levels (LLs) – a phenomenon unique to graphene. In the region of copropagating electrons and holes at the interface, the electric field is high enough to modify the Landau levels resulting in increased scattering that tunes equilibration of edge states and this results in large longitudinal resistance. [Sudipta Dubey]

Nanoscale electromechanics to measure thermal conductivity, expansion and interfacial losses

We study the effect of localized Joule heating on the mechanical properties of doubly clamped nanowires under tensile stress. Local heating results in systematic variation of the resonant frequency; these frequency changes result from thermal stresses that depend on temperature dependent thermal conductivity and expansion coefficient. The change in sign of the linear expansion coefficient of InAs is reflected in the resonant response of the system near a bath temperature of 20 K. Also, local heating allows us to independently vary the temperature of the nanowire relative to the clamping points pinned to the bath temperature. We suggest a loss mechanism originating from the interfacial clamping losses between the metal and the semiconductor

nanostructure. [John P Mathew, Raj Patel, Abhinandan Borah, Carina B Maliakkal, TS Abhilash]

Low tension graphene drums for electromechanical pressure sensing

We present a process to fabricate electromechanical pressure sensors using multilayer graphene in a sealed drum geometry. The drum resonators are fabricated on insulating sapphire substrates with a local back gate for direct radio frequency actuation and detection of the mechanical modes. Using this scheme, we show the detection and electrostatic tuning of multiple resonant modes of the membrane up to 200 MHz. The geometry of the device also helps in attaining low tensile stress in the membrane, thereby giving high gate tunability (~ 1 MHz/V) of the resonator modes. We study the resonant frequency shifts in the presence of helium gas and demonstrate a sensing capability of 1 Torr pressure in a cryogenic environment. [Raj Patel, John P Mathew, Abhinandan Borah]

Dynamical strong coupling and parametric amplification of mechanical modes of graphene drums

Mechanical resonators are ubiquitous in modern information technology. With the possibility of coupling them to electromagnetic and plasmonic modes, they hold promise as the key building blocks in future quantum information technology. Graphene-based resonators are of interest for technological applications due to their high resonant frequencies, multiple mechanical modes and low mass. The tension-mediated nonlinear coupling between various modes of the resonator can be excited in a controllable manner. Here we engineer a graphene resonator with large frequency tunability at low temperatures, resulting in a large intermodal coupling strength. We observe the emergence of new eigenmodes and amplification of the coupled modes using red and blue parametric excitation, respectively. We demonstrate that the dynamical intermodal coupling is tunable. A cooperativity of 60 between two resonant modes of ~ 100 MHz is achieved in the strong coupling regime. The ability to dynamically control the coupling between the high-frequency eigenmodes of a mechanical system opens up the possibility of quantum mechanical experiments at low temperatures. [John P Mathew, Raj Patel, Abhinandan Borah, R. Vijay

Members

Pushan Ayyub, Arnab Bhattacharya, Sabyasachi Bhattacharya, Somnath Bhattacharyya, S.K. Dhar, Mandar Deshmukh, A.V. Gopal, Sandip Ghosh, Shankar Ghosh, Arun K Grover, K.B. Maiti, A.K Nigam, P.L. Paulose, S.S. Prabhu, Pratap Raychaudhuri, S. Ramakrishnan, E.V. Sampathkumaran, A. Thamizhavel, R. Vijayaraghavan

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Ashwin Mohan, Tanmoy Chakrabarty, Madhavi Chand, Venkatesh Chandragiri, Somnath Karmakar, Nikhil Kumar, Md. Matin, Dileep K Mishra, Sutirtha Mukhopadhyay, Bhaktiben Parekh, Swapnil Patil, Anuradha Patra, Uday B. Pramanik, Chi. Nageswara Rao, Bagvanth R. Sangla, Harkirat Singh, Sanjay Kumar Upadhyay, Megha Vagadia, Arvind Yogi

JRF / SRF

Borah Abhinandan, P. Deshmukh, Nagarajan Arvind, Aproov Jindal, A.P. Merin, Tanusree Saha, Naveen

Short Term Visitors

Prof. G.H. Dohler (Max Planck Research Group, Institute of Optics, Information and Photonics University, Erlangen, Germany)

Administrative Staff

Saleem Akhtar

National and International Involvement

E.V. Sampathkumaran: 1. Member, Management Board, TIFR Centre for Interdisciplinary Sciences at Hyderabad; 2. Member, Editorial Board, Solid State Communications; 3. Member, Editorial Board, Scientific Reports (NPG); 4. Member, Sectional Committee, Physical Sciences, INSA, Delhi; 5. Convener, Sectional Committee, Physics, Indian Academy of Sciences, Bangalore; 6. Member, International Advisory Board, International Conference on Low Temperature Physics, 2014; 7. Member, International Conference on Magnetic Materials and Applications (MAGMA2014), 2-4 Nov.; 2015, VIT Vellore; 8. Honorary Professor, JNCASR, Jakkur, Bengaluru. *S. Ramakrishnan* 1. Vice Chairman, IUPAP committee (C5) on Low Temperature Physics, from Sept. 2014. 2. Member of the International Advisory Committee for the International Conference on Strongly Correlated Systems (SCES 2016) held in Hangzhou, China. 3. Member of the International Advisory Committee for the International Conference on the Low Temperature Physics (LT28) to be held in Gothenburg, Sweden (2017). 4. Member of the Scientific Advisory Committee for the Inter University Centre since Dec. 2015. 5. Member of the Editorial board of Indian Journal of Cryogenics. 6. Member of the Academic council of Homi Bhabha National Institute, DAE. 7. Member of the program evaluation committee (Physics) of NISER, Bhubhaneswar. 8. Adjunct Professor of Indian Institute of Science Education and Research (IISER), Pune, from April, 2013. *S.K Dhar* 1. Member of Programme Advisory Committee (PAC) on Physical Sciences under Science and Engineering Research Board (SERB) of the Department of Science and Technology (DST) since September, 2015. 2. Chief Vigilance Officer, TIFR, from August, 2015. 3. Member of the Low Temperature Facility Committee. 4. Member of the Advisory Editorial Board of Journal of Physics: Condensed Matter from January 2011 onwards. 5. Referee for Phys. Rev. B and Phys. Rev. Lett. since 1996. 6. Occasionally reviewed papers submitted to Journal of Alloys and Compounds. *A. Thamizhavel* 1. Referee for Journal of Alloys and Compounds, Journal of Magnetism and Magnetic Materials. *A. K. Nigam* 1. Member, Project Review and Steering Group (PRSG) for several projects of Department of Electronics and Information Technology (DeitY), New Delhi. 2. Co-Chairperson, Materials Research Society of India (Mumbai Chapter). 3. Member, Organizing Committee, 60th DAE Solid State Physics Symposium held at Amity University, Noida, during December 21 – 25, 2015. 4. External Expert, Research and Recognition Committee for the Ad-hoc Board of Studies in Nano-Sciences and Nanotechnology, University of Mumbai, Mumbai. *K. Maiti* 1. Member, Selection committee for Inspire Faculty Award, DST, Govt of India. 2. Member, Subject expert committee for Physical Sciences, Fund for Improvement of S&T Infrastructure in Universities & other Higher Educational Institutions (FIST), DST, India. 3. Member, Thematic subcommittee for Physics and Material Sciences, DAE – BRNS, Govt. of India. 4. Guest Editor – J. Electron Spectroscopy and Related Phenomena, Elsevier. 5. Associate Editor – Science Letters Journal, Cognizure. *Arnab Bhattacharya* 1. Senior Member, IEEE; Associate Editor for Journal of Crystal Growth. 2. Member, Board of Studies, Dept. of Physics, Indian Institute of Space Science and Technology, Trivandrum, Syllabus committee for courses of Physics Dept. (autonomous), Mumbai Univ. 3. Member, Programme and Planning Committee, Nehru Science Centre, Mumbai. 4. Member, Academic Committee for the International Physics Olympiad 2015. *A. V. Gopal* 1. Editorial board member of Scientific Reports. 2. Senior Member of IEEE 3. Member of Optical Society of America (OSA). 4. Member of the Review Editorial Board of Frontiers in Physics, Astronomy and Space Sciences and Materials. *S. S. Prabhu* 1. Member of Optical Society of America (OSA). *P. Ayyub* 1. Member of the Nano Mission Council of the Govt. of India (Ministry of Science and Technology). 2. Member of the Internal Working Group (Materials Science & Technology) of the Department of Atomic Energy.

Invited Talks

E.V. Sampathkumaran

1. “Ca₃Co₂O₆” at the international conference ICMAT 28-30, 2015 June, Singapore.
2. “Short-range magnetic correlations induced ferroelectricity and re-entrant multiglass-like behaviour in spin-chain systems”, at the 7th APCTP (Asia Pacific Center for Theoretical Physics) – Academy Joint Meeting on Multiferroics, held at Orange County, Coorg, Karnataka, 29-30, Nov. 2015.
3. Plenary talk on “Magnetic and multiferroic behaviour of Haldane spin-chain systems, R₂BaNiO₅” at the Int. Conf. Mag. Mat. and App. held at VIT, Vellore, 2-4 Nov., 2015.
4. Valedictory address at the end of ICMAGMA, held at VIT Vellore on 4 Nov. 2015.

S. Ramakrishnan

1. “Unconventional superconductivity in Bi related crystals”, at the International conference on “New Quantum Phases Emerging from Novel Crystal Structure” at Minami-Osawa Campus of Tokyo Metropolitan University (TMU) Sept. 2015.
2. “Superconductivity in a noncentrosymmetric BiPd”, at the Physics Department, University of Bayreuth, Germany, July 2015.

3. “Novel CDW states in R₂Ir₃Si₅ crystals”, at the Max Planck Institute for Chemical Physics of Solids, Dresden, Germany June 2015.

A. Thamizhavel

1. “Crystal Growth of Strongly Correlated Electron Systems”, at National conference on microscopy and advances in material sciences, held during 2 - 4th March, 2015, in the Department of Physics, University of Jammu, Jammu 180 006.
2. “Anisotropic magnetic properties of binary Cerium compounds”, at the Department of Physics, IISER Thiruvananthapuram, 21st Aug. 2015
3. “Crystal Growth”, at Children's Academy, Ashok Nagar, Kandivali for grade IX school kids, 14th Nov. 2015

K. Maiti

1. “Interesting surface states in a topological insulator, Bi₂Se₃”, Invited talk, ICFMST – 2015, National Institute of Science and Technology, Berhampur, Odisha, 10-12 December, 2015.
2. “Enigmatic behavior of a topologically ordered surface states”, Invited speaker and Session Coordinator, 60th DAE Solid State Physics Symposium, Amity University, 21-25 December, 2015.

3. "Surface states and topological order in Bi_2Se_3 ", Invited talk, Symphy – 2015, IIT Mumbai, 9th – 10th May, 2015.
4. "Enigmatic Surface – Bulk differences", Invited talk, Discussion Meeting on Science using Free-electron Laser and User Meeting, 25th – 26th February, 2016.
5. "Interesting surface states of a topological insulator, Bi_2Se_3 and their aging", Invited speaker and session chair, Indo-Japan Meeting, IISc, Bangalore, 28th – 30th March, 2016.
2. "Broadband dispersionless metamaterials", Colloquium at IISER, Kolkata, 8th April 2016.
3. "Plasmonics", National Fluorescence and Raman Workshop (FCS2016), 13-15 March 2016.
4. "Metamaterials with broadband response", Colloquium at IISER, Pune, 10th March 2016.
5. "Broadband Dielectric and metal-dielectric metamaterials", Frontiers in Light-Matter Interaction (FiLMI), IIT, Ropar, 4-5 March 2016.

R. Vijayaraghavan

1. "Quantum Computing with Superconducting Circuits": IIT Bombay Physics Symposium, May 10 2015.
2. "Quantum Error Correction with superconducting circuits": Discussion Meeting on Quantum Information Processing, IISc, Bangalore, June 29, 2015.
3. "Quantum Error Correction with superconducting circuits": Indian Association for the Cultivation of Science, July 31, 2015.
4. "Quantum Error Correction with superconducting circuits": Quantum Information Processing and Applications 2015, HRI, Allahabad, Dec 12, 2015.
6. "Metamaterials : Sub-wavelength structures for manipulating light", ICSMTEE2016, Mangalore, 20-21 Feb 2016.
7. "International Conference on Physics of Semiconductor Devices (IWPSD)", Bangalore, 7-10 December 2015.
8. "Light modulation in photonic and plasmonic metamaterials", Ultrafast Spectroscopy (UFS2015), SN Bose Center, Kolkata, 19-20 November 2015.
9. "Light control using sub-wavelength structures", Colloquium at IISER, Bhopal, 21st August 2015.
10. "Dielectric and metal-dielectric metamaterials", META2015, New York, 4-7 August 2015.
11. "Dielectric and metallo-dielectric structures for broadband response", Center for Nanoscience and Technology (CNST), USA 30th July 2015.
12. "Metasurfaces for light harvesting", Recent Advances in Nanoscience and Technology (RAINSAT2015), 8-10 July 2015.
13. "Light manipulation with metal-dielectric and dielectric nanostructures", IIT, Madras, 7th July 2015.

Arnab Bhattacharya

1. "50 Years of Moore's Law: Looking back, Looking forward", Colloquium, TCIS-Hyderabad, Mar. 11, 2016; also at Vellore Institute of Technology, Vandalur campus, Chennai, Mar. 14, 2016
2. "III-V semiconductor nanowires: from basic growth mechanisms to device structures", National Conference in Semiconductor Materials and Devices 2016, Jodhpur, Mar. 4-6, 2016
3. "GaN nanowires: from basic growth mechanisms to device structures", 26th National Seminar On Crystal Growth and Epitaxy (XXVI-NSCGE) Crystal Growth Centre, Anna University, Chennai, Mar. 14-15 2016,
4. "Seeking N-lightenment - The bright world of nitride semiconductors", Plenary lecture at the National Workshop on N-lightening and LASERS, GVG Visalakshi College, Udumalpet, Tamil Nadu, Dec. 30, 2015
5. "2D Layered Materials: Novel Substrates for III-Nitride Growth.", International Workshop on Advanced Materials Challenges for Alternative Energy Solutions (AMAES-III-2015) Delhi, Dec. 18-19, 2015
6. "Seeking N-lightenment - The bright world of nitride semiconductors", Keynote lecture at the International Conference on Photons: Multiple and Creative Solutions to Challenges (ICPMCS 2015) NES Ratnam College, Bhandup, Mumbai, Dec. 4-5, 2015
7. "In-situ reflectometry of MOVPE-grown epilayers", 16th European Workshop on Metalorganic Vapour Phase Epitaxy, Lund, Sweden, Jun. 7-10, 2015
4. "THz Spectroscopy Sources, Detectors and Applications", Semiconductor Meeting, IISER, Pune March 2016.
2. "THz Spectroscopy Sources, Detectors and Applications", IC-SMTEE, Sahyadri College of Engineering, Mangalore, February 2016.
3. "Pulsed and Continuous Wave (CW) Tera Hertz (THz) Antenna Structures on C-Irradiated GaAs Substrates", THz Conference, IIT-Delhi, 21 December 2015.
4. "Continuous Wave (CW) Tera Hertz (THz) Antenna Structures on C-Irradiated GaAs Substrates", UFS2015, SINP, Kolkata, December 2015.
5. "Continuous Wave (CW) and Pulsed Tera-Hertz (THz) Structures on C-Irradiated GaAs Substrates", NPL -Delhi, November 2015.
6. "Novel Antenna Structures For Tera Hertz (THz) Applications", URSI-Delhi, JNU, November 2015.
7. "Tera-Hertz (THz) Spectroscopy: Applications in Defence and Security", DRDO Meeting, IIT-Delhi, November 2015.
8. "Microwave to Infrared Journey on Red Path", IISER, Bhopal, November 2015.

S.S. Prabhu

Sandip Ghosh

A. V. Gopal

1. "Photonic and Plasmonic structures for information processing", BRICS First Photonics Meeting, Moscow, Russia, 30-31 May 2016.
1. "Optical transitions in bulk and monolayer MoS_2 ", Conf. on Computers and Devices for Communication (CODEC 2015), Institute of Radio Physics and Electronics, University of Calcutta, Kolkata, Dec 17, 2015.

2. “A relook at exciton related spectral features in bulk MoS₂”, Optics of Excitons in Confined Systems (OECS 2015), Jerusalem, Oct. 15, 2015

Shankar Ghosh

1. “A contemporary perspective on friction”, Statistical Physics of Soft Matter, Banaras Hindu University, Varanasi, (26-30 November 2015)
2. “Mechanics of an underwater sea column”, Compflu 2016, IISER Pune, (4th January 2016)
3. “Mechanics of an underwater sea column”, FRACMEET 2016, IMSC Chennai, (4thFeb 2016)

Pusban Ayyub

1. “High energy laser meets nanostructured metal: A brief but intense affair”, *International Conference on Frontiers in Advanced Materials*, IISc Bangalore, 15.6.2015
2. “Complexity in Elementary Systems”, *Condensed Matter Days 2015*, Visva Bharati University, 28.08.2015
3. “Does particle size control crystal structure?”, *Nanoscale Excitations in Emergent Materials (NEEM 2015)*, INFN Rome, 14.10.2015
4. “Unusual structural transition in elemental Se leads to Multiferroic order”, *International Workshops on Multiferroics (APCTP Series) 2015*, Coorg, 30.11.2015
5. “Futuristic nanoscale devices based on laser-nanoparticle interaction”, *6th International Conference on Computers and Devices for Communication (CODEC 2015)*, Kolkata 17.12.2015
6. “Experimental realization of a two-phase composite nanoglass”, *7th International Conference of Nanoscience and Technology (ICONSAT)*, IISER Pune, 02.03.2016

Mandar Deshmukh

1. “Nanoscale electronics and mechanics with one atom thick graphene Institute Colloquium”, IIT Mandi, 25th May 2015
2. “Quantum Hall Effect in tunable 1-D lateral superlattice in graphene NanoTR meeting”, Ankara, Turkey, 23rd June 2015,
3. “Tuning equilibration of edge states in a 1D graphene superlattice EPQHS 2016”, Mumbai India, 8th January 2016,
4. “Mechanical modes of graphene drums and the strong coupling regime India-Singapore meeting”, at National University of Singapore, 24th February 2016

Pratap Raychaudhuri

1. “Disordered Superconductors: A TIFR Story”, at DAE-SSPS-2015 Symposium (Diamond Jubilee event) organized at Amity University UP, Noida, Uttar Pradesh during December 21-25, 2015 and at Indo-Dutch meeting on Emerging phenomena at low dimensions (14-16 December, 2015).
2. “Real space investigation of the order-disorder transition of a vortex lattice using scanning tunneling spectroscopy”, - PRL conference on “Condensed Matter Physics”, during 11th April to 13th April 2016 at Physical Research Laboratory (PRL), Ahmedabad and at School and workshop on “Current Frontiers in Condensed Matter Research, International Centre for Theoretical Science, Bangalore, 27-29 June, 2016.

Conferences Organized by the Department

International conference on “**New Quantum Phases Emerging from Novel Crystal Structure**” at Minami-Osawa Campus of Tokyo Metropolitan University (TMU) Sept. 2015.

International Conference on “**Advances in Electron Spectroscopy – Experiment and Theory (AESET – 2016)**” at IIT Mandi, India, 18th – 21st January, 2016.

International Discussion Meeting on “**Emerging Themes in Plasmonics and Nanophotonics**”, Goa, 2-4 December 2015.

International Workshop on “**Emergent Phenomena in Quantum Hall Systems (EPQHS)**”, January 7-9 2016.

Non-DAE Research Projects

K. Maiti:

1. “Electronic structure of correlated electron systems”, PI: Kalobaran Maiti and Thomas Pruschke; Co-PI: Martin Wenderoth; Funding agency: DST, India and DAAD, Germany.
2. “Understanding the properties of the rare earth hexaborides - A synergistic approach based on spectroscopy and computational methods”, PI: Thomas Pruschke, Peter Bloechl, Martin Wenderoth and Kalobaran Maiti; Funding Agency: DFG, Germany.
3. “Study of inhomogeneities and nanostructure on solid surfaces using spectroscopy and microscopy”, PI:

Kalobaran Maiti; Funding Agency: DAE-BRNS, India. (DAE-SRC-OI Award)

A.V. Gopal:

1. “Plasmonic nanostructures with magnetic and semiconductor constituents for nanophotonics”, Venu Gopal Achanta, V. I. Belotelov, DST-RFBR, September 2013 to August 2015.
2. “Optical and nonlinear optical properties of nanopatterned novel glasses”, Venu Gopal Achanta, Gopi Sharma, DST, April 2015 to March 2017.

3. “Design, Fabrication and Characterization of Whispering Gallery Mode (WGM) resonators in Planar Waveguides for Detection of Bio-Molecules Using Terahertz Radiation.”, Niraj Joshi, Venu Gopal Achanta, S. S. Prabhu, R. Pinto, DST, April 2016 to March 2018.

Pratap Raychaudhuri

“Real Space Imaging of the mixed state in unconventional and disordered superconductors using scanning tunneling spectroscopy”, DST, 3 years.



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Department of High Energy Physics

CMS Experiment at LHC

The LHC machine at CERN restarted in 2015 after a two year long shut down, operating at a higher centre-of-mass energy, $\sqrt{s} = 13$ TeV compared to that of $\sqrt{s} = 7$ and 8 TeV earlier. Various components of the LHC machine were upgraded in order to have a stronger and a safer machine capable of colliding protons at much higher energies and intensities. The experiments at LHC utilized this maintenance period to improve their detectors. The LHC provided about 400 Trillion proton-proton collisions during 2015 which amounted to an integrated luminosity (L) of 4.6 fb^{-1} of data, reaching a maximum instantaneous luminosity of $5 \times 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$. This data was used to study the behaviour of the machine and tackle the technical issues during its operation.

The hadron calorimeter (HCAL) subsystem of the CMS detector suffered considerable amount radiation damage during the previous LHC operation, particularly in the forward and endcap regions, leading to a loss of its response. The CMS experiment took corrective measures by replacing the photo-detectors with silicon photomultipliers as well as the front-end and back-end microTCA based readout electronics. These upgrades make the HCAL suitable for future high luminosity operation of LHC. TIFR has taken the responsibility for the upgrade of front-end electronics for the Hadron Endcap calorimeter. During 2016 about 200 silicon photomultipliers control boards as well components for about 50 calibration units have to be produced in India and delivered. TIFR has also participated in the R&D for the aluminium housing for the calibration unit. Engineers from the Central Workshop at TIFR contributed significantly to the R&D efforts.

HCAL data analysis

Group members are coordinating the "HCAL data analysis Group of CMS HCAL group", where main goal is to look for possible improvement of algorithms in HCAL reconstruction code to have better impact on the CMS physics analysis. In that direction, members have guided many students from TIFR and from other universities

and laboratories of the CMS collaboration. Work has been completed or is continuing on the following topics, (i) Relative weight factor of the outer hadron calorimeter (HO). The amount of collision data collected in 2015 was insufficient to estimate the usefulness of HO and this relative weight factor as a function of transverse momentum and pseudo rapidity of jets could be calculated with precision only after collecting enough experimental data in 2016. (ii) Layer-wise clustering in the CMS hadron end cap calorimeter. Upgraded CMS hadron calorimeter will read out information at different depths using a layer wise clustering algorithm. This study was made to validate that algorithm using the three existing depths in the end cap calorimeter. Group members also worked on many other topics, e.g., (i) effect of LHC bunch pattern on the HCAL reconstruction algorithm – since the instantaneous luminosity for different bunches at LHC are not all same, this can affect the reconstruction of Jet/Missing transverse energy, (ii) Calibration of the silicon photomultiplier installed on HO, which is based on single photo-electron spectrum in the noise data - this technique will be used in the upgraded CMS HCAL, (iii) Inter calibration of HO using isolated muons in proton-proton collisions.

Physics with the CMS detector

Group members are actively participating in different physics analysis, using data collected by CMS detector, which are briefly presented in the following.

Search for Higgs bosons in the Minimal Supersymmetric Standard Model (MSSM)

Search for the neutral Higgs bosons in the context of the minimal supersymmetric standard model (MSSM) are carried out in their decay to 2 tau leptons (both of which further decay into hadrons) using the full Run-I data set (4.9 fb^{-1} at 7 TeV and 19.7 fb^{-1} at 8 TeV center of mass energy) recorded by the CMS experiment at the LHC. The QCD background reduction was done efficiently in this analysis by optimizing the signal selection criteria in bins of tau p_T . In the absence of any evidence for

the MSSM Higgs boson, limits have been set on the cross section of the Higgs boson production with respect to its mass.

Search for Di-Higgs production

Search for Resonant and Non Resonant di-Higgs boson production followed by their decay into 2 bottom quarks and 2 tau leptons are studied. Kinematic distributions of signal and background processes were studied in detail for two different production mechanisms. In one case the two Higgs bosons are assumed to originate from a heavy resonance (e.g radion or graviton in the warped extra dimension model) and in the second case, non-resonant production in the standard model gives rise to the two Higgs bosons. In the absence of any signal events, limits were computed on cross section times branching fraction for di-Higgs production in both scenarios as shown in Figures below. The limits obtained for the non-resonant di-Higgs production are better than the corresponding ones obtained by ATLAS for the same channel.

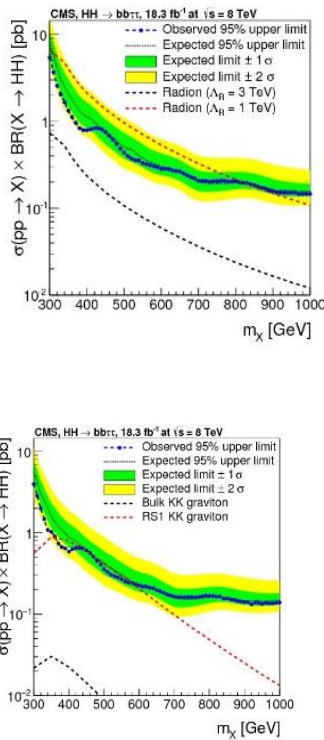


Figure: Upper limits of resonant di-Higgs production at 95% CL. The limits for resonant di-Higgs boson production have been computed for a spin 0 (left) and for a spin 2 (right) resonance X and are shown as a function of the resonance mass m_X . The theory prediction for the graviton case were based on KK graviton production in the bulk and RS1 models respectively. To obtain the radion theory predictions, cross section for radion production via gluon fusion were computed (to NLO electro weak and NNLO QCD accuracy) for different values of fundamental theory parameter Λ_R .

Measurement of the muon charge

The differential cross section and charge

asymmetry for inclusive $pp \rightarrow W X \rightarrow \mu + X$ production at 8 TeV centre-of-mass energy are measured as a function of muon pseudorapidity. The data sample corresponds to an integrated luminosity of 18.8 fb⁻¹ recorded with the CMS detector at the LHC. These results provide important constraints on the parton distribution functions of the proton in the range of the Bjorken scaling variable x from 10⁻³ to 10⁻¹.

*** spectrum using Drell-Yan events in dimuon channel**

Measurements of f differential cross sections for inclusive Drell–Yan events in the di-electron and dimuon final states are presented. The kinematic variables are constructed from the lepton angles, is correlated with the transverse momentum of the vector boson. The data were collected with the CMS experiment at a centre-of-mass energy of 8 TeV and correspond to an integrated luminosity of 19.7 fb⁻¹. The differential cross section normalized to the total cross section within the fiducial volume is measured with a precision of about 1% and is compared with theoretical predictions. The measured spectrum, for the range $f < 0.1$, differs from the theoretical predictions by at most 5% (ResBos), 4% (MADGRAPH) and 9% (POWHEG). For higher values of the deviations are as high as 9%, 5% and 18% in the three cases respectively.

Double parton scattering

In Double parton scattering which is short distance interaction can produce two same sign W pair. It has been studied in this final state using Run 1 data.

Measurement of the transverse momentum spectra of vector bosons

The transverse momentum distribution of vector bosons W,Z are studied in charge and Drell-Yan processes proton–proton collisions at the 8 TeV center of mass energy. These results have great impact to compare theory predictions based on higher order calculations and also to constrain parton distribution function.

Supersymmetry searches in vector boson topology

The search targets final states with at least two leptons, large missing transverse momentum, and two jets with a large separation in rapidity. The data sample corresponds to an integrated luminosity of 19.7/fb of proton-proton collisions at 8 TeV center of mass energy collected with the CMS detector at the CERN LHC. The observed di-jet invariant mass spectrum is found to be consistent with the expected standard model prediction. Upper limits are set on the cross sections for chargino and

neutralino production with two associated jets, assuming the supersymmetric partner of the lepton to be the lightest slepton and the lightest slepton to be lighter than the charginos.

Trigger studies

Members are responsible for making skimmed (passing loose analysis selection criteria) samples from the raw data set for the CMS Tau Physics Object Group for Tau Trigger efficiency measurements with 13 TeV data collected in 2015 and 2016.

13 TeV Data Analysis

Members have completed setting up the framework for analyzing data collected by CMS in proton-proton collisions at 13 TeV. This framework is being used for Higgs searches in the di-tau channel. The framework has been tested with simulated data. After the collection of proton-proton collision data, this framework is extensively used for synchronizing the signal selection criteria used by various groups.

Hadronic event shape variables at $\sqrt{s} = 13$ TeV

Members have looked for the better choice of input objects, e.g., hadronic jets, all particles in the event, only charged particle in the event etc for better theoretical interpretation of this result and with minimum detector effect. We are almost in final stage to make this result public.

Looking for lepton flavour violation in Supersymmetry at the LHC

In this work models of supersymmetry which can incorporate sizeable mixing between different

generations of sfermions have been studied. While the mixing is constrained by the non-observation of various flavor changing neutral current (FCNC) processes, there exist regions of SUSY parameter space where the effects of such mixing, specially in the slepton sector, can be probed at colliders. Sleptons are produced through cascade decays in direct neutralino-chargino pair production at the LHC and the final state is characterized by 3 leptons and missing energy. The lepton flavour violating vertex arising in 2nd neutralino, decay by identifying a distinct and unambiguous combination of the tri-lepton final state containing a lepton pair with same flavor and same sign in addition to a pair with opposite flavor and opposite sign. This combination of tri-lepton final state, differentiate between the flavour violating decays and the flavor conserving decays. Results for various signal benchmark points for two luminosity options (100 fb^{-1} and 1000 fb^{-1}) $\sqrt{s} = 14$ TeV has been presented.

Light Higgs Bosons in NMSSM at the LHC

The next-to-minimal supersymmetric standard model with an extended Higgs sector offers at least one Higgs boson as the Standard model (SM) like Higgs with a mass around 125 GeV. The mass spectrum and couplings of non-SM-like Higgs bosons has been studied and the relevant parameter space has been identified by taking into consideration the most relevant constraints. For a substantial region of parameter space the two-photon decay mode for these non-SM-like Higgs bosons is found to have a reasonably large rate which can be potentially utilized to distinguish the NMSSM from the MSSM at the LHC.

D-Zero Experiment at Fermilab

The D0 Experiment operated at the Tevatron Collider, which collided protons with anti-protons at a centre of mass energy of 1.96 TeV. It was located at the Fermi National Accelerator Laboratory in Batavia, USA. This experiment collected an integrated luminosity of $\sim 11 \text{ fb}^{-1}$ and was active till September 30, 2011 at which point of time the Tevatron accelerator closed down after 30 years of successful operation. Properties of many new particles have been studied with this data. A couple of the famous physics results from the D0 experiment are the discovery of the production of top-antitop quark pairs, production of single top quarks and a very precise measurement of the W boson mass. Following is one of the interesting results published by the D0 experiment in September, 2015.

At the Tevatron, topquark pairs are predominantly produced in valence quark-antiquark annihilations. The standard model (SM) predicts this process to be slightly forward-backward asymmetric. The top quark (antiquark) tends to be emitted in the same direction as the incoming quark (antiquark), and thus, in the same direction as the incoming proton (antiproton). The forward-backward asymmetry in the production is mainly due to positive contributions from the interference between tree-level and next-to-leading-order (NLO) box diagrams. It receives smaller negative contributions from the interference between initial and final state radiation. The interferences with electroweak processes increase the asymmetry. In the SM, the asymmetry is predicted to be $\approx 10\%$. Within the SM, the longitudinal polarizations of the top quark and antiquark are due to parity violating

electroweak contributions to the production process. The polarization is expected to be $<0.5\%$ for all choices of the spin quantization axis. Physics beyond the SM (models with axigluons) can induce a large positive or negative asymmetry together with a sizable polarization. A simultaneous measurement of the forward-backward asymmetry of $t\bar{t}$ production and the top quark spin polarization in the decays of top and anti-top quarks in dilepton final states, using 9.7 fb^{-1} of D0 data was performed. The results, $A_{\text{FB}}^{t\bar{t}} = (15.0 \pm 8.0)\%$, $k_P = (7.2 \pm 11.3)\%$ are presented in the Figure (asymmetry). There is a correlation of -56% between the measurements.

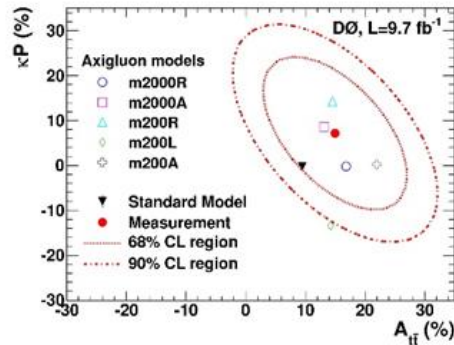


Figure (asymmetry): Two-dimensional visualization of the $A_{\text{FB}}^{t\bar{t}}$ and k_P measurements and comparison with benchmark axigluon models.

India-based Neutrino Observatory (INO)

Development of a medical imaging device using MRPCs

Multigap Resistive Plate Chambers (MRPCs) are gas ionisation detectors with multiple sub-gaps (six in our case) separated by highly resistive plates (glass in our case). MRPCs offer excellent time resolutions due to their very narrow sub-gaps and thus find applications in medical imaging. We obtained typical time resolution of ~ 60 ps after the time walk correction using chambers with sub-gaps of 250 microns.

We designed and fabricated MRPCs of dimensions $305\text{ mm} \times 305\text{ mm} \times 7.5\text{ mm}$ and setup an experiment using two of these chambers to demonstrate their PET imaging capability. A positron emitter radioactive source (^{22}Na) is placed between the chambers. The emitted positrons get annihilated with electrons in the surroundings and two 511 KeV gammas are emitted with opposite momenta. These gammas are detected by the MRPCs, which record the time of arrival of the gammas at the respective detectors. Using this timing as well as the X, Y position hit information of the gammas, absolute position of the source is reconstructed. Front-end electronics boards using Anusparsh ASICs were designed and fabricated. These boards provide both analog signals as well as LVDS logic signals of all signal pickup strips, thus allowing for offline time walk correction. Initial results of this experiment are very encouraging.

Development of low form factor analog front-end board

The Iron Calorimeter (ICAL) experiment of the INO project will deploy about 28,800 Resistive Plate Chambers (RPCs) as active detector elements and provide signals of extremely low amplitudes

(0.5-2mV) on about 3.6 million electronic channels, to be readout. An 8-channel analog front-end board for the RPCs is designed and produced using NINO ASICs produced by the CERN ALICE group along with differential signal driver ICs. The board receives single-ended RPC strip signals, converts them to differential signals, amplifies and produces discriminator signals on LVDS logic bus. Attractive feature of this board is its very low form factor - $200\text{mm} \times 23\text{mm}$, which allows it to be mounted vertically in the RPC tray, and thus help increasing the sensitive detector area considerably. After carrying out extensive tests and characterisation studies, these boards are installed in a $2\text{m} \times 2\text{m}$ RPC in the detector stack at IICHEP Madurai campus. Encouraged by its designed performance, 200 such boards are now being produced.

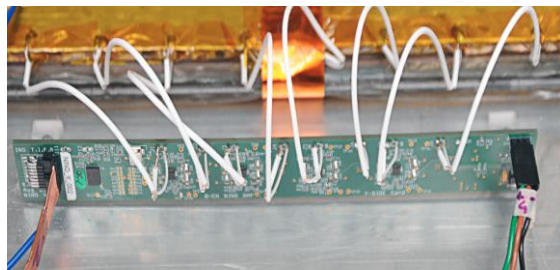


Figure 1: 8-channel analog front-end board for RPCs

Design of Calibration and Auxiliary Unit

The Iron Calorimeter (ICAL) experiment will use distributed digital data acquisition (DAQ) modules which are mounted on the RPC detectors. Collected data is transmitted to the backend servers over the Ethernet interface. The Calibration and Auxiliary Unit (CAU) is a central node which generates and distributes all the global services, such as Global Trigger, Global Clock and Global

PPS, and thus facilitating synchronized data acquisition as well as calibrated signals for reconstruction of particle trajectories. The unit synchronises its Real Time Clock (RTC) operating on Global Clock, with clocks of all the DAQ modules within 1 μ s accuracy. This is achieved using a GPS based PPS signal. Round trip delays of all DAQ modules with reference to the unit are measured using with a 200ps least count and thus the local TOF information is translated to common Global reference for 3D trajectory reconstruction of the particles. This complex unit is designed using state-of-the-art FPGA, TDC ASIC and Network controller. Even design of the PCB posed huge challenge due to the requirement of tracks of matched lengths for providing equal delays. Three CAU units are fabricated and assembled. The firmware development and extensive bench-marking tests are currently under process.

Detector Simulation code for INO-ICAL

To study the response of various particles in the ICAL experiment, a Monte Carlo simulation code has been used. The code uses GEANT4 package to build the detector geometry, to propagate the particles in the detector as well as to obtain information of energy deposition in the sensitive detector. Digitisation algorithms were coded into the package which transforms this information into the output that is similar to what we will obtain from the real detector. An event reconstruction algorithm is also integrated into the code, for reconstructing the event using the digitised output. A number of upgrades were carried out to the simulation code, which are listed below:

1. Updating the RPC geometry as per the current design.
2. Updating various detector properties listed below based on extensive studies using prototype RPC detector stacks: Strip multiplicity, Signal propagation and timing data, Correlated and random noise, and Detector inefficiencies
3. Algorithm for tagging fully contained and partially contained events
4. Algorithm for defining fiducial volume
5. Algorithm for track extrapolation in the shower layers
6. Modification for handling Engineering Module detector simulations

The detector response to hadrons traversing through the detector volume is investigated using hadron hit multiplicity. A clustering algorithm is implemented to choose proper hadron cluster in presence of noise in Monte Carlo neutral-current neutrino interaction events as well as actual experimental data. If a hit within the cluster (or

total hits) is at the boundary of an RPC (one strip on both sides is chosen as the boundary) or in top or bottom layers, it will be tagged as partially contained event. The shape of the hit distribution is fitted by the Vavilov distribution. In the first method, the hadron energy resolution at each fixed energy, was expressed in terms of parameters of the Vavilov function. In the second method, the calibration of hadron energy as a function of hit multiplicity is obtained using parameters of the Vavilov function. The hadron energy is estimated using this information and is further used for obtaining the hadron energy resolution of charged pions with uniform energy distribution in the range of 0-10 GeV. It is observed that the hadron energy resolution becomes poorer in presence of noise. This work is followed by another study of energy resolution of the hadrons produced in the neutral-current and charged-current interactions of neutrinos with uniform energy distribution in the range of 0-30 GeV, simulated using GENIE event generator.

Installation and commissioning of 12-layer 2m \times 2m RPC stack at IICHEP, Madurai

A detector stack comprising of 12 layers of 2m \times 2m RPCs was commissioned in the transit campus of IICHEP, Madurai. These RPCs are readout through 60 pickup strips (of pitch 3cm) on the x-plane and 63 on y-plane. The signals which are induced on strips due to passage of charged particles through RPC detectors are processed by a series of electronic elements such as preamplifier, Analog-Front End (AFE), Digital-Front End (DFE) and backend data acquisition (DAQ) system. On an even trigger mostly caused by passage of atmospheric muon through the detector stack, the coordinates of all strip hits and their timing with reference to the global trigger signal are recorded by the DAQ system. Main goal of this study is to obtain the angular distribution of incident cosmic ray muons. The steps involved in the analysis procedure are: (a). reject the noisy layers during the fit of muon trajectory, (b). Fit accepted muon hits in all layers with straight line in both X-Z and Y-Z planes, (c). Extract the slope, intercept, Chi-square and NDF from the fit and finally (d). Extract the theta (zenith) and phi (azimuthal) of the muon track. The cosmic ray spectrum follows $I = I_0 \cdot \cos^n \theta$. Using the data recorded by this stack, we obtained a value of 2.49 ± 0.04 for the exponent, n.



Fig: 2: 2m x 2m RPC detector stack in operation at IICHEP, Madurai

Automated estimation of leak rate of an RPC gap

The magnetised Iron Calorimeter (ICAL) detector of India-based Neutrino Observatory (INO) is designed to use 28,800 single gap Resistive Plate Chambers (RPCs) of $2\text{m} \times 2\text{m}$ in size as its active detector elements. Large scale industrial production of these chambers poses a huge QC challenge in terms of ensuring that the RPC gas gaps are leak tight. The measurement from a manometer over a long period shows a large variation due to solar atmospheric tides. But the measurements of absolute pressure, both outside and inside of Resistive Plate Chamber (RPC), are independent of each other. Therefore a reliable, yet fast method

and a device to quantitatively measure the leak rate of the gas gaps is designed and developed as part of the industrial production of the RPCs. The system is based on high precision pressure sensors, which are interfaced to a Raspberry Pi module and hence to a PC. By monitoring the absolute pressures, at both outside and inside of the RPC, along with the temperature, the leakage rate is estimated quantitatively. During the test period, the supporting button spacers inside the RPC may get detached due to any manufacturing defect. This effect is also detected clearly by observing the sudden fall of the inside pressure.

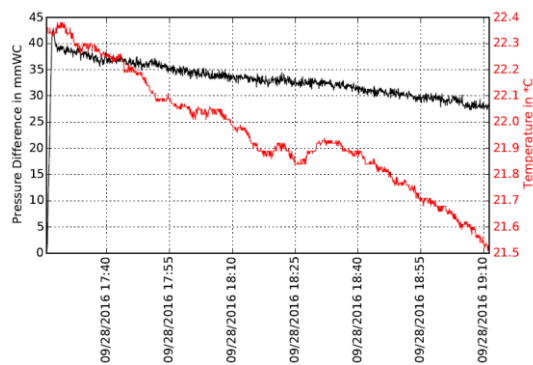


Figure 3: Typical leak test plot of an RPC gap

Ground-based TeV Gamma Ray Astronomy (in collaboration with IIA, Bengaluru, SINP, Kolkata and BARC)

Observations

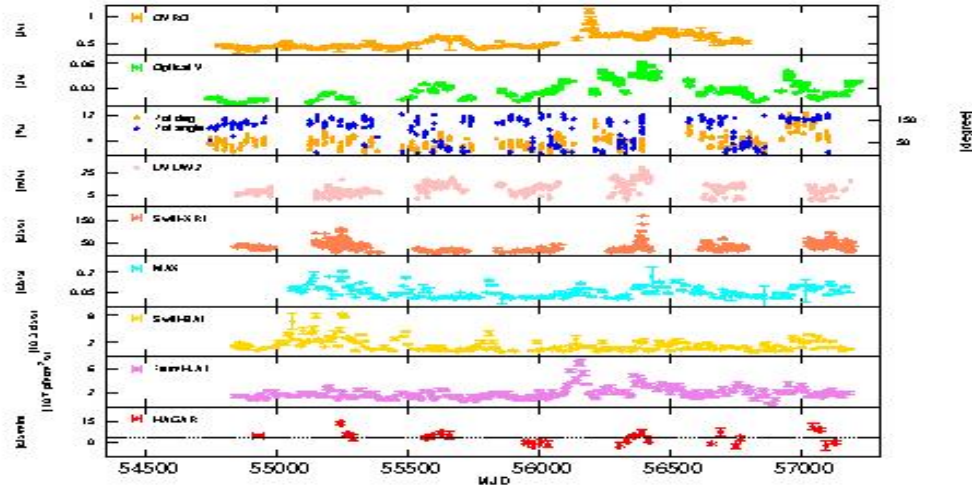
Observations of various astronomical sources with HAGAR telescope array at Hanle (Ladakh) were continued throughout this year without any interruption. About 800 hours of data were collected in various observational and calibration runs. During this year several Blazars (Mkn421, Mkn501, 1ES1011+496, 1ES1218+304, 1ES1959+650, 1ES2344+514, BL Lac etc), pulsars (Crab, Geminga, PSR 1846+0919, PSR 2055+2539 etc) and binary object LSI+61 303 were observed. In addition to this, several calibration runs as well as runs to estimate systematic errors in data were conducted. [B. S. Acharya, V. R. Chitnis, R. L. Deshmukh, P. Dorjey, N. Dorji, A. I. D'Souza, S. Duhan, K. S. Gothe, Manoranjan, B. K. Nagesh, N. K. Parmar, S. R. Patel, P. N. Purohit, S. K. Rao, L. Saha, B. B. Singh, A. Sinha, S. S. Upadhyya and collaborators from IIA and SINP]

Data Analysis

Analysis of HAGAR data on various sources continued during this year. Software was developed

for comparison of data acquired with three types of data acquisition systems : CAMAC, VME and Acqiris waveform digitizer. Common events recorded by these three systems were studied to check for the stability of event arrival time and shower direction as well as to investigate the correlation between three systems.

Long term study of multi-waveband data of blazar, Mkn 421, was done using data collected by HAGAR over seven years' period (2009-15). Data were collected over 21 observation seasons. HAGAR data as well as contemporaneous multiwaveband data from various ground based or satellite based experiments from radio to low energy gamma ray were analysed or publicly available data were used to generate multiwaveband light curves and spectral energy distributions (SEDs). Variability in various wavebands was studied and flux distribution was found to show lognormality. SEDs were fitted with Synchrotron Self-Compton model and flux variations were attributed mainly to changes in particle distribution.



Multiwaveband light curve of blazar, Mkn421, from 2009-2015, panel 1) radio fluxes at 15 GHz from OVRO, panel 2) optical V band fluxes from CCD-SPOL, panel 3) degree and angle of the optical polarization using data from CCD-SPOL, panel 4) UV flux in the Swift-UVOT UW2 band, panel 5) soft X-ray count rates from Swift-XRT, panel 6) soft X-ray count rates from MAXI, panel 7) hard X-ray count rates from Swift-BAT, panel 8) gamma ray fluxes from Fermi-LAT and panel 9) VHE gamma ray count rates (counts/minute) from HAGAR.

Hard spectrum in gamma ray band was often noticed for the blazar Mkn501. We have investigated the origin of hard spectrum. For this purpose, occasions with spectral hardening were identified from gamma ray data from Fermi-LAT and using contemporaneous X-ray data from satellites and VHE data from VERITAS, multiwaveband SEDs were generated. In addition to usual shock-in-jet component, hard component was seen in the emission spectra of gamma rays. This hard component was explained in terms of leptonic scenarios for generation of gamma rays, like narrow powerlaw electron distribution or relativistic Maxwellian distribution of electrons.

Multiwaveband data for TeV binary, LSI+61 303 were studied. This binary consists of a B0 main sequence star with circumstellar disk (Be star) and a compact object which could be a neutron star or a black hole. Two periodicities have been seen in this system : orbital period of 26.496 days and superorbital period of 1626 days. Analysing or using publicly available multiwaveband data from radio to gamma rays, superorbital modulation was studied as a function of orbital phase and its wavelength dependence was investigated. Wide band SEDs were generated for various states which were explained in terms of one zone microquasar jet model consisting of synchrotron emission from electrons, its inverse Compton and Comptonization of external photons from companion star. [B. S. Acharya, V. R. Chitnis, A. R. Rao (DAA), L. Saha, A. Shukla, B. B. Singh, A. Sinha along with collaborators from IIA, SINP and Wurzburg University]

Monte Carlo Simulations

Simulations of atmospheric Cherenkov showers incident on HAGAR system were continued during this year. Effect of variation in PMT gain on QDC distributions was studied. Showers initiated by heavier cosmic ray species like carbon, lithium and iron were simulated in order to see their contribution in resultant space angle distributions. Comparison of space angle distributions from simulated cosmic ray and gamma ray showers was carried out in order to estimate systematics arising from normalization of space angle distributions and its effect on estimated gamma ray signal. Performance parameters were estimated for various zenith angles and for different incident gamma ray spectra.

Simulations were performed for proposed 256 pixels, G-APD based camera, to estimate performance parameters like trigger rate, energy thresholds for various trigger conditions. G-APD pulse shape measured in the laboratory was parameterised in terms of Landau distribution and was used in these simulations. Also the work on estimation of Hillas parameters from the simulated Cherenkov photon images to improve gamma-hadron segregation was initiated.

Simulations to improve gamma-hadron segregation for MACE telescope, which is being installed at Hanle under the leadership of BARC, were initiated. This study is based on timing information and efficacy of two parameters, time gradient (arrival time variation across major axis of image) and time RMS (RMS of arrival times of all pixels in

image) is investigated. [B. S. Acharya, V. R. Chitnis, S. Parolia (Savitribai Phule Pune University), S. R. Patel, L. Saha along with collaborators from BARC]

Geiger-mode avalanche photodiodes (G-APD) based camera

Work on various subsystems of proposed G-APD based imaging camera progressed further during this year. This camera will consist of 256 pixels, with each pixel comprising of 4×4 array of G-APDs with area of 13×13 mm². Camera will be modular, consisting of 16 identical modules of 16 pixels each.

Camera electronics: A camera module consists of signal processing electronics, bias supplies and low voltage dc supplies for 16 pixels. A prototype, 4 pixel low power amplifier, is designed following some extreme considerations such as wide dynamic range of 1-1500 photoelectrons per pixel, resolution of single photoelectron up to few tens of photoelectrons with a good signal to noise ratio, wide bandwidth to retain the single photoelectron pulse profile from G-APD etc. PCBs for the first prototype version of the amplifier and low dc voltage supplies are fabricated and they are undergoing various tests to validate the required design goals.

An 8-channel programmable bias supply system for G-APD based on a step-up DC-to-DC converter is developed and tested successfully. It can give a voltage up to 80 V @ 4 mA with 5 mV resolution by varying the input control voltage between 0 to 2.5 V. The system monitors the variations in temperature and the quiescent current and applies the correction to the bias voltage in order to maintain the G-APD gain constant. The number of channels in the system can be extended in multiples of eight by daisy chaining the boards using SPI interface for communication and control.

FPGA based design for the G-APD signal digitizer board : A 16-bit serializer with Dual-Clock First-In-First-Out (DCFIFO) module of 2K word (16-bit) depth and 16-bit deserializer with DCFIFO of same depth are synthesized in the Altera FPGA. Both of these modules were tested successfully up to a clock speed of 50MHz. This design would be adopted in the final version of the camera electronics for the ADC data buffering and

transferring. *G-APD characterization :* A G-APD, when biased above the breakdown voltage, turns on in saturation stage as an incident photon induces an avalanche breakdown of the pn junction and allows the detection of a single photon. We carried out laboratory measurements on Hamamatsu make 2×2 (3 mm size, 4-ch, S10985-50C) and 4×4 (3 mm size, 16-ch, S12642-0404PB-50) to characterize their performance. Detailed measurements of quenching resistance, dark count rates (thermal and after pulsing), breakdown voltage and its temperature dependence, absolute gain and its overvoltage/temperature dependence and photon detection efficiency (PDE) have been carried out. [B. S. Acharya, V. R. Chitnis, R. L. Deshmukh, A. I. D'Souza, S. Duhan, K. S. Gothe, Manoranjan, B. K. Nagesh, N. K. Parmar, P. N. Purohit, S. K. Rao, B. B. Singh, S. S. Upadhyay, S. Parolia (Savitribai Phule Pune University)]

Cherenkov Telescope Array (CTA)

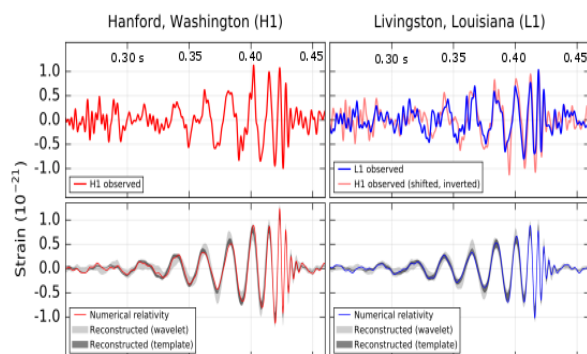
As part of the next generation experiment, Cherenkov Telescope Array (CTA), an international collaboration involving 31 countries, we designed and developed a calibration box for the prototype large size telescope (LST) of CTA in collaboration with SINP. This calibration box will be mounted at the centre of the reflector of LST and will illuminate the camera in the focal plane at a distance of 28 m. It consists of a pulsed UV laser with wavelength of 335 nm, a set of neutral density filters and a diffuser. The calibration device will be controlled by a single board computer (raspberry pi) which is also OPC-UA enabled. The calibration device is assembled in our laboratory and fully tested.

We are also contributing towards the software development for CTA. An OPC UA server is developed and tested successfully in a laboratory setup for the calibration box. The OPC-UA client application across the network can interact with the server to trigger the calibration events with a required periodicity. All Sky Camera is another device that will be used in CTA and for which the OPC-UA server development is in progress. [B. S. Acharya, V. R. Chitnis, R. L. Deshmukh, A. I. D'Souza, S. Duhan, K. S. Gothe, Manoranjan, B. K. Nagesh, N. K. Parmar, S. K. Rao, L. Saha, B. B. Singh, S. S. Upadhyay, Anshu Chatterjee (SINP), Pratik Majumdar (SINP)]

Gravitation and Non-accelerator particle Physics

Detection of gravitational waves and gravitational wave astronomy

Direct detection of gravitational waves has been accomplished from orbiting and merging binary black holes by the LIGO Scientific Collaboration.



The chirpy gravitational wave signals detected by the advanced LIGO detectors (upper panel). The calculated waveforms from Einstein's theory are in the lower panel.

This event is designated 150914 and had a large signal to noise of about 23. The fact that another reliable detection after about 3 months, 151226, increases confidence in the detectors and techniques. The calculated waveforms and parameter set agrees well with general relativity to about 10%. LIGO will start its second phase of observation run with 2-3 times increased sensitivity late this year. The new laboratory for a prototype interferometer detector is fully ready and is being populated with essential equipment for ultra-high vacuum and tests and monitoring. The LIGO-India project for the construction and operation of an advanced gravitational wave detector in India has been approved by the union cabinet. This is a very significant development for gravitational wave astronomy in India. [C. S. Unnikrishnan, as member of the LIGO Scientific Collaboration]

Detector and Associated Electronics Development

Our group in DHEP is involved in developing indigenous photo-readout detection techniques with associated electronics and its application to high energy physics experiments. After carrying out extensive simulations of Silicon Photo Multiplier (SiPM) and fabricating large array of micro-resistors with lower thermal budget, we are in final stages of fabricating this device with an Indian foundry. Unique facilities for characterizing and operating this device, such as Micron Resolution Optical Scanner (MROS), Programmable Multichannel Power Supply with built-in thermal compensation, High Speed Amplifier, FPGA based systems for data acquisition etc. have been developed by our group.

The MROS capabilities have been upgraded to provide multiple wavelength excitations of SiPM photo-detector. The MROS provides monochromatic optical beam with size of about 2

Quantum Optics and quantum vacuum

A source of correlated and entangled photon pairs at 810 nm, based on parametric down-conversion of 405 nm light in a nonlinear BiBO (BiB_3O_6) crystal, is set up and being tested. With an input pump power of about 30 mW, 10^5 photons pairs/s can be generated. Relatively large area (500 micron diameter) APD (avalanche photo-diode) single photon detectors optimized for about 800 nm, with high quantum efficiency (70%-80%), have been procured and tested for low dark count requirement. A multi-channel photon counter and correlator using an FPGA board with stable counting characteristics up to 90 MHz was already constructed and tested earlier. This will now be integrated into the experiment with software interface to LabView, along with several APD single photon detectors, for studies on quantum vacuum and induced coherence effects. [Ninad R. Jetty, P. V. Sudersanan, C. S. Unnikrishnan]

Instrumentation

A 20-bit digital to analog converter AD 5791 by Analog Devices has been implemented as a precision digitally controlled 1-ppm voltage source with a range of $\pm 10\text{V}$ using AD8676 as reference buffers and the AD8675 as the output buffer. A 3-pin SPI interface in vhdl was integrated with it for the data communication between FPGA board and the DAC. Precision $\pm 10\text{V}$ reference for the DAC was designed with Linear LT series voltage reference IC. [Vaishali, P.V.Sudersan, C.S.Unnikrishnan]

microns and automated target plane movement capability with precision of 0.1 micron. Detailed characterization SiPM with different characterization wavelength studies have been performed while biasing SiPM with temperature compensated power supply developed in-house. Use of temperature compensated power supply provides compensation in the bias to nullify the gain variation of SiPM due to temperature changes. These scans have provided vital information on properties of SiPM at microscopic level. Use of different wavelength for excitation provides insight into response of the SiPM at different depths of light absorption. These studies will provide insight into many interesting parameters of SiPM and are quite novel. Studies have also been performed with different bias voltages.

On the CMS experiment front, we had taken up a major responsibility of upgrading neutron radiation

monitoring data acquisition and control system. Neutron detectors are located around forward hadron calorimeter (HF). The upgrade was necessary to improve data acquisition rate with faster electronics and high-speed communication interface compatible with CMS standards. HF radiation monitoring system (HFRADMON) caters to 16 proportional counter based radiation detectors sensitive to neutrons. It is responsible for configuring individual radiation detectors, measuring the rate of each detector and monitoring health of each detector by measuring bias voltage and current. The upgrade of the system was jointly taken up by MSU, Russia and TIFR, India. The HF-Radiation Monitoring (HFRADMON) system was developed with state of the art FPGA, providing high performance and flexibility. System is responsible for controlling operation of the detector, recording rate (TTL pulses) and monitoring voltage and current parameters of the neutron detector. System provides ability to monitor neutron rate up to 1 MHz simultaneously for 16 counters and voltages (voltage and current) are acquired with 12-bit ADC providing resolution of 2.5 mV in 10V dynamic range. Complete hardware design, fabrication as well as firmware development for FPGA and micro-controller was undertaken by our group. The system had two independent modules; an interface board (digital) and an ADC board. All the digital logic along with Ethernet interface was built into an FPGA on the interface board. All the analog sampling operation was built into an independent ADC board developed around a PIC micro-controller. The ADC board had an I²C interface to configure the acquisition parameters and read out the converted data. Typical acquisition time interval required by the detector is around 0.5 to 1 second whereas the system was tested to operate at 200 ms acquisition interval. Development of firmware for FPGA was a challenging task. Firmware for counters, status monitoring, ADC board management and Ethernet communication was developed in Verilog HDL. The system has been successfully installed into the CMS experiment in 2015 and acquiring the data

since then. Interface and ADC Boards are shown in Figure 1. Voltage and current as function of time for one of the neutron detector during pp collisions is shown in Figure 2. [V.G. Achanta, S.R. Dugad, S.K. Gupta, S. S. Prabhu, R. A. Shukla]

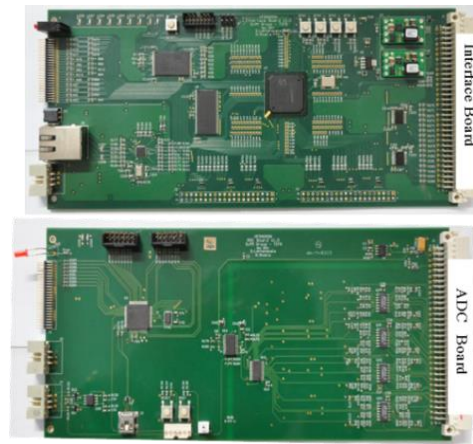


Fig 1: FPGA based Interface Boards and the ADC Board

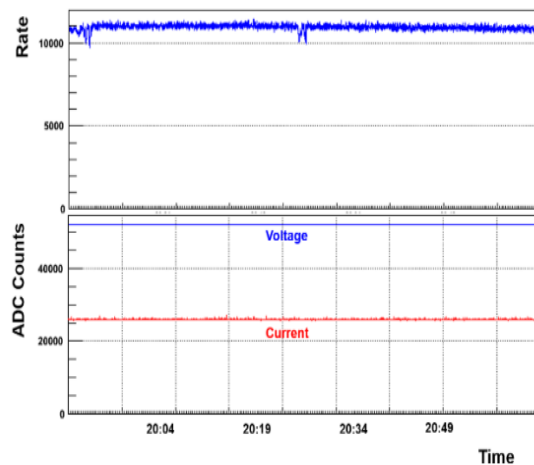


Fig 2: Data from one of the neutron radiation detector during collision.

GRAPES-3 Experiment at Ooty

Investigation of a cosmic-ray burst

The high solar activity during 2015-16 witnessed a large number of solar flares and coronal mass ejections (CMEs) in the present solar cycle. A strong earth-directed CME, associated with double peaked M2-class solar flare was erupted on 21 June 2015. It reached Earth on 22 June 2015 18:40 UT and triggered a severe G4-class geomagnetic storm (storm). As shown in Figure 1, starting 19:00 UT,

the GRAPES-3 muon telescope recorded a 2 hour high-energy (~ 20 GeV) burst of galactic cosmic rays (GCRs) strongly correlated with a 40 nT surge in the interplanetary magnetic field (IMF). We thoroughly investigated the event through a Monte Carlo simulation by calculating the cosmic ray trajectories in the geomagnetic field perturbed by IMF and found a large ($17 \times$) compression of the IMF to 680 nT. Its subsequent reconnection with

the geomagnetic field (GMF) leads us to understand that lowering of cutoff rigidities could generate this burst.

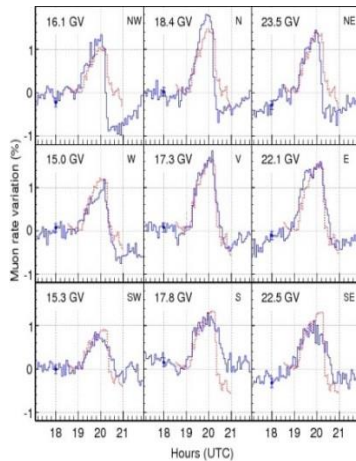


Figure 1: Muon-rate variation in nine directions observed by GRAPES-3 on 22 June 2015 shown by solid-line. Simulation results normalized to data by scaling the IMF 17 times shown by broken-line.

Here, 680 nT represents a short-term change in GMF around the Earth, averaged over seven times its volume. The GCRs, due to lowering of cutoff rigidities, were deflected from Earth's day-side by ~ 210 in longitude, offering a natural explanation of its night-time detection by GRAPES-3. The occurrence of this burst indicates a transient weakening of the Earth's magnetic shield, and may unfold clues for a better understanding of future super-storms.

Seasonal variation of muon intensity

We investigated the seasonal variation in muon intensity due to atmospheric temperature using 6 years of data (2005 - 2010) recorded by the GRAPES-3 muon telescope. About 7 trillion of muons recorded during this period were used in the analysis. As the atmosphere expands with increase of temperature, it results decrease in density of atmosphere and increase of the mean altitude of muon production. The increased flight time results in decay of more muons before they reach the detector causing a decrease in muon rate. We obtained the temperature data set for different atmospheric pressure levels above the atmosphere of Ooty from MDISC site <http://disc.sci.gsfc.nasa.gov/daac-bin/FTPSubset.pl>.

The temperature variation over a year is found to be only ~ 1 K. Furthermore, our analysis based on fast Fourier transform revealed a strong dependence of muon intensity variation with temperature, thanks to very high statistics. The temperature coefficient was measured to be $-0.194 \pm 0.001\% / ^\circ\text{K}$. Efforts are underway to investigate

the IMF and cosmic ray intensity correlation, after correcting data for seasonal variation.

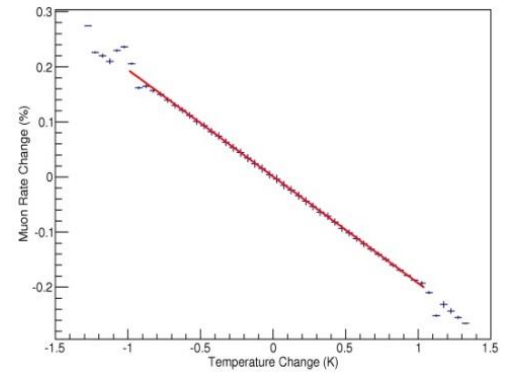


Figure 2: Temperature dependence of muon rate over 2005-2010.

Acceleration of muons during thunderstorms

Investigation of charged particle acceleration by the large scale electric field of the atmosphere during thunderstorms has emerged as an exciting area with several discoveries in the recent past. The GRAPES-3 has observed directional muon intensity variation during thunderstorms. An extensive search of GRAPES-3 data for the period of 2006-2014 found a total of 300 statistically significant events. These events were observed to be well-correlated with electric field measured by 4 widely separated electric field monitors installed by us. In an interesting event observed on 30 September 2015, about 4.5 % change in

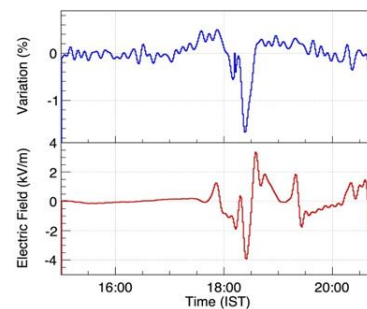


Figure 3: Muon rate variation (upper panel) during thunder storm event on 30 September 2015.

muon rate was observed within a short span of 20 minutes. (Figure 3). Detail Monte Carlo simulation study suggested electric potential as large as 1 GV in thunderstorm is required to obtain this effect.

Solar diurnal anisotropy studies

Investigation of solar diurnal anisotropy in cosmic rays was initiated using the high statistics muon data of 2006. A fast Fourier transform based analysis of the GRAPES-3 muon data revealed a

clear presence of the first three harmonics with signature of the fourth harmonic component. We extended this analysis for the period up to 2010, and observed the consistent presence of fourth harmonics in all these 5 years data, though the amplitude shows a solar activity dependency (Figure 4). Prior to the harmonics analysis, efficiency correction of data was extensively carried out.

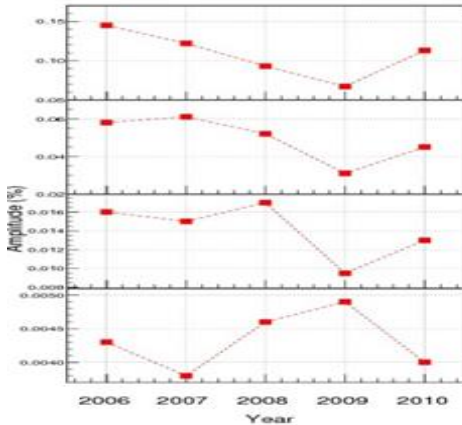


Figure 4: Solar diurnal harmonics measured for the period 2006-2010. Panels from top to bottom represent amplitude variation of 1st, 2nd, 3rd and 4th harmonics, respectively.

Analysis of shower data

Reconstruction of extensive air shower (EAS) events for 2014 measured by the scintillator array was initiated with a better understanding of various calibration parameters. On comparing the response of two types of scintillator detectors (cone-design and WLS fiber based design), it was found that the cone-design detectors observed 7 % less particles, warranting a correction of the gain for these detectors. As accurate estimation of time offsets or tdc zeros are important for better determination of shower direction, we determined tdc zeros (with an accuracy of 0.2 ns) using a novel technique. Extensive studies were performed to understand the temperature and pressure effects in EAS trigger rate and particle measurement, extensively for each detector.

Setting up of a large computing cluster

A computing cluster with 40 nodes comprising of 1280 computing threads was set up at Ooty by in-house expertise. It provides 1280 GB of memory and 660 TB of storage space. Scripts were developed in-house for exhaustive cluster monitoring. The installed cluster occupies 36th rank in Rocks-Cluster ranking. A full control of the configuration with design optimization as per our requirements was achieved. We used the cluster for performing cosmic ray trajectory computation in

the earth's magnetic field. Using CORSIKA, we simulated 9 billions of proton and helium primary events from each in the energy range of 10 to 1000 GeV to investigate muon angular distribution. Further, 1.5 million events were simulated from proton, helium and γ -ray primary each in the range of 1 TeV to 1 PeV. This data bank will be used for diffuse γ -ray and cosmic ray composition studies.

Muon detector construction activities

Our group is in the process of constructing additional 560 m² area muon detector that will double the area of the existing one. It requires nearly 3800 proportional counters to be fabricated, upgrade of signal processing electronics and civil construction. In the last one year, substantial progress has been made in all these fronts as summarized below.

Fabrication of proportional counters

A mass production and testing facility for PRC fabrication was setup. The fabrication procedure involves cleaning of the PRC tubes, cutting and welding of end plates, fixing of various components including tungsten anode wire and hermetic seals, degassing, vacuum and leak tests, filling of P10 gas and measurement of MCA spectrum. The procedure has been streamlined.



Figure 5: Pictures on upper panel show PRC fabrication and testing. Lower panel shows platforms for new muon detector.

After the fabrication, PRCs are being tested for a period of few weeks for studying their gain variations. Five test stacks were created for this purpose where 128 PRCs are placed in one stack. Software tools were developed to monitor and validate the PRC performances and after they passed thorough quality checks, they are installed in the actual platform (Figure 5).

Front-end electronics development

For 3800 PRCs, proportional numbers of front-end

electronics channels are needed. As the existing front-end electronics of PRCs (amplifier and discriminator) had suffered from high noise, input bias current and power consumption, development was undertaken taking the advantage of latest and superior electronics. These new amplifier-discriminator modules have exhibited low noise and have shown far better performances compared to the old ones with a factor of 3 saving in the cost. Now they are in the production phase.

DAQ Electronics Development

Attempts were made to upgrade the two-decade old DAQ electronics of the muon detector. The new electronics are FPGA based and provides lot of flexibility with additional features. New TCP/IP interface board for muon DAQ system, programmable logic unit with 64-channel scalar and USB interface, and a pulse width analyser with USB interface for 64-channel were developed.

Analysis of total solar eclipse data

We have collected background data for studying the variation in cosmic γ -ray flux during total solar eclipse on 22 July 2009 at Raja Ramanna Centre for Advanced Technology (RRCAT), Indore. This experiment was essentially aimed at studying variation in cosmic γ -ray flux during the total solar eclipse. An MS structure was constructed to house the two sodium iodide detectors along with about 150 kgs of lead bricks. We used two NaI(Tl) detectors for γ -flux studies and a muon counting set up for obtaining complementary information. Additionally, we included a weather station for keeping track of the atmospheric parameters. In the beginning stage, the emphasis was on thorough testing and calibration of the instruments. Actual un-interrupted data taking was started from one week prior to one week after the day of total solar eclipse (i.e. 22 July 2009). This additional data was required for successful understanding of the phenomena of γ -ray flux variation during total solar eclipse in planned and controlled manner.

However, it was found that though similar arrangements were made at both places, but data was affected by variable amount of rain and the data on 22 July 2009 was highly-affected by rain,

and there is a need to logically remove the effect of rain from data to obtain meaningful conclusion. We could successfully model the data by using ROOFIT (used in ROOT, an extended framework), by using several of its features like simultaneous addition of multiple probability distribution functions such as Gaussian functions and Exponential functions. In the new devised model, we were able to add two Exponential functions along with 12 Gaussian functions simultaneously, to generate a single compound energy spectrum. This model can be well fitted to individual spectrum of different time duration, irrespective of amount of rain and/or time, and has the potential to isolate the impact of rain quite convincingly. Based on this model, on reanalysing the Indore data for a period of more than two weeks, the variation in γ -ray flux has reduced to 5 % after modeling, which was more than 100 % at pre-modeling stage. The new devised model does not depend on rain information, and we have successfully implemented this newly devised model for analysing Siliguri data, which was otherwise impossible due to unavailability of proper rain information.

Members

B.S. Acharya, T. Aziz, S. Banerjee, V.R. Chitnis, S.R. Dugad, M. Guchait, S.K. Gupta, N. Krishnan, G. Majumder, K. Mazumdar, G.B. Mohanty, N.K. Mondal, C.S. Unnikrishnan, P.K. Mohanty

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Bhattacharya, Uttiya Sarkar, Rajat Kumar Mandal, Mohammad Nizam, Divya Divakaran, Abhijit Garai, Neha Panchal, Apoorva Bhatt, Suryanarayan Mondal, Aswathi V. Balagopal, Pragati Mitra, S. Pethuraj, Noor M. Mohamed, Dhruv Mulmule, Aparajita Mazumdar, Jaydeep Dutta

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Vipin Gaur, Susnata Seth, Deepanwita Dutta, Arun Babu, Manu S., Sandhya Jain, Kolahal Bhattacharya, Nelli Kunnumel Nisar, Muzamil Ahmad Bhat, Akhil M Kurup, Sonal Ramesh Patel, Ravindra Kumar Verma, B.S. Mallikarjuna, Anuj Chandra, Meeran Zuberi, Subham Negi, Akshay M. Manjare

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Administration

V.S. Lotankar, M.P. Rane, D.K. Srivastava, V. Viswanathan

National and International Involvement

Sudeshna Banerjee: Member of CMS Statistics Committee. *B.Satyannarayana*: 1. Editor, DBIT Journal of Science and Engineering (DBJSE). 2. Member, Department Advisory Board (DAB), Department of Electronics & Telecommunication Engineering, Fr. C. Rodrigues Institute of Technology, Mumbai. 3. Member, Department Advisory Board (DAB), Department of Electronics & Telecommunication Engineering, Don Bosco Institute of Technology, Mumbai. *C.S. Unnikrishnan*: 1. Member of the council of the IndIGO consortium for development of gravitational wave research in India. 2. Member of the LIGO-Scientific Collaboration (LSC) and a member of its Council.

Visits

B. S. Acharya: 1. The IceCube Particle Astrophysics (IPA-2015) Symposium, UW-Madison, May 4, 2015. 2. 14th International Conference on Topics in Astroparticle and Underground Physics (TAUP-2015), Torino (Italy), Sept 7-11, 2015. 3. International Conference on Space and Plasma Science (ICSPS-2015), Maihar (M.P., India), September 22-24, 2015. *B. S. Acharya and V. R. Chitnis*: 1. International workshop on Advances in Astroparticle Physics and Cosmology (AAPCOS-2015), SINP (Kolkata), October 12-17, 2015. 2. A National Conference on 'Current Issues in Cosmology, Astrophysics and High Energy Physics', CICAHEP-2015, Dibrugarh, Assam, Nov 2-6, 2015. *V. R. Chitnis and A. Sinha*: 1. Workshop on Timing and Spectroscopy : Wideband X-ray Astronomy, TIFR Balloon Facility, Hyderabad, 12-14 January 2016. *A. Sinha*: 1. Conference on 'Extragalactic Relativistic Jets - Cause and effects', ICTS, Bangalore, 12-20 Oct 2015. *B. B. Singh*: 1. 10th winter Workshop on Astro Particle Physics (WAPP-2015), Bose Institute, Darjeeling, 17-19 December 2015. *C. S. Unnikrishnan*: 1) Current Trends in Atomic, Molecular and Optical Physics, University of Delhi, 11-14 March 2015. 2) 25th Meeting of the Indian Association for General Relativity and Gravitation (IAGRG), Raman Research Institute, Bangalore 18-20 March, 2015. 3) 50th Rencontres de Moriond (Gravitation, 100 years after GR), La Thuile, Italy, 21-28 March, 2015.

Invited Talks

Gobinda Majumder

1. Construction and characterisation of Resistive Plate Chamber with toughened glass electrodes
2. Improvement of time resolution in large area single gap RPCs.

Presented in The XIII workshop on Resistive Plate Chambers and Related Detectors (RPC2016), Ghent University, Belgium, Feb 22-26, 2016.

Kajari Mazumdar

1. Status of CMS experiment at CERN-LHC. Talk presented on behalf of CMS collaboration, at 17th Lomonosov Conference, Moscow, 20-25 August, 2015.
2. A common connection: Computing in CMS experiment at LHC, CERN. Talk presented at 2-day workshop on Accelerating International Collaboration in Science Through Connective Computation, University of Chicago Centre, Delhi; 10-11 March, 2015.
3. The Large Hadron Collider, Plenary talk presented in national conference: Current Issues in Cosmology, Astrophysics and High Energy Physics, Dibrugarh University, 2-5 November, 2015.

B.Satyannarayana

1. Technologies of basic science research: Spinoffs to the Society, Two-day Seminar on Frontiers of Experimental Physics, Wilson College, Mumbai, February 10, 2016
2. Physics, detector and instrumentation of the INO project, Two-day Seminar on Frontiers of Experimental Physics, Wilson College, Mumbai, February 10, 2016
3. An overview of research paper review process, Workshop on Research Paper Publication and Patent Search, Bharatiya Vidya Bhavan's Sardar Patel Institute of Technology, Mumbai, February 5-6, 2016
4. Technology spinoffs of basic science research, Fourth National Conference on Advances in Communication & Computing (NCACC-15), R. C. Patel Institute of Technology, Shirpur, April 18, 2015
5. Trends and technologies of VLSI devices, Fourth National Conference on Advances in Communication & Computing (NCACC-15), R. C. Patel Institute of Technology, Shirpur, April 18, 2015

B. S. Acharya

1. Seminar on 'The status of India-based Neutrino Observatory (INO)' at the Dept. of Physics, University of Wisconsin at Madison, USA, April 23, 2015
2. Contributed talk on 'The status of Himalayan Gamma Ray Observatory (HiGRO)' at the IceCube Particle Astrophysics (IPA-2015) Symposium, UW-Madison, May 4, 2015
3. Contributed talk on 'The status of India-based Neutrino Observatory (INO)' at the IceCube Particle Astrophysics (IPA-2015) Symposium, UW-Madison, May 5, 2015
4. Invited talk on 'The status of Ground-based Gamma-ray Astronomy' at the scientific seminar, 'Cosmic Connection: Underground to Space Experiments at TIFR', Mumbai, July 10, 2015
5. Invited lecture on 'Universe viewed in Gamma Rays' at the DST-Inspire Internship Camp at Pt. Ravishanker Shukla University, Raipur, July 27-31, 2015
6. Invited lecture on 'Universe viewed in Gamma Rays' at the DST Inspire Internship Science Camp 2015 at Smi. Veeramma Gangasiri College for Women, Kalaburagi (Karnataka, India) Aug. 24-28, 2015
7. Contributed talk on 'Status of HiGRO' at 14th International Conference on Topics in Astroparticle and Underground Physics (TAUP-2015), Torino (Italy), Sept. 7-11, 2015
8. Invited talk on 'The Universe viewed in Gamma-rays' during an International Conference on Space and Plasma Science (ICSPS-2015), Maihar (M.P., India), September 22-24, 2015
9. Invited talk on "The Cherenkov Telescope Array (CTA)" at the International workshop on "Advances in Astroparticle Physics and Cosmology (AAPCOS-2015), SINP (Kolkata), Oct. 12-17, 2015
10. Invited talk on "Universe viewed in Gamma Rays" for the Physical Society, at the Dept. of Physics, Guwahati University, Gauhati on Nov 6, 2015.
11. Outreach talk on 'Universe viewed in Gamma rays' for the Embryo Club at BITS, Pilani on April 9, 2016

V. R. Chitnis

1. Invited talk on 'Very High Energy Gamma Ray Astronomy from Hanle' at the International workshop on 'Advances in Astroparticle Physics and Cosmology (AAPCOS-2015)', Saha Institute of Nuclear Physics, Kolkata, 12-17 October 2015
2. Invited talk on 'Very High Energy Gamma Ray Astronomy using HAGAR Telescope System' at a National Conference on 'Current Issues in Cosmology, Astrophysics and High Energy Physics (CICAHEP)', Dibrugarh University, Dibrugarh, 2-5 November 2015
3. Invited talk on 'ASTROSAT Observations of TeV Blazars' at a Workshop on 'Timing and Spectroscopy :

Wideband X-ray Astronomy, TIFR Balloon Facility, Hyderabad, 12-14 January 2016

B. B. Singh

1. Invited talk on 'Observation of VHE sources @ HAGAR telescope array' at 10th winter Workshop on Astro Particle Physics (WAPP-2015), Bose Institute, Darjeeling, 17-19 December 2015

A. Sinha

1. Contributed talk on 'On the spectral curvature of 1ES1011+496' at the conference on 'Extragalactic Relativistic Jets - Cause and effects', ICTS, Bangalore, 12-20 Oct 2015
2. Seminar on 'Underlying particle distribution in blazar jets' at SINP, Kolkata on 6 November 2015
3. Contributed talk on 'Importance of the hard X-ray spectrum: constraining particle distribution in blazar jets' at a Workshop on 'Timing and Spectroscopy : Wideband X-ray Astronomy, TIFR Balloon Facility, Hyderabad, 12-14 January 2016
4. Contributed talk on 'Lognormal flux variability in blazars: Observations and Implications' at the conference on 'Jet Triggering Mechanisms in Black Hole Sources', TIFR, Mumbai, 20-23 Jan 2016

S.K. Gupta

Precision measurements in Astroparticle Physics by the GRAPES-3 experiment, WAPP-2015, Darjeeling, December 17, 2015.

B. Hari Haran

Simulation of tracking muon detector in GRAPES-3, WAPP-2015, Darjeeling, December 17, 2015. on 17-12-2015

Jhansi Bhavani

Search for γ -ray component in EAS and calculation of the real-time gain of the scintillator, WAPP-2015, Darjeeling, December 18, 2015.

K. Ramesh

Current status of fabrication of PRC at GRAPES-3, WAPP-2015, Darjeeling, December 18, 2015.

Meeran Zuberi

Dependence of PMT gain on temperature, WAPP-2015, Darjeeling, December 18, 2015.

P.K. Mohanty

1. Cosmic Ray Studies with GRAPES-3 Experiment", ICRR, Tokyo, February 8, 2016.
2. Ultra High Energy Cosmic Rays, TIFR VSRP seminar, June 15, 2016.

Conferences Organized by the Department

1. Workshop on CMS calorimeter upgrade, October, 2015, TIFR, Mumbai, organized by Prof. S.R. Dugad.
2. National seminar on Current Issues of Cosmology, Astrophysics and High Energy Physics (CICAHEP),

November 2-5, 2015, Dibrugarh University, organized by Dr. V. Chitnis.

3. Workshop on High Energy Physics Phenomenology

(WHEPP XIV), December 4-13, 2015, IIT Kanpur - Prof. M. Guchait (member of NOC, DAE contact).

4. 10th Workshop on Astroparticle physics and winter school, December 18-29, 2016, Darjeeling, organized by Prof. S.K. Gupta.

5. Belle Analysis Workshop, January 11-20, 2016, Bhubaneswar, organized by Prof. G.B. Mohanty.

6. DHEP Annual meeting, April 7-8, 2016.

7. Winter school on Beyond the Standard Model Physics, Banaras Hindu University, Varanasi, January 24 - February 14, 2016, organized by B. Satyanarayana.

8. IEEE Bombay Section Symposium (IBSS-2015), Usha Mittal Institute of Technology, SNDT, Mumbai, September 10-11, 2015, organized by B. Satyanarayana.



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Department of Nuclear and Atomic Physics

Nuclear structure and Dynamics

Longitudinal Wobbling mode in ^{133}La

Excited states of ^{133}La have been investigated to search for the wobbling excitation mode in the low-spin regime. Wobbling bands with $n = 0$ and 1 are identified along with the interconnecting $\Delta I = 1$, E2 transitions, which are regarded as fingerprints of the wobbling motion. An increase in wobbling frequency of the $n = 1$ band with spin suggests longitudinal wobbling for ^{133}La , in contrast with the case of transverse wobbling observed in ^{135}Pr . This is the first observation of the phenomenon of longitudinal wobbling in nuclei. The experimental observations are discussed using tilted axis cranking (TAC), quasiparticle triaxial rotor (QTR) and triaxial projected shell model (TPSM) approaches. It is shown that mean-field approaches of TAC and QTR models are unable to describe the observed transition from transverse to longitudinal wobbling motion. On the other hand, the TPSM framework, which includes correlations beyond the mean-field level, reproduces this transition. [S. Biswas, R. Palit, J. Sethi, S. Saha, Purnima Singh, D. Choudhury (TIFR), U. Garg, S. Frauendorf, W. Li, T. Matta, A. D. Ayangeakaa (Notre Dame Univ), G. H. Bhat, J. A. Sheikh, J. W. A. Dar (Kashmir Univ), V. Singh, S. Sihotra (Panjab Univ)]

Study of nuclear isomers for application of energy storage

Isomeric states of nuclei play an important role in the development of shell and collective models for nuclear structure. Apart from this basic nuclear structure studies, isomers are crucial in nuclear astrophysics as well as energy storage in isomeric states. The nuclear isomers have the potential to provide material with highest energy storage capacity with controlled release of its energy on demand. Spectroscopic measurement of the excited states around these isomers has become a topic of immense importance due to its crucial role in estimating the depletion pathway of the isomer and the concerned rate. The ^{108}Ag nucleus has been a subject of investigation for the study of isomer depletion due to presence of long-lived isomer with $T_{1/2} = 438$ years at low spin and high production of this isomer through (n, gamma) cross-section using stable ^{107}Ag isotope. Our recent work suggests a total of three possible transitions at energies below

500 keV from the isomer to the higher excited levels, whose subsequent decay can branch to the ground state. Our measurement will help in an improved estimation of the cross section for induced isomer depletion via these states. [J.Sethi, R.Palit, S.Saha, S.Biswas, T.Trivedi, R.Donthi, S.Jadhav, H.C.Jain, B.S.Naidu (TIFR), J.J.Carroll, M.S.Litz, S.Karamian (DUBNA), Z.Naik (Sambalpur Univ), P.Datta, S.Chattopadhyay (SINP), U.Garg (Notre Dame Univ), S.Kumar (Delhi Univ), G.H.Bhat, J.A.Sheikh (Kashmir Univ), D.Mehta, S.Sihotra (Panjab Univ), P.M.Walker (Surrey)]

High spin structure of ^{132}Te : The Two-Particle and Two-Hole Spectrum of ^{132}Sn

High-spin states in ^{132}Te , an isotope with two proton particles and two neutron holes outside of the ^{132}Sn doubly magic core, have been extended up to an excitation energy of 6.17 MeV. With the two proton-particles and two neutron-holes, the ^{132}Te isotope is an interesting case since it should allow to study the competition of protons and neutrons in forming sequences of states up to the highest spin-states requiring involvement of both kinds of nucleons. The prompt-delayed coincidence technique has been used to correlate states above the $T_{1/2} = 3:70(9)$ s isomer in ^{132}Te to the lower states using $^{232}\text{Th}(^7\text{Li}, f)$ at 5.4 MeV/u and the Indian National Gamma Array (INGA). With $^9\text{Be}(^{238}\text{U}, f)$ at 6.2 MeV/u and EXOGAM-array coupled with the VAMOS++ spectrometer, the level scheme was extended to higher excitation energies. The experimental level scheme has been compared with the large scale shell model calculations. A reduction in the p-n interaction strength resulted in an improved agreement with the measurements up to the spin of 15~. In contrast, the comparison of the differences between the experiment and these calculations for the $N = 76; 78$ isotones of Te and Sn shows the increasing disagreement as a function of spin, where the magnitude is larger in Te than in Sn. This behavior could possibly be attributed to the deficiencies in the p-n correlations, in addition to the n-n correlations in Sn. [S.Biswas, R.Palit, D.Choudhury, V.Nanal, R.G.Pillay, S.Saha, J.Sethi, P.Singh (TIFR), A.Navin, M.Rejmund, O.Delaune, F.Farget, G.de

France, B.Jacquot, A.Lemasson, E.Clement (GANIL), M.Caamano(USC), S.Bhattacharyya (VECC), D.C.Biswas, L.S.Danu, S.Mukhopadhyay (BARC), M.P.Carpenter (ANL), S.S.Hota (ANU), A.Bisoi, M.S.Sarkar (SINP), S.Sarkar (IEST), P.C.Srivastava (IITR), S.K.Tandel(CBS)]

Nuclear structure studies in the vicinity of ^{68}Ni

In recent years, the structure of neutron-rich nuclei in the vicinity of ^{68}Ni has been the subject of considerable interest. Several experimental and theoretical efforts have been made to investigate the magicity of ^{68}Ni and to understand the existence of multiple coexisting shapes in this region, however, a satisfactory description of nuclear structure is still lacking. Further experimental information on these nuclei is an important step towards providing a firmer understanding of their properties through comparisons with modern theoretical models. In this regard, odd-odd Cu isotopes are expected to provide a good laboratory for nuclear theory due to their relatively simple proton states. Moreover, odd-odd nuclei are more sensitive to the proton-neutron interaction and configuration mixing and provide a more severe test to the calculations.

An experiment was performed to study the odd-odd Cu isotope ^{66}Cu using multinucleon transfer reaction between a ^{30}Si beam and a ^{65}Cu target with the INGA spectrometer. Our measurements have resulted into the change in excitation energy and spin assignments of previously known states. In addition, we have observed three new levels above the 590 ns isomeric state. The experimental results were compared with large-scale shell model calculations using two modern effective interactions. It was observed that none of the interactions give a proper description of experimental observations. The present work emphasized that there is a need to develop an optimized interaction, which includes both $f_{7/2}$ and $g_{9/2}$ orbitals, for a proper description of nuclei in the vicinity of ^{68}Ni . Further experimental information on these nuclei especially the odd-odd isotopes is also required. [Purnima Singh, R. Palit, J. Sethi, S. Saha, S. Biswas, D. Choudhury]

GEANT4 Simulation for INGA

A Geant4 simulation code for the Indian National Gamma Array (INGA) has been developed. The calculated properties in the energy range that is of interest for nuclear g-ray spectroscopy are spectral distributions for various standard radioactive sources, intrinsic peak efficiencies and peak-to-total (P/T) ratios in various configurations such as singles, add-back and Compton suppressed mode. The comparison between simulation results and experimental data demonstrate the need of

incorporating the exact geometry of the clover detectors, Anti-Compton Shield and other surrounding materials in the array to explain the detector response to the g-ray. Several experimental effects are also investigated. These include the geometrical correction to angular distribution, crosstalk probability and the impact of heavy metal collimators between the target and the array on the P/T ratio. [S. Saha, R. Palit, J. Sethi, S. Biswas, P. Singh]

Evaporation residue cross-section measurements for compound nucleus around $Z_{\text{CN}}=82$ region.

We report about our measurements of Evaporation Residue (ER) cross-sections of ^{198}Pb , ^{190}Pb and ^{192}Po compound nuclei to investigate the role of proton shell closure on the formation of ER. The experiments were carried out at the Inter University Accelerator Centre, New Delhi by bombarding ^{48}Ti on $^{150,142}\text{Nd}$ and ^{144}Sm targets. The ERs were detected at the focal plane of the HYbrid Recoil Mass Analyzer (HYRA) in gas-filled mode. In order to extract the transmission efficiency of the HYRA for the measured ERs another reaction ($^{48}\text{Ti}+^{122}\text{Sn}$) with known ER cross-sections was also carried out. The average transmission efficiency for the $^{48}\text{Ti}+^{122}\text{Sn}$ reaction was determined to be 28.71 (5.6) %. The ER cross-sections for the $^{48}\text{Ti}+^{142,150}\text{Nd}$, ^{144}Sm systems were determined for the entire range of beam energy. Statistical model calculations were performed using Bohr-Wheeler formalism for the fission width (Γ_f) including shell correction in the level density and fission barrier. Coupled channel calculations were also performed to obtain the compound nucleus (CN) spin distribution. The calculated spin distribution was fed in to the statistical model calculations. Comparison of the theoretical model calculations with the experimentally determined ER cross sections indicates very little contribution of quasi-fission in the reaction involving ^{144}Sm target. [I. Mazumdar, S.M. Patel, M.Dhibar with P. Sharma, B.R. Behera (Panjab Univ.), N. Madhavan, S. Nath, J. Gehlot, T. Verugheese (IUAC)]

Experimental determination of spin-distribution of compound nuclei, for different target-projectile combinations.

We have determined experimental spin distribution for a variety of target-projectile combinations over wide range of beam energies. The different reactions studied were, $^{16}\text{O}+^{197}\text{Au}$, $^{19}\text{F}+^{197}\text{Au}$, $^{48}\text{Ti}+^{142,150}\text{Nd}$, and $^{48}\text{Ti}+^{144}\text{Sm}$ producing ^{213}Fr , ^{216}Ra , ^{198}Pb , ^{190}Pb and ^{192}Po , respectively. The γ -ray fold distributions were measured using the TIFR 4π spin-spectrometer. The calculated spin distributions for all the reactions were converted in

to fold distributions which, in turn, were convoluted with the response matrix of the 4π spin-spectrometer. The calculated distributions, so obtained, were compared with the experimental fold distributions. It is found that for the $^{16}\text{O}+^{197}\text{Au}$ and $^{19}\text{F}+^{197}\text{Au}$ systems the most probable values of the fold distributions keep increasing with beam energies. This trend is in good agreement with the statistical model calculations for the spin distributions. Very similar behaviour was observed for the $^{48}\text{Ti}+^{142,150}\text{Nd}$, and $^{48}\text{Ti}+^{144}\text{Sm}$ systems. A typical fitted spin-distribution is shown in Fig.1. [I. Mazumdar, M.Dhibar with P. Sharma, B.R. Behera (Panjab Univ.), N. Madhavan, S. Nath, J. Gehlot, T. Verugheese (IUAC), Y. Yeremen (Dubna)]

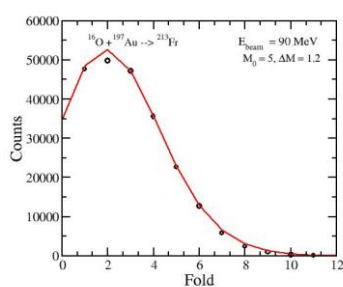


Fig 1

Giant dipole resonance and shape transitions in hot and rotating ^{88}Mo .

The giant dipole resonance (GDR) observables were calculated within the thermal shape fluctuation model (TSFM) by considering the probability distributions of different angular momentum (I) and temperature (T) values estimated recently in the de-excitation process of the compound nucleus ^{88}Mo . These results were found to be very similar to the results obtained at the average T and average I corresponding to those distributions. The shape transitions in ^{88}Mo at different T and I were also studied through the free energy surfaces calculated within the microscopic-macroscopic approach. The deformation is found to increase considerably with T and I leading to Jacobi shape transition at $I \sim 50$ hbar. The combined effects of increasing deformation, larger fluctuations at higher T and larger Coriolis splitting of GDR components at higher I lead to a rapid increase in the GDR width. [A. K. Rhine Kumar, I. Mazumdar, P. Arumugam, A.K Gourishetty (IIT-Roorkee), N. Dinh Dang (RIKEN), M. Ciemala, M. Kmiecik, A. Maj (IFJ-Krakow)]

Characterisation of an array of large square bars of $\text{LaBr}_3:\text{Ce}$ detectors up to 22.5 MeV.

We report about our complete characterisation of the large volume square bars of $\text{LaBr}_3:\text{Ce}$ detectors, individually, and in a compact array of four bars. The square bars have dimensions of $2'' \times 2''$ in cross

section and length of $8''$ and are manufactured and supplied by St. Gobain Inc.. The energy and timing resolutions, linearity of response, uniformity of the crystal, internal activity and efficiencies of detection have been measured using different radioactive γ -ray sources and also using in-beam reactions. We have carried out detailed realistic simulations using GEANT4 package to reproduce the measured spectra. We have carried out the measurement of γ -rays up to 4.43 MeV using Am-Be radioactive source. In order to determine the response at higher energies we have carried out an experiment at the TIFR-BARC Pelletron machine using low energy proton beam. A 7.2 MeV proton beam was used to bombard natural Boron target of around 1 mg/cm^2 . The $p(^{11}\text{B}, \gamma)^{12}\text{C}$ reaction produced monochromatic γ -rays of 22.5 MeV. The γ -rays were measured in a compact array of four square bars (mentioned above) kept at around 15 cm from the target position. The experimental γ -ray spectrum and its GEANT reproduction for 22.5 MeV are shown in Figure 2. [I. Mazumdar, M. Dhibar, P.B. Chavan, S.M. Patel, S. Basu, A.K. Gourishetty (IIT-Roorkee)]

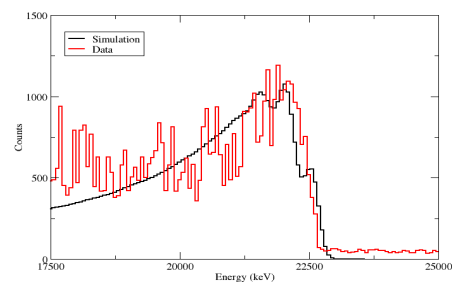


Fig.2

Efficiency calibration and coincidence summing correction for a large volume (946cm^3) $\text{LaBr}_3(\text{Ce})$ detector: GEANT4 simulations and experimental measurements.

We report our studies on efficiency calibration and coincidence summing correction for a $3.5 \times 6''$ cylindrical $\text{LaBr}_3(\text{Ce})$ detector. GEANT4 simulations were done with point sources, namely, ^{60}Co , ^{94}Nb , ^{24}Na , ^{46}Sc and ^{22}Na . The simulated efficiencies, extracted using ^{60}Co , ^{94}Nb , ^{24}Na and ^{46}Sc that emit coincident gamma rays with same decay intensities, were corrected for coincidence summing by applying the method proposed by Vidmar *et al.* The method was applied for the first time for correcting the simulated efficiencies extracted using ^{22}Na that emits coincident gamma rays with different decay intensities. The measured results obtained using ^{60}Co and ^{22}Na were found to be in good agreement with simulated results. [M. Dhibar, I. Mazumdar, D. Mankad, A.K. Gourishetty (IIT-Roorkee)].

Testing the performance of LaBr₃:Ce crystals coupled with SiPM.

We report the performance of LaBr₃:Ce crystals coupled with Silicon Photomultipliers (SiPM) in measuring γ -rays from 662 keV to 4.43 MeV. The advantages of SiPMs over conventional vacuum photo tubes have led to a flurry of activities to test and characterize SiPMs over last one decade. We have tested the performances of both small (1"X1" cylinder) and large (2"X2"X8" square bar) volume LaBr₃:Ce crystals coupled with SiPMs. We have used 6 mm X 6 mm SiPMs from SenSL Inc. with

optimum operating voltages around 29 V. The SiPMs are blue sensitive and work at a peak wavelength of 420 nm. We have tested the performances of the crystals by varying the number of SiPMs viewing the crystals. For a crystal of 1" diameter the resolution is rather poor at $\sim 12\%$ when viewed by just one SiPM. However, for the same crystal, the resolution improves to $\sim 4.5\%$ for Cs (662 keV) and 2.2% for AmBe (4.43 MeV). For a square bar viewed by 14 SiPM the resolution at 662 keV is $\sim 8.8\%$. [I. Mazumdar, S.M. Patel, P.B. Chavan, D.A. Gothe]

Nuclear Dynamics

Collective flow in event-by-event parton transport plus hydrodynamics hybrid approach.

Complete evolution of the strongly interacting matter formed in ultrarelativistic heavy-ion collisions was studied within a coupled Boltzmann and relativistic viscous hydrodynamics approach. For the initial nonequilibrium evolution phase, the AMPT model was employed that explicitly includes event-by-event fluctuations in the number and positions of the participating nucleons as well as of the produced partons with subsequent parton transport. The ensuing near-equilibrium evolution of quark-gluon and hadronic matter was modeled within the (2+1)-dimensional viscous hydrodynamics. The role of parton dynamics in generating and maintaining the spatial anisotropy in the pre-equilibrium phase was probed. Substantial eccentricities e_n were generated in the event-by-event fluctuations in parton production from initial nucleon-nucleon collisions. For ultra-central heavy-ion collisions, the model explained qualitatively the unexpected hierarchy of the harmonic flow coefficients $v_n(pT)$ ($n=2-6$) observed at LHC. The results for $v_n(pT)$ were found rather insensitive to the variation of switch-over time from AMPT parton transport to hydrodynamic evolution. The model described well both the RHIC and LHC data for $v_n(pT)$ at various centralities, with a constant shear viscosity to entropy density ratio of $\eta/s = 0.08$ and 0.12 , respectively. The event-by-event distributions of v_2 and v_3 were in good agreement with the LHC data for midcentral collisions. The linear response relation $v_n = k_n e_n$ was found to be true for $n=2,3$, except at large values of e_n , where a larger value of k_n was required, that suggest a small admixture of positive nonlinear response even for $n=2,3$. [A. Jaiswal, R.S. Bhalerao, S. Pal]

Initial state effects in a transport plus hydrodynamic hybrid approach.

The initial conditions in the relativistic viscous hydrodynamic modeling, such as the energy

densities, velocity fields, viscous shear tensor and bulk pressure are unknown, which in fact presents the largest uncertainty in the extraction of the quark-gluon plasma properties. In most studies, these initial variables are either parametrized and then fitted to the final spectra, or simply set to zero. Complete evolution of matter formed in ultrarelativistic heavy-ion collisions was studied within a coupled AMPT transport and (2+1)D relativistic viscous hydrodynamics approach where all the initial conditions were explicitly obtained from the parton transport phase. Compared to the usual assumption of zero initial velocity field, the estimated initial parton velocities were found to have a very small effect on the flow observables. On the other hand, the nonzero/finite shear pressure, lead to quite a significant suppression of the anisotropic flow harmonics v_n . This presented the first clear indication of the importance of all the realistic initial variables in understanding the transport properties of quark-gluon plasma. [C. Chattopadhyay, R.S. Bhalerao, J.-Y. Ollitrault, S. Pal]

Hydrodynamic fluctuation and its application to Bjorken and Landau expansion.

The event-by-event fluctuations in the initial spatial geometry of the colliding nuclei has been extensively studied in the relativistic dissipative fluid dynamics. However, it is important to note that the fluctuation-dissipation theorem inherently requires the presence of hydrodynamic (or local thermal) fluctuations in the otherwise deterministic theory. A formulation for the evolution of these hydrodynamic fluctuations was obtained and then applied to (1+1)D expansion of the medium with Bjorken (boost invariant) and Landau flow profiles. For realistic lattice equation of state, the stochastic equations were solved numerically and the standard Cooper-Frye mechanism was used to convert the fields to particles at freeze-out. Long-range rapidity correlations of the fluctuations was observed for

charged pions. These correlations were found to spread out over larger rapidity when the ratio of the shear viscosity to entropy density $\eta/s=0.08$ was increased and also when Landau instead of Bjorken dynamics was used. [C. Chattopadhyay, R.S. Bhalerao, S. Pal]

Evolution of fluctuations in an expanding fluid.

In contrast to the density fluctuations in the initial-state and thermal/hydrodynamic fluctuations during evolution, fluctuations can also be induced due to energy deposition by a jet during its propagation in an expanding medium. The latter fluctuations were studied by treating these as space-time dependent

perturbations within linearized hydrodynamic framework. A set of linearized coupled hydrodynamic equations, on top of the background Bjorken and Landau flow, was obtained. The energy loss parameter \hat{q} , that depends on the path-length of the jet and local temperature of the medium, can be related to the amplitude of the perturbation induced at that instant of time. The longitudinal sound-wave amplitude correlations were investigated under various jet energy loss scenarios in ultra-relativistic heavy-ion collisions at RHIC/BNL and LHC/CERN. [C. Chattopadhyay, R.S. Bhalerao, S. Pal]

Accelerator based Condensed Matter Physics

Hyperfine field of Ba impurity in ferromagnetic Ni host.

Measurement of magnetic hyperfine field for impurity atom in ferromagnetic hosts has been a topic of considerable interest over many years. While, systematic studies have been made for variety of impurities in Fe, Co and Ni, the hyperfine field values in many cases, especially heavy impurities like Cs, Ba and La, have large scatter. It is therefore important to make accurate measurements of hyperfine field for these impurity atoms. In this work we present our results on the hyperfine field for Ba in Ni measured by time differential perturbed angular distribution technique using the $13\text{ ns } 10^+$ isomeric state in ^{132}Ba as probe which was populated in the reaction $^{12}\text{C}(^{124}\text{Sn}, 4n)^{132}\text{Ba}$ at beam energy of 60 MeV. The hyperfine field extracted from the observed Larmor precession frequency comes out to be $B_{\text{hf}} = -84(5)\text{ kG}$. Supplementing the experimental measurements we have carried out theoretical calculation of hyperfine field for Ba in Ni using density functional method. Our calculations performed using a large $3\times 3\times 3$ supercell with 108 atoms (107 Ni + 1 Ba) and local spin density approximation for exchange correlation, yielded the B_{hf} of Ba in Ni to be -108 kG , which is very close to the value observed experimentally. Surprisingly the B_{hf} of Ba in Ni is larger than the value reported for Ba in Fe. The hyperfine field data obtained from our measurement and theoretical studies will be useful towards accurate determination of g-factor of high spin states in Ba isotopes. [Sudipta Saha, S.K. Mohanta, Sayani Biswas, R. Palit and S.N. Mishra]

Spin fluctuation and local magnetism of isolated Fe impurities in $\text{Pd}_{1-x}\text{V}_x$ alloys studied by time differential perturbed angular

distribution spectroscopy.

The local susceptibility and spin relaxation time of isolated Fe impurity implanted into $\text{Pd}_{1-x}\text{V}_x$ ($0 \leq x \leq 0.15$) alloys was studied by measuring the local susceptibility and spin relaxation time of ^{54}Fe nucleus using time differential perturbed angular distribution (TDPAD) technique with an aim to study the influence of ferromagnetic host spin polarization on the spin fluctuation rate and hence moment stability. Fe impurity in Pd matrix is known to induce strong ferromagnetic spin polarization of Pd-4d electrons leading to the observation of giant magnetic moment for Fe with moment exceeding $12\ \mu_B$. On the other hand Fe in V is known to be nonmagnetic with high spin fluctuation temperature arising from negative spin polarization of V-d band electrons. Doping of V in Pd is expected to induce a progressive change of host spin polarization from ferromagnetic to antiferromagnetic and is therefore ideal for studying the role of the sign and strength of host spin polarization on spin fluctuation. With an increase of the V content in Pd matrix, we observed a large non-linear reduction of the local magnetic moment accompanied with an exponential increase in the spin fluctuation temperature T_{SF} , derived from the observed Curie-Weiss type temperature dependent local susceptibility of Fe. At and beyond $x = 0.12$, the Fe atoms are found to be nonmagnetic characterized by small temperature independent local susceptibility. As an important feature, T_{SF} was observed to vary *quadratically* with composition dependent changes in host spin polarization, which changes sign from positive to negative at $x = 0.1$. These results clearly illustrate that sign and strength of host spin polarization plays an important role of the spin fluctuation rate and hence stability of Fe moment. [S.K. Mohanta and S.N. Mishra]

g-factor measurement in La isotopes.

Nuclei in the vicinity of $A \sim 130$ region have exhibited a rich variety of collective modes like, shape coexistence and magnetic rotation. A number of high-K isomeric states have also been observed here. Hence the shell structure of this region of the nuclear landscape is of considerable interest. The ^{135}La ($Z=57$, $N=78$) nucleus is nearly spherical in the ground state due to its vicinity to $N = 82$ shell closure. The valence proton configurations of the low spin states are expected to be admixture of $g_{7/2}$ and $d_{5/2}$ orbitals. At higher angular momentum, there can be proton excitation to the $h_{11/2}$ orbital. Hence, to ascertain the contribution of the intruder $h_{11/2}$ orbital the wave function of the high spin states are needed to be examined.

The nuclear magnetic moment of a state has contribution from the orbital and spin angular momenta of the unpaired nucleons. Hence, g-factor measurement of an isomeric state can provide the necessary experimental insight to the single particle configuration of the nucleus at high spins. We have measured the g-factor of the $23/2^+$ isomeric state in ^{135}La using the time differential perturbed angular distribution (TDPAD) method. From the observed spin rotation spectrum measured in external field of 5 T we obtain the g-factor to be 0.047(5). The configuration of the isomeric $23/2^+$ state has been proposed to be $\pi h_{11/2} \times \nu h_{11/2} (s_{1/2}d_{3/2})$. Assuming standard single particle g-factors, the experimental observation of near zero g-factor can be interpreted as one neutron particle shared between $s_{1/2}$ and $d_{3/2}$ orbitals with 53.1% and 46.9% respectively. [Sudipta Saha, S.K. Mohanta, Sayani Biswas, R. Palit and S.N. Mishra]

Observation of Hund's rule magnetism for Fe in hexagonal Ag.

3d impurities in noble metal hosts are known to

show spin magnetism with orbital moment have been a test bed for understanding local moment formation in metallic alloys. The magnetic moments of d impurities in noble metal hosts Cu, Ag and Au are mostly described by an effective spin S_{eff} with orbital moment expected from Hund's rule being generally believed to be quenched due to strong crystal field effects. We have made TDPAD measurements of local susceptibility and 3d spin relaxation for isolated Fe atoms embedded in bulk face centered cubic (fcc) Ag and nanocrystalline hexagonal 4H-Ag, the later, obtained through controlled electro-chemical deposition process. In contrast to the spin dominated itinerant magnetism of Fe in fcc Ag, we have observed large orbital magnetic moment ($\sim 1 \mu_B$) for Fe in nano-4H-Ag, reflected by the Curie-Weiss type local susceptibility (χ_{loc}) with huge positive hyperfine field of ~ 580 kG. The high positive hyperfine field combined with the small spin line width (~ 2 meV) obtained from the observed Korringa type spin relaxation rate, suggest Hund's rule magnetism for Fe in hcp-4H-Ag with spin orbit coupling stronger than crystal field splitting. These features of Fe magnetism in hcp-Ag are akin to the behavior of 4f ions. The existence of large orbital moment on Fe in 4H-Ag is corroborated by detailed *ab-initio* electronic structure calculations performed within the frame work of density functional theory. A comparison of the calculated band structure of Fe in fcc and hcp-Ag hosts reveal sharp reduction in the Fe-d virtual bound state for the latter case indicating greater localization of Fe-3d electrons in 4H-Ag host. We suggest that the crossover from itinerant moment in fcc-Ag to Hund's rule behavior in hcp-4H-Ag arise from enhanced localization of Fe-d electrons due to size induced changes in unit cell volume and symmetry. [S.K. Mohanta, Subranghsu Sarkar, Pushan Ayyub and S.N. Mishra]

Accelerator based Atomic Physics

Development of a supersonic gas jet target and initial tests

The ongoing development of a supersonic gas jet target has been completed and test measurements have been carried out to characterize the supersonic gas jet setup. We used Nitrogen and Argon gases at the first place and a well localized supersonically cooled gas jet has been obtained. This was characterized by looking at the ionization signal in the recoil ion momentum spectrometer. The ionization contributions coming from the gas jet and the supersonic beam have been identified. From the measured pressure increase in

the skimmer and dump chambers, a gas jet density of about 10^{10} per cc has been estimated. We are now in the process of carrying out experiments with the supersonic gas jet beam to look for the state selective electron-capture process in highly charged ion-atom collisions using the ECR based ion accelerator (ECRIA). Efforts are on to produce inert gas dimers such as Ar_2 , Ne_2 and He_2 etc. to look for the quantum mechanical two center interference effect in molecular-axis orientation dependent charge transfer reactions [A. Khan, L. C. Tribedi and D. Misra].

Development of a projectile final charge state analyzer for electron capture studies

During the beginning of this year, the design, ion-optical simulations and the construction of a final projectile charge state analyzer was initiated and it has now been completed. The charge state analyzer has now been tested for its performance using highly charged ion beams from ECRIS. N^{2+} and N^{4+} ion beams of energies 260 and 520 keV, respectively were used to characterize the charge state analyzer by looking into the charge transfer process in collision of these ions with N_2 gas jet from the supersonic beam source. The charge state analyzer utilizes a trapezoidal electrostatic deflector assembly and an 80 mm MCP delay line anode detector system. The design allows to separate adjacent charge states of Ar^{9+} and Ar^{8+} with a reasonably low electric field applied to the trapezoidal electrostatic deflectors. This charge state analyzer, together with the supersonic gas jet, will now be used to perform state selective electron transfer measurements in collisions with highly charged ion beams from ECRIS. We also plan to perform molecular breakup studies induced by various mechanisms such as pure ionization, pure electron-capture and transfer ionization processes [A. Khan, C. Bagdia, L. C. Tribedi and D. Misra].

Dissociation dynamics of nitrous oxide upon the impact of highly charged ions

We have carried out measurements and completed data analysis to study the fragmentation dynamics of a linear asymmetric tri-atomic molecule, N_2O . The motivations for this study was to look for the concerted and sequential decay mechanisms in the fragmentation of N_2O^{q+} ($q=3-6$) and to study the projectile charge-state dependence of fragmentation of N_2O . 1 a.u. Ar^{8+} and Xe^{15+} beams from ECRIS were used to study the breakup dynamics. In this study, we have measured the kinetic energy release (KER) distributions for various multiple charged N_2O^{q+} ($q=3-6$) molecular ions. We have shown that for N_2O^{3+} and N_2O^{4+} both concerted and sequential mechanisms are present however, highly charged molecular ions mostly decay in a concerted manner. We were also able to measure the KER distributions for inter mixed channels where the central and the terminal N atoms have different charges on them with the total charge on the molecular ion being the same. Currently, a manuscript has been written and will soon be submitted for publication [A. Khan, L. C. Tribedi and D. Misra].

Fragmentation of H_2O_2

We have investigated the two- and three-body breakup dynamics of a tetra-atomic system, H_2O_2 , in collisions with highly charged Ar ions. A

preliminary analysis of the different two and three body decay channels have been carried out. Initial results show the evidence of a sequential decay of H_2O_2 in the tree-body decay channel where the molecule dissociates into $H^+ + H^+ + O_2^+$ ions. A detailed study of the two- and three-body breakup of these molecules will be carried out by analyzing the Newton diagrams and three-body Dalitz plots. The angular correlation of the fragment ion momenta will allow the determination of the structure of the precursor molecular ions just before the fragmentation process [D. Misra, A. Khan, L. C. Tribedi].

Development of a new RIMS

Recoil ion momentum spectroscopy (RIMS) is one of the techniques, which is capable of unfolding molecular fragmentation dynamics by measuring three momentum components of all fragment ions. Here we report the new development of recoil ion momentum spectrometer, which will be used to study the ion induced fragmentation of different molecules, especially the big molecules of biological relevance or polycyclic aromatic hydrocarbons. The spectrometer provides the momentum information of all recoil ions by measuring their time of flight (ToF) and the hit position on the 2D imaging detector. It is a Wiley-McLaren type spectrometer with three separate parts namely, extraction region, acceleration region and the field free drift region. It ensures excellent time focusing which is required for good longitudinal momentum resolution. For better transverse momentum resolution we have introduced a weak nonlinear field just before the drift region. This lensing effect ensures the space focusing at the detector plane as well as larger 4π collection efficiency. We are using the 40 mm active diameter MCP with delay line anode for ion detection. [S. Biswas, D. Misra, L.C. Tribedi]

Development of CSA

In case of ion impact fragmentation, the reaction mechanism depends on the energy of the projectile. In the intermediate energy region ($\sim keV/u$), electron capture to the projectile and transfer ionization are important reaction channels along with the usual direct ionization channel. To distinguish these channels, post collision projectile charge state analysis is required. To do that we have developed a post collision projectile charge state analyser (CSA), which is coupled at the end of the scattering chamber. It consists of an electrostatic trapezoidal plate analyser, which is employed after the interaction region. Different charged ions, separated from each other, are detected by channeltron detectors mounted at about 1 m away from the interaction region. This whole experimental setup is connected to the TIFR-

ECRIA 0° beamline. During the experiment, the base vacuum of all the chambers and the beamline is maintained better than 2×10^{-8} Torr. For data acquisition and analysis we are using the TDC multi-channel card with CoboldPC software [S. Biswas, L.C. Tribedi].

Ionization and electron capture induced fragmentation dynamics of N₂

With the newly developed setup we have studied momentum resolved ionization and electron capture induced fragmentation dynamics of N₂. We have uniquely identified capture induced recoil ions, capture-ionization induced fragmentation channel, capture-double ionization induced fragmentation channel and capture-triple ionization induced fragmentation channel. In each case we have analysed the momentum distributions and from that we have derived kinetic energy release (KER) distributions. These are thoroughly compared with the available data in the literature [S. Biswas, C. Bagdia, L. C. Tribedi].

Ionization and electron capture induced fragmentation dynamics of CH₄

In a similar fashion we have also studied the fragmentation dynamics of CH₄ molecule. In this case, the ToF spectrum shows different H loss peaks. In addition it also shows H₂⁺ loss and H⁺ loss peak. In the ion-ion coincidence plot different combinations of these channels are clearly identified. From the fragmentation of doubly charged parent ion, we could see nine different channels. Moreover from the fragmentation of triply charged parent ion, five different fragmentation channels are identified. Most of these channels involve one neutral fragment also. For all these channels the KER distributions are derived from the recoil ion momentum information. The study of fragmentation dynamics of CH₄ molecule in the keV energy range, where electron capture is dominant process, is very rare in the literature [S. Biswas, L.C. Tribedi].

Fragmentation dynamics of fluorene (PAH) molecule

In extension to these above studies, we have also studied the ion induced fragmentation dynamics of fluorene (C₁₃H₁₀) molecule which is one of the important members of the polycyclic aromatic hydrocarbon (PAH) family. In this case, the ToF spectrum is seen to be much more complicated. It contains intact molecular ion peaks as well as many different fragment ion peaks. After each molecular ion peak we have clearly identified sequential H loss peaks. The detailed analysis of this data is under process [S. Biswas, L.C. Tribedi].

Differential electron spectroscopic measurements of Coronene (C₂₄H₁₀) and plasmon resonance

Coronene is also one of the members of the PAH family, which gained tremendous interest in recent times because of their astrophysical relevance. The other important aspect related to these molecules is the collective electronic excitation, namely plasmon resonance. For systematic investigation of these aspects, we have measured the absolute DDCS for electron emission in ionization of Coronene molecule under the impact of 3.75-MeV/u O⁸⁺ ions. The experimental data has been compared with the CB1 calculations. Detailed analysis of the data indicates some features which are completely different from simple atomic or molecular targets. As the direct signature of the collective excitation effect is extremely hard to find out in DDCS spectrum for these molecules, (Earlier the direct signature of the collective excitation effect in DDCS spectrum has been seen in case of C₆₀ by our group.) we have derived the amount of forward-backward angular asymmetry as a function of ejected electron energy which shows a prominent signature of the plasmon resonance as peak structure. We also modeled this kind of asymmetric electron emission due to plasmon resonance by photo electron emission model, taking into account upto the first retardation term in the transition matrix element expansion [S. Biswas, L.C. Tribedi].

DDCS measurements for heavy fast ion-fluorene (C₁₃H₁₀) collision

With the similar motivation as above, we wanted to study the aspect of collective excitation in relatively smaller PAH molecule. For that we have chosen the fluorene molecule. In this case also, the absolute DDCS of electron emission from this molecule under the impact of 3.75 and 5-MeV/u O⁸⁺ ions are measured. The analysis of forward-backward angular asymmetry does not show any clear peak in the energy distribution as shown by the coronene. But the DDCS angular distribution data in case of the higher energy projectile impact show relatively larger forward-backward angular asymmetry compared to the ion-atom collision cases. It resembles that the less number of available electrons, because of smaller in size, makes the oscillator strength of plasmon excitation small. As a result the signature of this resonance is hard to get in this kind of analysis. In this case also we have compared the data with the CB1 calculations [S. Biswas, L.C. Tribedi].

Electron impact ionization of diatomic molecules and interference effect

Double differential cross section (DDCS) of electrons emitted in collision of 7 keV electrons

with O₂ and N₂ were measured for different emission angles. The aim for the present experiments were to check for existence of interference oscillation which was not observed in case of heavy ion impact for the above mentioned molecules. Signature of 1st order oscillation have been observed in the DDCS ratios (molecular/atomic) for both the di-atomic molecules, for all the emission angles, unlike the result seen in heavy ion impact previously. The oscillatory structures were further fitted by the Cohen-Fano model. The frequency distribution as a function of emission angles showed backward angles having higher oscillation frequency as compared to the forward angles. The forward-backward angular asymmetry also showed clear signature of oscillation which was further fitted by the 1st order Cohen-Fano model. The asymmetry parameter showed signatures of higher order effects, which were revealed by dividing the asymmetry parameter by the 1st order model fit. [M. Roy Chowdhury, N. Mhatre, W. A. Fernandes, L. C. Tribedi]

Ionization of Bromouracil under highly charged heavy ion impact

Interaction of ionizing radiation with biomolecular systems has been a subject of study in recent years. In this context, the effect caused due to highly charged ion impact on uracil (one of the four nucleobases of RNA) has been studied in our group previously. The addition of high Z-atom loaded compounds to the biomolecule, such as bromouracil, is known to enhance the effect of ionizing radiation. Absolute DDCS measurement of bromouracil has been performed with 42 MeV bare C ions for which data on uracil exists. A detailed analysis of the present experiment and further comparison with the existing data of uracil, shows that the total cross section of electron emission from bromouracil is four times larger than that obtained for uracil previously. This observation indicates the efficiency of nano-particle insertion in biomolecule. [M. Roy Chowdhury, S. Bhattacharya, C. Bagdia, D. Misra, L. C. Tribedi]

1s-1s electron transfer in fast ion collisions with Adenine

To measure state selective charge K-shell-to-K-shell electron capture an elaborate experiment was performed using Pelletron accelerator. A new technique based on the charge state dependence of the KLL Auger electron yields was employed. Experiment was done to measure energy dependence of charge capture from Adenine by carbon, oxygen and silicon ions at four different energies. Also charge capture from CO₂ and N₂ gas by C beam of four different energies was measured

in order to make comparison between the capture from the gaseous atoms and the bio-molecule [C. Bagdia, S. Bhattacharjee, M. Roychowdhury, D. Misra, L. C. Tribedi]

e-Capture measurement for keV energy ions from TIFR-ECRIA

Electrostatic trapezoidal plate charge state deflector was used to measure electron capture cross section in intermediate energy range ion, from TIFR-ECRIA. Charge state deflector setup was optimized. A suitable optimization of the detector assembly, shielding of CEMs and electron suppression was tried out to improve the results, particularly, the ratio of double to single capture events. Energy dependence of single electron and double electron capture from N₂ was measured for doubly charge ion beam, such as He⁺² and Ne⁺² in energy range of 40 keV to 500 keV. Energy dependence of single electron capture cross section is measured for H⁺ on He in energy range 10 keV – 200 keV and also compared with existing data. Detail analysis is in progress [C. Bagdia, L. C. Tribedi].

Ionization and electron emission from N₂ induced by protons: Electron Spectroscopy

Double differential cross section (DDCS) of electron emission from N₂ on collision with proton of intermediate energy range were measured at two different energies **150 and 280 keV**. This is to explore the two-centre interference effect at this low energy. There has been a debate in the community regarding the visibility of the interference oscillations in case of heavy ions. This work is still in progress [C. Bagdia, L C Tribedi]

Measurement of double differential cross section of Adenine under the impact of bare Carbon ions

Measurement of cross section of emitted secondary electrons for collisions between high velocity ions and biologically relevant molecules are of prime interest in different areas, like radiation biology and radiation therapy (hadron therapy). The ejected secondary electrons are known to play a decisive role in biological effects. Low-energy electrons may induce single and double strand breaks of DNA and RNA. So it is very important to examine differential cross section of these secondary electrons. Despite its extreme importance there is not much data available for ionization of DNA-RNA base molecules by high velocity ions. We have measured the double differential cross section (DDCS) of emitted secondary electrons from vapor phase adenine molecule (C₅H₅N₅), under the impact of two different velocity (3.5 MeV/u and 5 MeV/u) bare carbon projectile. The projectile beams were generated using the BARC-TIFR Pelletron

accelerator facility. The generated electrons were energy analyzed by using a hemispherical deflection analyzer. The double differential cross section was calculated from the first principle and it was compared with the continuum distorted wave-eikonal initial state (CDW-EIS) approximation. From the double differential cross section data we have, after integration, obtained the single differential cross section (SDCS) and total ionization cross section (TCS) [S. Bhattacharjee, M. Roychowdhury, L. C. Tribedi]

Measurement of double differential cross section of helium under the impact of bare proton beam

The proton beams were generated using the ECR ion accelerator. Data was taken for 7 different beam energies 50 KeV, 75 KeV, 100 KeV, 125 KeV, 175 KeV, 250 KeV and 300 KeV. Data was analyzed and it was compared with the CDW-EIS model calculations. We have seen an overall overestimation of experimental results by theoretical models. From the DDCS results after integration we obtained the single differential cross section (SDCS) and the total ionization cross section (TCS). The present total cross section results for 7 different beam energies were compared with other existing results in this energy range. From the comparison we have seen that our present data points are falling below all the available existing data as well as theoretical models. Some more investigations are planned to understand these differences [S. Bhattacharjee, L. C. Tribedi].

Development of a new charge state deflector (CSD) setup at 50° N for the electron cyclotron resonance ion accelerator (ECRIA)

For collision between ion and atoms/molecules in the ECR energy range, electron capture plays a significant role. Currently the 50° north ECR beamline has an existing electron spectroscopy

setup to study ionization events. So we have started the development of a new charge state deflector setup which will allow us to study both ionization and electron capture in the same beamline of the ECR ion accelerator. For this purpose, a two stage gas cell and a charge state deflector plate has already been made. Some of the parts are currently with the central workshop facility and will be completed shortly. The detector system consists of a two channel electron multiplier and one Faraday cup. This whole setup will be connected after the existing electron spectroscopy setup [Shamik Bhattacharjee, A. Mandal, L. C. Tribedi]

Study of ECR plasma by VUV and Crystal spectrometers

Highly charged ions (HCI) in the plasma produced in the ECR ion source can be studied using various spectroscopic techniques. Two spectroscopic systems are being developed for the high resolution optical spectroscopy of HCIs. One of them is based on a VUV/EUV grazing incidence Rowland circle type spectrometer (McPherson 248/310). With a 1200 g/mm grating this setup can be used to scan the energy range from 35 eV to 1 keV. The other system is based on a Johansson type bent crystal spectrometer that is used to scan the soft x-ray region. With the use of three different Bragg crystals (KAP, ADP and LiF) this setup can cover the energy range from 500 eV to 14 keV. The VUV monochromator had mechanical issues in the movement of the exit slit-detector assembly on the Rowland circle. This problem is rectified by fixing the ball-bearing system responsible for this movement and replacing the driving stepper motor. The existing vacuum chamber of the bent crystal x-ray spectrometer is modified so that it can be used for the current experiment on the ECR plasma. One port is added on the chamber as the incident port of the spectrometer [A. Mandal, L. C. Tribedi].

Atomic and Molecular Physics

Observation of rotationally stabilized O_2^- ions from Dissociative electron attachment to O_3

In dissociative electron attachment to O_3 for electron energy of 8.4eV and beyond, we observe O_2^- ions with two kinetic energy distribution in the momentum image, fast ions forming an outer along with a blob with thermal kinetic energy. The inner blob must arise from the channel with higher threshold. The possible DEA channel at this energy with maximum threshold is known to be $O(^1S)$ with O_2^- in the ground state. The expected threshold for this

channel is about 4.8 eV, leaving about 3.6eV excess energy in the system. O_2^- can sustain only 0.44 eV as vibrational excitation as above that energy the anion curve crosses the neutral curve opening the auto-detachment channel for the species which will make the anion observation in time of flight mass spectrometer impossible. The only other channel available is molecular rotation and excess energy of the order of 3 eV will lead to about $J=105$ excitation. Such excitation will make the O_2^- stable against auto-detachment as the effective

potential energy curve for anion drops below corresponding neutral curve. This is just the second example of such a dynamic stabilization of the anion, first being that for H_2^- anion. [Krishnendu Gope, Nigel J. Mason (*Open University UK*), Vaibhav S. Prabhudesai, E. Krishnakumar]

Study of dissociative electron attachment to SO_2

Dissociative electron attachment (DEA) to sulphur dioxide is important from the atmospheric chemistry as well astrochemistry point of view. We have obtained kinetic energy distribution and angular distribution for all the ions formed via DEA to SO_2 using velocity slice imaging technique. From the kinetic energy analysis of S^- channel we have observed a direct competition between stretching mode and bending mode in the parent transient negative ion (SO_2^*) via symmetric dissociation (SD) process. For the O^- channel, we observe that mainly $\text{O}^- + \text{SO}$ ($^3\Sigma^-$) channel is active. Simple impulse model with small vibrational excitation of SO ($^3\Sigma^-$) is sufficient to understand the kinematics of the channel. For the SO^- channel we have concluded that at lower energies only $\text{SO}^- + \text{O}$ (^3P) channel is active whereas at higher energies both $\text{SO}^- + \text{O}$ (^3P) and $\text{SO}^- + \text{O}$ (^1D) channels are active out of which the first channel get depleted from detected signal due to auto-detachment of SO^- . [Krishnendu Gope, Nigel J. Mason (*Open University UK*), Vaibhav S. Prabhudesai, E. Krishnakumar]

Study of dissociative electron attachment to NO_2

The angular distribution and kinetic energy release for DEA to NO_2 was measured using velocity slice imaging technique for the first time. From the kinetic energy release across the peak around 3.2 eV for O^- ion, we conclude that simple impulse approximation with small vibrational excitation is sufficient to explain the production of O^- along with NO ($\text{X}^2\Pi$). We also observed the production of two different sets of vibrational population in the same electronic ground state in NO ($\text{X}^2\Pi$) along the higher energy tail of this peak. Since the electron energy is considerably lower than the three-body fragmentation threshold (8.24 eV), O^- in both the structures are strictly formed

with NO as neutral fragment. The threshold for O^- formation with NO in its first electronic excited state ($\text{a}^4\Pi$) is 6.5 eV. This implies that the O^- contributing to both the structures is formed with NO ($\text{X}^2\Pi$) in its ground electronic state. This is very unique and no such dissociation dynamics has been reported so far. [Krishnendu Gope, E. Krishnakumar, Vaibhav S. Prabhudesai]

Study of dissociative electron attachment to CO

Dissociative electron attachment to CO leading to the formation of O^- was studied using the new velocity slice imaging spectrometer at TIFR. The angular distributions we obtained for the $\text{C}(^3\text{P})$ and the $\text{C}(^1\text{D})$ limits were found to be considerably different from a recent set of measurements [Tian et al., *Phys. Rev. A* **88**, 012708 (2013); Wang et al., *J. Chem. Phys.* **143**, 066101 (2015)] using a similar technique. The analysis of our results indicated incoherent contributions from states of Σ and Π symmetries to both these dissociation channels and ruled out the need to invoke coherent excitation of several resonances, in contrast to what had been done in the above publications. We tried to correlate these resonances to those observed in inelastic scattering and transmission experiments. We also confirmed the presence of a third dissociation channel leading to $\text{C}(^1\text{S})$ limit. [Krishnendu Gope, Vishvesh Tadsare, Nigel J. Mason (*Open University UK*), Vaibhav S. Prabhudesai, E. Krishnakumar]

Absolute cross section measurements of DEA to aromatic organic molecules

In order to investigate the functional group dependence in dissociative electron attachment, which is crucial for control of electron induced chemistry we investigated several organic molecules in a systematic way. These aromatic molecules are also the starting point in understanding the behaviour of DNA bases with respect to electron interaction. We used the new velocity slice imaging technique to study benzene (C_6H_6), pyridine ($\text{C}_5\text{H}_5\text{N}$), pyrimidine ($\text{C}_4\text{H}_4\text{N}_2$), aniline ($\text{C}_6\text{H}_5\text{NH}_2$), deuterated aniline ($\text{C}_6\text{D}_5\text{NH}_2$), and benzylamine ($\text{C}_6\text{H}_5\text{CH}_2\text{NH}_2$) in this respect. We have also measured the absolute cross sections for formation of the fragment negative ions from

these molecules as a function of electron energy. [Vishvesh Tadsare, Vaibhav S. Prabhudesai and E. Krishnakumar]

Resonant production of ozone from condensed O₂

Production of ozone (O₃) from O₂ under various conditions is important in the context of industrial ozonisers, the maintenance of ozone layer in earth's atmosphere as well in astrochemistry. Using our low energy electron collision experiments we have come across a not yet identified channel in the production of ozone, which is operable only at a specific energy. Our systematic measurements show that around the electron energy of 16 eV there is an increase in the production of ozone from cold molecular films of O₂. We interpret this unique phenomenon due to the creation of two specific reactants, possible only at this electron energy. At around 16 eV there are several strong autoionizing states of O₂. The dominant one in this has been known to decay forming O₂⁺ ions in very high vibrational levels. At the same time the electron which created the autoionizing state has lost all its energy in the excitation process. This scattered electron immediately gets attached to the neighbouring O₂ molecules forming O₂⁻. This attachment process peaks strongly at zero energy with rapidly decreasing cross section as the electron energy increases. This O₂⁻ ion immediately could react with the vibrationally excited O₂⁺ forming O₃ as one of the products. [Sramana Kundu, Vaibhav S. Prabhudesai, E. Krishnakumar]

Electron induced synthesis of new compounds in cold films of CH₄ and its mixtures with O₂ and NH₃

Breaking C-H bond and its activation is extremely important for variety of applications in industrial chemistry. Also are important the chemistry involving partial oxidation of CH₄ and the production of compounds with C-N bonds. In most of these situations, the goals are achieved using specific catalysts. The production of various organic molecules containing oxygen and nitrogen is also of importance in the context of astrochemistry and the origin of life. In this context we have studied low energy electron induced chemistry in pure methane films and its mixtures with

oxygen and nitrogen respectively. With pure methane we could identify the formation of ethane for electrons of energy as low as 8 eV. In the mixture of methane and oxygen we identified the production of acetaldehyde and methanol and in the mixture of methane and ammonia we could detect the formation of HCN and methylamine. All these molecules were found to be produced starting from 8 eV. Detailed analysis of these measurements as a function of electron energy is in progress. [Sramana Kundu, Vaibhav S. Prabhudesai, E. Krishnakumar]

Photodetachment studies of stable excited state of TaC⁻

We analysed the photodetachment data on TaC⁻ which we had obtained several years back in a photodetachment experiment that was totally indigenously built, but had to be decommissioned due to lack of space. From the data we could obtain the electron affinity for TaC⁻ to be 1.928(0.056) eV. Vibrational frequencies for the electronic states were obtained from the analysis of the measured data. Most importantly, we could identify for the first time an excited-electronic state of the anion, stable against autodetachment, lying 0.828 eV above the ground-electronic state. Such excited negative ion states are very few and our observation of it TaC⁻ * raises the probability of having such states in several other systems. These could be of importance to variety of other areas dealing with negative ions where efforts on developing new techniques for cooling the ions are going on. [G. Aravind (*IIT Madras*), E. Krishnakumar]

Quantum interference due to light-induced conical intersections in diatomic molecule

The two potential energy curves of a diatom with same symmetry cannot cross due to geometric constraints. No such restrictions exist in polyatomic molecules providing at least one point of crossing for the two surfaces. Such points are called conical intersection (CI). However, in a diatom as well light can be used to create such conical intersection if the intensity of light is strong enough to couple two potential energy curves with the rotation of the molecular axis with respect to the light polarizations as the additional dimension required to relax the geometrical restrictions.

Such conical intersections are called light induced conical intersection (LICI). The dynamics of the system around such intersections involves non adiabatic coupling between electronic, vibrational and rotational degrees of freedom for diatom. This manifests in the different phase shifts for different paths traversed by the quantum wavepacket around the conical intersection. These phase shifts will cause the interference among the wavepackets which shows up in the dissociation angular distribution. We have observed energy-dependent angle-resolved diffraction patterns in

angular distribution of protons from strong-field dissociation of the molecular hydrogen ion H_2^+ . The interference magnitude and angular period depend strongly on the energy difference between the initial state and the LICI, consistent with coherent diffraction around a cone-shaped potential barrier whose width and thickness depend on the relative energy of the initial state and the cone apex. [Vaibhav S. Prabhudesai *in collaboration with* Adi Natan, Mathew Ware, Phil Bucksbaum (*Stanford University USA*) Barry Bruner, Oded Haber (*Weizmann Institute Israel*)]

Intense Field Physics

Ion Acceleration using nano-structured targets Gated Thomson parabola spectrometer for Improvement of signal-to-noise ratio

Intense short pulse lasers interacting with a target produce a large number of hot electrons. During the time scale of the interaction, the ions are stationary and the laser energy is directly deposited to the electrons. The electrons thus start to escape the target. This process sets up a quasi-static electric field between the electrons and the ions. The ions respond to this field and are accelerated. The accelerated ions are measured by use of a Thomson parabola spectrometer. The interaction of such a laser with the target leads to a production of copious amount electromagnetic pulse (EMP) noise. This can have adverse effects on electronic measurement systems such as amplifiers as used with the time-of-flight (TOF) measurements.

A laser of intensity 5×10^{18} W/cm² was incident on a target at 45° with *p*-polarization and 30 fs pulse duration. The target is Al coated BK-7 glass. Ions along with the proton are accelerated from the front surface of the target and are detected by the trace produced on the detector. The accelerated ions were measured with a Thomson parabola spectrometer placed in the target normal direction to detect the backward laser accelerated ions. A MCP (Hamamatsu F2225-21PGF) was used as the detector with a phosphor screen and is imaged by a 12-bit CCD camera. The MCP detector of the Thomson parabola was placed at 1.1 m from the target surface. The bias configuration of -1.6 KV at the front plate, the back plate was grounded and 2.2 KV on the phosphor screen was used. The front plate of the MCP was wired through a Behlke fast bipolar high voltage switch (HTS 31-03-GSM) used to turn the detector off when gain reduction is required. The switch is controlled by an SRS delay

generator (DG535) triggered by the master clock of the laser.

The Thomson parabola trace consists of two separate spatial regions, a part of the signal is deflected off center which is due to the ion contribution. The un-detected portion consists of photons and neutral particles not deflected by electric and magnetic field. Electromagnetic emission up to the optical wavelength (from the x-ray) ends within few 10's of nanoseconds (as also seen by other detectors). Ions reaching faster than the above are multi MeV protons of energy > 3 MeV. Ion acceleration with our laser system in the backward direction from the irradiated surface of the target typically reaches energy of a few 100 KeV. By gating the detector a region can be selected which is devoid of photons and ions. Further, translating later in time the signal reaching the detector consists of only ions and their corresponding un-deflected neutrals.

Due to the reduced noise around the central region, negative ions of hydrogen have also been made more decipherable. This is one of the few observations of high energy negative ions of protons from solids. Using time translation the method can be applied to decipher the spectrum of high energy neutral particles reaching the detector. High energy ions are generated when protons are accelerated to MeV energies. This leads to arrival time of a few 80 ns. This time being very close to the position where EMP noise is dominant makes it difficult for the measurement. Thus gating the detector and observation of the signal on the phosphor, one can decipher the ion flux in the given time window especially for high energy neutrals that are accelerated from thin foils.

The Behlke high voltage switch used has a minimum on time of 80 ns. The collection window can be reduced further by the use of a gated camera. It has to be ensured that the detector is off before the camera gate allows the signal. Thus the camera gate decides the integration time of the image by the intersection of the electronic gate of the MCP and the electronic gate of the camera. Thus by translation of the effective gate in time we can build up the high energy neutral atom energy spectrum even if the MCP is using a phosphor screen having a long decay time. This has had significant signal to noise improvement on the measurement and has enabled the observation of H⁻. By the method of gating the detector we have developed a single shot method to measure the neutralization fraction of ions in a given energy window. This method is useful for experiments where EMP noise makes such a measurement difficult. This is typically in the case where targets such as thin foils are used.

The work led to the measurement of single-shot neutralization events. It is, furthermore, to be used to measure high energy neutralization free of electromagnetic pulse noise from rear surface of thin foil targets. [Sheroy Tata, Angana Mondal, Soubhik Sarkar, Jagannath Jha, Amit D. Lad, and M. Krishnamurthy]

Negative ion formation and acceleration in intense laser plasma experiments

Plasma that is formed with a high intensity laser is thought to be containing highly ionized positive ions. Electron attachment to neutral atoms has shown the existence of negative ions. H⁻ with a cut-off of ~ 70 KeV has been observed.

Negative ion formation is dependent on the target used such as Al coated BK-7 and BK-7(glass). The flux of negative ions from the coated target is ~ 2.4 times that of the uncoated target. Although the relative flux of protons at maxima of the two is only about 1.1 times higher in the coated target. Negative ion formation is thus thought to be highly dependent on the target itself due to the plasma formation threshold being different. [Sheroy Tata, Angana Mondal, Soubhik Sarkar, Jagannath Jha, Amit D. Lad, and M. Krishnamurthy]

Role of pre-pulses in ion acceleration, recombination and electron attachment

Ion acceleration from the front surface of targets has been investigated. Addition of pre-pulses on the target leads to an enhanced proton cut-off due to increased pump absorption in the plasma.

Ions have been shown to be accelerated to MeV energies when intense femtosecond lasers are

incident on thin foils. The mechanism of acceleration is a charge separation and the ions are subsequently drifted in the field. We have carried out measurements to show neutral particle acceleration is also possible by the interaction. Ions initially charged undergo atomic processes in the pre-plasma to convert them to high energy neutral atoms. These neutral atoms have energies similar to that of the initial ion. The accelerated ions and the neutral particles are studied using a Thomson parabola spectrometer and time-of-flight to quantify the neutralization fraction. Using a laser of contrast 10^{-5} we have studied ion and neutral acceleration from the front surface of solid targets. Defocusing the target from the best focus of the laser leads to a two fold increase in the neutralization. To further study the formation of neutrals, a pre-pulse was applied by using a high contrast intense femtosecond laser of contrast 10^{-9} . An optimum for the interplay between the neutralization and ion flux conversion was found. [Sheroy Tata, Angana Mondal, Soubhik Sarkar, Jagannath Jha, Deep Sarkar, Moniruzzaman Shaikh, Amit D. Lad, and M. Krishnamurthy]

Preferential enhancement of laser-driven carbon ion acceleration from optimized nanostructured surfaces

High-intensity ultrashort laser pulses focused on metal targets readily generate hot dense plasmas which accelerate ions efficiently and can pave way to compact table-top accelerators. Laser-driven ion acceleration studies predominantly focus on protons, which experience the maximum acceleration owing to their highest charge-to-mass ratio. The possibility of tailoring such schemes for the preferential acceleration of a particular ion species is very much desired but has hardly been explored. We experimentally demonstrated how the nano-structuring of a copper target can be optimized for enhanced carbon ion acceleration over protons or Cu-ions. Specifically, a thin (≈ 0.25 μm) layer of 25–30 nm diameter Cu nanoparticles, sputter-deposited on a polished Cu-substrate, enhances the carbon ion energy by about 10-fold at a laser intensity of 1.2×10^{18} W/cm². However, particles smaller than 20 nm have an adverse effect on the ion acceleration. Particle-in-cell simulations provide definite pointers regarding the size of nanoparticles necessary for maximizing the ion acceleration. The inherent contrast of the laser pulse is found to play an important role in the species selective ion acceleration. [M. Dalui, W. M. Wang, T. M. Trivikram, S. Sarkar, Sheroy Tata, J. Jha, P. Ayyub, Z. M. Sheng, M. Krishnamurthy]

Laser-driven proton beam detection in Cu foil and Cu foam using Thomson parabola spectrometer and proton damage study

The ion energy spectrum is an important parameter for the damage production study. In the Institute of Laser Engineering, Osaka 2014 experiment, Osaka team could understand the details of proton damage on Fe sample. However, proton spectrum was not measured. Osaka team developed new Thomson parabola spectrometer for ion beam spectrum measurement. We mounted Osaka as well as TIFR Thomson parabola on two different locations onto our experimental chamber in a geometry in such a way that it faces rear side of the target. I specially made a zero-length adapter to connect Osaka Thomson parabola to our experimental chamber (discussed in Section 2.7). The UIL is focussed using $f/3$ off-axis parabolic mirror on to the Cu targets with an intensity as high as 2×10^{19} W/cm². With the help of Thomson parabola we could measure the ion energy spectrum, protons, and neutral atoms during the laser interaction with

copper foils ranging from 2 to 20 μm . Proton energy is found to be maximum ~ 1.4 MeV for 4 μm Cu foil. Also, we measured the proton energy with structured foam target (diameter of foam ranging from 0.5 to 4 μm). In the case of Cu foam targets we obtained the maximum proton energy as high as ~ 1.6 MeV in the case of 1.8 μm diameter Cu foam. Also radio-chromic film (RCF) is used for analysis of proton angular divergence.

We produced protons using 2 μm Cu foil and the Fe sample placed at the rear side of the Cu foil. The protons generated by Cu foil irradiate the Fe sample. Osaka team will carry the X-ray diffraction of such proton irradiated target to study the radiation defects developed due to irradiation. [Amit D. Lad, Sheroy Tata, Angana Mondal, Moniruzzaman Shaikh, Deep Sarkar, Kamalesh Jana, Indranuj Dey, and G. Ravindra Kumar, and M. Krishnamurthy in collaboration with Y. Yoshida, Y. Yusuke, S. Nakaguchi, H. Habara, and K. A. Tanaka (Osaka University, Japan).]

High Energy Density Physics

Setting-up optical Kerr gated measurement of Cherenkov emission to measure lifetime of relativistic electrons produced in the ultra-intense laser matter interaction

The interaction of ultra-intense laser (UIL) ($> 10^{18}$ W/cm²) with a solid creates relativistic electrons whose current is as large as mega-amperes. Cherenkov radiation is emitted when a charged particle passes through a dielectric material with a velocity larger than the speed of light. In the UIL matter interaction studies Cherenkov radiation provides unique imprint of energy of hot, relativistic electrons. We realize that the measurement of Cherenkov radiation lifetime can provide unique signature of life span these electrons inside the bulk target. The measurement of lifetime of Cherenkov emission is extremely challenging due to the requirement of picosecond time resolved gate (none of the electronic device can deliver such time gate and hence one has to employ the optical gating technique). The present experiment involves two ultrashort laser pulses, first UIL to create hot, relativistic electrons, and thereby Cherenkov radiation; and other moderately intense (10^9 W/cm²) to create the Kerr effect. The arrival of Cherenkov photons to the Kerr cell needs to be spatially and temporally overlapped with Kerr 'gate pulse'.

To create picosecond time gate we used the two laser pulses. The Kerr probe pulse forced to travel the optical path as same as that of the Cherenkov radiation. Carbon di sulphide (CS₂) in a 10.0 mm

thick quartz cuvette is used as the Kerr medium. 'Gate pulse' to create optical Kerr effect is derived from the main laser pulse with 150 μm thick pellicle beam splitter of 8% reflectivity and is loosely focused on the Kerr medium with a BK-7 lens ($f = 700$ mm) on to a spot of 5 mm diameter. The intensity of the gate pulse is kept at 10^9 W/cm². We obtain the temporal zero (simultaneous arrival of gate and signal) at Kerr medium by delaying the gate pulse with a computer controlled delay stage with precession of 3.3 fs. The FWHM of the optical Kerr gate is found to 2.0 ps in time duration, which is much smaller than the gate width of any electronic shutter.

A p -polarized ultra-clean (intensity contrast of 10^{-9}) UIL of 25 fs pulse duration at central wavelength 800 nm with 1.0 J energy is focused with an $f/3$ off axis parabolic mirror to 10 μm spot at near normal angle of incidence ($\leq 5^\circ$) resulting an intensity 4.2×10^{19} W/cm² on Al-coated BK-7 glass. The Cherenkov radiation is measured at the rear side of the target using ICCD. The time delay and the width of the ICCD is chosen in a such a way that it gates only Cherenkov radiation and the plasma emission can be completely blocked. The typical time window of the ICCD is around 5 ns. After the successful iteration of the Cherenkov radiation time window with the help of ICCD, we introduce Kerr gating technique in the optical path of ICCD to find of the lifetime of Cherenkov radiation. We measure relativistic electrons are living for tens of picoseconds generated in an UIL interacting with

bulk dielectric medium. Such a long lifetime of Cherenkov radiation indicates the transport and the refluxing of hot, relativistic electrons. As per our best knowledge this is the first measurement of lifetime of hot, relativistic electrons inside the bulk target. We are further continuing the experiment to measure the thickness dependent lifetime, the spectrum of the Cherenkov radiation. [Moniruzzaman Shaikh, Amit D. Lad, Deep Sarkar, Kamalesh Jana, Indranuj Dey, and G. Ravindra Kumar].

Multiple picosecond optical Kerr gates in CS₂ with intense laser pulses

When an intense linearly polarized light pulse travels through an optically isotropic medium, the material becomes temporarily anisotropic. The material behaves optically as though it was a uniaxial crystal in which the electric field of the light pulse defines the optic axis. The mechanism responsible for this effect has been attributed to the disturbance of the molecular motions from equilibrium and the distortion of the electron clouds. The induced birefringence in the material is short lived and lasts as long as it takes the system to return to equilibrium. For a typical liquid, the relaxation time is usually less than one nanosecond.

We created supercontinuum in air by focusing *p*-polarized pump laser beam using off-axis parabolic mirror. Supercontinuum was collected from the very near of the focal point, just by reflection with a bulk polished aluminium mirror. Due to the damage created by the laser, the aluminium reflector was translated accordingly, to make sure that the supercontinuum was reflecting from a bulk aluminium mirror. This supercontinuum was collected by an achromatic lens of focal length of 100 mm. Then it was passed through one Glean-Taylor and one thin sheet polarizers in parallel to choose one polarization direction of the supercontinuum signal, focused by a BK7 lens ($f = 600$ mm) on the Kerr medium. The gate laser pulse was derived from the reflection of the main pump-pulse using a 40/60 (R/T) beam splitter of thickness 2.1 mm. Then it was passed through a delay stage of micron precession. To control the polarization direction of the *p*-polarized 800 nm gate pulse, we have introduced one $\lambda/2$ wave plate. Then it was focused on the Kerr medium using a BK-7 lens ($f = 700$ mm). The vertical and horizontal orientation was controlled by one micron precession mirror mount. The gate pulse and the signal were spatially matched on the Kerr medium. The vertical and horizontal angle between the two pulses was 5.2° and 4° respectively.

The Kerr medium was mounted on a micron-precession linear stage for better spatial and volumetric matching of signal and gate pulses. Then the gated pulse was passed through a crossed polarization condition with respect to the input polarization of the signal pulse, with the help of one thin sheet plastic polarizer and one Glean-Taylor polarizer in parallel with each other. Then the signal was focused on a photo-diode with an achromatic lens ($f = 200$ mm). We have used one beam dumper after the Kerr cell to block the Gate laser pulse. Two apertures were introduced in the signal line to reduce more noise coming from the Kerr cell, due to scattering.

We found multiple gates for supercontinuum signal in CS₂ with 800 nm gate pulse (40 fs) with intensity 10^9 W/cm². We have observed maximum six gates that are being created in 10 mm long cuvette. Changing the gate pulse polarization orientation we also controlled the relative strengths as well as total number of the gates. We believe that the present technique will be very useful in scenarios where picosecond time gates. [Moniruzzaman Shaikh, Amit D. Lad, Deep Sarkar, and G. Ravindra Kumar].

Observation of hot, relativistic electron distribution inside the target using infrared Cherenkov radiation, x-ray characteristic emission, and electron energy spectrum

To understand laser-plasma interaction the knowledge of hot, relativistic electron distribution is extremely necessary. The energy distribution of relativistic electrons is modified by giant self-generated electric and magnetic fields at target boundaries. To study the fast electron distribution inside the target one can use three techniques, namely measurement of Cherenkov Emission and X-ray single hit photon counting, and electron spectrometer. We conducted an experiment on fast electron energy distribution (>500 KeV) using a BK7 prism target in the past [Habara *et al.* Phys, Rev. Lett. **104**, 055001 (2010)]. Measurement of Cherenkov radiation in this paper is limited to visible Cherenkov emission, whereas low energy electrons (40-100 KeV) lies in the infrared region. We decided to explore this region in the present rum using special targets such as, Si prism (> 40 KeV) and LAH79 prism (80 KeV). But the measurement of Cherenkov radiation in infrared region is extremely challenging task due unavailability of ICCD in this region. We decided to overcome this issue by using triggerable IRCCD and a Pockels cell. To benchmark the experiment we used Si targets. But we were unable to detect the Cherenkov radiation due to low gain of present IRCCD and the long exponential decay time of the

Pockels cell driver. In future experiment we will try to use better IRCCD and Pockels cell driver having a TTL time gate of few nanoseconds.

We also used X-ray CCD in single photon counting mode to observe electron distribution (>50 KeV) by fitting the result of CuK_α . Laser parameter. Single hit are completed to count the photon numbers generated by characteristic X-ray on X-ray CCD. The electron beam generated by Si layer contributes to CuK_α fluorescence. The thicker Si layer is, the more high energy electrons are stopped. The relation between number and energy of electron is observed by changing the thickness of Si layer. We used targets as follows (electron energy): Si 50 μm coated Cu 10 μm + Al foil (~ 50 KeV), Si 100 μm coated Cu 10 μm + Al foil (~ 140 KeV), Si 150 μm coated Cu 10 μm + Al foil (~ 260 KeV), Si 200 μm coated Cu 10 μm + Al foil (~ 380 KeV).

Electron energy spectrum at the rear of the target is obtained using ESM. We used four different targets 10 μm Cu foil, 50 μm Si, 150 μm Si, and 200 μm Si. We observe the maximum electron flux for the Cu foil and flux decreases with increase in Si target thickness. [Amit D. Lad, Deep Sarkar, Moniruzzaman Shaikh, Sheroy Tata, Indranuj Dey, M. Krishnamurthy, and G. Ravindra Kumar in collaboration with S. Nakaguchi, Y. Yoshida, Y. Yusuke, H. Habara, and K. A. Tanaka (Osaka University, Japan)].

Intense terahertz from laser plasma interaction on solid surface

Intense THz pulse generation can open new frontiers of THz science, such as nonlinear THz spectroscopy and THz nonlinear optics. A strong half-cycle electromagnetic pulse in the THz region can be used as the streaking field for temporal measurement of femtosecond charged particle bunch from the modern accelerator. They can also be used for temporal measurement of extreme ultraviolet (XUV) pulses from free electron laser. Today, there are a large number of techniques available for THz pulse generation. However, most of them do not generate sufficiently intense THz pulses for the above-mentioned applications.

THz pulse generation from laser plasma interaction has drawn considerable attention, because extremely intense THz pulse have been predicted via these process. THz field of GV/cm has been predicted *via* interaction of high-intensity lasers with low-density plasmas at relativistic intensity. Intense THz pulse emission from laser-plasma interaction has been investigated from gaseous targets (low-density plasmas), foil targets and solid targets (high-density

plasmas). Recently, THz pulse emission from high-intensity laser irradiation of bulk targets has attracted scientific interest. Conditions inside plasmas from bulk targets can be very different and can simultaneously support different mechanisms of THz emission, such as electromagnetic mode conversion and oscillating surface current.

We have experimentally studied intense THz pulse generation from intense laser-plasma interaction on solid surface (bulk target) at relativistic intensities. A 40 fs, 800 nm Ti:sapphire laser pulse with maximum energy of 350 mJ on target is focused on a polished bulk Cu target (size: 50 mm \times 50 mm \times 3 mm) using an $f/3$ off-axis parabolic mirror to a spot of 20 μm diameter. Maximum intensity on target is 2.7×10^{18} W/cm². High-field THz pulse is emitted as a result of the laser-plasma interaction. THz radiation in the specular direction has been collected by using off-axis parabolic mirror and is detected by a calibrated pyroelectric detector. In this experiment, we investigate the mechanism responsible for THz emission from the interaction of high-intensity laser and solid-density plasma. We have also optimized conditions favourable for THz emission by engineering the laser pulse as well as the target surface condition. [Indranuj Dey, Moniruzzaman Shaikh, Deep Sarkar, Amit D. Lad, and G. Ravindra Kumar in collaboration with Sudipta Mondal and T. Ozaki (INRS-Énergie Matériaux Télécommunications, Varennes, Canada)]

Intense terahertz generation during laser filamentation

The generation of intense sub-picosecond pulses in the terahertz (THz) spectral range (~ 0.1 – 20 THz) using table-top ultrashort-pulse lasers is an important and contemporary area of research in the field of ultra-fast spectroscopy. The main emphasis of the research is the efficient generation of few-cycle THz pulse with peak energies of the order of a few μJ to sub-mJ, utilizing the non-linear interaction of an intense femtosecond laser pulse (peak energies \sim few mJ to sub-J) with matter. Two colour laser filamentation in air (or gas) is a very popular method of generating high intensity THz of the order of few μJ . However, the effect of the presence of vapours and gases in the filamentation medium has not been investigated in details. In this work, an 800 nm pulse of 40 fs duration with peak energy in the range 4 - 40 mJ (maximum repetition rate = 10 Hz) is focused by a convex lens of to form a 5 mm long filament. A second harmonic generator crystal (type-I BBO) is placed between the lens and the filament to generate 400 nm second harmonic which is co-focused onto the same filament. The filament is enclosed by a glass pipe with inlet and outlet for circulation of gas and vapours. The

generated THz is filtered from the accompanying supercontinuum and remnant laser by HRFZ-Si filter, and collimated by a 90° off-axis parabola (OAP) on to an EFISH setup for field measurement. A pyroelectric detector is used for measuring the integrated THz intensity. It is

expected that the variation in generated THz will carry the signature of the filamentation medium and its immediate surroundings. [Indranuj Dey, Moniruzzaman Shaikh, Kamalesh Jana, Deep Sarkar, Amit D. Lad, and G. Ravindra Kumar]

Optical Sciences

Exponentially-tempered Levy Sums

The statistical behavior of random lasing intensity was modeled on exponentially tempered Levy sums, which provides a universal platform for studying random lasing statistics. This result was published in Physical Review Letters in May 2015. [Ravitej Uppu and Sushil Mujumdar].

Anderson localization in semiconductor

membranes Using near-ir light, we measured the systematic development of Anderson localized modes in GaAs semiconductor membranes. The study covered periodic samples that exhibited photonic modes, weakly randomized samples that revealed weakly localized modes, and aperiodic samples with Anderson modes. [Randhir Kumar, Martin Kamp and Sushil Mujumdar]

Members

D. Mathur, E. Krishnakumar, S.V.K. Kumar (retired on January 31, 2016), S.N. Mishra, R.G. Pillay, G. Ravindra Kumar, L.C. Tribedi, V. Nanal, M. Krishnamurthy, I. Mazumdar, S. Mujumdar, R. Palit, S. Pal, D. Misra, V. Prabhudesai

S.M. Davane, Aditya Dharmadhikari, Rajnish Donthi, W.A. Fernandes, J. Jha, S.V. Jadhav, Amit Lad, N.U. Mhatre, B.S. Naidu, Mahesh Pose, M.A. Rahman, Bernard Rodney, K.V. Thulasiram, Y.V. Upalekar, Avinash Shinde, M.E. Sawant, Mallikarjunchary, P.B. Chavan, V.V. Pawaskar, S. N. Manjrekar, Satej Tare, Kiran Divekar

Research Scholars

C. Chattopadhyay, Farhan Babra, Krishna Joshi, Krishnendu Gope, Moniruzzaman Shaikh, Randhir Kumar, Shubhdeep BiswaSayani Biswas, Sudipta Roy, Md. S. R. Laskar, Tabish Shibli, Angana Mondal, Chandan Bagadia, Chandan Ghosh, Deep Sarkar, Kamalesh Jana, Nafis R. K. Chowdhury, Shamik Bhattacharjee, Sramana Kundu, Soubhik Sarkar, Suvasis Swain, Sheroy Tata, Tajinder Singh, Vishvesh Tadsare

Visiting Fellows

Arnab Khan, Arpit Rawankar, Anuvab Mandal, Balaram Dey, Ananta Prasad Mishra, Chandani Palshetkar, Indranuj Dey, M. Balasubrahmaniyam, Neha Dokania, A.K. Rhine kumar, Santosh Roy

Junior / Senior Research Fellows

Ghnashyam Gupta, Madhusree Chowdhury

Administration

Anuya Mahambrey

National and International Involvement

R. Palit: Member of the Organizing Committee of DAE-BRNS Symposium on Nuclear Physics, organized at SSSIHL, Prasanthi Nilayam - 515134, India, 7- 11 Dec 2015. *Lokesh C Tribedi*: 1. Member of International committee, ICPEAC 2011-15 (International Conference on the Physics of Electronic and Atomic Collisions): Toledo Spain 2015. 2. Member of International advisory body, MPS conference (2012 onward). 3. Member of International committee of SHIMEC. "Swift Heavy ions in Materials Engineering and Characterization, SHIMEC", IUAC Delhi [since 2012]. 4. Member of International governing body of the SPARC collaboration, GSI (since last 10 years). 5. Member of International advisory committee for the ISIAC (Int. seminar Ion-atom collisions) (Since 2005). 6. Member of the international advisory board, International conference on the physics of highly charged ions(HCI) 2008 onwards. *E. Krishnakumar*: 1. Member, International Advisory Committee, Asian International Seminar on Atomic and Molecular Physics. 2. Member, Council of Management of DAE-UGC Consortium for Scientific Research. 3. Member, DST Programme Advisory Committee on Lasers, Optics, and Atomic and Molecular Physics (part of the year). 4. Member, Board of Virtual Atomic and Molecular Data Centre (VAMDC). 5. Chair, International Advisory Committee for Electron-Molecule Symposium. 6. Member, Editorial Board of *European Journal of Physics D* for the POSMOL Special Issue 2015. 7. Member, International Advisory Board for *Journal of Physics B* (from Jan. 2016). *Vaibhav S. Prabhudesai* 1. Treasurer and Member, Executive Committee of Indian Society of Atomic and Molecular Physics. *G. Ravindra Kumar* 1. Executive Member, International Committee on Ultra Intense Lasers (ICUIL). 2. Member of the Scientific Advisory Board, "Inertial Fusion Science and Applications" International Conference (held every two years in Japan, Europe and the USA on rotation). 3. Was a member of the national organizing committees of National Laser Symposium 2015 and the annual Plasma Science Society of India conference 2015 (Plasma 2015).

Visits

Subrata Pal : 1)Frankfurt Institute for Advanced Studies (FIAS), Frankfurt, Germany, May 1-31, 2015. 2)Institut de Physique Theorique (IPhT), Saclay, France, May 2015. 3)XXV Quark Matter 2015 Conference, Kobe, Japan, September 27- October 3, 2015hairperson, National. *Lokesh C Tribedi*: visited University of Toulouse, France; 2. ISAC 2015- Barcelona, Spain; 3. ICPEAC 2015- Toledo, Spain; *Deepankar Misra*: ICPEAC 2015, Toledo, Spain, 22-28 July 2015. *Arnab Khan*: ICPEAC 2015, Toledo, Spain, 22-28 July 2015. *Subhadeep Biswas*: ICPEAC 2015, Toledo, Spain, 22-28 July 2015. 2. ISAC 2015, Barcelona, ICPEAC 2015 Toledo, Spain. *M. Krishnamurthy and Amit D. Lad* visited Horia Hulubei National Institute of Physics and Nuclear Engineering (IFIN-HH) and Extreme Light Infrastructure – Nuclear Physics (ELI-NP) construction site, Bucharest, Romania during November 23-27, 2015.

G. Ravindra Kumar, M. Krishnamurthy, and Amit D. Lad visited X-ray free electron laser (SACLA) and a Synchrotron Radiation (SPring-8), Riken, Japan during January 05-07, 2016. *G. Ravindra Kumar, Amit D. Lad, and Indranil Dey* visited Hebrew University, Israel during February 22-25, 2016.

Invited Talks

R. Palit

1. Experimental work on degenerate dipole bands with INGA Chiral Bands in Nuclei, Nordita, Stockholm, 19–22 April 2015.
2. “Wobbling Excitation in A~130 Region Gordon Research Conference on Nuclear Chemistry”, Colby-Sawyer College New London, NH USA, 31 May – 5 June, 2015.
3. “Study of isomers and novel excitation modes of nuclei using INGA Gamma15”, International Symposium, Frontier of Gamma-ray spectroscopy, Osaka University, Toyonaka, October 1 -3, 2015.
4. NUSTAR Program at FAIR Workshop on Detectors for FAIR, 19-20 February 2016, Puri.
5. “High resolution spectroscopy for novel excitation modes of nuclei: results and challenges”, Colloquium at SINP, 18 Nov 2015.

Indranil Mazumdar

1. “Search for rare shape-phase transitions in hot rotating heavy nuclei”, International COMEX5 conference held in Cracow, Poland from 14th to 18th September.
2. “ Studies in Scintillator Detectors”, WHEPP held in IIT-Kanpur from 4TH TO 13th Dec.
3. “Nuclear structure studies with low-energy light ions: fundamental & applied”, Recent Trends in Nuclear Science, (RTNS) 4th to 7th Jan 2016.
4. “Shape-phase transitions in hot-rotating heavy nuclei”, oral presentation in DAE-BRNS Symposium on Nuclear Physics at SSSIHL, Puttaparthi, 7th to 11th Dec,

Subrata Pal

“Principal component analysis of flow”, 2nd Heavy Flavour Meet-2016, Saha Institute, Kolkata, February 3-5, 2016.

Lokesh C Tribedi

1. “Ion-atom collisions” (ISAC 2015), Barcelona, Spain, July 19-21, 2015
2. “Electronic processes in mesoscopic objects probed by fast ion collisions”, Colloquium, IISc Bangalore Aug 21st 2016.
3. “Probing large molecules using accelerators”, IPA lecture in the Baroda University, Sept 7th 2016, Applied Physics Dept.
4. “Basics of Fast ion collisions with atoms, molecules and clusters”, SVP University, Anand, VP & RPT Patel Science College, Sept 8, 2016.

5. “Charged Particle Collisions and Electronic processes in Atoms, Molecules and Materials”, Plenary Talk: ISM Dhanbad ISAMP, January 9-11 2016, Topical conference of ISAMP.

6. “Electronic processes in mesoscopic objects probed by fast ion collisions”, IIT Bombay, National Symposium on Physics, April 10, 2016

7. “Atomic and molecular collisions with fast ions and interdisciplinary science”, Guest lecture, Physics, Khalsa College, Mumbai for undergraduate students, Jan 30, 2016

8. “Recent trends in atomic collision studies in biomolecules, PAHs and fullerenes”, Physics colloquium: IIT, Kanpur, March 04, 2016,

E. Krishnakumar

“Dynamics of Electron – Molecule Resonances: A Challenge to Computational Physics” in Int. Conference on Computational Physics (CCP2015), IIT Guwahatti, Dec. 2 - 6, 2015.

Vaibhav S. Prabhudesai

1. “Unravelling molecular dynamics of dissociative electron attachment using velocity slice imaging” at 2nd International Workshop on Dissociative Electron Attachment and 2nd DEA club meeting, TIFR Mumbai India from 18th – 20th November 2015

2. “Momentum imaging of dissociative electron attachment: some recent results” at Topical conference on charge particle collisions with atoms, molecules and materials (q-PaCE-2016) at Indian School of Mining, Dhanbad, India from 9th to 11th January 2016

G. Ravindra Kumar

1. “HEDS in India - Ultrafast plasma dynamics, particle acceleration and astrophysical analogues”, ASHULA Grand Seminar/Symposium 2016 held in Osaka, Japan during January 05-07, 2016.

2. “Extreme Light, Extreme States” , J C Mahanty Distinguished Lecture, IIT Kanpur 05 Feb 2016.

3. “Ultrafast plasma dynamics in laser-solid interactions: Femtosecond shocks, Terahertz acoustics, Turbulent magnetic fields”, Conference on High Intensity Lasers and Attosecond Science in Israel (CHILI 2016) held in Tel-Aviv during February 22-25, 2016.

M. Krishnamurthy

“Enhancements in x-ray emission and ion acceleration by particle coating on a solid”, ASHULA Grand Seminar/ Symposium 2016 held in Osaka, Japan during January 05-07, 2016.

Amit D. Lad

1. “Ultrafast-optics of solid density plasma micro-optics for ultra-intense laser”, ASHULA Grand Seminar/ Symposium 2016 held in Osaka, Japan during January 05-07, 2016.

2. “Turbulent, Megagauss Magnetic Fields in Intense, Ultrashort Laser”, Conference on High Intensity Lasers

and Attosecond Science in Israel (CHILI 2016) held in Tel-Aviv during February 22-25, 2016.

3. “Turbulent, megagauss magnetic fields in intense laser produced plasmas”, First Newton-Bhabha, India-UK bilateral meet on High-Field Science 2016 held in Trivandrum, Kerala during March 01-03, 2016.

J. Jha

“Convolution effects on ion spectra in clusters”, First Newton-Bhabha, India-UK bilateral meet on High-Field Science 2016 held in Trivandrum, Kerala during March 01-03, 2016.

Conferences Organized by the Department

1. “Recent Trends in Nuclear Structure and its implication in Astrophysics-2016”, during 4-8 January, 2016 in Puri (India) organized by TIFR and IOPB. 1)
2. “6th Asian Triangle Heavy-Ion Conference”, New Delhi, February 15-19, 2016.
3. International Workshop on Dissociative Electron Attachment, 2nd International meeting of the DEA Club, 18th to 20th Nov. 2015 at TIFR, Mumbai. (Convener: E. Krishnakumar)

Non-DAE Research Projects

G. Ravindra Kumar:

(1) Extreme states of matter created by ultraintense, femtosecond laser pulses, J C Bose fellowship Project, DST, Government of India

(2) Triggering and guiding of lighting by plasma filaments induced by high power femtosecond laser, University Grants Commission- Israel Science Foundation (UGC-ISF) project



Department of Theoretical Physics

Cosmology and Astroparticle Physics

Self-induced temporal instability from a neutrino antenna

It has been recently shown that the flavor composition of a self-interacting neutrino gas can spontaneously acquire a time-dependent pulsating component during its flavor evolution. In this work, a more detailed study of this effect in a schematic model was performed. The linear and nonlinear results were found to be in good agreement in the linear regime, while a dramatic speed-up of the flavor conversions occurs in the non-linear regime due to the interactions among the different pulsating modes. It was shown that large flavor conversions can take place if some of the temporal modes are unstable for long enough, and that this can happen even if the matter and neutrino densities are changing, as long as they vary slowly. [Basudeb Dasgupta with F. Capozzi (Padua U. & INFN, Padua), and A. Mirizzi (Bari U. & INFN, Bari)]

Photons, photon jets, and dark photons at 750 GeV and beyond

In new physics searches involving photons at the LHC, one challenge is to distinguish scenarios with isolated photons from models leading to photon jets. For instance, in the context of the 750 GeV diphoton excess, it was pointed out that a true diphoton resonance can be mimicked by a light pseudoscalar decaying to two collinear photons. Photon jets can be distinguished from isolated photons by exploiting the fact that a large fraction of photons pair-convert inside the inner detector. In this note, this discrimination power was quantified, and a study of how the sensitivity of future searches differs for photon jets compared to isolated photons was made. It was also investigated how these results depend on the lifetime of the particle(s) decaying to the photon jet. These results will be useful, more generally, in any new physics search involving hard photons. [Basudeb Dasgupta with J. Kopp (U. Mainz, PRISMA & Mainz U.), P. Schwaller (DESY)]

Temporal instability enables neutrino flavor conversions deep inside supernovae

It was shown that a self-interacting neutrino gas can spontaneously acquire a nonstationary pulsating component in its flavor content, with a frequency that can exactly cancel the multiangle refractive effects of dense matter. This can then enable homogeneous and inhomogeneous flavor

conversion instabilities to exist even at large neutrino and matter densities, where the system would have been stable if the evolution were strictly stationary. Large flavor conversions, especially close to a supernova core, are possible via this novel mechanism. This may have important consequences for the explosion dynamics, nucleosynthesis, as well as for neutrino observations of supernovae. [Basudeb Dasgupta with A. Mirizzi (Bari U. & INFN, Bari)]

Sterile neutrinos with secret interactions: lasting friendship with cosmology

Sterile neutrinos with mass around 1 eV and order 10% mixing with active neutrinos have been proposed as a solution to anomalies in neutrino oscillation data, but are tightly constrained by cosmological limits. It was recently shown that these constraints are avoided if sterile neutrinos couple to a new MeV-scale gauge boson A' . However, even this scenario is restricted by structure formation constraints when A' -mediated collisional processes lead to efficient active-to-sterile neutrino conversion after neutrinos have decoupled. In view of this, the viability of sterile neutrinos with such "secret" interactions was reevaluated. Their evolution in the early Universe was carefully dissected, and it was argued that there are two regions in parameter space - one at very small A' coupling, one at relatively large A' coupling - where all constraints are satisfied. Interestingly, the large A' coupling region is precisely the region that was previously shown to have potentially important consequences for the small scale structure of dark matter halos if the A' boson couples also to the dark matter in the Universe. [Basudeb Dasgupta with X. Chu (ICTP, Trieste), J. Kopp (U. Mainz, PRISMA & Mainz U.)]

Sunyaev-Zeldovich (SZ) effect fluctuations and mass bias in Coma cluster

The SZ fluctuations in the intracluster medium (ICM) of Coma cluster was detected using Planck data. This is first such detection in any cluster and has very important implications for using the clusters as cosmological probes. The SZ fluctuations are an indirect measurement of turbulence in the intracluster medium which provided non-thermal support against gravity and is therefore a source of bias when using X-ray or SZ data to measure the mass of the cluster. In particular substantial non-thermal pressure support

was found, implying hydrostatic mass bias $b_M = -15\%$ to -45% from the core to the outskirts region, respectively, much larger than previously expected. This mass bias is one of the main uncertainties in using clusters for cosmology and may be the cause of tension between cosmological parameter from primary CMB and clusters in Planck papers. It was demonstrated that we can estimate the mass bias accurately using the SZ data itself. [Rishi Khatri with M. Gaspari (Princeton U.)]

Interaction of x-rays with the Galactic molecular clouds

The interaction of x-rays with the Galactic molecular clouds was studied. It was shown using the Monte-Carlo simulations that by studying the reflected X-rays from the molecular clouds we can learn about the internal structure of these clouds. [Rishi Khatri with M. Molaro (Max Planck Institute for Astrophysics, Garching) and R. Sunyaev (Max Planck Institute for Astrophysics, Garching, & Space Research Institute, Moscow & Institute for Advanced Study, Princeton)]

An alternative validation strategy for the Planck cluster catalog and y-distortion maps

A very important contaminant in the Planck cluster catalog is carbon monoxide (CO) emission from Galactic molecular clouds. This work demonstrated and proved a new method of distinguishing between the CO emission and SZ signal and thus validates the clusters in the Planck catalog. One main result was that most of the unconfirmed clusters in the Planck catalog are likely to be molecular clouds. [Rishi Khatri]

Using cross-correlation to probe cosmic baryons

The cross-correlation of distribution of galaxies, the Sunyaev-Zeldovich (SZ) and X-ray power spectra of galaxies from current and upcoming surveys

were shown these to be excellent probes of the nature, i.e. extent, evolution and energetics, of the circumgalactic medium (CGM). A Fisher matrix analysis found that the gas fraction in the CGM can be constrained to a precision of $\sim 34\%$ (23%) by the SPT-DES and $\sim 23\%$ (14%) by the eROSITA-DES surveys in the presence (absence) of an unknown redshift evolution of the gas fraction. It was also demonstrated that the cross-correlated SZ-galaxy and X-ray-galaxy power spectrum can be used as powerful probes of the CGM energetics and potentially discriminate between different feedback models recently proposed in the literature; for example, one can distinguish a ‘no AGN feedback’ scenario from a CGM energized by ‘fixed-velocity hot winds’ at greater than 3σ . [Subhabrata Majumdar with P. Singh (RRI), B. B. Nath (RRI), A. Refregier (ETH, Zurich) and J. Silk (IAP, Paris)]

Dark Energy Constraints from Planck CMB plus LSS observations

Plausible dark energy models, parametrized by multiple candidate equations of state, using the recently published Cosmic Microwave Background (CMB) temperature anisotropy data from Planck together with the WMAP-9 low- l polarization data and data from low redshift surveys was studied. It was shown that a clear tension exists between dark energy constraints from CMB and non-CMB observations when one allows for dark energy models having both phantom and non-phantom behavior; while CMB is more favorable to phantom models, the low- z data prefers model with behavior close to a Cosmological Constant. The results motivate construction of phantom models of dark energy, which is achievable in the presence of higher derivative operators as in string theory. [Subhabrata Majumdar with D. Hazra (APCTP, Korea), S. Pal (ISI, Kolkata), S. Panda (IOP, Bhubaneswar) and A. A. Sen (JMI, New Delhi)]

Condensed Matter and Statistical Physics

Condensate Formation in a Zero-range Process with Random Site Capacities

It is known that quenched disorder can strongly influence both static and dynamic properties of statistical systems. These effects were studied by analyzing a disordered one-dimensional lattice model of nonequilibrium transport, namely a zero-range process (ZRP) in which the maximum capacity of each site is a quenched random variable. The question of interest was the possible occurrence of a phase transition to a condensate phase, in which a single site holds a finite fraction of the particles. This is a quintessential feature of

the normal (non-disordered) ZRP in which the capacity is unrestricted. An interesting interplay between interactions, modelled through hop rates, and randomness, modelled by the distribution of capacities, was found, and the exact conditions for condensate formation were determined. Interestingly, for a given realization of disorder, the condensate relocates on a small subset of sites with the largest capacities. The critical particle density was found to exhibit extremely large sample to sample fluctuations; the corresponding scaled distribution was shown to assume a Gaussian or a Lévy-stable form depending on parameter values.

[Mustansir Barma with Shamik Gupta (Université Paris-Sud, Orsay, France, Università di Firenze, Italy, & Max Planck Institute for Physics of Complex Systems, Dresden, Germany)]

Singular ferromagnetic susceptibility of the transverse-field Ising antiferromagnet on the triangular lattice

A transverse magnetic field Γ is known to induce antiferromagnetic three-sublattice order of the Ising spins σ^z in the triangular lattice Ising antiferromagnet at low enough temperature. This low-temperature order is known to melt on heating in a two-step manner, with a power-law ordered intermediate temperature phase characterized by power-law correlations at the three-sublattice wavevector \mathbf{Q} : $\langle \sigma^z(\vec{R})\sigma^z(0) \rangle \sim \cos(\mathbf{Q} \cdot \vec{R})/|\vec{R}|^{\eta(T)}$ with the temperature-dependent power-law exponent $\eta(T) \in (\frac{1}{9}, \frac{1}{4})$. In this work, a newly developed quantum cluster algorithm was used to study the *ferromagnetic* easy-axis susceptibility $\chi_u(L)$ of an $L \times L$ sample in this power-law ordered phase. The results were consistent with a recent prediction of a singular L dependence $\chi_u(L) \sim L^{2-9\eta}$ when $\eta(T)$ is in the range $(\frac{1}{9}, \frac{2}{9})$. This finite-size result implies, via standard scaling arguments, that the ferromagnetic susceptibility $\chi_u(B)$ to a uniform field B along the easy axis is singular at intermediate temperatures in the small B limit, $\chi_u(B) \sim |B|^{-\frac{4-18\eta}{4-9\eta}}$ for $\eta(T) \in (\frac{1}{9}, \frac{2}{9})$, although there is no ferromagnetic long-range order in the low temperature state. [Kedar Damle and S. Biswas]

Field-driven quantum phase transitions in $S=1/2$ spin chains

A valence bond solid (VBS) is a long-range ordered nonmagnetic state with broken lattice symmetries that can appear in certain quantum spin systems with competing interactions. Recent innovations in models and simulation techniques have enabled large scale numerical studies of these states and associated quantum phase transitions to the standard antiferromagnetic (Neel, for two or more dimensions) or power-law critical states (in one dimension). This work studied the VBS order and induced magnetization as a function of an external magnetic field in a one-dimensional extended Heisenberg model -- the J - Q_2 model -- using the stochastic series expansion quantum monte carlo method with directed loop updates and quantum replica exchange. It was found that the magnetization jumps to the fully polarized state (metamagnetism) for $q \equiv Q/J \geq q_{\min} = \frac{2}{9}$ where J represents the traditional AFM Heisenberg

exchange and Q represents a competing four-spin interaction. An exact solution for $q = q_{\min}$, where the jump first appears, was found. It was found that two flipped spins on a fully polarized background behave as effectively noninteracting particles. For smaller values of q , two flipped spins repel, while for larger values, they attract. [Kedar Damle with A. Iazzi and A. Sandvik (Boston U.)]

Vacancy-induced low-energy states in undoped graphene

This work demonstrated that a nonzero concentration n_v of static, randomly-placed vacancies in graphene leads to a density w of zero-energy quasiparticle states at the band-center $\epsilon = 0$ within a tight-binding description with nearest-neighbour hopping t on the honeycomb lattice. It was shown that w remains generically nonzero in the compensated case (exactly equal number of vacancies on the two sublattices) even in the presence of hopping disorder, and depends sensitively on n_v and correlations between vacancy positions. For low, *but not-too-low* $|\epsilon|/t$ in this compensated case, we show that the density of states (DOS) $\rho(\epsilon)$ exhibits a strong divergence of the form $\rho_{1D}(\epsilon) \sim |\epsilon|^{-1}/[\log(t/|\epsilon|)]^{(y+1)}$, which crosses over to the universal low-energy asymptotic form expected on symmetry grounds $\rho_{GW}(\epsilon) \sim |\epsilon|^{-1} e^{-b[\log(t/|\epsilon|)]^{2/3}}$ below a crossover scale $\epsilon_c \ll t$, ϵ_c is found to decrease rapidly with decreasing n_v , while y decreases much more slowly. [Kedar Damle with S. Sanyal (ICTS, Bangalore) and O. I. Motrunich (Cal. Insti. of Tech.)]

Two-step melting of three-sublattice order in $S=1$ easy-axis triangular lattice antiferromagnets

This work focused on $S = 1$ triangular lattice Heisenberg antiferromagnets with a strong single-ion anisotropy D that dominates over the nearest-neighbour antiferromagnetic exchange J . In this limit of small J/D , the low temperature ($T \sim J \ll D$) properties of such magnets were studied by employing a low-energy description in terms of hard-core bosons with nearest neighbour repulsion $V \approx 4J + J^2/D$ and nearest neighbor unfrustrated hopping $t \approx J^2/2D$. Using a cluster Stochastic Series Expansion (SSE) algorithm to perform sign-problem-free quantum Monte Carlo (QMC) simulations of this effective model, it was established that the ground-state three-sublattice order of the easy-axis spin-density $S^z(\vec{r})$ melts in zero field ($B = 0$) in a *two-step* manner via an intermediate temperature phase characterized by power-law three-sublattice order with a

temperature dependent exponent $\eta(T) \in (\frac{1}{9}, \frac{1}{4})$. For $\eta(T) < \frac{2}{9}$ in this phase, it was found that the uniform easy-axis susceptibility of an $L \times L$ sample diverges as $\chi_L \sim L^{2-9\eta}$ at $B = 0$, consistent with a recent prediction that the thermodynamic susceptibility to a uniform field B along the easy axis diverges at small B as $\chi_{\text{easy-axis}}(B) \sim |B|^{-\frac{4-18\eta}{4-9\eta}}$ in this regime. [Kedar Damle with D. Heidarian (U. of Toronto)]

Sign-problem-free Monte Carlo simulation of certain frustrated quantum magnets

This work introduced a Quantum Monte Carlo (QMC) method for efficient sign-problem-free simulations of a broad class of frustrated $S = 1/2$ models using the basis of spin eigenstates of clusters to avoid the severe sign problem faced by other QMC methods. The utility of the method was demonstrated in several cases with competing exchange interactions. Important limitations as well as possible extensions of the method were also flagged. [Kedar Damle with F. Alet (CNRS), and S. Pujari (U. of Kentucky)]

Classical spin-liquid on the maximally frustrated honeycomb lattice

This work demonstrated that the honeycomb Heisenberg antiferromagnet with $J_1/2 = J_2 = J_3$, where $J_{1/2/3}$ are first-, second- and third-neighbour couplings respectively, forms a classical spin liquid with pinch-point singularities in the structure factor at the Brillouin zone corners. Upon dilution with non-magnetic ions, fractionalised degrees of freedom carrying $1/3$ of the free moment emerge. Their effective description in the limit of low-temperature is that of spins randomly located on a triangular lattice, with a frustrated interaction of long-ranged logarithmic form. The XY version of this magnet exhibits nematic thermal order by disorder, which comes with a clear experimental diagnostic. [Kedar Damle with J. Rehn (Max-Planck-Institut, Dresden), A. Sen (IACS, Kolkata), and R. Moessner (Max-Planck-Institut, Dresden)]

Quantum cluster algorithm for frustrated Ising models in a transverse field

This work introduced and characterized a new quantum cluster algorithm for quantum Monte Carlo simulations of transverse field Ising models with frustrated Ising exchange interactions. As a demonstration of the capabilities of this new algorithm, which works within the framework of the stochastic series expansion, it was shown that a relatively small ferromagnetic next-nearest neighbour coupling drives the transverse field Ising antiferromagnet on the triangular lattice from an

antiferromagnetic three-sublattice ordered state at low temperature to a ferrimagnetic three-sublattice ordered state. [Kedar Damle, S. Biswas, and G. Rakala]

Melting of three-sublattice order in easy-axis antiferromagnets on triangular and Kagome lattices

When the spins have an energetic preference to lie along an "easy-axis", triangular and Kagome lattice antiferromagnets often develop long-range order that distinguishes the three sublattices of the underlying triangular Bravais lattice. This "three-sublattice order" melts in zero field *either* via a "two-step melting" transition, with an intermediate-temperature phase characterized by power-law three-sublattice order controlled by a temperature dependent power-law exponent $\eta(T) \in (\frac{1}{9}, \frac{1}{4})$ or via a transition described by the three-state Potts model. In this work, it was predicted that the uniform susceptibility to a small easy-axis field B diverges as $\chi(B) \sim |B|^{-\frac{4-18\eta}{4-9\eta}}$ in a large part of the intermediate power-law ordered phase (corresponding to $\eta(T) \in (\frac{1}{9}, \frac{2}{9})$, providing a thermodynamic signature of two-step melting. This work also demonstrated that these two generic melting scenarios are separated from each other by an interesting multicritical point with central charge $c_M \in (1, \frac{3}{2})$. Numerical estimates of multicritical exponents were also obtained. [Kedar Damle]

Random Coulomb antiferromagnets: from diluted spin liquids to Euclidean random matrices

This work studied a disordered classical Heisenberg magnet with uniformly antiferromagnetic interactions which are frustrated on account of their long-range Coulomb form, i.e., $J(r) \sim -A/\ln(r)$ in $d = 2$ and $J(r) \sim A/r$ in $d = 3$. This arises naturally as the $T \rightarrow 0$ limit of the emergent interactions between vacancy-induced degrees of freedom in a class of diluted Coulomb spin liquids (including the classical Heisenberg antiferromagnets in checkerboard, SCGO, and pyrochlore lattices) and presents a novel variant of a disordered long-range spin Hamiltonian. Using detailed analytical and numerical studies it was established that this model exhibits a very broad paramagnetic regime that extends to very large values of A in both $d = 2$ and $d = 3$. In $d = 2$, using the lattice-Green-function-based finite-size regularization of the Coulomb potential (which corresponds naturally to the underlying low-temperature limit of the emergent interactions between orphans), it was found that freezing into a glassy state occurs only in the limit of strong

coupling, $A = \infty$, while no such transition seems to exist in $d = 3$. This work also demonstrates the presence and importance of screening for such a magnet. Additionally the spectrum of the Euclidean random matrices describing a Gaussian version of this problem was analyzed, and a corresponding quantum mechanical scattering problem was identified. [Kedar Damle with J. Rehn (Max-Planck-Institut, Dresden), A. Sen (IACS, Kolkata), A. Andreanov, R. Moessner (Max-Planck-Institut, Dresden), and A. Scardicchio (ICTP, Trieste)]

Phase transitions in a system of hard rectangles

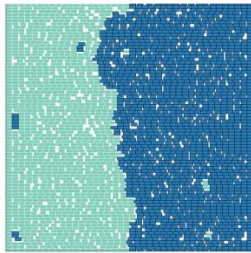


Figure 1: An interface between two differently ordered layered phases of 2×7 hard rectangles on the square lattice.

A system of $2 \times \ell$ hard rectangles on square lattice is known to show four different phases for $\ell \geq 14$. As the covered area fraction ρ is increased from 0 to 1, the system goes from low-density disordered phase, to orientationally-ordered nematic phase, to a columnar phase with orientational order and also broken translational invariance, to a high density phase in which orientational order is lost. Interestingly, simulations have shown that the critical density for the second transition ρ_2^* tends to a non-trivial finite value ≈ 0.73 , as $\ell \rightarrow \infty$, and $\rho_2^* \approx 0.93$ for $\ell = 2$. We provide a theoretical explanation of this interesting result. We develop an approximation scheme to calculate the surface tension between two differently ordered columnar phases. For all values of d , these estimates are in good agreement with Monte Carlo data. [Deepak Dhar]

Optical Lattice Modulation Spectroscopy for Spin-orbit Coupled Bosons

Interacting bosons with two "spin" states in a lattice show novel superfluid-insulator phase transitions in the presence of spin-orbit coupling. Depending on the parameter regime, bosons in the superfluid phase can condense to either a zero momentum state or to one or multiple states with finite momentum, leading to an unconventional superfluid phase. The response of such a system to modulation of the optical lattice potential was studied and it was shown that the change in momentum distribution after lattice modulation produces distinct patterns in the Mott and the

superfluid phase and these patterns can be used to detect these phases and the quantum phase transition between them. Further, the momentum resolved optical modulation spectroscopy can identify both the gapless (Goldstone) gapped amplitude (Higgs) mode of the superfluid phase and clearly distinguish between the superfluid phases with a zero momentum condensate and a twisted superfluid phase by looking at the location of these modes in the Brillouin zone. [Rajdeep Sensarma with S. D. Sarkar and K. Sengupta (IACS)]

Spin-Density Wave States in Biased Bilayer Honeycomb Lattice

An experimental setup using ultracold atoms was proposed to implement a bilayer honeycomb lattice with Bernal stacking. In presence of a potential bias between the layers and at low densities, Fermions placed in this lattice form an annular Fermi sea. The presence of two Fermi surfaces lead to interesting patterns in Friedel oscillations and RKKY interactions in presence of impurities. Further a repulsive Fermion-Fermion interaction leads to a Stoner instability towards an incommensurate spin-density wave order with a wave-vector equal to thickness of the Fermi sea. The instability occurs at a critical interaction strength which goes down with the density of the Fermions. It was found that the instability survives interaction renormalization due to vertex corrections and possible experimental signatures of this instability was discussed. [Rajdeep Sensarma and S. Dey]

Berry phase mechanism of the anomalous Hall effect in a disordered two-dimensional magnetic semiconductor structure

The anomalous Hall effect (AHE) arises from the interplay of spin-orbit interactions and ferromagnetic order and is a potentially useful probe of electron spin-polarization, especially in nanoscale systems where direct measurement is not feasible. While AHE is rather well understood in metallic ferromagnets, much less is known about the relevance of different physical mechanisms governing AHE in insulators. As ferromagnetic insulators, but not metals, lend themselves to gate-control of electron spin-polarization, understanding AHE in the insulating state is valuable from the point of view of spintronic applications. Among the mechanisms proposed in the literature for AHE in insulators, the one related to a geometric (Berry) phase effect has proved elusive in past studies. The recent discovery of quantized AHE in magnetically doped topological insulators - essentially a Berry phase effect - provides strong additional motivation to undertake more careful search for geometric

phase effects in AHE in the magnetic semiconductors. Careful measurements were performed of the temperature and magnetic field dependences of AHE in insulating, strongly-disordered two-dimensional Mn delta-doped semiconductor heterostructures in the hopping regime, and the data analyzed for evidence of the Berry phase mechanism of AHE. The main find is that at sufficiently low temperatures, the mechanism of AHE related to the Berry phase is favoured. [Vikram Tripathi with L. N. Oveshnikov, V. A. Kulbachinskii (Kurchatov Inst., Moscow), A. B. Davydov, B. A. Aronzon (Lebedev Inst., Moscow), I. V. Rozhansky, N. S. Avkeriev (Ioffe Inst., St. Petersburg) and K. I. Kugel (ITAE, Moscow)]

A Kondo route to spin inhomogeneities in the honeycomb Kitaev model

Paramagnetic impurities in a quantum spin-liquid can result in Kondo effects with highly unusual properties. In this context, the authors studied the effect of locally exchange-coupling a paramagnetic impurity with the spin-1/2 honeycomb Kitaev model in its gapless spin-liquid phase. The (impurity) scaling equations were found to be insensitive to the sign of the coupling. The weak and strong coupling fixed points were shown to be stable, with the latter corresponding to a noninteracting vacancy and an interacting, spin-1 defect for the antiferromagnetic and ferromagnetic cases respectively. The ground state in the strong coupling limit in both cases has a nontrivial topology associated with a finite Z_2 flux at the impurity site. For the antiferromagnetic case, this result can be obtained straightforwardly owing to the integrability of the Kitaev model with a

vacancy. The strong-coupling limit of the ferromagnetic case is however nonintegrable, and to address this problem, exact-diagonalization calculations were performed with finite Kitaev fragments. The exact diagonalization calculations indicate that the weak to strong coupling transition and the topological phase transition occur rather close to each other and are possibly coincident. An intriguing similarity between the magnetic response of the defect and the impurity susceptibility in the two-channel Kondo problem was also noted. [Vikram Tripathi with S. D. Das (Bristol) and K. Dhochak (Weizmann)]

Parity-time symmetry-breaking mechanism of dynamic Mott transitions in dissipative systems

The critical behavior of the electric field-driven (dynamic) Mott insulator-to-metal transitions in dissipative Fermi and Bose systems was described in terms of non-Hermitian Hamiltonians invariant under simultaneous parity (P) and time-reversal (T) operations. The dynamic Mott transition was identified as a PT symmetry-breaking phase transition, with the Mott insulating state corresponding to the regime of unbroken PT symmetry with a real energy spectrum. The imaginary part of the Hamiltonian was shown to arise from the combined effects of the driving field and inherent dissipation. The renormalization and collapse of the Mott gap at the dielectric breakdown was obtained and this was used to describe the critical behaviour of transport characteristics. The obtained critical exponent was found to be in an excellent agreement with experimental findings. [Vikram Tripathi and H. Barman with A. Galda and V. Vinokur (Argonne)]

High Energy Physics

Principal Component Analysis of Event-by-Event Fluctuations

The method of principal component analysis was applied to the study of event-by-event fluctuations in ultrarelativistic heavy-ion collisions. This method brings out all the information contained in two-particle correlations in a physically transparent way. Multiplicity fluctuations and anisotropic flow fluctuations were studied using ALICE (LHC) data as well as a sample of events simulated using A Multi-Phase Transport (AMPT) model. In particular, elliptic and triangular flow fluctuations were studied as a function of transverse momentum and rapidity. This method revealed previously unknown subleading modes in both rapidity and transverse momentum for the momentum distribution as well as elliptic and

triangular flows. [R.S. Bhalerao and S. Pal with J. Y. Ollitrault (Saclay), and D. Teaney (Stony Brook)]

Collective Flow in Event-by-Event Partonic Transport plus Hydrodynamics Hybrid Approach

Complete evolution of the strongly interacting matter formed in ultrarelativistic heavy-ion collisions was studied within a coupled Boltzmann and relativistic viscous hydrodynamics approach. For the initial nonequilibrium evolution phase, A MultiPhase Transport (AMPT) model that explicitly included event-by-event fluctuations in the number and positions of the participating nucleons as well as of the produced partons with subsequent parton transport was employed. The ensuing near-equilibrium evolution of quark-gluon and hadronic matter was modeled within the (2+1)-dimensional

relativistic viscous hydrodynamics. [R.S. Bhalerao, A. Jaiswal and S. Pal]

Wilson Flow with Staggered Quarks

Scale setting was examined for QCD with two flavours of staggered quarks using Wilson flow over a factor of four change in both the lattice spacing and the pion mass. The statistics needed to keep the errors in the flow scale fixed was found to increase approximately as the inverse square of the lattice spacing. Tree level improvement of the scales t_0 and w_0 was found to be useful in most of the range of lattice spacings explored. The scale uncertainty due to remaining lattice spacing effects was found to be about 3%. The ratio $w_0/\sqrt{t_0}$ is N_F dependent and its continuum limit was found to be 1.106 ± 0.007 (stat) ± 0.005 (syst) for $m_\pi w_0 \simeq 0.3$. [Saumen Datta, Sourendu Gupta, and A. Lahiri with A. Lytle (Glasgow), and P. Majumdar (IACS, Kolkata)]

Study of deconfinement transition with new order parameters

At finite temperatures, strongly interacting matter undergoes a transition to a deconfined plasma. We studied the transition for the theory with gluons, where we used the technique of flowing the gauge fields to define a new, renormalized order parameter. We also used the flow to calculate the renormalized Polyakov loop and the renormalized electric and magnetic gluon condensates. The condensates were found to have very interesting thermal dependence. The differential flow behavior of the electric and magnetic condensates was shown to act as a marker of deconfinement. [Saumen Datta and Sourendu Gupta, with A. Lytle (Glasgow)]

Quantifying the physics potential of the ICAL detector at INO

A comprehensive "White Paper", quantifying the physics potential of the ICAL detector as obtained from realistic detector simulations, was completed. It described the simulation framework, the neutrino interactions in the detector, and the expected response of the detector to particles traversing it. The report outlined the analyses carried out for the determination of neutrino mass hierarchy and precision measurements of atmospheric neutrino mixing parameters at ICAL, and gave the expected physics reach of the detector with 10 years of runtime. The potential of ICAL for probing new physics scenarios like CPT violation and the presence of magnetic monopoles was also explored. This would be the first reference to go to for all future ICAL-INO-related publications. [Amol Dighe with the ICAL-INO Collaboration]

Unravelling Medium Effects in Heavy Ion Collisions with Zeal

Since the seminal proposal of Bjorken in 1982 of using energy loss of fast particles and the related jet-quenching as a probe to study the nature of the hot medium formed in heavy ion collisions, a lot of experimental and theoretical studies have enriched our understanding of the medium produced in relativistic heavy ion collisions. For instance, R_{AA} obtained from the ratios of single particle inclusive transverse momentum (p_T)-spectra of nucleus-nucleus (AA) to that of suitably normalized proton-proton (pp) spectra shows a large suppression at RHIC and at the LHC. Arguing it to stem from the leading particle in the corresponding jets, this has been identified as the shining example of jet quenching by the medium, especially since no such suppression is seen in ratios constructed for pA collisions. LHC has now produced exciting results on reconstructed jets in heavy ion collisions, showing almost uniform suppression compared to pp collisions as a function of the jet transverse momentum. QCD based models using either strong or weak coupling pictures seem capable of explaining the data, obscuring its full potential to enhance our understanding of the hot medium. We proposed a new observable, called zeal, to analyze events with jets in heavy ion collisions. It measures how a thermal medium affects the multiplicity and distribution of energetic particles in a jet, and is therefore more discriminating than R_{AA} of the leading partons. Its advantage is that it weighs the energetic partons more heavily and hence is particularly sensitive to the processes that lead to the energy loss of the leading partons. For frequent medium induced bremsstrahlung with several gluons carrying a tiny fraction of the energy of the leading partons, the peak of the zeal distribution should move towards lower zeal values unlike the case where induced bremsstrahlung is rare and the emitted gluons carry significant fractions of the energy of the leading partons. Using few known models for energy loss and jet quenching, we demonstrated its capability to distinguish the physics of these models, thus splitting their degeneracy to some extent. [Rajiv Gavai and Rishi Sharma with A. Jain (IISER, Bhopal)]

The QCD Critical Point : An Exciting Odyssey in the Femto-World

Strongly interacting matter, which makes up the nuclei of atoms, is described by a theory called Quantum Chromodynamics (QCD). A critical point in the phase diagram of Quantum Chromodynamics (QCD), if established either theoretically or experimentally, would be as profound a discovery as the familiar gas-liquid critical point discovered in the nineteenth century.

Due to the extremely short lived nature of the concerned phases, novel experimental techniques are needed to search for it. The Relativistic Heavy Ion Collider (RHIC) in USA has an experimental programme which can fit the bill to do so. Theoretical techniques of Lattice QCD, which is QCD defined on a discrete space-time lattice, have provided glimpses into where the QCD critical point may be, and how to search for it in the experimental data. An invited brief overview of the theoretical and experimental attempts was written for "Contemporary Physics" journal of Taylor & Francis, UK. [Rajiv Gavai]

Charmed-bottom mesons from Lattice QCD

We present ground state spectra of mesons containing a charm and a bottom quark. For the charm quark we use overlap valence quarks while a non-relativistic formulation is utilized for the bottom quark on a background of 2+1+1 flavour HISQ gauge configurations generated by the MILC collaboration. Results are obtained at three lattice spacings: 0.12, 0.09 and 0.06 fermi in a box size of about 3 fermi. While the pseudoscalar mass of B_c^* meson is known, nothing is known for mesons of other quantum numbers. We predicted that the hyperfine splitting between the vector and pseudoscalar B_c^* mesons is 55(3) MeV, which will be helpful for the future discovery of vector B_c^* meson. We are also studying the leptonic decay constants of such mesons. [Nilmani Mathur with M. Padmanath (University of Graz, Austria)]

Radion Candidate for the LHC Diphoton Resonance

A mixed Higgs-Radion state was proposed as an explanation for the (now defunct) CERN diphoton excess reported in December 2015. Tuning of the mixing parameter to the 'conformal point', where the heavier mixed state decouples from most Standard Model fields led to an elegant explanation of the observed facts, provided one allows for the existence of an extra generation of vectorlike fermions on the IR brane. [Sreerup Raychaudhuri, D. Bardhan, D. Bhatia, A. Chakraborty, U. Maitra, and T. Samui]

Diphoton Resonance at 750 GeV in the Broken MRSSM

The MRSSM or the R -symmetric version of the minimal supersymmetric Standard Model is a useful construct which allows the possibility of very heavy gluinos without forcing the squarks of the third generation to become correspondingly heavy. This model also contains two scalars, of which one has dominant decays into diphotons. It was shown that if this scalar has a mass of 750 GeV, it could explain the (now defunct) CERN diphoton excess

reported in December 2015. [Sreerup Raychaudhuri, A. Chakraborty, and S. Chakraborty]

A Detailed Analysis of Flavour-changing Decays of Top Quarks as a Probe of New Physics at the LHC

If direct evidence for new physics eludes the LHC, one can still look for new physics effects through virtual particle exchanges in loop-induced processes. One of the most interesting of these is the flavour-changing decays of the top quark, which is extremely rare in the Standard Model. In a detailed study, the conditions on a new physics model which ensure an enhanced rate for this decay were determined, and illustrated by comprehensive studies of the constrained minimal supersymmetric Standard Model, with and without conservation of R -parity. [Sreerup Raychaudhuri and D. Bardhan, with G. Bhattacharyya (SINP, Kolkata), D. Ghosh (Weizmann Inst.), and M. Patra (Boskovic Inst., Zagreb)]

R -parity violation in warped GUT scale Randall-Sundrum Framework

A bulk Randall-Sundrum type warped extra-dimensional model is invoked at the GUT scale to provide a high-energy completion to a TeV-scale R -parity violating supersymmetric model. This turns out to be a predictive framework of R -violating supersymmetry with distinctive and testable low-energy predictions.

[K. Sridhar and A. M. Iyer with B. C. Allanach (Cambridge U., DAMTP)]

Kaluza Klein Gluon+jets associated production at the LHC

Models of warped extra dimensions are viable and consistent with precision electroweak measurements only if the Standard Model particles are localised in the bulk. Electroweak precision also places strong constraints on bulk warped models but by either invoking a bulk custodial symmetry or by deforming the bulk metric it is possible to have testable models with gauge boson Kaluza-Klein modes within the reach of the LHC. Of these the Kaluza-Klein excitation of the gluon is the most interesting; yet given that it is about 2-3 TeV in mass it seriously challenges collider searches at the LHC. It is suggested that searching for the KK gluon in association with hard jets may provide a better search strategy and will be very useful in pinning down this signal. A complete simulation of the Kaluza-Klein gluon + associated jet process has been carried out. [K. Sridhar and A. M. Iyer with F. Mahmoudi (Lyon U. & CERN) and N. Manglani (Mumbai U.)]

Status of the MSSM Higgs sector using global analysis and direct search bounds, and future prospects at the High Luminosity LHC

In this paper, we searched for the regions of the phenomenological minimal supersymmetric standard model parameter space where one can expect to have moderate Higgs mixing angle (α) with relatively light (up to 600 GeV) additional Higgses after satisfying the current LHC data. We performed a global fit analysis using updated data (till December 2014) from the LHC and Tevatron experiments. The constraints coming from the precision measurements of the rare b-decays are also considered. It was found that low M_A (≤ 350) and high $\tan\beta$ (≥ 25) regions are disfavored by the combined effect of the global analysis and flavour data and in the allowed regions Higgs mixing angle $\alpha \sim 0.1-0.8$. Existing direct search bounds on the heavy scalar/pseudoscalar and charged Higgs bosons masses and branchings at the LHC were also studied. [A. Chakraborty with B. Bhattacharjee (IISC, Bangalore), and A. Choudhury (Harish-Chandra Res. Inst.)]

Status of the 98-125 GeV Higgs bosons scenario with updated LHC-8 data

We studied the possibility of having the lightest Higgs boson with mass $M_h = 98$ GeV to be consistent with the 2.3σ excess observed at the LEP as well as the heavier Higgs boson (H) with mass $M_H \sim 125$ GeV to be consistent with the combined 7 and 8 TeV LHC data. We scanned the minimal supersymmetric standard model parameter space and then imposed constraints coming from flavour physics, relic density of the cold dark matter as well as direct dark matter searches. We also studied the possibility of observing the 98 GeV Higgs boson in vector boson fusion process and associated production with W/Z boson at the high luminosity (3000 fb^{-1}) run of the 14 TeV LHC. [A. Chakraborty with B. Bhattacharjee (IISC, Bangalore), M. Chakraborti, U. Chattopadhyay, and D. K. Ghosh (IACS, Kolkata)]

Probing $(g-2)_\mu$ at the LHC in the paradigm of R-parity violating MSSM

The measurement of the anomalous magnetic moment of the muon exhibits a longstanding discrepancy compared to the Standard model prediction. In this paper, we considered the framework of effective supersymmetric theory with relevant R-parity violating operators. Such a framework provides substantial contributions to the anomalous magnetic moment of the muon while satisfying constraints from low energy experimental observables as well as neutrino mass. In addition, we pointed out that the implication of such operators satisfying muon $(g-2)$ are immense from the perspective of the LHC experiment, leading to a spectacular four muon final state. Finally, we proposed an analysis in this particular channel which might help to settle the debate of R-parity violation as a probable explanation for $(g-2)_\mu$. [A. Chakraborty and S. Chakraborty]

Looking for lepton flavour violation in SUSY at the LHC

We consider models of supersymmetry which can incorporate sizeable mixing between different generations of sfermions. We probe the lepton flavour violating (LFV) vertex originating from decay of heavier neutralino and identify a distinct and unambiguous combination of the tri-lepton final state which include a lepton pair with same flavour and same sign (SFSS) in addition to a pair with opposite flavour and opposite sign (OFOS). [M. Guchait, A. M. Iyer, and R. Samanta]

The 750 GeV diphoton resonance as an sgoldstino: a reappraisal

Out of the many proposals offered as an explanation to the reported 750 GeV resonance, one of the attractive proposals was the sgoldstino. This proposal was made by three separate groups. We took a closer look at the explanation in realistic models of gauge mediated supersymmetry breaking. We concluded that there is a lot of difficulty in such an explanation, coming from several diverse lines of reasoning. [D. Bardhan with P. Byakti (IISC, Bangalore), D. Ghosh (Weizmann Inst.), and T. Sharma (Weizmann Inst.)]

String Theory and Mathematical Physics

Thermalization studies in quantum field theory and gravity: Local thermalization in integrable models and higher spin black

In recent years quantum quench experiments conducted in cold atom systems have shown thermalization in integrable systems. Theoretically this apparent oxymoron has been understood as part of the general story of "subsystem

thermalization", described by the time development of pure excited states of a system such that the reduced density matrix of a subsystem approaches that in a thermal state. In the present work, this has been rigorously shown for a general class of conformal integrable models for a general class of initial states. The final 'thermal' state is a generalized Gibbs ensemble (GGE), defined by the

infinite number of conserved charges characterizing the initial excited state. The approach to equilibrium is exponential; the relaxation rates are explicitly computed in perturbation in the chemical potentials. In cases where the the GGE have an AdS/CFT dual description, in terms of a new class of three dimensional black hole solutions (in a higher spin generalization of Einstein gravity), the phenomenon of relaxation of perturbations to the GGE quantitatively match the decay of scalar perturbations to these black holes. [Gautam Mandal, R. Sinha and N. Sorokhaibam]

Thermalization studies in quantum field theory and gravity: Mass quench in two dimensions and exact results

Free massive scalars and fermions are subjected to a fast quench (time dependence) and the resulting time development of various observables are theoretically studied. Analytic results are obtained for specific time-dependence of the mass function. Late time behaviour is shown to be consistent with the results described above in the perturbative regime of chemical potentials. In the nonperturbative regime, all chemical potentials are shown to be important; in particular the late time behaviour is affected by operators of arbitrary high dimensions. [Gautam Mandal and N. Sorokhaibam with S. Paranjape (IISER, Pune)]

AdS/QCD and deconfinement

In an earlier work, it was shown (G.Mandal and T.Morita, 2011) that the conventional gravity dual description of deconfinement transition in four dimensional Yang-Mills theory was phase separated from the actual deconfinement transition line. A new gravity dual description was proposed in that work which was free from this problem. In the present work, the Mandal-Morita model is extended further to include the effect of dynamical quarks. [Gautam Mandal]

A Membrane Paradigm at Large D

$SO(d + 1)$ invariant solutions of the classical vacuum Einstein equations in $p + d + 3$ dimensions are studied. In the limit $d \rightarrow \infty$ with p held fixed we construct a class of solutions labelled by the shape of a membrane (the event horizon), together with a 'velocity' field that lives on this membrane. We demonstrate that our metrics can be corrected to nonsingular solutions at first sub-leading order in d if and only if the membrane shape and 'velocity' field obey equations of motion which we determine. These equations define a well posed initial value problem for the membrane shape and this 'velocity' and so completely determine the dynamics of the black hole. They may be viewed as governing the non-linear

dynamics of the light quasi normal modes of Emparan, Suzuki and Tanabe. [Shiraz Minwalla, R. Mohan, and A. Saha with S. Bhattacharyya (Indian Inst. Tech., Kanpur), A. De (IISER, Pune)]

Unitarity, Crossing Symmetry and Duality in the Scattering of $N=1$ Susy Matter Chern Simons Theories

We study the most general renormalizable $N = 1$ $U(N)$ Chern-Simons gauge theory coupled to a single (generically massive) fundamental matter multiplet. At leading order in the 't Hooft large N limit we present computations and conjectures for the 2×2 S-matrix in these theories; our results apply at all orders in the 't Hooft coupling and the matter self interaction. Our S matrices are in perfect agreement with the recently conjectured strong weak coupling self duality of this class of theories. The consistency of our results with unitarity requires a modification of the usual rules of crossing symmetry in precisely the manner anticipated in arXiv:1404.6373, lending substantial support to the conjectures of that paper. In a certain range of coupling constants our S matrices have a pole whose mass vanishes on a self dual codimension one surface in the space of couplings. [Shiraz Minwalla, K. Inbasekar, S. Mazumdar, and V. Umesh with S. Jain (Cornell U.), and S. Yokoyama (Technion)]

Chern Simons Bosonisation along RG Flows

It has previously been conjectured that the theory of free fundamental scalars minimally coupled to a Chern Simons gauge field is dual to the theory of critical fundamental fermions minimally coupled to a level rank dual Chern Simons gauge field. In this paper we study RG flows away from these two fixed points by turning on relevant operators. In the 't Hooft large N limit we compute the thermal partition along each of these flows and find a map of parameters under which the two partition functions agree exactly with each other all the way from the UV to the IR. We conjecture that the bosonic and fermionic RG flows are dual to each other under this map of parameters. Our flows can be tuned to end at the gauged critical scalar theory and gauged free fermionic theories respectively. Assuming the validity of our conjecture, this tuned trajectory may be viewed as RG flow from the gauged theory of free bosons to the gauged theory of free fermions. [Shiraz Minwalla with S. Yokoyama (Technion)]

A Charged Membrane Paradigm at Large D

We study the effective dynamics of black hole horizons in Einstein-Maxwell theory in a large number of spacetime dimensions D . We demonstrate that horizon dynamics may be recast

as a well posed initial value problem for the motion of a codimension one non gravitational membrane moving in flat space. The dynamical degrees of freedom of this membrane are its shape, charge density and a divergence free velocity field. We determine the equations that govern membrane dynamics at leading order in the large D expansion. Our derivation of the membrane equations assumes that the solution preserves an $SO(D - p - 2)$ isometry with p held fixed as D is taken to infinity. However we are able to cast our final membrane equations into a completely geometric form that makes no reference to this symmetry algebra. [Shiraz Minwalla and M. Mandlik with S. Bhattacharyya (Indian Inst. Tech., Kanpur), and S. Thakur (Indian Inst. Tech., Kanpur)]

Quantum gravity effect in torsion driven inflation and CP violation

We have derived an effective potential for inflationary scenario from torsion and quantum gravity correction in terms of the scalar field hidden in torsion. A strict bound on the CP violating θ parameter, $\mathcal{O}(10^{10}) < \theta < \mathcal{O}(10^9)$ has been obtained, using Planck+WMAP9 best fit cosmological parameters. [S. Choudhury with B. K. Pal (IUCAA, Pune), B. Basu (ISI, Kolkata), and P. Bandyopadhyay (ISI, Kolkata)]

Constraining brane inflationary magnetic field from cosmoparticle physics after Planck

In this work, I have studied the cosmological and particle physics constraints on a generic class of large and small field models of brane inflationary magnetic field in case of RSII framework. I also establish a direct connection between the magnetic field at the present epoch and primordial gravity waves, which give a precise estimate of non-vanishing CP asymmetry in leptogenesis and baryon asymmetry in baryogenesis scenario respectively. Further assuming the conformal invariance to be restored after inflation in the framework of RSII, I have explicitly shown that the requirement of the sub-dominant feature of large scale coherent magnetic field after inflation gives two fold non-trivial characteristic constraints- on equation of state parameter and the corresponding energy scale during reheating epoch. Finally giving the proposal for avoiding the contribution of back-reaction from the magnetic field I have established a bound on the generic reheating characteristic parameter, to achieve large scale magnetic field and further apply the CMB constraints as obtained from recently observed Planck 2015 data. [S. Choudhury]

Hysteresis in the Sky

Cosmological hysteresis has interesting and vivid implications in the scenario of a cyclic bouncy universe. This, purely thermodynamical in nature, is caused by the asymmetry in the equation of state parameter during expansion and contraction phase of the universe, due to the presence of a single scalar field. When applied to variants of modified gravity models this phenomenon leads to the increase in amplitude of the consecutive cycles of the universe, provided we have physical mechanisms to make the universe bounce and turnaround. This also shows that the conditions which create a universe with an ever increasing expansion, depend on the signature of $\oint pdV$ and on model parameters. [S. Choudhury and S. Banerjee]

Reconstructing inflationary paradigm within Effective Field Theory framework

In this work my prime objective is to analyze the constraints on a sub-Planckian excursion of a single inflaton field within EFT framework. For a generic single field inflationary potential I have derived the most general expression for the field excursion in terms of various inflationary observables. By explicit computation I have reconstructed the structural form of the inflationary potential within EFT. I also provided two simple examples of Effective Theory of inflation- inflection-point model and saddle-point model to check the compatibility of the prescribed methodology in the light of Planck 2015 and Planck 2015 +BICEP2/Keck Array data. Finally, I have also checked the validity of the prescription by estimating the cosmological parameters and fitting the theoretical CMB TT, TE and EE angular power spectra with the observed data. [S. Choudhury]

Effective Field Theory of Dark Matter from membrane inflationary paradigm

In this work, we have studied the cosmological and particle physics constraints on dark matter relic abundance from EFT of inflation in case of RSII model. We establish a direct connection between the dark matter relic abundance and primordial gravity waves in the present work. We have explicitly shown that the membrane tension, bulk mass scale, and cosmological constant, in RSII membrane plays the most significant role to establish the connection between dark matter and inflation, using which we have studied the features of various mediator mass scale suppressed EFT "relevant operators" induced from the localized s, t and u channel interactions. Further we have studied an exhaustive list of tree-level Feynman diagrams for dark matter annihilation within the prescribed setup and to check the consistency of the obtained

results, further we apply the constraints as obtained from recently observed Planck 2015 data and Planck+BICEP2+Keck Array joint datasets. Using all of these derived results we have shown that it is possible to put further stringent constraint on r within, $0.01 \leq r \leq 0.12$, for $\langle \sigma v \rangle \approx \mathcal{O}(10^{28} - 10^{27})\text{cm}^3/\text{s}$. [S. Choudhury with A. Dasgupta (IOP, Bhubaneswar)]

COSMOS-e'-GTachyon from String Theory

In this work, our prime objective is to study the inflationary paradigm from GTachyon living on the world volume of a non-BPS string theory. The tachyon action is considered here is getting modified compared to the original action. One can quantify the amount of the modification via a power q instead of $1/2$ in the effective action. Using this set up we study inflation from various types of tachyonic potentials, using which we constrain the index q within, $1/2 < q < 2$, Regge slope, string coupling constant and mass scale of tachyon, from the recent Planck 2015 and Planck+BICEP2/Keck Array joint data. We explicitly study the inflationary consequences from single field, assisted field and multi-field tachyon set up. For single field and assisted field case we derive-the inflationary flow equations, new sets of

consistency relations and the field excursion formula. We also put constraints from the temperature anisotropy and polarization spectra, which shows that our analysis is consistent with the Planck 2015 data. Finally, using ΔN formalism we derive the expressions for inflationary observables in the context of multi-field GTachyons. [S. Choudhury with S. Panda (IOP, Bhubaneswar)]

S-duality invariant perturbation theory improved by holography

We studied the anomalous dimensions of unprotected low twist operators in the four-dimensional $SU(N) N = 4$ supersymmetric Yang-Mills theory. We constructed a class of interpolating functions to approximate the dimensions of the leading twist operators for arbitrary gauge coupling τ . The interpolating functions were consistent with previous results on the perturbation theory, holographic computation and full S-duality. We use our interpolating functions to test the recent conjecture by the $N = 4$ superconformal bootstrap that upper bounds on the dimensions were saturated at one of the duality-invariant points. [S. Thakur with A. Chowdhury (Harish-Chandra Res. Inst.), and M. Honda (Weizmann Inst.)]

Members

Mustansir Barma (till December 31, 2015), Rajeev S. Bhalariao, Kedar Damle, Basudeb Dasgupta, Saumen Datta, Deepak Dhar, Amol Dighe, Rajiv V. Gavai, Sourendu Gupta, Rishi Khatri (from August 3, 2015), Subhabrata Majumdar, Gautam Mandal, Nilmani Mathur, Shiraz Minwalla, Sreerup Raychaudhuri, Tuhin S. Roy, Rajdeep Sensarma, Rishi Sharma, K. Sridhar, Vikram Tripathi, Sandip P. Trivedi.

Adjunct Faculty:

Gunnar Bali (Univ. of Regensburg, Germany), Gautam Bhattacharyya (SINP, Kolkata), Sumit R. Das (Univ. of Kentucky, USA), Frederik Deneff (Leuven University, Belgium) [till January 6, 2016], Ribhu Kaul (Univ. of Kentucky, USA)[till September 30, 2015], Satya N. Majumdar (CNRS, Univ. of Paris, France), Prof. Jean-Yves-Ollitrault (CNRS, France), Alexandre Refregier (ETH, Zurich).

Visiting Fellows:

Himadri Barman (till February 4, 2016), Amit Chakraborty, Sabyasachi Chakraborty (from October 23, 2015), Sayantan Choudhury Karthik Inbasekar, Abhishek Iyer, Anirban Lahiri, Ushoshi Maitra (from August 3, 2015), Sourav Mondal (from March 2, 2016), Rohan Poojary (from November 18, 2015), Arunabha Saha, Prakash Sarkar (till July 8, 2015), Salman Silotri (till October 10, 2015), Somyadip Thakur,

Research Scholars:

Sandeepkumar Acharya (from August 2015), Mahammad Sabir Ali (from August 2015), Debjyoti Bardhan, Disha Bhatia, Soumya Bhattacharyya (from August 2015), Sounak Biswas, Ahana Chakraborty, Yogesh Dandekar, Anirban Das, Adwait Jayant Gaikwad, Pranay Gorantla (from August 2015), Subhajit Ghosh (from August 2015), Abhijit Guria, Indranil Halder (from August 2015), Lavneet Janagal, Bhawik Jani, Amith Kini (from August 2015), Sarbajaya Kundu, Mangesh Mandlik, Pranjal Nayak, Subhajit Mazumdar, Mainak Pal, Geet Rakala, Tousik Samui, Abhishek Samanta, Rickmoy Samanta, Sarath Sankar, Manibrata Sen, Ashish Shukla, Ritam Sinha, S. Nilakash Singh, Ronak M Soni, Anurag Tiwari, V. Umesh, Vishal M.V.

Scientific and Technical Staff,

Ajay Salve, Kapil Ghadiali, Rajendra Pawar

Administrative Staff:

Raju Bathija, Girish Ogale, Aniket Surve (from May 14, 2015)

National and International Involvement

Mustansir Barma: 1) Fellow of the Indian Academy of Sciences, Bangalore. 2) Fellow of the Indian National Science Academy, New Delhi. 3) Fellow of the National Academy of Sciences, Allahabad. 4) Fellow of the Academy of Sciences for the Developing World (TWAS), Trieste, Italy. 5) J. C. Bose Fellow of the Department of Science and Technology. *Rajeev S. Bhalaria*: 1) Member of the Advisory Committee for The 60th DAE-BRNS Symposium on Nuclear Physics, Sri Sathya Sai Institute of Higher Learning, Prasanthi Nilayam, 7-11 December 2015. *Sayantan Choudhury*: 1) Referee for Journal of High Energy Physics, Journal of Cosmology and Astroparticle Physics, Physics Letters B, International Journal of Modern Physics A, Journal of Astrophysics and Astronomy, Frontiers in Physics, Mathematical Reviews, and General Relativity and Gravitation. 2) Lead Editor for Advances in High Energy Physics. *Kedar Damle*: 1) Member, Organizing Committee, IUPAP Conference on Computational Physics CCP2015, Guwahati. 2) Member, Editorial Board of Texts and Readings in Physical Sciences (Hindustan Book Agency). 3) Member, Program Committee, ICTS-TIFR Bengaluru. *Deepak Dhar*: 1) Member of the Science Education Panel. 2) Member of the Council of Indian Academy of Sciences. 3) Member of Editorial Board of J. Stat. Phys. 4) Member of Editorial Board of J. Phys. A: Math. And Gen. *Amol Dighe*: 1) Fellow, Indian Academy of Sciences (IASc). 2) Fellow, Indian National Science Academy (INSA). 3) Member, Physical Sciences Research Committee, CSIR. 4) Member, C11 Commission (Particles and Fields) of IUPAP (International Union of Pure and Applied Physics). 5) Member, Secretary, Scientific Management Board, INO. 6) Member, Academic Core Committee, International Physics Olympiad, Mumbai, July 2015. 7) Member, International Advisory Committee, Lepton-Photon 2015, Ljubljana, Slovenia, August 2015. 8) Member, National Organising Committee, WHEPP 2015, IIT Kanpur, December 2015. *Rajiv Gava*: 1) Associate Editor of the journal "Nuclear Physics A". 2) Member, DAE-DST Task Force for CMS & ALICE. 3) Member, PAC-International Cooperation (Physics, Astronomy and Lasers), DST. 4) Fellow, Indian Academy of Sciences. 5) Fellow, Indian National Academy of Science. *Sourendu Gupta*: 1) Member of International Advisory Committee for The 33rd International Symposium on Lattice Field Theory, held in Kobe, Japan during 14--18 July, 2015. 2) Member of the International Advisory Committee for the 6th Asian Triangle Heavy-Ion Conference, held in New Delhi, India during 15--19 February, 2016. 3) Editor of Pramana 4) Member of the Sectional Committee 1, INSA 5) Fellow, Indian Academy of Sciences 6) Fellow, Indian National Academy of Science. *Subhabrata Majumdar*: 1) Core Member, ESA proposal 'THEIA - The Universe in Motion'. 2) Core member of the Red-Sequence Cluster Surveys -2 (RCS2). *Nilmani Mathur*: 1) Organizer, QCD and heavy ion session, WHEPP 2015, 4th -13th December, 2015. *Shiraz Minwalla*: 1) Member of the Indian Academy of Sciences Bangalore. *Sreerup Raychaudhuri*: 1) Member of the International Organising Committee for the Asia-Europe-Pacific Schools in High Energy Physics (AEP-SHEP) from 2011 till 2016. 2) Co-convenor for SUSY-2017 (to be held at TIFR in 2017). *Tubin Roy*: 1) Affiliated faculty member of Los Alamos National Laboratory, USA. 2) Referee for Physical Review Letters and Physical Review D. *Rajdeep Sensarma*: 1) Referee for Physical Review Letters, Physical Review B, Journal of Low Temp. Physics, Solid State Communications. 2) Member, Organizing Committee, International Conference on Emergent Phenomena in Quantum Hall Systems (EPQHS 6), TIFR Mumbai, Jan 2016. *Rishi Sharma*: 1) Organizer, QCD and heavy ion session, WHEPP 2015, 4th -13th December, 2015. *K. Sridhar*: 1) Member of Faculty Selection Committee, University of Chandigarh, September 2015. 2) Member of Academic Review Committee, Physical Research Laboratory, Ahmedabad, December 2015. *Sandip Trivedi*: 1) Fellow, Indian Academy of Sciences, Bangalore. 2) Fellow, Indian National Science Academy, New Delhi.

Visits

Mustansir Barma: visited Rudolf Peierls Centre for Theoretical Physics, University of Oxford for a month (May 2015). *Sayantan Choudhury*: visited IUCAA, Pune, during 13.02.2016 to 26.02.2016; IACS, Kolkata, during 24.10.2015 to 1.11.2015; IUCAA, Pune, during 1.09.2015 to 16.09.2015; ISI, Kolkata, during 18.05.2015 to 19.05.2015; IACS, Kolkata, during 20.05.2015 to 25.05.2015. *Kedar Damle*: visited ECT* Trento, October 2015; ICTP Trieste, September 2015; ICTP Trieste, August 2015. *Deepak Dhar*: visited C. I. R. M., Marseille for January 18-22, 2016. *Rajiv Gava*: visited Kavli Institute for Theoretical Physics China at the Chinese Academy of Sciences, Beijing, May 11-29, 2015; Panjab University, Chandigarh, August 17-18, 2015; Saha Institute of Physics, Kolkata, September 7-9, 2015; Central China Normal University, Wuhan, China, September 21-26, 2015; University of Regensburg, Germany, October 19-30, 2015; Pt. Vidyacharan Shukla University of Raipur, December 21-22, 2015; *Sourendu Gupta*: visited Kavli Institute for Theoretical Physics, Beijing, China during the period 11 May--5 June, 2015. *Kartik Inbasekar*: visited IMSc, Chennai Jan 25- Jan 29 2016; National Taiwan University, Taiwan Jan 04 - Jan 06 2016; ICTS Bangalore, India Dec 14-15 2015; IISER Mohali, Dec 6-12, 2015; ETH-Zurich, Switzerland Nov 23-26, 2015; DESY- Hamburg, Germany Nov 16-22. 2015; IOP Bhubaneswar, India Sept. 28-30 2015. *Abhishek M. Iyer*: visited CERN during 05 to 17 October 2015; INFN Padua during 17 to 20 October 2015; LPT Orsay during 20 to 27 October 2015; University of Cambridge during 21 - 23 March 2016; Kings College London during 23 to 28 March 2016; IPN Lyon during 3 to 5 April 2016; and IISc Bangalore during 2 to 12 May 2016. *Subhabrata Majumdar*: visited ICTP, Trieste, May 1 - June 9, 2015, June 19 - July 3, 2015; University of Bonn June 10 - 14, 2015; MPA and LMU, Munich, June 15 - 19, 2015; ETH, Zurich, July 4 - 10, 2015; SINP Kolkata, October 13 - 18, 2015; IUCAA, Pune, February 8 - 11, 2016. *Gautam Mandal*: visited IACS, Kolkata, February 2016; ICTS, Bangalore, December 2015; Perimeter Institute, Waterloo, Canada, October 2015; University of Kentucky, Lexington, USA, October 2015; IIT, Kharagpur, September 2015. *Nilmani Mathur*: visited University of Regensburg, Germany, October 24-November 4, 2015. *Sreerup Raychaudhuri*: visited University of Calcutta, Department of Physics (Kolkata, Jan 18 - 28, 2016); Physical Research Laboratory (Gandhinagar, Mar 16 - 18, 2016); Institute of mathematical Sciences (Chennai, Mar 22 - 25, 2016). *Tubin S. Roy*: visited Institute of Mathematical Sciences (IMSc), Chennai, March 22nd-25th, 2016. *Rajdeep Sensarma*: visited IACS Kolkata, December 2015; IMSc Chennai, March 2016. *Rishi Sharma*: visited PRL, Ahmedabad, September 2015. *K. Sridhar*: had a 3-day visit to IIT, Guwahati in July, 2015; 1-month visit to Theory Division, CERN, Geneva in August 2015; 3-day visit to Physical Research Laboratory, Ahmedabad in March, 2016. Vikram Tripathi visited Argonne National Laboratory and University of Chicago, 15 January 2015 - 23 December 2015.

Invited Talks

Mustansir Barma:

1. Order parameter scaling in Fluctuation-dominated Phase Ordering, Growing Length Scale Phenomena in Condensed Matter Physics, JNCASR, Bengaluru, October 2015.
2. Fluctuation-dominated Phase Ordering, Workshop on Nonequilibrium Statistical Physics, ICTS-TIFR, Bengaluru, October 2015.

Rajeev S. Bhalerao:

Creating and Probing Extreme Temperatures in the Laboratory, National Symposium on Physics (SymPhy-2015), IIT Bombay, May 9-10, 2015.

Amit Chakraborty: Boosted objects and Jet substructure technique, WHEPP - 2015, IIT Kanpur, December 6, 2015.

Sabyasachi Chakraborty:

1. R-symmetric SUSY, phenomenology and collider aspects, The First Workshop on Beyond Standard Model Physics at IISER Mohali, April 07, 2016.

2. Diphoton resonance at 750 GeV in the broken R-symmetric MSSM, talk given at conference 750 GeV Excess @LHC under scrutiny held at ICTS, May 05, 2016.

Sayantana Choudhury:

1. Modulus stabilization in higher curvature dilaton gravity, in quantum gravity session of ICGC 2015, IISER, Mohali, India from 14/12/2015 to 18/12/2015.

2. Constraining brane inflationary magnetic field from cosmoparticle physics after Planck, in cosmology session of ICGC 2015, IISER, Mohali, India from 14/12/2015 to 18/12/2015.

3. Effective Field Theory of Cosmological Collider Physics, in COSMOASTRO 2015: A discussion Meeting on Cosmology and Astroparticle Physics at IOP, Bhubaneswar, India on 5/11/2015.

Saumen Datta:

1. Heavy quarks in deconfined plasma: insights from lattice QCD, in CNT QGP Meet 2015, 16-20 November 2015, Variable Energy Cyclotron Centre, Kolkata.

2. Heavy quark systems in gluon plasma, in Heavy Flavor Meet 2016, 3-5 February 2016, Saha Institute of Nuclear Physics, Kolkata.

Kedar Damle:

1. Vacancy-induced low energy states in undoped

2. graphene, The International Workshop on Disordered Quantum Systems at IMSc Chennai, March 2016.

3. $c > 1$ multicritical phenomena in frustrated magnets, The ICTS-TIFR International Workshop on Field Theories of Condensed Matter Systems, Bengaluru, December 2015.

4. Sign-problem free Quantum Monte Carlo method for certain frustrated quantum magnets, The IUPAP Conference on Computational Physics CCP2015, Guwahati, December 2015.

5. Crossover from Dyson to Gade-Wegner asymptotics in the chiral orthogonal class of two dimensional disordered systems, The International Workshop on Non-equilibrium Statistical Physics NESP15 at ICTS-TIFR Bengaluru, October 2015.

6. Cluster algorithms for frustrated classical and quantum Ising magnets, The ECT* workshop on Recent Advances in Monte Carlo methods, Trento, October 2015.

7. Vacancy induced Majorana zero modes in an SU(2) symmetric Majorana spin liquid, The ICTP Workshop on "Frustration, Disorder and Localization: Statics and Dynamics", Trieste, September 2015.

8. Multicritical behaviour of easy-axis triangular lattice antiferromagnets, The ICTP Workshop "Novel Materials meet novel theories", Trieste, August 2015.

9. Basudeb Dasgupta:

10. What's the matter with Dark Matter?, Wednesday Colloquium, TIFR Mumbai, 23 March 2016.

11. Neutrinos in Cosmology, talk at Nu-HoRIZONS VI, Harishchandra Research Institute, Allahabad, 18 March 2016.

12. A Fresh Look at Dark Matter, Plenary talk at DAE-BRNS Workshop on High Energy Physics Phenomenology, WHEPP-

XIV, Indian Institute of Technology, Kanpur, 4 December 2015.

13. Neutrinos and Supernovae, Plenary talk at Topics in Astroparticle and Underground Physics 2015, Torino, 11 September 2015.

14. Particle Physics at the Intensity Frontier, at Kavli Frontiers of Science Symposium at US National Academy of Sciences, Irvine, 12 August 2015.

Deepak Dhar:

1. Modelling proportionate growth, Lecture Workshop on Research Trends in Physics, Guru Nanak Dev University, September 18-19, 2015.

2. Rocks, rivers and sand: Simple models of complex systems, Lecture Workshop on Research Trends in Physics, Guru Nanak Dev University, September 18-19, 2015.

3. Universality classes of growing avalanches in sandpile models, invited talk in the conference 'Growing length Scales in Physics', J.N.C.A.S.R., Bengaluru, October 8-10, 2015.

4. Dynamical networks of agents with degree preference, invited talk at Econophysics -2015, Jawaharlal Nehru Univ., New Delhi, November 27 - December 1, 2015.

5. Proportionate growth and pattern formation in growing sandpiles, invited talk at 'Nonequilibrium: Physics, Stochastics, and Dynamical Systems', C.I.R.M., Marseille, January 18-22, 2016.

6. Proportionate growth and pattern formation in growing sandpiles, invited talk at 'Complex Systems approach to self-organization-2016', held at I.I.T. Madras, February 1-4, 2016.

7. Network of agents with degree preference", Indian Statistical Physics Community Meeting, Bengaluru February 12-14, 2016.

8. Proportionate growth in sandpile patterns, invited talk at APS March Meeting, Baltimore, USA, 14-18 March, 2016.

Amol Dighe:

1. Physics potential of INO-ICAL, Workshop on Neutrino Programs with facilities in Japan, August 2015 (over video-conferencing).

2. Changing Flavours of Neutrinos: the journey to Nobel 2015 and beyond, Homi Bhabha Distinguished Public Lecture, IISER Pune, Nov 2015; UM-DAE CEBS Colloquium, February 2016.

3. Universe through the Neutrino Eye, Physics Colloquium, IISc Bengaluru, November 2015.

4. Astroparticle physics of neutrinos: Nobel 2015 and beyond, International Centre for Theoretical Sciences (ICTS) Colloquium, Bengaluru, November 2015; Saha Institute of Nuclear Physics (SINP) Colloquium, December 2015; Indian Association for Cultivation of Sciences (IACS), Kolkata, December 2015.

5. Supernova Neutrinos, Nu-HoRIZONS Workshop, HRI Allahabad, March 2016.

Rajiv Gavai:

1. A Simple Idea for Lattice QCD at Finite Density, in the workshop "sQGP and extreme QCD", KITPC/ITP-CAS, Beijing, May 14, 2015.

2. Some Conceptual Issues in Finite Density QCD, Saha Theory Seminar Series, Saha Institute of Physics, Kolkata, September 7, 2015.

3. QCD Critical Point : A Continuing Odyssey, in the workshop "Extreme QCD 2015", Central China Normal University, Wuhan, China, September 21, 2015.

4. Unravelling Medium Effects in Heavy Ion Collisions with Zeal, in the workshop "Looking Beyond Mini-Bangs, CGCs, Perfect Fluids, and Jet Tomo/Holo-graphy", Wuhan, China, September 25, 2015.

5. QCD Critical Point : An Exciting Odyssey in the Femto-World, Physikalisches Kolloquium, Fakultät fuer Physik, Universitaet Regensburg, October 26, 2015.

Sourendu Gupta:

1. Quantum Mechanics, Relativity, Supercomputing, IEEE International Conference on High Performance Computing, Bengaluru, 17 December, 2015.
2. Screening Masses, Festcolloquium, Department of Physics, University of Bielefeld, Germany, 30 November, 2015.
3. What happens when you cool mixtures of elementary particles, colloquium, Institute of Theoretical Physics, University of Heidelberg, Germany, 26 November, 2015.
4. Freezeout, coalescence and Nuclei, Workshop on New Progress in Heavy-Ion Collisions, Central China Normal University, Wuhan, China, 6 October, 2015.
5. The Gluon Plasma", seminar, Kavli Institute of Theoretical Physics, Beijing, China, 3 June, 2015.
6. Criticality and the equation of state of dense QCD, seminar, Department of Physics, Peking University, Beijing, China, 26 May, 2015.
7. Criticality and the equation of state of dense QCD, seminar, Kavli Institute of Theoretical Physics, Beijing, China, 26 May, 2015.

Karthik Inbaskar:

1. 2 to 2 scattering in supersymmetric matter Chern-Simons theories at large N, at :
 - IMSc, Chennai, India, January 28, 2016.
 - Taiwan University, Taipei, Taiwan, January 5, 2016.
 - Fourth Indo-Israel conference in string theory, Goa, India, December 23, 2015.
 - International Center for Theoretical Sciences, Bengaluru, India, December 14, 2015.
 - Strings Meeting 2015, IISER - Mohali, India, December 9, 2015.
 - ETH - Zurich, Switzerland, November 25, 2015.
 - DESY, Hamburg, Germany, November 17, 2015.
 - Young Researchers' Conference, Institute of Physics, Bhubaneswar, India, September 29, 2015.
2. On-Shell supersymmetry and the S matrix, IMSc, Chennai, India, January 27, 2016.
3. Chern-Simons Matter theories, IMSc, Chennai, India, January 25, 2016.

Rishi Khatri:

1. The information hidden in the anisotropies of the CMB spectral distortions, CMB workshop "B mode from Space", IPMU Tokyo Japan, December 10, 2015.
2. New constraints on CMB spectral distortions using Planck data, NCRA colloquium, NCRA Pune, February 1, 2016.

Subhabrata Majumdar:

1. Non-gravitational Energy Feedback in the ICM, Colloquium, Argelander Institute for Astronomy, Bonn, June 11, 2015.
2. ICM Physics and Modelling Workshop, MPA, Garching, June 16, 2015.
3. Two Topics in Cluster Physics - What is CoolCore cluster & End of Preheating, Cosmology Seminar, Observatory LMU, Munich, June 18, 2015.
4. Probing the Circumgalactic Baryons, HEP Seminar, MPA, Garching, June 19, 2015
5. Energetics at the Cluster Outskirts, ETH, Zurich, July 7, 2015.
6. Searching for Baryons, Plenary talk, AAPCOS, SINP, Kolkata, October 15, 2015.
7. Dark Matter Velocities in our Galaxy, Dark Matter@BUE, Cairo, December 15, 2015.
8. Energetics in the Largest Cosmic Structures, Plenary Talk, LSS@IUCAA, February 12, 2016.

Gautam Mandal:

1. Thermalization, entanglement and holography, Colloquium, IACS, Kolkata, February 24, 2016.
2. 2D critical quench: thermalization, entanglement and holography, ICTS Discussion meeting: New Questions in Quantum Field Theory from Condensed Matter Theory, Bangalore, December 31, 2015.
3. Thermalization and entanglement: exact results in 2D critical quench, Indo-Israel String meeting, Goa, 21 December 2015.
4. Non-standard thermalization in critical quench in 2D, seminar, Perimeter Institute, Canada, 27 October 2015
5. Gregory-Laflamme as the confinement/deconfinement transition in holographic QCD, Plenary talk, QCD Applications of AdS/CFT to QCD and condensed matter physics, CRM, University of Montreal, October 20, 2015
6. Gregory-Laflamme as the holographic dual of deconfinement transition, Seminar, University of Kentucky, Lexington, USA, October 2015.
7. Thermalization in integrable models and conformal field theories, talk, Workshop: SPOCK, Cincinnati, USA; 17 October 2015.
8. Thermalization in integrable models and conformal field theories, Seminar, IIT Kharagpur, 14 September, 2015.
9. Thermalization in integrable models and conformal field theories, Plenary talk, Mid-year meeting, IASc, 23 June, Bengaluru.
10. Some results on thermalization in 2D CFT and their holographic interpretation}, Plenary talk, 23 June, Strings 2015, ICTS, Bangalore.

Nilmani Mathur:

1. Heavy quark physics using large scale simulations : XXVII IUPAP Conference on Computational Physics CCP2015, IIT Guwahati (December 2-5, 2015).
2. Hadron spectroscopy with heavy flavours in lattice : 2nd heavy flavour meeting, Saha Institute (Feb 3-5, 2016).

Shiraz Minwalla:

1. A Charged 'Membrane Paradigm' at large D, Quantum Field Theory, String Theory and Beyond, Jerusalem, Israel, Feb 2016.
2. A Charged 'Membrane Paradigm' at large D, String Math, Sanya, China, Jan 2016.
3. A Membrane Paradigm at large D, KIAS - KIAS-YITP Joint Workshop 2015: Geometry in Gauge Theories and String Theory, Seoul, Korea, Sept 2015.
4. A 'Membrane Paradigm' at large D, Andyfest, Harvard, Cambridge, USA, July 2015.
5. Unitarity, Crossing Symmetry and Duality in the scattering of supersymmetric Chern Simons Matter theories, Amplitudes 2015, Zurich, Switzerland, July 2015.
6. A membrane paradigm at large D, Gauge/Gravity Duality 2015, GGI Florence, Italy, April 2015.

Sreerup Raychaudhuri:

1. Much Ado about Nothing – The Curious Case of the Electroweak Vacuum, Seminar at the Department of Physics, University of Mumbai. August 2015.
2. The nu Story, Colloquium at ISI, Kolkata, January 2016.
3. The Early Days of Particle Physics in India, Conference Talk at the Department of Physics, University of Calcutta (Jan 2016); Colloquium at the Department of Physics, Presidency University, January 2016.
4. Discovering the Attoworld, Institute Colloquium at IACS, Kolkata, January 2016.
5. Flavour-changing Decays of the Top Quark in the LHC Context, Conference Talk at PRL, Gandhinagar, March 2016.
6. The 750 GeV Resonance – Portent or Chimæra?, Conference Talk at IMSc, Chennai. March 2016.

Tubin S. Roy:

1. Supersymmetry 101, Seminar given at the Indian Institute of Technology, Bombay, India, October 12, 2015.
2. Generalized Supersoft Supersymmetry, Seminar given at the meeting "Frontiers in High Energy Physics (FHEP), Institute of Mathematical Sciences (IMSc), Chennai, March 24th, 2016.

Arunabha Saba:

Black Holes as Membranes in large D, 4th Indo-Israel Conference on String Theory, Goa, India, 22nd December, 2015

Rajdeep Sensarma:

1. Spin-Density Wave Instabilities of Repulsive Fermions in Biased Bilayer Honeycomb Lattice, IACS Kolkata, December 2015.
2. Spin-Density Wave Instabilities in Biased Bilayer Graphene at Conference on Emergent Phenomena in Quantum Hall Systems (EPQHS-6), TIFR Mumbai, January 2016.
3. Superfluidity in Ionic Hubbard Model: RVB Physics rears its head again at Conference on Quantum Disordered Systems, IMSc Chennai, March 2016.

Rishi Sharma:

1. Recent developments in effective field theory at finite T and μ , at The 6th Asian Triangle Heavy-Ion Conference, 15-19 February 2016 IIC, New Delhi.
2. Quarkonia in heavy ion collisions at WHEPP 2015, IIT Kanpur, 4-13 Dec, 2015.

3. Invited Talk on Quarkonia in heavy ion collisions at Heavy Quarks 2016, SINP Calcutta, 3-5 February, 2016.

K. Sridhar:

1. Near Threshold Production of Tops, Meeting on Top Physics, Physical Research Laboratory, Ahmedabad, March, 2016.
2. Gauge Symmetry: Seeking and Hiding, The Physical Research Laboratory, Ahmedabad, March 2016.
3. Bulk Randall-Sundrum Model, The Workshop on Frontiers in High Energy Physics, Institute of Mathematical Sciences, Chennai, March 2016.

Vikram Tripathi:

Magnetoresponse of strongly disordered superconductors, Conference on quantum disordered systems, IMSc (Chennai), on 03 March, 2016.

Sandip Trivedi:

1. Constraints on Inflationary Correlators From Conformal Invariance, Strings 2015 Conference, ICTS, Bangalore, June 19-27, 2015.
2. Symmetry Constraints in Cosmological Correlators, National Strings Meeting, IISER, Mohali, December 5-12, 2015
3. Entanglement Entropy in Gauge Theories, Indo-Israeli Workshop on Quantum Field Theory and Strings Theory, Goa, Dec. 21-26, 2015.

Conferences Organized by the Department

"6th Asian Triangle Heavy-Ion Conference", New Delhi, 15-19 February, 2016.

[This meeting continues the tradition of bringing the Asian heavy-ion physics community together to discuss new developments in the field. Physicists from CIJK (China, India, Japan and Korea) are critical partners in the international group of physicists working to understand hot and dense QCD. This meeting provides

a platform for discussions and reviews of these studies, and provides a place for young as well as experienced researchers from these countries to meet each other.]

The 4th Indo Israel Meeting on Quantum Field Theory and String Theory, Goa, Dec 2015
Strings 2015, ICTS, Bangalore.

Non-DAE Research Projects

R.S. Bhalerao, R.V. Gawai, S. Gupta:

1. Title: International Associated Laboratory (LIA) Indo-French Collaboration in Theoretical High Energy Physics (IFTHEP), Funded by : CNRS (France), Duration: 1 January 2015 to 31 December 2018, Coordinators: Rohini Godbole and Fawzi Boudjema.
2. Title: Indo-French Network on High Energy Physics (INFRE-HEPNET), Funded by: Indo-French Centre for the Promotion of Advanced Research, Duration: 1 January 2016 to 31 December 2019, Principal Coordinators: Sudhir Vempati and Fawzi Boudjema.

Gunnar S. Bali (University of Regensburg) and Rajiv V. Gawai: Institutspartnerschaft, (Research Linkage Grant) between the University of Regensburg, Germany and TIFR. Funded by Alexander von Humboldt Foundation, Germany, Sept. 2014-August 2016.

Basudeb Dasgupta:

1. Neutrino-Neutrino Interactions in Stars and Galaxies, DST and Max-Planck-Society, 2015-2018;
2. Ramanujan Fellowship awarded by the Department of Science and Technology (continues from 2015).

Shiraz Mirmalla: UGC/ISF Indo Israel Grant.

Anindya Datta (U. of Calcutta) and Sreerup Raychaudhuri (TIFR): "Glimpsing New Physics Through the Large Hadron Collider." Funded by BRNS: 2013 – 2016.

Vikram Tripathi and B. Aronzon (Kurchatov Institute, Moscow): Spin-dependent phenomena in quasi two-dimensional structures and films with magnetic impurities, funded by Department of Science and Technology (India) and Russian Foundation for Basic Research (Russia), November 2013 - November 2015 (Funding amount: Rs. 832400).



Research Facilities

National Balloon Facility, Hyderabad

Technical Activities

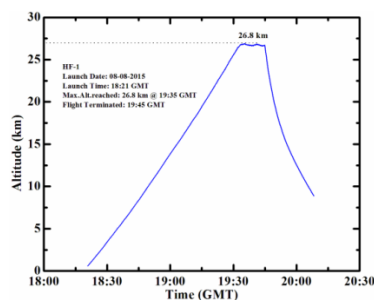
Balloon Designing and Fabrication

The following balloons with detailed specifications as given below were custom designed and fabricated in TIFR Balloon Facility during April 2015 to March 2016:

1. Three balloons of volume 47,957 m³ were fabricated using 25 microns film as shell for carrying 350 kg payload up to an altitude of 30.9 km. Out of 3 balloons fabricated; one balloon was supplied to World View Enterprises, Arizona, USA and the other two to In-Genius, Singapore.
2. A balloon of volume 300 m³ was fabricated using 8 microns film as shell to carry 8 kg payload (BATAL-ZF) to reach an altitude of 17 km.
3. Two balloons with volume of 3,026 m³ were fabricated using 13 microns film as shell to carry 60 kg payload (BATAL-HF) to reach an altitude of 25.3 km.
4. A balloon with volume of 8,728 m³ was fabricated using 80 (20x4) microns film as shell to carry 2000 kg payload to reach an altitude of 11.3 km.
5. A total of 8 sounding balloons with volume of 4,077 m³ were fabricated using 5.0 microns film.

Balloon Launches and Recovery Operations

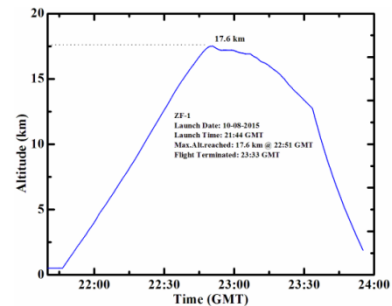
During the reporting period following balloon launches were conducted and the details of the launches are described below:



Time –Height curve of HF-1 experiment

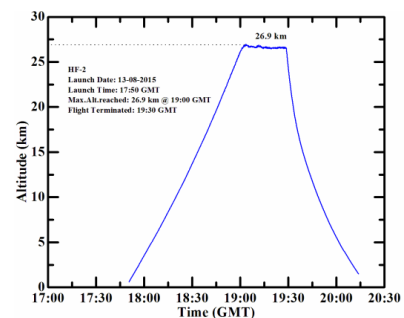
1. Flight No- 486: Balloon-borne experiment for Asian Tropopause Aerosol Layer (BATAL-HF1) in collaboration with NARL, University of Wyoming and NASA-SSA was conducted using balloon of volume 3,026 m³ fabricated with 13 microns film as shell. This flight was successfully launched on 08-08-2015 at 23:50 hrs. (IST) with a total suspended payload of 41.4 kg. The flight was terminated using

the single board timer after reaching the 26.8 km altitude at 01:16 hrs. All the sub-systems worked well during the flight. The payload was recovered 155 km west of Hyderabad. The height-time curve of the flight is shown below.



The complete ascent and descent phase of ZF flight.

2. Flight No- 487: Balloon-borne experiment for Asian Tropopause Aerosol Layer (BATAL-ZF) was conducted using balloon of volume 300 m³ fabricated with 8 microns film as shell. This flight was successfully launched on 11-08-2015 at 03:16 hrs. (IST) with a total suspended payload of 8.0 kg. The flight was terminated using the single board command timer after reaching the 17.6 km altitude at 04:36 hrs. All the sub-systems worked well during the flight. The payload was recovered 166 km west of Hyderabad. The height-time curve of BATAL-ZF experiment is shown below.



Time –Height curve of HF-2 experiment

3. Flight No- 488: Balloon-borne experiment for Asian Tropopause Layer (BATAL-HF2) was conducted using balloon of volume 3,026 m³ fabricated with 13 microns film as shell. This flight was successfully launched on 13-08-2015 at 23:19 hrs (IST) with a total suspended payload of 44.4 kg. The flight was terminated using the single board

command timer after reaching the 26.9 km altitude at 00:58 hrs. All the sub-systems worked well during the flight. The payload was recovered 176 km west of Hyderabad. The height-time curve of BATAL-HF2 Experiment is shown below.

For all the above, flight payloads and accessories were recovered in good condition. For this campaign, along with the three zero pressure balloon flights, seven rubber balloon launches were also conducted, one including a rubber balloon launch with boomerang.

Tropical Tropo-pause Dynamics Experiment

As a part of collaborative research project of SPL-VSSC and TIFR Balloon Facility under Tropical Tropopause Dynamics (TTD), balloon-borne experiments were conducted from Balloon Facility between March, 2015 and January, 2016, to investigate the vertical distributions of ozone, water vapor in the upper troposphere and lower stratosphere (UTLS) region along with other meteorological parameters.

Balloon Hoisting

A balloon hoisting was carried out on 7 December, 2015 for NARL. A balloon of volume 275 m³ with 76 microns (38 microns X 2 layers) was used for hoisting. The payload weight was 50 kg. The balloon was hoisted up to an altitude of 750 m AGL from TIFR Balloon Facility.

Research and Developmental Activities:

Balloon Designs and Developments

1. Large size balloon: A zero pressure balloon has been designed for carrying a payload of 2000 kg up to an altitude of 11 km. The balloon has been designed with 80 microns (20 microns X 4 layers) and fabricated.

2. Load tape fabrication and testing: A load tape of 380 kg breaking strength has been fabricated. This has been developed for balloons carrying 4000 kg payload and above. Tensile tests carried out for this load tape at room temperature and at low temperature (-80°C) gave satisfactory results.

Recent Developments in Balloon Support Instrumentation

Telemetry ground station upgradation:

With implementation of new down converter and digital Tracking receiver a better pointing accuracy during auto tracking of the balloon and an increase in gain of 10dB has been achieved leading to improved performance. We now have standby for the complete S-band receiving chain.

Customized orientation platform

Specific to a balloon experiment planned, control electronics has been designed and developed to obtain a 2 rpm uniform payload gondola rotation at all altitude levels.

GNSS receivers

GNSS receivers that can accept Navstar, Galileo, BeiDou and QZSS satellite signals have been introduced in order to have redundancy and achieve better positional accuracy in balloon flights. This 72 channel receiver is SBAS ready and can work beyond 18 km altitude, needs to be flight-tested.

Time Tagged Command

A command system based on 375 MHz SD4 modem has been developed to cater to experimenters having small payloads. Commands sent with time tagged get executed when the time matches with the onboard RTC. It has a programmable timer for flight termination in case command fails. The status also is telemetered down making it a low capability stand alone TM/TC. The system has been satisfactorily tested in lab and will be flight-tested in the proposed test flight.

Non-magnetic ballast Control

In cases where the presence of a large mass of iron ballast under the gondola can affect an onboard balloon experiment, small pellets of glass or sand can be used instead and controlled by a non-magnetic system. To meet this requirement a prototype linear actuator using commercial components was developed and tested. A flight model will be made using space qualified components. With this design, we can also have different drop rate depending on the gross load and experimental needs. It can be used with iron ballast too.

Mechanical and Electrical

This group is responsible for payload gondola fabrication, mechanical integration of flight packages, hydrogen gas readiness for flights, making machined components, civil work, maintenance of electrical supply to the campus, generators, LAN network, cable network and telephone lines. The field illumination and standby power were also arranged during balloon flight work.

Fabrication of Gondola for Development Flight

One Gondola of size of 1m X 1m X 1.5m has been fabricated for test flight for flight performance validation of several newly developed electronic packages as well as mechanical flight packages.

Payload Orientation System

One set of payload orientation system has been machined and assembled in workshop. This unit is aimed to use for pointing of medium weight payloads of 150-300 kg. The weight of this new payload orientation assembly is 18 kg compared to 35 kg used previously.

Civil and electrical work

The construction of five new guest rooms with modern amenities is in progress. This group is coordinating with the builder and regularly monitoring the quality of the construction and materials used. Air cooling plant impeller was refurbished. The rewirable Switch Fuse Units (SFU's) – 63 and 100A of AC plant were replaced with new HRC SFU's. One 3 KVA portable Generator was procured and installed for illumination during night time balloon launch operation. The old 100 lines EPABX has been replaced by new NEC 200 lines EPABX.

Research Activities

This Group is mainly involved in the measurements of aerosols and trace gases as part of National network of ISRO- Geosphere Biosphere Program (ISRO-GBP). The data monitored from various equipment for atmospheric science studies are used for research activities at TIFR Balloon Facility and also sent to the Network data bank periodically. It is involved in maintenance and operation of Astronomical telescope, Thermovac chamber, X-ray beam line, Vibration table and Clean room. Following is the summary of the work carried out during the reporting period.

Seasonal variation of wind in troposphere

Six years (2008-2013) wind data from GPS-radiosonde were used to establish the climatology of seasonal variations of zonal and meridional winds in the troposphere and stratosphere over tropical station Hyderabad. The zonal wind showed the strong seasonal variation, while a weak seasonality was observed in meridional wind. The average zonal wind over Hyderabad up to 10 km altitude was westerly in zonal component and northerly in meridional component throughout the year. For the altitude range 10-42 km, complete easterlies were observed during the South-West (SW) monsoon season (June - September). Interestingly, the signature of low level jet (LLJ), tropical easterly jet (TEJ) and subtropical westerly jet (STJ) were clearly observed during the study period. The LLJ, TEJ and STJ were stronger and longer lived during normal monsoon years.

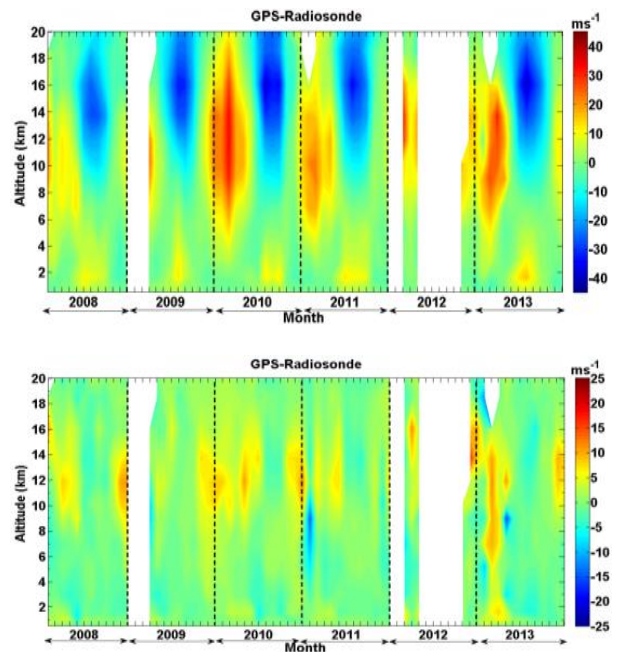


Fig: Time-Height cross section of zonal and meridional winds from GPS-Radiosonde over Hyderabad during 2008 - 2013 from surface to 20 km altitude.

Measurements of black carbon aerosol in the Arctic

Black carbon (BC) aerosol particles are emitted from both natural and anthropogenic incomplete combustion of carbon-based fuels. They influence the radiation budget of the earth's atmosphere by strongly absorbing solar radiation in the visible wavelengths and by changing the snow albedo through the deposition of BC. It is critically important to establish accurate measurement of BC for improved estimates of its effects on the climate of the Arctic, where BC concentrations are generally lower than those at mid-latitudes in the northern hemisphere. The simultaneous measurements of mass concentrations of black carbon (BC) aerosol particles (M_{BC}) were carried out using a continuous soot monitoring system (COSMOS) at Barrow (71°19'N, 156.6°37'E) and Zeppelin (78°55'N, 11°56'E) in the Arctic during three year period from 2012-2015.

Diurnal variation

Monthly mean diurnal variations of M_{BC} at Barrow and Zeppelin for January, April, July, and October 2013 do not show significant well-defined diurnal variations ($< 10\%$ of the mean) at these sites throughout the year. The absence of diurnal variability in M_{BC} suggests small influence of localized BC emissions on the measured M_{BC} . Considering this, we interpret M_{BC} at these sites to be regionally representative values of M_{BC} .

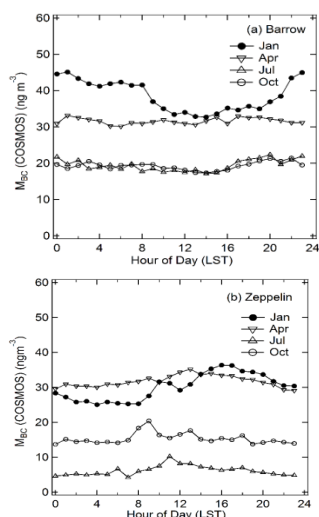


Fig: Monthly mean diurnal variation of M_{BC} (COSMOS) calculated from hourly mean at (a) Barrow and (b) Zeppelin for January, April, July and October 2013.

Measurements of Size Distribution of BC in rain / snow samples at Zeppelin

An improved measurement of BC aerosol particles in snow is critically important to improve our quantitative understanding of the wet deposition of BC in the Arctic. The number / mass size distributions of BC in rain and snow samples collected at Zeppelin on 16 and 17 September 2014, respectively were measured using a single particle soot photometer (SP2) coupled with a nebulizer. The mass median diameters of BC

particles in snow were larger than those in rain. The observed BC mass is found to be in the range of 75 – 2000 nm which indicates the need of BC measurement up to about 2 μm .

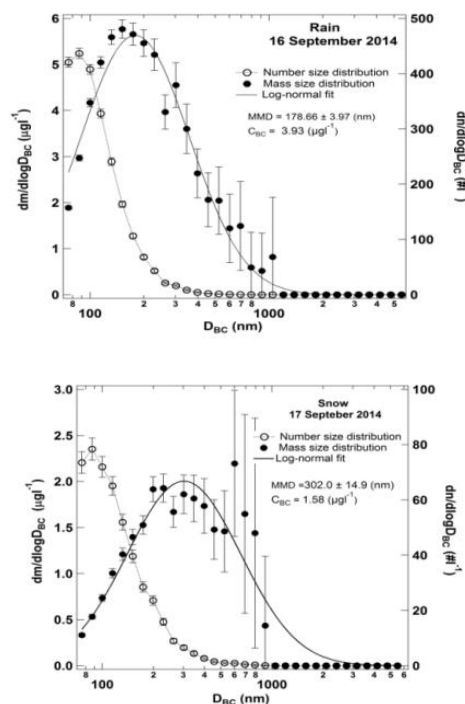


Fig: Number and mass size distributions of BC in rainwater and snow samples at Zeppelin.

Members

D. K. Ojha, B. Suneel Kumar, P. M. Kulkarni, D. Anand, V. Anmi Reddy, T. V. Rao, K. Sakram, P. R. Sinha, Nagendra Neerudu, Stalin Peter G, Ashish A. Rodi (at Mumbai Hq), B. V. N. Kapardhi, Dharmesh B. Trivedi, Santosh K. Koli, Rohit Kumar Lodha, S. Selva Kumar, D. L. Hari Naik, T. Malleshham, T. Chandra Mohan, P. V. S. Prasad, Jagan Tenukunta, K. Uma Maheshwara Rao, A. Sampath, N. Saravanan, T. Ashok, G. Praveen Reddy, MD. Jahangir Pasha, K. Goutham Reddy, G. Sagar, Santosh Maruti Patil, P. Balachary.

Administration & Auxiliary Staff

D. Manohar, M. Rama Krishna, K. Kishore Kumar, N. Subramaniyan, P. Ravinder Babu, B. Pramod, K. Srikanth, S. K. Mukhtar Ali, K. Shekar, B. Venkataiah, P. Laxman, K. Nava Krishna, Rakesh Roshan Mishra, D. Balakrishna, Md. Riyaz Pasha, P. Venkatesh, Prathamesh Gawde.

Vehicle Drivers

K. Venkatesham, Dilip Vithal Rao

Workshop / Conference / Out-reach program:

Conducted an outreach program at Balloon Facility for the nurture camp students of Astronomy Olympiad 2015 on 11 December 2015.

Non DAE Research Projects:

R.K.Manchanda, P.R.Sinha and S.Sreenivasan:

1. *Aerosol Radiative Forcing* over Hyderabad and its impact on Mega city climate under ISRO-GBP-ARFI, 2007-2017.

2. Long term measurement of Ozone, NO_x, SO₂ and total solar radiation at a remote site to study the emission fluxes and change in their concentrations. jointly with IICT Hyderabad (in collaboration).



Low Temperature Facility

Low Temperature Facility provides liquid helium, liquid nitrogen and cryogenic support services to various facilities and laboratories of the institute.

LTF meets the cryogen demands of more than 40 users under various research facilities of the institute. Helium gas is liquefied with the Linde make, Model-L280 helium liquefier (installed in the year 2008) and Liquid nitrogen from Stirling Cryogenics make, Model: STIRLIN-8 liquid nitrogen plant (installed in the year 2010)

Liquid Helium

A total of 1,08,022 liters of liquid helium was consumed by various users of the institute during the report period, which is about 8.5% higher than that of last financial year. LTF handles largest numbers research users in India supporting more than 45 active helium setups within TIFR. To cater the helium dispensation to the users, LTF operates more than 30 liquid helium dewars of various sizes and capacities. LTF dispensed more than 840 liquid helium dewars annually, to cater the users in an uninterrupted and on-demand basis. LTF's helium gas recovery system handles a large quantity of boil-off helium gas sent by various laboratories through the large network of recovery lines connecting various building / blocks of the institute with LTF. Our continuous attempt to reduce the helium gas loss enabled to achieve the loss rate of 11%, which is about 1.8% lower than that of previous financial year.

Decontamination of the helium liquefier; cold seal replacement of helium liquefier; Breakdown maintenance of regenerative gas purifier unit; preventive maintenance of the high-pressure helium recovery compressors; installation of additional flowmeters for gas monitoring; repair of high flow impure helium gas regulator; etc., are some of the few major jobs taken up during this period.

Liquid Nitrogen

To cater the institute's liquid nitrogen demands, LTF produced about 2,40,925 liters of liquid nitrogen in this year. About 50 liquid nitrogen dewars are in regular service to facilitate various nitrogen users within the institute. During the year 2015-2016, LTF dispensed more than 600 liquid nitrogen dewars. In addition to the above, LTF also supplied large quantities of liquid nitrogen through the vacuum jacketed liquid nitrogen pipeline for the Pelletron Accelerator Facility (PLF) and to the LINAC hall#2 for the beam hall (INGA) experiments. The Cryogenerator #2 of STIRLIN-8 liquid nitrogen plant suffered a major breakdown with the breakage of engine connecting rod, piston liner, gudgeon pin along with the minor damage to the connected parts. Critical spare parts of the damaged cryogenerator is being procured. The plant operation and liquefaction of nitrogen was restored with the cryogenerator #1. In order to compensate the regular demands of nitrogen supply, LTF procured about 50,000 liters of liquid nitrogen from external sources.

Developmental Activities in Cryogenics

Calibration of cryogenic temperature sensor for BARC, Mumbai

LTF actively participated in the development of cryogenic temperature calibration setup in co-ordination with Shri. Arun Patade (DCMP&MS). More than 50 silicon diode sensors of Cryo-Technology Division, CrTD, BARC Mumbai were calibrated using in-house developed magnetoresistance setup at TIFR. These calibrated sensors were successfully installed, tested at various cryogenic heat exchangers at BARC.

Cold leak repair of Light weight helium Dewar

The cold leak repair of lightweight aluminium alloy, liquid helium dewar C14 is being attempted by LTF. The dewar was observed to have cold leak at its neck tube joint, which was plugged using Stycast® Epoxy sealant and successfully tested with Mass Spectrometer Leak Detector (MSLD). The dewar is now currently in the final stage of its assembly.

Cryogenic Support Services

Besides these main cryogenic plants. LTF also handles and maintains other auxiliary support services such as Mass-Spectrometer-helium-leak-detector (MSLD) and vacuum related services to various users whenever required. Mandatory HST

testing of five high pressure helium gas quads were carried out and successfully brought back into regular service after leak testing, evacuation and purging for safe helium use. LTF continue to provide technical assistance in cryogenics related

jobs to the various laboratories/departments of the institute and also to other institutes such as IISER Trivandrum; IPR, Gandhinagar including the engineering support services to TCIS Hyderabad, whenever required.

Members

Engineering: K V Srinivasan (Engineer In-charge), K A Jaison, V A Arolkar

Technical: D S Sandal, Bosco Augustine, A G Hedukar, D G Puroa.

National and International Involvement

K V Srinivasan: life member in Indian Cryogenics council; an expert member of the special committee constituted by IPR, Gandhinagar for their Helium Plant Up gradation of SST-1 in 2015; member – Expert Committee on formulation of comprehensive plan for setting up a new cryogenic facility at IISER, Thiruvananthapuram, 2015; member of Indian Cryogenic Council (Western Zone) in the zonal election held in August 2015; office bearer of Indian Cryogenic Council (Western Zone) as Treasurer – ICC(WZ).

Visits

K V Srinivasan attended the 26th International Cryogenic Engineering Conference International Cryogenic Materials Conference 2016 (ICEC 26 - ICMC 2016) during 7 – 11, March 2016 at New Delhi, India

Invited Talks

K V Srinivasan:

1. “Cryogenic refrigeration cycles for the liquefaction of gases” on the National Workshop on Cryogenics in Space Exploration & Superconductivity (CRYO-2016) organized by the Center for Rural & Cryogenic Technologies, Jadavpur University, Kolkatta on March 28, 2016
2. “Achieving the ultimate low temperature” invited talk - cum - interactive session as a part of INSPIRE Internship Science Camp -2015 sponsored by the DST, GOI held at Guru Nanak Khalsa College, Matunga, Mumbai on 10th December, 2015.



National Facility for High Field NMR

Kinetics of Protein Aggregation

Using different biophysical tools, the effects of osmolytes, betaine, citrulline, proline and sorbitol which differ significantly in terms of their physical characteristics such as, charge distribution, polarity, H-bonding abilities etc, on the fibrillation of insulin, have been studied. The results of these observations have significant biological implications, since insulin fibrillation is known to cause injection amyloidosis and our data may help in designing lead drug molecules and development of potential therapeutic strategies. (Sinjan Choudhary & R.V. Hosur)

Structure, dynamics and interaction of Ca²⁺-binding proteins

In an attempt to understand the functional similarity of the calcium binding protein, EhCaBP6 with CaM, the 3D solution structure of EhCaBP6 has been determined using NMR. The structural similarity between EhCaBP6 and CaM, despite their low sequence similarity, suggests towards their similar functions during the cell cycle. Intriguingly, the EhCaBP6 binds and hydrolyzes adenosine and guanosine triphosphates. This is the first known instance of a CaBP that hydrolyzes adenosine and guanosine triphosphates. This serendipitous discovery of EhCaBP6 as an NTPase gave birth to several questions to be addressed which are being investigated. (Deepshikha Varma & K.V.R. Chary)

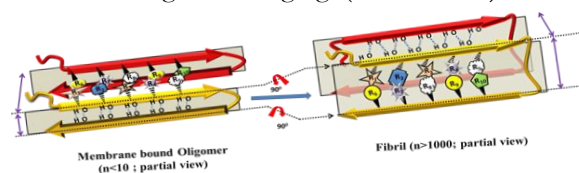
Functional manipulation of a putative UV inducible protein (UVI31+) from *Chlamydomonas reinhardtii*

Chlamydomonas reinhardtii is a single celled alga that undergoes apoptosis in response to UV-irradiation. UVI31+ in *C. reinhardtii* exhibits DNA and RNA endonuclease activity, which is induced upon UV-stress. UVI31+ that normally localizes near cell wall and pyrenoid regions gets redistributed into punctate foci within the whole chloroplast, away from the pyrenoid, upon UV-stress. The 3D solution state NMR structure of the putative UV inducible protein UVI31+ from *C. reinhardtii* revealed $\alpha_1\beta_1\alpha_2\beta_2\alpha_3\beta_3$ fold similar to that of BOLA and KH-domain type II protein families. Three α -helices of UVI31+ form one side of the protein surface while three-stranded β -sheet forms other side. A strong hydrophobic core, providing a compact 3D protein structure, glues these secondary structural elements. Twenty-three residues (D54-H76) long polypeptide stretch connecting β_1 and β_2 strands is found to be highly flexible as confirmed by ¹⁵N-relaxation NMR

study. UVI31+ is found to recognize the DNA primarily by its b-sheet. The search for the catalytic triad in UVI31+ revealed the involvement of following residues: Ser 114, His 95 and Thr 116. Further, the S114A mutant of UVI31+, chosen for mutational study as Ser hydroxyl group is implicated as nucleophile in the catalysis of nucleases action, intriguingly showed significant loss of DNA endonuclease activity. (Himanshu Singh & K.V.R. Chary)

Solid state NMR Investigations on Amyloid Fibrils

Structural details (Fig below) have been obtained of the oligomers of A β and insight into their transition to fibrils also elucidated through a combination of solid-state NMR, IR, and SERS methods along with imaging. (P.K. Madhu)



Oligomer to fibrils transition model in A β_{40}

Solid-State NMR: Methods Development

Heteronuclear spin decoupling schemes have been refined and improved by the addition of supercycled rCW scheme. This has been shown to be more robust and efficient than those in vogue. This scheme also takes care of rotary-resonance-recoupling effects and give good decoupling performance at both high and low MAS frequencies. Simultaneous acquisition of different coherent pathways was implemented using dual receiver strategy and making efficient use of unused pathways in a multi-dimensional experiment. This allows recording of several 2D experiments within one pulse scheme thereby leading to substantial reduction of experimental time. Proton-detected multi-dimensional experiments have been recorded at moderated MAS frequencies making use of homonuclear dipolar decoupling schemes during the proton acquisition period. This is expected to add another degree of freedom in multi-dimensional solid-state NMR experiments on biomolecules. Pulse schemes were introduced to map out the order parameter of proteins making use of homonuclear spin decoupling and dipolar recoupling which is an improved version of the DIPSHIFT separated local-field spectroscopy method. (P.K. Madhu)

Members

R.V. Hosur, K.V.R. Chary, P.K. Madhu

Manoj Naik, Mamata Joshi, Devidas Jadhav, Jayesh Malkan, Mohan Dabholkar

Administartion

Jayesh Malkan

National & International Involvement

R.V. Hosur: Director: UM-DAE Centre for Excellence in Basic Sciences, University of Mumbai, Kalina, Chairperson: INSPIRE Faculty Selection Committee, Council, UoM-DAE CBS, Mumbai, 2009-, Academic Board, UoM-DAE CBS, 2009-, Member: DAE-SRC young scientist award committee, Member: NASI young scientist award selection committee, Member: NASI Fellowship Scrutiny Committee, Member: Editorial Board, The Scientific World, International Journal of Chemistry, Member: Council, International Society of Magnetic Resonance (ISMAR 2014-), Member, Scientific Advisory Committee of ISMAR, 2014- Member: DBT task force on Modern Biolog, 2014-. *K.V.R. Chary*: Member, International Advisory Board, 27th International Conference on Magnetic Resonance in Biological Systems, (ICMRBS; 2014-16), Elected Fellow of The World Academy of Sciences (FTWAS) 2014-, Treasurer, Asian Biophysics Association (ABA) 2013-, Convenor, TIFR Hyderabad Project Management and Implementation Committee 2013-2015., Advisor, Royal Society of Chemistry, Member, Steering Committee of Asian Biophysics Association, Member, J.N. Tata Endowment Selection Committee. *P. K. Madhu*: Convenor, MagRes Academic Advisory body (MRAAB) TIFR, Hyderabad, Member: Editorial Board, Journal of Magnetic Resonance, Journal of Biomolecular NMR, Solid State NMR, International Advisor, European School on Solid-state NMR, Member: Board of Trustees of EUROMAR, European Magnetic Resonance Meeting, Scientific Committee Member: ISMAR 2017

Invited Talks*K.V.R. Chary*

1. Invited talk on, "Structure and Dynamics of UV inducible protein (UVI31+) from *Chlamydomonas reinhardtii* that exhibits RNA and DNA endonuclease activity", during the Asian Biophysics Association Conference, held at the Hongzhou, China, from May 9-12, 2015.
2. Invited talk on, "Echoes in NMR", at National Workshop on "NMR in Biological Systems", held at SGPGIMS, Lucknow, on June 23, 2015.
3. Invited talk on, "NMR of Nucleic Acids", at National Workshop on "NMR in Biological Systems", held at SGPGIMS, Lucknow, on June 25, 2015.
4. Invited talk on, "Evolution through Structure", at National Workshop on "NMR in Biological Systems", held at SGPGIMS, Lucknow, on June 25, 2015

5. Invited talk on, "An unusual calcium binding protein from *Entamoeba histolytica*", *DCS Annual Talks*, held at TIFR, on November 4, 2015.

6. Invited talk on, "βγ-crystallins: Intrinsic Order & Disorder", at the International Cconference of FAOBAB, on Sunday, November 29, 2015

R.V. Hosur

1. Visted USA for attending international conference on Biomolecular Stereodynamics, June 9-13, 2015
2. Visited USA for giving lecture at Stanford, Berkeley, Washington, New York, San Diego, June 18-30, 2015

Conferences Organized**NMR Meets Biology: An Interaction Week: January 14-19, 2016, Kerala, India**

The interaction meeting focused on the state-of-the-art solid- and solution-state NMR methods to tackle challenging issues in biology. The workshop sessions consisted of tutorials on methods and applications of NMR to biological problems and hands-on-sessions on structure solving and spin systems simulations. There were only oral presentations at the meeting. The number of participants was limited to 50.

Non-DAE Research Projects*K.V.R. Chary*:

DST-DIISRTTE joint Research Project under Australia-India Strategic Joint Research Fund (AISRF).

with Matthias Ernst, ETH, Zurich, Switzerland

P.K. Madhu:

1. Indo-Swiss PEP entitled "Heteronuclear decoupling under homonuclear recoupling sequences"

2. Danish-Indian collaboration programme entitled "Solid-state NMR methods and applications" (with Niels Nielsen, University of Aarhus, Denmark).





Tata Institute of Fundamental Research टाटा मूलभूत अनुसंधान संस्थान

CENTRES



International Centre for Theoretical Sciences
(ICTS, Bangalore)



TIFR Centre for Interdisciplinary Sciences
(TCIS, Hyderabad)



Homi Bhabha Centre for Science Education
(HBCSE, Mumbai)



National Centre for Biological Sciences
(NCBS, Bangalore)



National Centre for Radio Astrophysics
(NCRA, Pune)



A science education vacation camp for students of Urdu medium BMC school, Shahaji Nagar focusing on the theme of “waste”. Part of an ongoing research project.



Douglas Allchin (University of Minnesota, USA) during his review talk, at epiSTEME 6, International Conference to Review Research on Science, Technology and Mathematics Education, Mumbai, December 15, 2015



Visitors to the Design and Technology lab during the National Science Day (held on Feb 26, 2016)



A student participant during the experimental exam, at the 46th International Physics Olympiad, held at Mumbai, July 7, 2015

Homi Bhabha Centre for Science Education, Mumbai

Research & Development in Science, Technology and Mathematics Education

The research projects in science, mathematics and technology education in HBCSE can be broadly grouped under three categories: Learning and Reasoning with Representations, Teaching and Pedagogy, Policy and Curriculum Redesign. Projects in the first two categories work towards improving teaching/learning within the current curriculum, projects in the last category seek to critique and extend the existing curriculum and policies.

Learning and Reasoning with Representations (LRR)

Interactive simulation to learn vectors

An interactive simulation in Javascript was developed for teaching and learning vectors. The system was tested with different groups of Grade 11 and 12 students, using a pre-post test format, combined with interviews and eye-tracking. The analysis of this data is ongoing, as is further development of the simulation system. [H. Agrawal, D. Karnam and S. Chandrasekharan]

Interactive simulation to learn oscillation

A simulation to teach and learn the oscillation concept was redesigned based on a pilot study, in collaboration with the Interdisciplinary Program in Educational Technology, IIT Bombay. A second study tracking students' interaction with this simulation was done using an eye tracker. Results from this study showed that interacting with the simulation allowed some Grade 7 students to understand the connection between equations, graphs and the pendulum, and make inferences based on this understanding, even though they had never encountered graphs, equations and trigonometry before. The eye-tracking data shows that students who could understand the connection between the representations had a more systematic interaction pattern, compared to students who did not understand the relationships. However, a systematic interaction pattern did not guarantee understanding. A paper reporting this result is currently in preparation. [A. Kothiyal, R. Majumdar (IDP-ET, IITB), H. Agrawal (IIT Roorkee) P. Pande and S. Chandrasekharan]

Interactive simulation to learn non-linearity

An interactive piecewise oscillator simulation was developed to help in teaching and learning the concept of non-linearity. This system will be tested in some engineering colleges during January 2017, which is when the related course would be next offered. [H. Agrawal and S. Chandrasekharan]

Signed quantities: Learning trajectory

The topic of integers is an important topic in middle school mathematics, which is difficult for students and a “hard spot” in the curriculum. Towards developing a learning trajectory on this topic, workshops for students on learning integers using the context of “Integer Mall” were held. Integer Mall is a representation that leverages the change, state and relation interpretation of integers, with change indicating movement; state the position; and relation the directed distance. This framework has been effective for teachers to invoke multiple contexts for teaching integers. A learning trajectory, which emerged from this framework is being implemented to track students' learning and participation. Preliminary findings indicate that the context of integer mall facilitates learning of different meanings of integers but requires further refinement for integer arithmetic. [K. Subramaniam, H. Raval and N. Ponnuru]

Inclusive science education with a focus on visually impaired students

Analysis of a study involving students with visual impairment (SVI) in inclusive settings was carried out. The study focused on understanding questions raised by students while observing diagrams and how students with and without visual impairments represented their visualisation. The study used adapted diagrams and models with small groups of students to facilitate peer to peer interaction. Contexts of collaborative learning through diagrams and models evoked higher order questions from students. The study also found that SVIs manipulate mental images, both visual and/or spatial. In another study with SVI, activities using multiple modes of perception were used specifically in the context of the science topic “historical approach to atomic models”. The study was

conducted with two groups of students in different educational settings: an inclusive setting, and a special educational setting. The study indicates that verbal descriptions, tactile perceptions, 3-dimensional models and objects, and making drawings of perceived concepts are effective in providing learning experiences to SVI, and that students in inclusive settings benefit through collaboration. The study highlights the process of visualising and learning science among SVI and suggests changes in educational methodologies to benefit SVI. [A. Sharma and S. Chunawala]

Teaching and Pedagogy

Research on science teaching at the middle school level

A paper on our study on the outcomes of inquiry teaching, as evident in students' reflective writing, was prepared, including additional extensive data analysis in the review stage after submission. It documents cognitive, affective and epistemic outcomes of teaching science through inquiry in middle school students and has been published in the September 2015 issue of *International Journal of Science Education*. [A. Kawalkar and J. Vijapurkar]

Knowledge of mathematics at the horizon

A longstanding problem in mathematics education has been to determine the knowledge that teachers need in order to teach mathematics effectively. A study was conducted where data of 14 teachers, teaching three content classes each, were analyzed to uncover knowledge of mathematics at the horizon. It was seen that this knowledge supported teachers in hearing students' mathematical insights, orienting instruction to the discipline, and making judgments about what is mathematically important. The study, rooted in practice, specifically looks at the encounters in the classroom, which place demands of mathematical knowledge at the horizon and identifies resources that lead to management of such demands. The analysis reveals multiple teaching actions aimed at managing "encounters with advanced mathematics" and reinforces specific tasks of teaching that have been identified previously. These teaching actions are important for effective mathematics teaching, and to address norms of equity in a classroom. [S. Naik, Deborah Ball (University of Michigan) and K. Subramaniam]

Teachers' specialized knowledge for teaching the topic of integers

Two journal articles were published reporting work done towards developing a framework for teachers' specialized knowledge for the topic of integers. The framework elaborates integer meanings through a synthesis of previous research, and reports on the

take up of the framework as teachers collaboratively planned and implemented lessons on the topic of integers. Analysis of teachers' talk in the collaborative meetings indicated a shift in teachers' role from reliance on textbook to using the knowledge of integer meanings to establish the connections between contexts and representations. [R. Kumar, K. Subramaniam and S. Naik]

Professional vision in practice-based professional development

What teachers notice in their own teaching impacts what decisions they make while teaching, what learning opportunities they design, and what constitutes their lesson for the next teaching sessions. Teaching labs were conducted at HBCSE and at Xavier's Institute of Education, where one teacher taught a group of school students and teachers/student-teachers observed this live. This was followed by intensive discussion on mathematical ideas in the work of teaching and of pedagogical practices adhering to fundamental practices of mathematics. This unusual context offered a site for looking into a particular form of practice-based professional learning, namely "professional vision of teachers". This is an ability of teachers to notice and interpret significant features of students' participation and engagement in a classroom setting. The study showed that practice-based training of noticing causes a shift in teachers' professional vision and in knowledge-based reasoning, which is applied to make sense of what they noticed. [S. Naik, T. Khan and K. Subramaniam]

Participatory Action Research Project under School Science Research & Development (SSRD)

HBCSE's School Science Research and Development group (SSRD), has undertaken a Participatory Action Research (PAR) project in collaboration with Nutan Vidya Mandir (NVM), a neighbouring government aided school. The project seeks to understand and attend to existing challenges in science teaching and learning through active involvement, reflection and collaborative action of researchers from HBCSE and teachers from NVM. Three workshops were held with teachers of the school followed by regular interactions with the teacher and students of the selected class. The programme emphasizes finding ways to involve each and every student in the learning process. In May 2015 a summer camp was held for students of Grade 3 at HBCSE. The objective of the camp was to help students relate their day to day experiences to what is taught in school and to help them develop communication skills through different modes, such as, drawing,

writing, mapping, expressing oneself, gesturing and raising questions. Collaborative action towards improving science teaching commenced in June 2015 with one division of Grade 3. The SSRD group taught all year round and designed relevant and effective science activities, worksheets, experiments and projects, for development of critical thinking and questioning abilities among students and problem-solving. The summer of 2016 will focus on students of Grade 4. Workshops with the teachers are planned to collaboratively assess the materials developed for teaching. [Core team: S. Chunawala, J. Ramadas, S. Bhide, N. D. Deshmukh, V. C. Sonawane, M. Kharatmal, P. Nawale, D. Gupta, V. Pawar, S. Chavan, T. Adangale, S. Ayare; Others: D. Prabhu, R. Shaikh, P. Sharma, S. Chopde, A. Muralidhar, S. Jaipurkar and B. Gera]

Health awareness among undergraduate students

Two visiting teacher fellows from R. J. Jhunjhunwala College of Arts, Science and Commerce carried out a short term project with support from HBCSE. The project was titled "Health, physical fitness and wellness: A study of awareness of selected variables amongst undergraduate students" and was conducted with around 700 students of the college. In a survey aimed at understanding the level of awareness amongst students about health issues, it was found that a majority of students were unaware about information related to their own height, weight, blood group, etc. They engaged in limited physical activity, had unhealthy eating habits and irregular sleep patterns. Intervention activities included street plays, poster competitions, debates by students and talks on physical and psycho social aspects of health, including demonstrations and physiological measurements by experts. A post intervention questionnaire administered to the student participants indicated raised awareness amongst them regarding health. [B. Dutta, S. Moorthy, S. Chunawala, P. Sharma and A. Muralidhar]

Policy and Curriculum Redesign

Study of rural innovators to inform engineering design education

An interactive simulation of micro-hydro turbine design was developed, for understanding the design thinking of rural innovators who with very little formal education develop micro-hydro turbines. [H. Agrawal, G. Date and S. Chandrasekharan]

Urban farming as a way to promote environment-oriented behavior

A study was developed to understand how environment-oriented actions and behavior could be promoted among urban school students by introducing them to terrace farming. A preliminary study of how terrace farming changed the behavior of adult volunteers was first done, to develop a template for setting up school-based terrace farms and collecting data on their impact on students, teachers and the wider community. A farm has been set up in one school in Mumbai, and data collection is ongoing. [D. Dutta, A. Muralidhar and S. Chandrasekharan]

Environmental studies and outdoor engagement

We developed a project to explore the possibility of children learning and engaging in their school lessons by learning outdoors through specifically designed outdoor activities. Our preliminary observations indicate that outdoor engagement can be a significant part of regular school curricula, particularly environmental studies at the primary levels of schooling. This engagement may be a viable way to provide students opportunities to connect with nature as well as society. [S. Bhide and S. Chunawala]

Science communications, media and scientific literacy

Science media is an important means through which people encounter science-related issues in the real world. A scientifically literate citizen will be able to perceive, interpret, analyze and participate knowledgeably in socio-scientific concerns. Some skills that may be required in making connections between science knowledge and socio-scientific issues relate to; identifying key concepts and theories (subject content knowledge); understanding practices of science (eg. controls, reliability, validity, bias, etc.), generalization of core concepts to a variety of issues, application of relevant knowledge to reason about diverse concerns, etc. We propose that students can be helped to acquire these skills through learning modules aimed at motivating critical thinking as well as analysis and synthesis of science/socio-scientific issues presented in mass media. As a step in this direction we are developing modules that will help students across ages and grades distinguish between 'opinion' and 'fact' - aspects that involve critical reading, thinking and communication. [S. Bhide and S. Chunawala]

Problem identification when no design brief is provided

Problem solving and problem identification are important components of design and technology curricula and research. Our interest is focused on “students' identification of problems”. We analysed a range of innovations registered on the website of the National Innovation Foundation, India (<http://nif.org.in/>). Preliminary analysis suggests that while the number of problems were similar in both groups, adults identified problems in a greater variety of areas. This result is surprising if one attributes greater flexibility to students, but attempts are being made to understand possible reasons for these differences and to identify conditions under which students can be made sensitive to problems in a diverse range of areas. [S. Datt and S. Chunawala]

Socio-scientific issues

Analysis of a study involving interviews of 20 biology high school students (Grades 11 and 12) and their deliberations in two workshops on a socio-scientific issue related to commercial surrogacy was completed. This study investigates the epistemic, as well as the social, political and ethical considerations students bring to bear on the topic. One part of the study investigated students' evaluation of the evidence involved in a socio-scientific issue. We focused on how students understand the reliability and authenticity of various sources of primary and secondary evidence. Findings reveal that students' understanding of the nature of various sources of secondary evidence and their reliability is sketchy. Not all students were able to evaluate the empirical adequacy of newspaper articles presented. Even when they did apply the criteria of empirical adequacy, they applied it inconsistently, often going by their biases or commitments towards stakeholders involved in the issue. [A. Raveendran and S. Chunawala]

Inclusive design and technology

Efforts were made to explore the “inclusive nature” of design and technology (D&T) education. A two-day D&T workshop was organized in which 8 students (4 girls and 4 boys, age 11-13 years) participated. Students were provided a context for developing a product (solution) for a real-world problem: they had to design and make a product which could keep a bottle of cold water chilled for the longest possible time. Despite diverse backgrounds, students were able to work collaboratively and communicate with each other through verbal and non-verbal modes to express their ideas and critique products. The products made by students were influenced by their home settings, their school learnings and their prior

exposure to the technology, skills and knowledge relevant to the D&T challenge. Further, the activity required them to use their cognitive and motor skills. Students tested their product on evaluation criteria that they developed, which also demonstrated their values on issues of economics, environment and aesthetics. [R. Kapil, S. Bhide, A. Muralidhar, D. Gupta, P. Sharma and S. Chunawala]

Exploring Ableism in mathematics education

A series of Mathematics lessons was conducted at a School for Blind Children. It was observed that on presenting mathematics as a process, the students would themselves explore the properties of numbers so as to debate about them. A student also constructed a novel, mathematically consistent definition of even and odd numbers and hypothesized its history with his peers. The study revealed that students resist Ableism in mathematics by consciously and actively not conforming to the imposed nature of mathematical form and content that constructs them as being less capable of doing mathematics. The study suggested possible approaches for addressing structural oppression that are produced and reinforced by curricular mathematics and dominant pedagogies. [R. D'Souza]

Science education and the possibility of social transformation

In order to understand the nature of formal education experience of 14-16 year old students of a marginalized community that lives close to the Deonar dumping ground, classroom observations were conducted in five schools in the area when topics related to waste management and health were taught. The science and social science teachers were subsequently interviewed to elicit their understanding of the subject matter, and their value commitments regarding waste, health and hygiene, and socio-economic development. The relevant textbook chapters were also analyzed from the Bernsteinian perspective of 'classification' and 'framing' of educational knowledge.

Preliminary analysis indicates that the topics on waste and health are presented as if they are well-insulated from each other. The classes run in didactic fashion with very little room for students to raise a concern, or ask a question. The pedagogical practices across schools disregard the lived reality of the community. The control over content lies mostly with the teachers, though the structure and the examples discussed in a class are largely determined by the textbook. The textbook works as a gatekeeper and maintains a 'strong' boundary between the knowledge worth-teaching

and the community-based experiential knowledge. There is a class bias in the chapter on waste management which adopts a managerial approach and remains silent on the political economy of

waste. Further analysis of the chapters and classroom data from a 'Critical Discourse Analysis' framework is underway. [H. Srivastava]

Development of Curricular and other Educational Materials

E-learning portal and educational materials in Hindi

The e-learning portal in Hindi (<http://ehindi.hbcse.tifr.res.in>) contains a variety of curricular, co-curricular, and popular science materials including pedagogic presentations, books, lectures, magazines, articles, reports, documentaries, glossaries, questionnaires and short biographies of some Indian scientists. Reviews of recent books of the Hindi Cell were published in periodicals and links added to the e-hindi site. [K. K. Mishra, K. Sinha, D. Mishra, A. Sankhwar, and R. Nichat]

A co-curricular book titled '*Gyan-Vigyan - Shaikshik Nibandh* (Book-4)' was published by HBCSE. It contains 17 selected educational essays based on pedagogic presentations by experts who participated in the 4th National Workshop on Development of Educational E-materials in Hindi (organized by HBCSE collaboratively with Vigyan Parishad Prayag in November 2014). [K. K. Mishra, K. Sinha, S. Deoram and D. Mishra]

Middle school inquiry science curriculum

Video records of our science classes with middle school students document several successful classroom strategies for teaching concepts in science, and involving students in the processes of science. Analysis of classroom interactions, to trace in detail the development of successful pedagogy of particularly difficult but essential concepts in introductory science was nearing completion towards the end of the period of this report. Writing up of the curricular material continued. [S. Patil, A. Sawant and J. Vijapurkar]

Marathi Vishwakosh

HBCSE has been working with the Maharashtra Rajya Vishwakosh Nirmiti Mandal to produce Kumar Vishwakosh (a junior encyclopedia) on 'Biology and environment' in Marathi, as reference material for teachers and students at Secondary and Higher Secondary School Levels. Two volumes of the Kumar Vishwakosh are already published in print and on the internet. During the period of this report, work continued on Volume 3, consisting of about 260 articles. About 80% of the work of this volume is completed, and has been prepared in Unicode for easy portability. [V. D. Lale, N. D.

Deshmukh, A. Ajgaonkar and Editorial Committee, Kumar Vishwakosh, Chaired by H. C. Pradhan]

An instrument to teach sound frequency to visually impaired students

A low-cost model which can be used by teachers to teach the concept of frequency to visually impaired students is being developed and tested. The model uses a IC LM555 with resistors, capacitors, buzzer, speaker and keys. This device has applications in designing circuits like sequential timing, time delay generation, pulse generation, pulse width modulation, pulse position modulation, linear ramp generator, precision timing; some of these were used in our model. Change in time delay leads to change in frequency, which in turn results in specific sounds which act as indicators for students with visual impairment (SVI) to identify different frequency ranges. Additionally, the knobs which control time delay have braille panels so that SVIs can themselves manipulate the model. Testing of the model has been done with one SVI. The circuit has been given to the blind school for further feedback. [S. Kulkarni and S. Chunawala]

Knowledge laboratory

New features were added to the GNOWSYS online platform and its stability was enhanced as a result of development carried out by lab members as well as interns from colleges. Notable among the new features are: (a) recording benchmarks for every registered procedure executed with the information of who initiated, when and time taken; (b) fine grained analytics based on benchmarks providing numerical and graphical reports to users on their performance; (c) an ABCD MOOC (Activity Based Collaborative Distributed Massive Open Online Course) framework; (d) distributed sync functionality between multiple instances of GNOWSYS servers; (e) packaging server software as a docker container (<http://docker.com>) for distribution in schools and colleges; (f) mutation of resources into various interactive types (reply, submit, voice response, single choice, multiple choice, check boxes); (g) User Interaction and User Interface Design for the Course Player. GNOWSYS started in 2013 is now considered a highly active project on openhub (<https://www.openhub.net/p/gstudio/>). Analytics from the code repository show 9700 commits made

by 73 contributors representing 197,387 lines of code at (<https://github.com/gnowledge/gstudio>).

HBCSE became a development partner with Tata Institute of Social Sciences (TISS) as a part of the CLIX (Connected Learning Initiative) project. The lab is contributing technical consultancy, distributed online platform, and the project's first course offering, 'Invitation to CLIX', dubbed i2c. Gnowledge Lab is involved in the development and implementation of Digital Literacy course, course platform and Management Information Systems (MIS) for National University Student Skill Development programme of TISS, Mumbai and in developing and maintaining the National Repository of Open Education Resources for Central Institute of Educational Technology, National Council of Educational Research and Training, New Delhi. [G. Nagarjuna, R. Thengodkar, A. Dhakulkar, R. Shaikh, S. Ghumre, S. Shende, U. Shah, M. Nachankar, N. Shinde, V. Sawant, K. Aitwadkar, R. Katkam, S. Bharswadkar, Keerthi K. R. D., and M. C. Arunan (Consultant)]

Collaborative Undergraduate Biology Education (CUBE)

The CUBE Studio regularly hosts 10 to 25 students and teachers for trouble-shooting of their respective research programs as well as for learning about CUBE projects. A distinctive feature of CUBE is that, unlike vacation research programs, it is ongoing during the college term, integrating serious research with regular curricular work. Continued engagement is evidenced through more than a thousand group mail interactions per month. [<http://gnnowledge.org/pipermail/cube/>]

New CUBE nodes emerged in Kudal, Delhi, Jaipur, Chandigarh, Patna, Chennai, Panjim, Thrissur, Cherthala and Guwahati. Senior 'CUBEists' at these locations have voluntarily assumed new roles in mentoring juniors, participating in conferences and conducting local workshops, apart from recording,

reporting and discussing their project data. CUBEists from Mumbai, Delhi and Jaipur presented posters at the Indian Academy of Neuroscience conference, Chandigarh, one of which 'Behavioural modifications through associative conditioning in putative giant bacteria' won the best poster award. Students of Acharya Narendra Dev College, Delhi, established a TH!NK CUBE stall to demonstrate their model systems, winning the best exhibit award at the college silver jubilee event.

Students from Deonar Colony Municipal School have been regularly working on culturing of Daphnia, following activity rhythms in wild fruit-flies and distinguishing Aedes from non-Aedes mosquitoes, recording data meticulously and reporting it weekly. Cross-mentoring between school and college students is common: for e.g., school students helped Smt Chandibai Himathmal Mansukhani College (CHM) college students to establish Daphnia cultures. [G. Nagarjuna, R. Thengodkar, V. Sawant, S. Ghumre, R. Shaikh, U. Shah, S. Shende, A. Dhakulkar, N. Shinde, A. Zakaria, M. C. Arunan (Consultant)]

Process Oriented Guided Inquiry learning (POGIL)

A project involving development of POGIL instructional material for undergraduate organic chemistry has been initiated by chemistry cell, HBCSE, since August 2015. The group is collaborating with Kelly Butler (Chestnut Hill College, Philadelphia, USA), a Fulbright-Nehru Scholar who visited HBCSE from January 7 to February 10, 2016. Several teachers from local colleges in Mumbai are participating in the project: G. Carnerio (Sophia College), T. Parulekar (SIWS Colleges, Wadala), L. Ravishankar (KET V. G. Vaze College), G. Shridhar (V.K. Menon College) and G. Shaikh (St. Xavier's College). [K. Butler, S. Ladage, I. D. Sen and S. Narvekar]

Consultations, Collaborations and Support to External Institutions

Maharashtra State Bureau of Textbook Production & Curriculum Research, Balbharati, Pune

HBCSE has had two members on the science committee of Balbharati constituted in April 2013. During the period of this report, Balbharati produced a textbook on Environmental Studies for Class 5 in Marathi, with content based on natural science, geography and social science. It is being translated by Balbharati into eight different languages. HBCSE members contributed to the

effort of streamlining the science curriculum from primary to higher secondary level and in scrutiny of e-learning material. [V. D. Lale and J. Ramadas]

Maharashtra Knowledge Corporation Ltd. (MKCL), Pune

HBCSE members are part of the Educational Content Committee for the Shikshan Pandhari Project, sponsored by Rajiv Gandhi Science and Technology Commission (RGSTC), Mumbai. Under this project, five secondary schools in

Pandharpur Taluka (Dist. Solapur, Maharashtra State) have been connected to MKCL through a node at a local engineering college. School visits were made between February 4-5, 2016. The content committee is guiding a team at MKCL to develop Open Educational Resources for the project schools, and also following up their implementation, including student projects on social and environmental issues. [H. C. Pradhan and V. D. Lale]

YCMOU Post Graduate Research Programme

HBCSE is the study centre in Mumbai for Yashwantrao Chavan Maharashtra Open University (YCMOU, Nashik)'s two-year Post Graduation Research Programme (M.Sc., M.A., and M. Com.) in Subject Communication and Education Communication through distance mode. The batch of 2014-16 has 41 students and the batch 2015-17 has 72 students. Fourteen workshops were conducted for both batches between September 2015 and March 2016. Besides participation in these workshops, students are counseled on various subjects. Student assignments were assessed and help was provided to students in formulating their research problems and in developing their research projects. [S. Chunawala - Coordinator, N. D. Deshmukh, D. Prabhu, D. Gupta, P. Sharma, D. Pednekar, R. Sandhya and J. Tambe]

AEES-HBCSE Junior Mathematics and Science Olympiad - 2015

The Atomic Energy Educational Society (AEES) and HBCSE continue to collaborate in several areas. The junior mathematics and science Olympiads, which is the first stepping stone for the National Olympiads, draw some of the best students of the Atomic Energy Schools from all over the country. The 16th camp was conducted in May 2015 with HBCSE academic, scientific and project staff along with the AEES teaching community. Interactive sessions on environment and sustainability, emotions, bio-mimicry, history of science, mathematics, computers, astronomy and simple pendulum were conducted during the 16th JSO-AEES programme. These sessions included besides lectures, hands-on and minds-on activities, where students worked in groups and performed tasks, activities and games. [S. Chunawala, K. Subramaniam, R. Vartak, A. Ronad, S. Pathare, P. Pathak, V. Ghanekar, S. Narvekar, I. D. Sen, V. C. Sonawane, A. Das, R. Dsouza, S. Takker, P. Ranadive, H. Misra, T. Khan, J. Rahaman, A. Muralidhar, D. Prabhu, S. Bhide and P. Sharma]

Support to national level assessment

HBCSE members contributed to various prestigious national level assessment and admission

processes organised by different external agencies and aimed at higher secondary students. Details of these cannot be listed for the reasons of confidentiality.

Support to teacher education institutions

As part of National Council for Teacher Education (NCTE) Bhopal's inspection of Gujarat's District Institute of Education and Training (DIET) in the context of their B Ed application, in February 8-10, 2016, N. D. Deshmukh visited DIETs of Vadodara, Anand, Dahod, Narmada and Kheda districts. He also visited the State Institute of Science Education, Nagpur to evaluate the Activity Based Science Learning ABSL kit and activity manual on June 20-21, 2015 at Bal Shivai Mandir School, Dombivli.

Royal Society of Chemistry

HBCSE members are collaborating with the Royal Society of Chemistry (India chapter) to conduct 'Innovative Teacher Training' as part of the 'Yusuf Hamied Inspirational Chemistry Programme'. The third workshop in the series was conducted in September 2015 to take a review of the programme and resource materials as well as to collect feedback from teacher developers. A course for chemistry teachers of Nashik Education Society was also conducted. Discussions are ongoing on evaluation of the program. [S. Ladage, V. D. Lale, I. D. Sen and S. Chunawala]

RMSA science teacher handbooks

Rashtriya Madhyamik Shiksha Abhiyan (RMSA), Maharashtra, had organized workshops for finalization of Science Teachers' Handbooks for Grades 9 and 10 at HBCSE on January 21-22, 2015. After printing 3500 copies of these handbooks, RMSA organized regional workshops for headmasters of Government schools, including tribal, municipal corporation and Zilla Parishad schools. N. D. Deshmukh was a coordinator for science teachers for the workshops organised by RMSA at Pune, Mumbai and Nashik regions during August to October, 2015.

MSTA- Dr. Homi Bhabha Young Scientists Camp

Maharashtra Science Teachers Association (MSTA) and HBCSE jointly organized Dr Homi Bhabha Young Scientist Camps during April 15-18, 2015. In these camps students from English and Marathi mediums, studying in Class 6 (105) and in Class 9 (62) participated. They were exposed to laboratory demonstrations and activities as well as content and enrichment sessions. [J. Ramadas, N. D. Deshmukh (Program Coordinator), V. C. Sonawane, V. D. Lale, P. K. Navale, A. Sule, P. K. Joshi, K. T.

Hambir, P. Ranadive, V. Pawar, S. Mukherjee, S. Ayare and project staff]

Bombay Association for Science Education

The Bombay Association for Science Education (BASE) is a voluntary organization run by TIFR scientists in collaboration with school and college teachers from Mumbai region. During the period of this report, BASE jointly with HBCSE organized two workshops on the themes: Application of light (August 8, 2015) and Managing School Laboratory (December 18-19, 2015).

National Children's Science Congress (NCSC)

The National Council of Science and Technology Communication (NCSTC) of the Department of Science and Technology, Government of India organises NCSC, a nation-wide programme of children's creative science projects every year in December. About 800 students and 200 teachers participate in this programme. H. C. Pradhan served as the Chair of the Programme Advisory Committee of NCSTC, conducted the "Meet the Scientists" programme in which scientists answer questions from students, and also conducted discussion sessions for teachers who accompany the participating children during the Congress. [H. C Pradhan]

National Teachers' Science Congress (NTSC)

The NCSTC organises a Science Teachers' Conference biennially in which about 250 teachers, selected through a rigorous selection procedure, present papers based on action research projects undertaken by them. The NTSC this year was hosted by Marathi Vidnyan Parishad, Mumbai and held in December 2015 at Indian Institute of Science Education and Research, Pune. H. C Pradhan served as the Chair of its National Organising Committee, and guided its proceedings. [H. C. Pradhan]

Support to schools and related activities

HBCSE members actively participated in various capacities (evaluators, judges, chief guest, interviewer, project guide) in academic and school events. In this endeavor, A. Sule visited Jamnabai Narsi School (August 27, 2015), Jaffree School, Shivaji Nagar, Deonar (October 15, 2015), St. Anthony's school, Chembur (December 3, 2015),

Hashu Adwani School, Govandi (December 8, 2015) and participated in the Techfest – Mars Habitation project competition (December 26, 2015) as well as the Homi Bhabha Young Scientist Examination (February 13-14, 2015). V. C. Sonawane participated in the P-Ward Science Exhibition & Co-curricular Activities Committee, at Adarsh Vidyalaya, Jogeshwari (October 29, 2015), H-Ward Science Exhibition 2015-2016, at St. Mary's High School & Jr. College, Kalina Santacruz (December 3, 2015), R-Ward Level Inter school Science Seminar, at Mother Teresa English Secondary School & Jr. College, of Commerce and Science (August 4, 2015) and 43rd Jawaharlal Nehru Science Regional Exhibition, at Kendriya Vidyalaya, Colaba (October 12, 2015). V. D. Lale visited Mar Thoma School, Govandi (December 2, 2015). S. Mukherjee participated in EXPISCOR 2015, held at Vasranji School, Andheri (December 5, 2015).

Student interns and visitors to HBCSE

As part of our collaboration with academic institutes, HBCSE had numerous visitors and interns this academic year, during which they either carried out small projects in their area of interest or gave talks and/or offered short courses.

Visitors included faculty members from the following national and international institutes: Azim Premji University, Bengaluru, Shri Bapusaheb Vispute College of Education, New Panvel, R. J. Jhunjhunwala College, University of Waikato, New Zealand, University of Wisconsin-Madison, Srishti Institute of Art, Design and Technology, Bangalore, Centre for Studies in Science, Technology and Innovation Policy- CSSTIP, Gujarat, Chestnut Hill College, Philadelphia, USA, etc. [N. Varadarajan, A. Bardapurkar, S. Mali, R. Inamdar, B. Datta, S. Murthy, J. Lockley, P. Kishor, J. Czaplowski, S. Kar, T. Rode, Y. Shetty, S. S. Varughese and K. Butler]

Students interns from the following institutes visited HBCSE for durations ranging from 1 to 3 months: Tata Institute of Social Sciences, Hyderabad, IIT Roorkee, IIT Kanpur, D. Y. Patil School of Engineering, Pune, Mumbai Education Trust College, BITS Pilani, BITS Pilani Goa, BITS Pilani Hyderabad. [B. Gera, S. Jaipurkar, R. Kapil, H. Agrawal, N. Ponnuru and S. Kulkarni]

Olympiads and Related Activities

The Indian Olympiad programmes in the sciences (Biology, Chemistry, Physics, Astronomy and Junior Science) and mathematics continued to flourish in 2015-2016, thanks to the dedicated hard work of the HBCSE Olympiad cell members,

teacher associations and resource persons from across the nation. The Olympiads being international competitions at the highest levels of performance, the programme provides an international level benchmark for high achievement

in science and mathematics at the Secondary, Higher Secondary and, by extension, even at the Undergraduate stage in the country. Of the 30 student team members who represented India in the International Olympiads in Astronomy, Biology, Chemistry, Junior Science, Physics and Mathematics, 27 bagged medals and these included 10 coveted gold medals. Over 200 of the best students from across the nation were given experimental and theoretical training.

One of the major highlights of the programme this year was the successful hosting of the 46th International Physics Olympiad (IPhO) in Mumbai in July, 2015. Apart from the 650 international participants, this event involved more than 250 teachers, researchers and undergraduate students from all over India. The quality of the academic programme as well as the overall organization of the event was highly appreciated by the international community.

By designing conceptual and challenging problems, developing novel experiments, actively participating in book writing for Olympiads, national and state bodies, participating in several national assessment committees, the members of the Olympiad programme have extended the fruits of the Olympiad programme to different layers of the national education scene. They have also contributed to research articles in peer-reviewed technical journals. More than three hundred teachers attended resource generation and exposure camps, some from Bangladesh, Sri Lanka, Nepal and Thailand. Through these activities, and further by providing support to voluntary Teacher Associations, the programme has disseminated the quality material developed as well as striven to evolve a positive atmosphere for excellence in science.

The Olympiad selection procedure in all the subjects (Astronomy, Biology, Chemistry, Junior Science, Mathematics and Physics) followed the standardized routine. The first level tests in science subjects (the National Standard Examinations, NSEs) were held in November, 2015 at 1328 centres spread all over the country. These were conducted by the Indian Association of Physics Teachers (IAPT), with the assistance of Association of Chemistry Teachers (ACT) and Association of Teachers in Biological Sciences (ATBS). The NSEs had mainly objective type questions. The participation in the NSEs for the year 2015-16 was nearly 14000 in Astronomy, 19000 in Biology, 36000 in Junior Science, 40000 in Chemistry and 44000 in Physics. This amounts to an average

increase of 20% in all subjects since last year, except Junior Science.

The second level examinations, the Indian National (Astronomy/Biology/Chemistry/Junior Science/Physics) Olympiad Examinations (INAO, INBO, INChO, INJSO and INPhO, respectively) were conducted by HBCSE at 18 centres nationwide. These tests had subjective problems, and were of high difficulty level, somewhat comparable to the international Olympiads. The top performers in NSE, numbering between 300 and 630 in each subject, participated in these examinations. In the next phase of selection, about 35 students in each subject were invited for Orientation cum Selection Camps (OCSC) held at HBCSE. Students appeared for several theoretical and experimental tests in these camps, leading to the selection of Indian teams for the international Olympiads. In mathematics, the first stage (Regional Mathematical Olympiad) was organized regionally and the second stage (Indian National Mathematical Olympiad) was organized by HBCSE and both stages had subjective questions. The selected teams for international Olympiads went through two weeks of pre-departure training (PDT) at HBCSE.

The Indian National Olympiad exams were organized during January 2016. The number of students selected were as follows: 308 students in Biology, 365 students in Physics, 402 students in Chemistry, 573 students in Junior Science, 634 students in Astronomy and 905 students in Mathematics. The OCSCs were organized during May-June 2016 and were attended by: 35 students in Biology, 35 students in Physics, 37 students in Chemistry, 35 students in Junior Science, 35 students in Astronomy and 32 students in Mathematics.

Orientation-cum-selection camps (OCSC) and Pre-departure training (PDT)

Astronomy

The Astronomy Olympiad Cell conducted Orientation Camp cum Selection Camp in two parts; May 2-7, 2015 and May 26-June 5, 2015, and PDT for the Indian team in was from July 20-24, 2015. Astronomy OCSC programme covers a wide range of topics in astrophysics from positional astronomy, stellar and solar physics to large scale structure of the universe and cosmology. The students were evaluated on basis of 3 theoretical, 2 practical and 2 observation tests conducted during the camp and top 5 students were selected for merit awards and the Indian team for the international Olympiad. The five-member team at the 9th International Olympiad on Astronomy and

Astrophysics held at Central Java, Indonesia from July 26- August 3, 2015 won three Gold and two Silver medals. Aniket Sule (HBCSE) and Swapnil Jawakar (S.I.E.S. College, Mumbai) were the team leaders and M. N. Vahia (TIFR, Mumbai), Najam Hasan (Moulana Azad National Urdu University, Hyderabad) and Ashok Kumar Mohapatra (NISER, Bhubaneswar) were the Scientific Observers. [A. Sule, A. Mazumdar, P. Ranadive and M. N. Vahia (TIFR)]

Biology

The Biology Olympiad Cell conducted OCSC during June 4-13, 2015 and the PDT for the Indian Team in July 1-10, 2015. Problem solving sessions in Cell Biology, Plant Sciences, Animal Sciences, Genetics & Evolution, Ecology and Ethology were conducted. Lab orientations and tests in the four lab areas namely Plant Anatomy, Biosystematics & Evolution, Animal Functional Morphology, Microbiology and Molecular Biology & Biochemistry were conducted during this camp. The four-member team to represent India at the international Olympiad was selected on the basis of two theoretical tests and four experimental tests during the camp. The 4 member Indian team at the 26th International Biology Olympiad held at Aarhus, Denmark from July 12-19, 2015 won two Silver and two Bronze medals. Kauresh Vachharajani (Maharaja Sayajirao University of Baroda), Rekha Vartak, (HBCSE) were the team Leaders and R. Radhakrishnan (Sardar Patel Vidyalaya, Delhi) and Anupama Ronad (HBCSE) were the Scientific Observers. [R. R. Vartak, A. Ronad and V. Ghanekar]

Chemistry

The Chemistry Olympiad cell conducted OCSC during May 26-June 5, 2015 and the PDT for the Indian Team in July 2015. The theoretical sessions at OCSC were related to chemical thermodynamics, spectroscopy, chemical kinetics, phase equilibria, biochemistry and fluorescence. The theoretical examinations at the camp were related to various phase equilibria of an organic compound, synthesis of drugs, inorganic reaction mechanisms, estimation of aluminium from different samples, fluorescence spectroscopy, biological redox reactions in mitochondria, thermodynamic cycles, protection and deprotection of functional groups in organic chemistry, chemistry of boron, use of reagents in organic synthesis and kinetics and catalysis-from laboratory to industry. The experiments that were developed and standardized for experimental examinations at OCSC covered the following areas:

1. Analysis of carbonate and bicarbonate content of a given sample,

2. Synthesis of copper acetylacetonato and estimation of its copper content,
3. Synthesis of an imine and its reduction using sodium borohydride, and
4. Identification of organic compounds by qualitative analysis
5. Synthesis of a dye, acid orange
6. Estimation of Fe (III) and Cu(II) ions in the given mixture by iodometric titrations
7. Estimation of Ca (II) and Mg (II) ions in the given mixture by complexometric and redox titrations

A four-member team was selected at the end of the camp to represent India at the international Olympiad. The Indian chemistry team at the 47th International Chemistry Olympiad held at Baku, Azerbaijan from July 20-29, 2015 won two Gold medals and two Silver medals. Anindya Dutta (IIT, Mumbai) and Prodeep Phukan (Gauhati University, Guwahati) were the team Leaders and Avinash Kumbhar (University of Pune) and Abhijit Chavan (S. P. College, Pune) were the Scientific Observers. [S. A. Ladage, A. Gupta, S. A. Narvekar and I. D. Sen]

Junior Science

The Junior Science cell conducted OCSC during May 7-26, 2015 and the PDT for the Indian Team was held from November 20-30, 2015. The camp consisted of around 30 lectures and 22 experimental sessions in advanced topics in Biology, Chemistry and Physics at the Class X level. Problems of high standard were set for theoretical and practical exams. On the basis of camp performance, a team of 6 students was selected for the international event. The Indian team at the 12th International Junior Science Olympiad held at Daegu, Republic of Korea from December 2-11, 2015 won five Gold and one Silver medal. Prodeep Kumar Burma (University of Delhi), Vinayak Katdare (Ruparel College, Mumbai), Surabhi Potnis (St. Xavier's College, Mumbai) were the team leaders and P. K. Joshi (HBCSE, Mumbai) was Scientific Observer. [P. K. Joshi and P. K. Nawale]

Physics

The Physics Olympiad cell of SGTB Khalsa College conducted OCSC during June 9-19, 2015. The PDT for the Indian team was held in IISER, Pune in July 2015. Apart from lectures in Special Theory of Relativity, Fermat's principle and Thermodynamics, rigorous training was imparted in experimental work. A five-member team was selected at the end of the camp to represent India at the International Olympiad. The Indian team at the 46th International Physics Olympiad, won four Silver and one Bronze medal. Subhash Chandra Samanta (Midnapore, West Bengal, Patrick Das

Gupta (University of Delhi) were the team Leaders and M. L. Ogalpurkar (IAPT, Pune), Ravi Bhattacharya (S.G T B. Khlasa College, Delhi), R. M. Dharkar (IAPT, Pune), and Pramendra R. Singh (Jagdam College, Bihar) were the Scientific Observers. Deepak Chandra (Delhi) and Mita Chowdhury (Kolkata) accompanied the team as Visitors.

The 46th International Physics Olympiad

HBCSE hosted the 46th International Physics Olympiad (IPhO) in Mumbai from July 5-12, 2015. This academic competition was fully supported by the Government of India and had delegations from 83 countries which included 382 students, 160 teacher leaders, 80 observers and 18 visitors. The preparation, administration, evaluation and moderation of the academic tasks were carried out by a team of 128 teachers, researchers, educationists and undergraduate students assembled from all over the country. The final theoretical and experimental tasks were selected through a rigorous academic exercise, initiated more than a year previous to the event, and involving about 80 teachers and scientists. One of the major challenges was the assembly and testing of 430 identical sets of experimental apparatus, a task handled by a group of about 60 teachers at an intensive workshop at HBCSE in April-May 2015.

The experimental examination at IPhO 2015, lasting five hours, dealt with the phenomenon of diffraction of light as a probe of matter. The first part, inspired by Rosalind Franklin's famous experiment to reveal the double-helical structure of DNA, used diffraction of a laser beam to determine the characteristic length scales of a spring and a double helical pattern. In the second part, the surface tension and viscosity of water were measured through the diffraction of laser light at grazing incidence by surface capillary waves. The theoretical examination at IPhO also was of five hours duration and consisted of three tasks. The first theoretical task focused on learning about the interior of the Sun from the photons and neutrinos that it emits. The second task dealt with the extremum principles in physics, connecting the thread of the ubiquitous variational principle between optics, classical mechanics and Schrodinger's wave mechanics. The third problem of IPhO 2015 was based on the design of nuclear reactors where students were guided to determine the optimum specifications of a nuclear reactor so that energy is released in a controlled fashion for safe operation.

The student scores followed closely the range and distribution recommended by the international

statutes, which indicate that the problems matched the desired level of difficulty. The international community present in IPhO unanimously expressed their appreciation for the excellent standard of the academic programme and the organisation of the event as a whole. The IPhO President and Secretary have described it as the "*best International Physics Olympiad we have ever had*". The questions, solutions and the scores of all the medal winners are available at the official homepage of IPhO 2015: www.ipho2015.in [Academic and organizational contribution: A. Mazumdar (Convener), R. B. Khaparde, S. R. Pathare, P. P. Pathak, H. C. Pradhan. Organizational contribution: J. Ramadas, A. P. Sule, R. R. Vartak, S. A. Ladage, K. R. Manoj, S. A. Narvekar, A. Ronad, V. Ghanekar, P. Ranadive, R. Nichat, A. Sankhwar, M. D. Gaitonde, S. V. Amin, V. P. Raul, G. Mestry and numerous other academic, scientific, administrative and technical staff]

Mathematics

The Mathematics Cell conducted IMOTC during April 20-May 18, 2015 and PDT for the Indian team during June 29-July 7, 2015. A six-member team was selected at the end of the camp to represent India at the 56th International Mathematical Olympiad held at Chiang Mai, Thailand in July, 2015. The team won one Silver medal, two Bronze medals and three Hon'ble Mentions. C. R. Pranesachar (IIS, Bangalore) and Rajendra Pawale (Mumbai University) were the leaders. K. N. Ranganathan (Vivekanand college, Chennai) and Prithwiji De (HBCSE, Mumbai) were the Scientific Observers. [P. De]

Resource Generation Camps (RGCs)

Several Resource Generation Camps (RGCs) in which teachers and scientists from across the nation gathered for development of curriculum and Olympiad material were held in all the subjects. The Biology RGCs were organized during: September 3-4, 2015; September 14-15, 2015; October 27-28, 2015; November 26-27, 2015 and December 7-8, 2015, having 4, 4, 3, 3 and 3 participants respectively. The Chemistry RGC were organized during: September 30-October 3, 2015, having 31 participants. The Junior Science RGCs were organized during: March 6-7, 2015; March 14-15, 2015; April 25-26, 2015; July 18-19, 2015; August 22-23, 2015 and October 31- November 1, 2015, having 30, 30, 25, 25, 20 and 14 participants respectively. The Physics RGCs were organized during: January 3-5, 2015; February 9-14, 2015; October 1-3, 2015; January 15-19, 2016 and February 5-9, 2016, having 5, 8, 12, 24 and 7 participants respectively.

Exposure Camps (EC)

Several short 3-4 day exposure camps were held in different subjects where a large number of school and college teachers were invited. Participants in these camps included teachers from neighboring countries. Olympiad problems and experiments were discussed in these camps. Towards the end of the camp the teachers were invited to suggest

challenging tasks for the students and critique existing textbooks. The Astronomy EC was held during November 10-13, 2015 for 45 participants; the Biology EC was held during October 14-16, 2015 for 18 participants; the Chemistry EC was held during November 16-18, 2015 for 38 participants and the Physics EC was held during November 30- December 3, 2015 for 42 participants.

Other activities

Several workshops were held during April to June, 2015 at HBCSE for the academic preparation of the 46th International Physics Olympiad (IPhO 2015), involving more than 70 teachers and scientists from across the nation. These included a five-week workshop with 50 college teachers to assemble, test and record data on 430 sets of the experimental apparatus of IPhO 2015.

Teacher orientation workshops for Junior Science Olympiad were held at multiple places throughout the year; for 32 teachers in Vapi, June 7 and 9,

2015; for 29 teachers Kutch University, June 15 and 17, 2015; for 60 teachers in Pal, Maharashtra, June 23-28, 2015; for 14 teachers at HBCSE in collaboration with Janakalyan Samiti, Mumbai, August 10-13, 2015; for 26 teachers in Majhihira, West Bengal, September 8-10, 2015; for 39 teachers in Dombivli, September 25-27, 2015; for 28 teachers in Guwahati, October 8-10, 2015; and for teachers at Atomic Energy Central School, Tarapur, January 21- 23, 2016. [P. K. Joshi, P. K. Nawale and S. Mukherjee]

National Initiative on Undergraduate Science (NIUS)

Since its inception in 2004, the primary aim of the National Initiative on Undergraduate Science programme (NIUS) of HBCSE has been to promote undergraduate research and learning. The programme has been contributing towards R&D in training of students and teachers in experimental science, development of theoretical and laboratory courses and preparation of pedagogical materials. Around 1300 undergraduate students have benefited from the NIUS programme in various ways by being a part of the exposure-cum-enrichment camps. This year about 91 undergraduate students were invited to attend the NIUS camp and many of the students were from non-metropolitan colleges. In these camps, students have intense interactions with scientists, researchers and passionate teachers and thus, experience the vibrant and exciting aspects about being engaged with science. The quality of these interactions reflect in the project work carried out by NIUS students and the resultant publications in national and international journals.

Biology

The NIUS camp for Biology (XII.1) was conducted at HBCSE from November 2-6, 2015. Forty-two students from regular B.Sc. or integrated M.Sc. courses were selected and the camp was attended by 37 students. The resource persons for the camp

included HBCSE resource persons and B. B. Nath (Pune University), D. Singh (MS University, Baroda), J. D'souza (Centre for Excellence in Basic Sciences, Mumbai), K. Vachharajani (MS University, Baroda), S. Menon (Therapeutic Drug Monitoring Lab, Mumbai). The theoretical sessions at the camp were related to basic concepts of biology, bio-analytical techniques in studies of medicinal plants, spectral identification of plants, marine biology, chromosome studies, and irreducible multi-protein complexes in cells and research in plant sciences. The laboratory sessions covered experiments related to biochemistry, molecular biology and animal behavior. From this batch, 3 students were selected to pursue NIUS projects in different areas of biology. In addition, 12 students from earlier batches of NIUS Biology visited HBCSE to complete their projects and are in process of writing their reports. [R.Vartak, A. Ronad and V. Ghanekar]

Chemistry

The NIUS camp for chemistry (XII.1) was held at HBCSE from December 23-31, 2015 and was attended by 49 students from regular B.Sc. /BS or integrated M.Sc. Courses. The speakers at the camp included A. Dutta (IIT Mumbai), A. Kumbhar (University of Pune), A. A. Natu (IISER Pune), D. Jain (BARC, Mumbai), L. Ravishankar (V. G.Vaze

College, Mumbai), M. Sundararajan (BARC, Mumbai), P. Chobe (Formerly, BASF India Limited, Mumbai), R.V. Jayaram (ICT, Mumbai), S. D. Samant (ICT, Mumbai), S.S. Bhagwat (ICT, Mumbai), S.K. Ghosh (BARC, Mumbai), T. Ghanty (BARC, Mumbai), T. Parulekar (SIWS College, Mumbai) G. Shridhar (V. K. Menon College, Mumbai) and S. Chunawala (HBCSE).

The theoretical sessions at the camp were related to fluorescence, overview of research areas in inorganic chemistry, nature of science, bio-inorganic chemistry, computational chemistry, quantum chemistry, organic synthesis and mechanisms of organic reactions, catalysis, overview of surfactant science, solid state chemistry, chemical thermodynamics and spectroscopic techniques for structural elucidation. The camp also included following workshops a) using Process Oriented Guided Inquiry Learning (POGIL) instructional material to understand concepts such as formal charge, structure and bonding in organic chemistry, b) reading of scientific papers, c) designing of experiments.

The laboratory sessions at the camp were aimed at planning the experiment for a specific purpose with the list of chemicals and glassware provided to students. They had to assess the merits and demerits of their planning and also look at the safety and risks involved. Example of representative experiments suggested were estimation of carbonate/bicarbonate in a mixture,

identification of type of organic mixture and separation procedure of mixtures, kinetic studies of methylene blue-glucose reaction and hydrogen peroxide-potassium iodide reaction.

At the computational chemistry laboratory sessions, students were introduced to GAUSSIAN-09 and Gaussview. Students did computational calculations about different conformations of hydrogen molecule, hydronium ion, ammonia/ ammonium ion, fumaric acid-maleic acid (cis-trans conformations). Twenty-seven students were selected for project work and in addition, 39 students from earlier batches of NIUS Chemistry visited HBCSE for further development of their projects. Seventeen students have completed the projects and submitted their reports. [A. Gupta, A. Kumar, S. Ladage, I. D. Sen and S. Narvekar]

Physics and Astronomy

In the summer of 2015, 13 students from earlier batches of NIUS physics and astronomy visited HBCSE, and 22 students visited HBCSE in winter 2015, to complete their projects and prepare their project reports.

Students from previous years of Astronomy and Physics Olympiad and NIUS were invited to participate in the Eleventh Nurture Camp held at Maulana Azad National Urdu University, Hyderabad from December 2-14, 2015. [A. Sule, A. Mazumdar, P. Ranadive and M. N. Vahia (DAA, TIFR)]

Professional Development of Teachers and Teacher Educators

Facilitating teacher professional development (TPD) through workshops for teachers has been a part of the activities of HBCSE from its inception. These workshops are held based on requests received from schools and organizations, and also as planned intervention programmes. Most of these workshops are collaborative with a number of HBCSE academic, scientific and project staff members from different laboratories coming together to enrich the training of teachers. This collaboration extends to numerous groups that approach HBCSE for TPD. This year, our collaborations included DSERT Karnataka, Zonal Institute of Educational Training (ZIET), Kendriya Vidyalaya Sangathan, Vissanji Academy, Rayat Education Society, Hemendra Kothari Foundation, Chiplun Taluka Vidnyan Mandal, Tata Institute of Social Sciences, etc. Apart from these, there have been workshops for DIET faculty, varied individual schools/teacher education colleges of Mumbai and

Maharashtra. Additionally, there were two residential courses organized by HBCSE for teachers and teacher educators from Sri Lanka and East Timor.

Since 2015, the School Science Research and Development (SSRD) cell of HBCSE has regularized the schedule for TPD workshops focusing on capacity building of school teachers/student-teachers and/or teacher educators. Details of these workshops catering to in-service or pre-service teacher training were uploaded on the HBCSE teacher education website: <http://teacher-ed.hbcse.tifr.res.in/>. The details are in the form of a yearly calendar for teacher education, and specify varying durations of courses and possible themes.

Teacher Workshops for Rayat Shikshan Sanstha Satara: Several workshops were organised for teachers of

this institution on the request of the Chairman and Secretary of the Sanstha. Three residential workshops of 5 days each were organised at HBCSE: (i) Elementary teachers' workshop was organised from June 8-12, 2015. The workshop had the aim of preparing worksheets for class III, Environmental Science, which the teachers can use for classroom teaching and learning. Totally 36 teachers participated in this workshop (ii) School science teachers' and Junior college teachers' workshop was organised from August 24-28, 2015 at HBCSE on the theme – Science Education and Introduction to Science Olympiads for 44 teachers (iii) Science teachers' workshop on 'Science Education, Science Project and INSPIRE Program' was organized at HBCSE from October 5-9, 2015 and was attended by 37 teachers. [N.D. Deshmukh (Program Coordinator), J. Ramadas, S. Chunawala, S. Ladage, R. Vartak, A. Gupta, P. K. Joshi, A. Sule, S. Pathare, M. Kharatmal, V. Ghanekar, A. Ronad, V. C. Sonawane, S. Bhide, P. K. Nawale, K. T. Hambir, S. Ayare, R. Shaikh, V. Pawar, T. Khan, H. Mishra, H. Raval, A. Sadanandan, P. Khatri, S. Kolambe, A. Kadam, R. Subedi, V. Kurmude, P. Choudhari, B. Dhebhe and S. Mukherjee]

Rayat's D.Ed College Workshop focussed on 'Students' conceptions in science' was conducted for students and teachers of Shahu Maharaj D. Ed. college at HBCSE from January 11-12, 2016 [N.D. Deshmukh (Program Coordinator), V. C. Sonawane, K.T. Hambir, V. Pawar, S. Chavan]. *Chiplun Teacher Professional Development Workshop* organised by Chiplun Taluka Vidnyan Mandal for 25 teachers, Chiplun, Ratnagiri was also organized at HBCSE on January 11, 2016. [V. C. Sonawane]

Karnataka DSERT TPD: On the request of the Department of State Educational Research and Training, Karnataka, a teachers' workshop for their physics teachers was held from June 22–26, 2015 at HBCSE, aimed at equipping the teachers in laboratory work based on grades 8-10 Karnataka State curriculum along with pedagogic strategies. [V. C. Sonawane (Program Coordinator), J. Ramadas, S. Chunawala, K. Haydock, A. Kumar, P. K. Joshi, K. Subramaniam, H. C. Pradhan, N. D. Deshmukh, M. Kharatmal, V. Pawar, S. Ayare, D. Gupta and R. Shaikh]

SIAC Project: For the past two years, HBCSE is involved in setting up 'Science and Innovation Activity Centers' (SIAC) in Maharashtra. A workshop on "Setting Sustainable Goals, Resources and Practices for Science and Innovation Activity Centers (SIAC) proposed in Maharashtra" was organized at HBCSE from July 13-15, 2015. This collaborative project involving HBCSE, the Nehru

Science Centre, Mumbai, Bharatiya Vidya Bhavan's Mukangan Exploratory Science Centre, Pune and Vigyan Ashram, Pabal was funded by the Rajiv Gandhi Science and Technology Commission. The workshop aimed to help institutions form detailed project proposals. Six representatives from three centers (Nashik, Satara & Amravati) attended the workshop, where sessions were held explaining 'the significance of activities and role of science centres in classroom teaching & learning'. Visits were also arranged to the collaborative institutions in Mumbai, Pune, and Pabal. [N.D. Deshmukh (Program Coordinator), J. Ramadas, V. C. Sonawane, K.T. Hambir, V. Pawar and R. Mishra]

Two-Week Residential Course on Science and Mathematics Education for Sri Lankan educators: The Science Branch of the Ministry of Education, Government of Sri Lanka requested HBCSE to organize a short course of 15 days for their science teachers and education officers. This course was conducted at HBCSE from November 13-30, 2015 for 20 participants. The course aimed to expose participants to science education research literature; models of learning and teacher professional development; designing worksheets for classroom use; and sharing and comparing Indian and Sri Lankan education systems. Sessions were conducted by HBCSE members on educational policies, curriculum frameworks, constructivist philosophies of learning, research readings, nature of science, socio-cultural aspects of education, design and technology education, textbook analysis, assessment, activity based teaching, and science through investigation. Visits to schools, teacher education institutes and Nehru Science Centre were also organised. Additionally, video screenings followed by discussions were organized on themes related to hands-on learning and sustainability. [N. D. Deshmukh (Program Coordinator), J. Ramadas, S. Chunawala, K. Haydock, S. Ladage, G. Nagarjuna, K. Subramaniam, H. C. Pradhan, A. Kumar, A. Gupta, M. Kharatmal, V. C. Sonawane, I. Das, S. Narvekar, S. Naik, S. Bhide, S. Varadarajan, G. Singh, K. T. Hambir, P. K. Nawale, R. Sandhya, R. Shaikh, V. Pawar, A. Muralidhar, D. Gupta, P. Sharma, R. Kapil, T. Khan, H. Mishra, P. Khatri, A. Sadanandan, S. Kolambe, B. Chirmure and S. Shende]

KV-ZIET Workshop on Project-Based Learning: As part of their regular Teacher Professional Development programmes, Kendriya Vidyalaya- Zonal Institute of Education and Training had organised a three day workshop on "Project Based Learning" (PBL) for TGT Science and TGT Social Science teachers from KVs all over India, from 18-20 November 2016. Resource persons were from HBCSE and

KV. HBCSE members conducted sessions on; Introduction to PBL, implementation and assessment of PBL. Teachers had to select a PBL topic and they worked in groups to collect data and present their work on the final day of the workshop. [S. Chunawala, S. Bhide, A. Muralidhar and R. Kapil] HBCSE members were involved in reviewing and editing learning materials in mathematics produced by Zonal Institute of Kendriya Vidyalaya for teachers of grades I to V. [T. Khan, J. Rahaman, H. Raval, H. Mishra, S. Takker and S. Naik]

Timor-Leste's Teacher Visit Program: A one week workshop on Science and Mathematics Education was organized for 11 teachers from Timor-Leste (a southeast asian nation) between January 18 to 23, 2016. Prof Curt Gabrielson (Watsonville Environmental Science Workshop) who was a mentor to the East Timor team also participated in the workshop. The sessions focused on sharing of experiences, insights and resources from HBCSE's science and mathematics education research, as well as development and outreach work done in India and Timor-Leste. Emphasis was also placed on educational research, curriculum design, hands-on science and mathematics, and design and technology. An excursion tour, visit to Pune Mukatangan Vigyan Shodika and visits to schools was also arranged. [N. D. Deshmukh (Program Coordinator), J. Ramadas, S. Chunawala, K. Subramaniam, J. Vijapurkar, V. C. Sonawane, S. Bhide, S. Naik, T. Khan, H. Raval, K. T. Hambir, S. Patil, A. Sawant, D. Gupta, P. Sharma, A. Muralidhar, V. Pawar, T. Adangale and S. Chavan]

Teacher Professional Development in Mathematics: The mathematics education research group continually conducts a variety of professional development workshops for in-service teachers. An important goal of the workshops is to address knowledge demands made by various tasks that are a part of teaching mathematics. Teacher preparation and education programs in India do not typically address such knowledge demands and hence do not adequately empower teachers for different tasks of teaching. The TPD workshops generally include sessions on the following: (a) profound understanding of school mathematics, (b) pedagogical content knowledge, (c) learning from students' thinking and errors, (d) understanding curriculum in depth to develop representations, (e) contexts and models for teaching, (f) learning from artifacts of teaching such as videos and lesson plans, and (g) learning through problems that integrate mathematical content and pedagogy. The sessions are conducted in an interactive mode and some of the resource materials used are uploaded

on the math-education website. Some of the schools/organizations for whom TPD workshops were conducted this year are – Anand Shala, Khopoli; Rayat Education Society, Pandharpur; Mukatangan Schools, Mumbai; St. Xavier's Institute of Education, Mumbai; CEQUE and Parle Tilak Vidyalaya, Mumbai; Nashik Education Society, Nashik; Atomic Energy Central Schools (AECS), Mumbai.

Workshops on making and using the mathematics laboratory were also conducted for secondary, middle-school and primary teachers on designing mathematical activities, puzzles and games and understanding their pedagogical affordances. Such workshops including those focused on using GeoGebra (a free software for dynamic geometry and algebra) were held for the following schools/organizations: Kendriya Vidyalaya; AECS schools; Rayat Shikshan Sanstha. Various short workshops (typically half a day) were also held for the following schools/organizations: Vissanji Academy, Mumbai; Indian Women Scientists Association; St. Stalisnaus High School, Mumbai. [S. Naik, T. Khan, H. Raval, R. D'Souza, J. Rahaman, H. Mishra and K. Subramaniam]

Astronomy Olympiad Exposure Camp: An Astronomy Olympiad Exposure Camp was organised from November 10-13, 2015 at HBCSE for 70 teachers selected from all over India. [A. Sule, A. Mazumdar and P. Ranadive]

Workshops organized elsewhere: HBCSE scientific staff are involved in conducting workshops for science teachers at various locations outside HBCSE. This year most of these workshops were in Maharashtra.

The 3rd Shivaji Vidnyan Parishad organised by the Shri Shivaji Education Society, Amravati focussed on 'Designing Constructivist Classroom Learning Environment'. This workshop was held at Jijamata Science College, Buldhana from December 21-23, 2015 and was attended by 58 science teachers. [N.D. Deshmukh (Program Coordinator), V. C. Sonawane and K. T. Hambir].

Pandharpur Primary Teachers Workshop organised by Lotus School Pandharpur was an activity based science teachers workshop. It was held in July, 29-31, 2015 and attended by more than 45 teachers [V. C. Sonawane (Program Coordinator), K.T. Hambir and R. Shaikh].

Akluj Teacher Workshop on Activity based science teaching was held on June 15, 2015, and was organised by Mohite Patil High School Akluj [N. D. Deshmukh and K. T. Hambir].

Wardha District Science Teacher Association Workshop held on February 13, 2016 focussed on 'Constructivist Science Learning and the Role of Experiments'. More than 200 science teachers participated in this workshop. [N. D. Deshmukh and K. T. Hambir].

The 3rd Rayat Vidnyan Parishad organised by Rayat Shikshan Sanstha, Satara on 'Science Learning' was held at Sadhana Sankul Hadapsar, Pune in collaboration with HBCSE from January 23-25, 2016. More than 600 science teachers participated

in this workshop. [N. D. Deshmukh, V. C. Sonawane and K. T. Hambir].

A workshop for Biology teachers was held at the Department of Microbiology, St. Ann's college for women, Santoshnagar Colony, Mehdiapatnam, Hyderabad. This 2 day workshop on 'Biology teaching-the missing link', was organised on January 6-7, 2016, and was a collaboration between HBCSE and Asian Association for Biology Education. Around 42 biology and science teachers participated in this workshop. [N. D. Deshmukh]

Science Popularization

Over the years, HBCSE has developed a variety of popular science materials and has aimed at disseminating it to the masses of the country. During the period of this report, HBCSE staff members contributed articles, gave popular science talks and featured in radio and TV programs as a part of science popularization and outreach efforts. Expository articles were published in leading national science and technology magazines and newspapers of the country.

Visits to HBCSE

HBCSE receives a number of visitors to its facilities and laboratories throughout the year including students from various schools and colleges along with their teachers, pre-service teachers from B.Ed. and D.Ed programmes along with teacher educators, children's visits to the Centre were also organized by non-governmental organizations of Mumbai region. In all, more than 450 students and teachers visited HBCSE during the year. Visitors from Parle Tilak, Kumud Vidyamandir, Aamchi Shala, AECS, Chhatrapati Shahu College, Rurki, Gokhale Education Society's HPT Arts & RYK Science College (Nashik) among other institutes had interactions with HBCSE members. [V. C. Sonawane (Coordinator), N. D. Deshmukh, K. T. Hambir, V. Pawar, T. Adangale, T. Khan and H. Ravall]

National Science Day 2016

As in every year, the National Science Day (NSD) was celebrated at the Centre by having an Open House that witnessed over 2000 visitors which included students, teachers, teacher educators and parents from Mumbai region. Some of the main attractions of the day were Rocket demonstration, Computer Corner, Botanical Garden tour, Design & Technology activities, Mathematics games, the Liquid Nitrogen Show, and Hindi Cell display of books and materials and exhibition of educational

posters. Posters on science and technology prepared by student volunteers were displayed on the occasion. Technical staff members of HBCSE displayed several gadgets and demonstrated the working of household equipment. The Design and Technology (D&T) Lab had arranged an array of activities aimed to spark creative problem solving and expression and give visitors opportunities to think, make and test while the Junior Science Olympiad cell demonstrated science experiments along with a question-answer session. An activity around the Gender and Science Exhibition was also organized for all students. The Centre's publications, as well as publications, resources, toys, posters of other organisations were displayed and kept for sale. [V. C. Sonawane (Coordinator) and all HBCSE staff members]

Web-based popular science materials

The Hindi Cell of the HBCSE developed a variety of popular science materials and made them available on its portal (<http://ehindi.hbcse.tifr.res.in>). The portal is aimed at improving scientific literacy in the country and inculcating scientific temper among its masses. Popular science articles, magazines and other related materials were uploaded on the portal throughout the year. [K. K. Mishra, K. Sinha, D. Mishra, A. Sankhwar and R. Nichat]

During the International Physics Olympiad organised in Mumbai by HBCSE, a print and web based newsletter titled *Reflections* was published. Nine issues were released and each issue contained information about the day's events, photo collage, puzzles, games, jokes, articles on famous Indian physicists, Mumbai and India. HBCSE members developed the design, layout, resources and content for *Reflections* 2015. All the issues are available online at <http://www.ipho2015.in/reflections/> [S.

Chunawala, M. Nair, A. Muralidhar, D. Prabhu, D. Gupta, P. Sharma and S. Ayare]

Science popularization at GMRT, Pune

HBCSE participated in the National Science Day programme held at Giant Meterwave Radio Telescope (GMRT) Center, Pune. GMRT organized a two-day programme on February 28-29, 2016 whose theme was "Make in India: Science & Technology Driven Innovations". HBCSE took active part in the programme and put up many gadgets, working models and exhibits including the rocket show and webcam microscopy. [V. C. Sonawane (Coordinator), K. T. Hambir, T. Adangale, D. Gupta and S. Kulkarni]

Science outreach at Bhiwandi

HBCSE in collaboration with Thakar Educational and Welfare Society organized an outreach program, Adbhut Vigyan on March 6, 2016 at Damodar Shishu Vihar School, Bhiwandi, Thane. More than 3000 students and parents visited this exhibition. [V. C. Sonawane (Coordinator) and other staff members]

Activities of the Hindi Cell and Rajbhasha Committee

The Hindi Cell was involved in promoting the use of Hindi language in general at the Centre and in particular in the area of development of educational and popular science materials. Hindi Cell also took care of the 'Aaj ka Shabd', where interesting educational poems, cartoons and other information were put up on the display board throughout the year. [K. K. Mishra, K. Sinha, D. Mishra and S. Deoram]

CUBE in media

Collaborative Undergraduate Biology Education (CUBE) initiative of HBCSE featured in the news several times this year: DNA Mumbai (October 19, 2015), Times of India, Chandigarh (November 21, 2015); Malayala Manorama (August 7, 8, 2015) and Dainik Samachar, Jaipur (October 2015). Additionally, a 3-day workshop on Do-It-Yourself, techniques in building laboratory equipment was organized in February 2016. The final day of the workshop was a public event towards popularizing Science, at Chembur, where participants of the workshop displayed the artefacts they created over the course of 3 days.

Members

J. Ramadas (Centre Director), K. Subramaniam, (Dean, HBCSE Faculty), B. J. Venkatachala (upto 31/10/2015), S. I. Chunawala, S. A. Ladage, R. R. Vartak, A. Mazumdar, G. Nagarjuna, K. K. Mishra, J. Vijapurkar, R. B. Khaparde, A. P. Sule, P. K. Joshi, P. De, K. Haydock (upto 29/02/2016), S. Chandrasekharan, A. Gupta

N. D. Deshmukh, V. D. Lale, V. C. Sonawane, S. R. Pathare, A. Das (upto 31/12/2015), A. D. Ghaisas (upto 30/04/2015), S. M. Narvekar, A. Ronad, R. P. Nichat, M. B. Kharatmal, D. D. Pednekar, T. S. Rajashekar, P. K. Nawale, Manoj K. R., S. S. Naik, P. P. Pathak, A. Muralidhar, I. Das, A. Sankhwar, V. S. Ghanekar, P. Ranadive, H. Raval

Visiting Fellows

S. Bhide, R. Thengodkar, S. Krishnan (upto 23/12/2015), D. Gupta, S. Datt

Research Scholars

A. Srivastava (upto 31/07/2015) S. Ghumre, (upto 31/07/2015), S. Takker (upto 31/07/2015), J. Rehaman (upto 31/07/2015) R. Shaikh, P. Pande, R. Varkey, G. Singh, R. D'Souza, H. Srivastava, G. Date, S. Kabir (upto 29/01/2016), K. Mishra, D. Karnam, D. Dutta, S. Philip (upto 31/07/2015), C. Navare, M. Shah, Ratna, S. Varadarajan

PhD students (external)

A. Raveendran, A. Sharma, A. Dhakulkar, R. Kumar, A. Kawalkar

INSA Senior Scientist

S. M. Roy, D. P. Roy

Raja Ramanna Fellow

H. C. Pradhan

Administration

M. D. Gaitonde (Sr. A. O.), V. P. Raul, M. M. Mastakar, (upto 31/05/2015) S. V. Amin, S. N. Burli, M. B. Bamne, M. P. Akhade, M. S. Thakur, S. L. Rasam, R. A. Shrotri, D. R. Mhapsekar, S. K. Desai, M. G. Shinde, G. A. Tawate, H. M. Mandlik, T. S. Shirodkar, R. Sawant, S. Shejwal, S. Wairkar

Technical

N. Y. Tribhuwan, S. D. Pardeshi, V. C. Jacob, H. H. Rane, V. P. Ahire, K. T. Hambir, J. J. Tambe, S. S. Chavan

Auxiliary

J. B. Waghmare, U. V. Shenoy, R. G. More, N. K. Kadam, B. L. Valvi, N. S. Thigale (upto 29/02/2016), G. V. Mestry, B. S. Bhagit

Consultants

P. K. Balakrishnan, M. C. Arunan, B. J. Venkatachala, C. R. Pranesachar

National And International Involvement

A. Mazumdar was 1) National Coordinator, Science Olympiads; 2) Convener and Coordinator for Theoretical component of the 46th International Physics Olympiad; 3) Member, Academic Committee of the 46th International Physics Olympiad. **A. Ronad** was 1) Executive Board Member, Association of Teachers in Biological Sciences. **A. Sule** was 1) Regional Coordinator (Asia-Pacific) for the International Olympiad in Astronomy and Astrophysics (IOAA) from January 1, 2012 to December 31, 2016; 2) Member of Coordination Committee for National Entrance Screening Test 2014, 2015; 3) Chair, Academic Committee, 11th Asia Pacific Astronomy Olympiad, Dhaka, Bangladesh, November 2015. **G. Nagarjuna** was 1) Member, Institutional Advisory Board, Central Institute of Educational Technology, NCERT, New Delhi; 2) Associate Editor, *International Journal of Conceptual Structures and Smart Applications* (IJCSSA), an Official Publication of the Information Resources Management Association; 3) Reviewer, *Science & Education*, Springer; 4) Chairperson, Free Software Foundation of India; 5) Member, Board of Software Freedom Law Centre of India, New Delhi; 6) Member, Advisory Board, K.J. Somaiya College of Engineering, Mumbai; 7) Member, Web Server Committee, National Board of Higher Mathematics. **J. Ramadas** was 1) Member, IUPAP International Commission on Physics Education (ICPE) for the period 2011-16; 2) Member, Governing Council of the Atomic Energy Education Society (AEES), 2011-16; 3) Member, Science Committee, Maharashtra State Bureau of Textbook Production & Curriculum Research, Pune. **K. K. Mishra** was 1) Member, National Academy of Sciences, India; 2) Member, Executive Council, Lok Vigyan Parishad, Delhi; 3) Joint Secretary, Peoples Council of Education, Allahabad; 4) Member, Vigyan Parishad Prayag, Allahabad; 5) Member, Advisory Board, Vigyan-Ganga, Banaras Hindu University, Varanasi; 6) Member, Advisory Board, Technical Today, a national science and technology magazine brought out by Mewar University; 7) Member, Editorial Board, Vigyan Prakash, World Hindi Foundation, Oswego, New York, USA. **K. Subramaniam** was 1) Member, National Council for Teacher Education (NCTE); 2) Member, Academic Committee, NCERT, New Delhi; 3) Country representative for India, International Commission for Mathematics Instruction; 4) Member, Journal Editorial board, Contemporary Education Dialogue; 5) Member, Journal Editorial board, At Right Angles; 6) Member, Advisory board, Information Age Publishing: International Sourcebooks in Mathematics and Science Education; 7) Member, Advisory Board, World Bank study on "Time on Task in Secondary Schools". **N. D. Deshmukh** was 1) Executive Director for 26th Biennial Conference of the Asian Association for Biology Education; 2) Executive Member, Asian Association for Biology Education; 3) Executive Member, Indian Ocean Comparative Education Society and Executive Committee member for 2015-2017 IOCES conference; 4) Editorial Board Member, Asian Journal of Biology Education (AJBE); 5) School Council Member, YCMOU Nashik B.Sc. Course; 6) Advisory Member, Shikshan Sankramann Journal; 7) Honorary Member, Vidnyan Warta Journal. **P. K. Joshi** was 1) President of the International Junior Science Olympiad for the period 2015 – 2018; 2) Chairman, Bombay Association for Science Education. **P. Pathak** was 1) Member, Academic Committee of the 46th International Physics Olympiad; 2) Member, International Advisory Committee of International Physics Olympiad for the period 2013-17. **R. Khaparde** was 1) Coordinator for Experimental component of the 46th International Physics Olympiad; 2) Member, Academic Committee of the 46th International Physics Olympiad. **R. Vartak** was 1) Executive Board Member, Association of Teachers in Biological Sciences; **S. Chandrasekharan** was 1) Adjunct Associate Professor, Interdisciplinary Program in Educational Technology, Indian Institute of Technology Bombay, Powai, Mumbai, India; 2) Grant Reviewer, Science Technology and Society program, National Science Foundation, USA; 3) Committee member, Ph.D. Thesis Advisory Committee for Paul Clifton, Digital Media Program, Georgia Institute of Technology, Atlanta, USA; 4) Advisory Board Member, Studies in Applied Philosophy, Epistemology and Rational Ethics, Springer book series; 5) Conference Convener, epiSTEME 6 International Conference, India, 2015 (with Sahana Murthy, IIT Bombay); 6) Program Committee Member, Technology for Learning of Thinking Skills, The 22nd International Conference on Computers in Education, 2016, Mumbai, India; Technology for Education (IEEE), 2015, Warangal, India; and Technology for Education (IEEE), 2016, Mumbai, India. **S. Chunawala** was 1) Reviewer for Indian Educational Review, NCERT; 2) Executive Council Member of the Peoples Council of Education for the year 2012-2015; 3) Member, Departmental Advisory Board (DAB), Department of Gender Studies, NCERT; 4) Member, Board of University Teaching and Research, YCMOU; 5) Member, Board of Studies, SNDT University, Marine Lines, Mumbai; 6) Local Management Committee member, KJ Somaiya Comprehensive College of Education, Training and Research; 7) Reviewer, epiSTEME 6 conference; 8) Executive Board Member, 2016-2018, Representative of South Asia, IOSTE. **S. Ladage** was 1) National Coordinator, National Initiative on Undergraduate Science (NIUS) programme; 2) Co-opted member, Executive Council, Association of Chemistry Teachers (ACT). **S. Narvekar** was 1) Secretary, Executive Council, West Zone, Association of Chemistry Teachers (ACT). **S. Pathare** was 1) Member, Academic Committee of the 46th International Physics Olympiad. **V. D. Lale** was 1) Editorial Committee Member, Kumar Vishwakosh (Biology & Environment), Maharashtra Rajya Vishwakosh Nirmiti Mandal, Wai; 2) Academic Committee Member, Shikshan Pandhari Project, Maharashtra Knowledge Corporation Limited, Pune; 3) Author and Member, Science Committee, Maharashtra State Bureau of Textbook Production & Curriculum Research, Pune.

Visits

G. Nagarjuna participated in the Design Workshop for Connected Learning Initiative (CLIX) at MIT Boston from August 3-14, 2015. **H. Srivastava** participated in the Design Workshop for Connected Learning Initiative (CLIX) at Massachusetts Institute of Technology, Boston from August 3-7, 2015. **K. Subramaniam** 1) participated in a research collaboration seminar-cum-workshop on Video Analysis of Classroom Mathematics Teaching at the Wits University, Johannesburg, August 11-20, 2015; 2) attended the meeting of the Internal Quality Assurance Cell of the St. Xavier's Institute of Education as an external member, February 13, 2016. **S. Chunawala** participated in an International Visual Methods Seminar, at the University of Antwerp from August 23- September 5, 2015. **A. Sharma** participated in the All India Association For Educational Research Annual Cum International Conference on Standards and Benchmarks for Excellence in Learning, Teaching and Research, Thiruvananthapuram, Kerala, November 26-28, 2015. **A. Sule** participated as the Chair of the Academic Committee of the 11th Asia Pacific Astronomy Olympiad, Dhaka, Bangladesh, November 2015. **S. Chunawala and A. Muralidhar** participated in the National Seminar on Education of Socially Disadvantaged Groups in India, Regional Institute of Education, Bhopal, March 5, 2016. **P. Pande** participated in the Visualization in Science and Education Gordon Research Conference, Bates College, Lewiston, Maine, USA, August 2-7, 2015;

Conference on Cognition, Brain and Computing, Indian Institute of Technology, Gandhinagar, December 5-7, 2015. **H. C. Pradhan** attended 1) Educators Academy, Intel International Science and Engineering Fair, Station Square Sheraton Hotel, Pittsburgh, PA, USA, May 10-15, 2015; 2) National Convention of the Indian Association of Physics Teachers, St Pious X College for Women, Nacharam, Hyderabad, October 30-November 1, 2015; 3) National Teachers' Science Congress, hosted by Marathi Vidnyan Parishad at Indian Institute of Science Education and Research, Pune, December 18-20, 2015; 4) National Children's Science Congress 2014, Chandigarh University, Mohali, Punjab, December 26-31, 2015. **R. D'Souza** participated in 'Mathematics Education and Society 8' conference held at Portland State University, Portland, USA, June 21-26, 2015.

Invited Talks

H. C. Pradhan

1. Multifarious physics of light (Keynote Address), *National Conference on Light and Its Applications*, organized by IAPT - Gogate College, Ratnagiri – Government College, Quepem, at District Library, Madgaon, Goa, March 18, 2016

2. History of the concept of light (Keynote Address), IAPT-GUJCOST Workshop to celebrate the International Year of Light and General Theory of Relativity, Science City, Gandhinagar, June 28, 2015

J. Ramadas (with Durgaprasad Karnam)

Spatial thinking in undergraduate science education, *International Conference on Innovations in Teaching, Learning and Evaluation in Higher Education*, Modern College, Shivajinagar, Pune, January 29-30, 2016

K. Subramaniam

Encouraging and supporting students' thinking in the learning of science", Chitra Natarajan Memorial Lecture

and Keynote Address, *One-day Teachers' Conference on Encouraging and Supporting Students' Thinking in the Learning of Science*, Navi Mumbai Science Foundation, Vashi, February 6, 2016

S. Chandrasekharan

Modeling Modeling: An incorporation account of model-based discovery, and how it informs learning sciences research (Keynote presentation over Skype), *Sixth International Conference in Model-based Reasoning*, Sestri Levante, Italy, June 26, 2015

S. Ladage

Research in chemistry education and its implications for teaching and learning of chemistry at tertiary level (Review Talk), *epiSTEME 6: International Conference to Review Research on Science, Technology and Mathematics Education*, December 17, 2015

Conferences / Workshops Organized By the Centre

Two-Day National Conference on "Creative Writing in Science for Children"

HBCSE, October 3-4, 2015

The Marathi Vidnyan Parishad and HBCSE (TIIFR) jointly organized a two-day national conference on *Creative Writing in Science for Children*, at HBCSE, October 3- 4, 2015.

Annual Research Meet

HBCSE, October 12-13, 2015

One-Day Seminar on "ROAD Ahead in Science, Technology and Mathematics Education in India,"

HBCSE, October 14, 2015

HBCSE organized a one day seminar on *Road Ahead in Science, Technology and Mathematics Education in India*, October 14, 2015. The seminar is in memory of Late Prof. Chitra Natarajan, former Dean, HBCSE. Speakers at the seminar were- Prof Anita Rampal (Central Institute of Education, Delhi University), Jayashree Ramadas, K. Subramaniam, Swati Mehrotra (Educational consultant, Singapore), Arvind Kumar, Aswathy Raveendran. Prof H. C. Pradhan chaired the seminar. It was followed by a function to release the book "Embracing lives, Chasing passions: Memoirs of Chitra Natarajan", edited by Dr. R. Rajagopal.

Two-Week Residential Course on "Science and Mathematics Education"

HBCSE, November 13 –30, 2015

A two week workshop was jointly organized by HBCSE and the Science Branch, Ministry of Education, Sri Lanka, HBCSE, for 20 Science Teachers and Education Officers of Sri Lanka.

International Conference epiSTEME-6

HBCSE, December 15-18, 2015

Conference epiSTEME-6, the sixth in the series of epiSTEME conferences, was jointly organized by HBCSE and the Inter-Disciplinary program in Educational Technology Program, Indian Institute of Technology, Bombay (IITB), from December 15-18, 2015. Conference epiSTEME-6 focused on three central research strands: Historical, Philosophical and Socio-cultural studies of STME, Cognitive and Affective Studies of STME, and Curriculum and Pedagogical Studies in STME. This year's conference had an additional focus theme – "Emerging Computational Media and Science Education". The conference consisted of review talks by invited speakers, paper and poster presentations, pre and post conference workshops, and a panel discussion. The conference received a total of 84 paper submissions, which were blind peer-reviewed; 26 papers (31%) were accepted for oral presentation, and a further 29 papers (34%) were accepted for poster presentation. Conference epiSTEME-6 was attended by 16 foreign participants (6 review speakers) and 102 Indian participants (not including HBCSE participants). There were 4 panel speakers. Sanjay Chandrasekharan from HBCSE and Sahana Murthy from IITB were the conveners of epiSTEME-6.

Infosys Award Function 2015 (in association with the Infosys Foundation and the TIIFR Endowment Fund)

December 22, 2015

Timor-Leste's Teacher Visit Program

HBCSE, January 18-23, 2016

A one week workshop on Science and Mathematics Education was organized for 11 teachers from Timor-Leste.

Inauguration And Workshop on “CLIX” Project (Joint venture of TATA Trusts, TISS, MIT and partners HBCSE, Eklavya, University of Mizoram, SCERT, CERP and the State Governments of Chhattisgarh, Mizoram, Rajasthan and Telangana)

HBCSE, Mumbai, January 27-30, 2016

One-Day Teachers’ Conference on “Encouraging and Supporting Students’ Thinking in Classroom Learning Of Science” (organized along with Navi Mumbai Science Foundation)

Vashi, February 6, 2016

Workshops for Students

- Homi Bhabha Young Scientist Awardees Student Camp (HBCSE, April 15-18, 2015);
- Sixteenth AEES Junior Science and Mathematics Olympiad Programme (HBCSE, May 6-15, 2015);
- Olympiad Orientation-cum-Selection Camps (OCSC) in Mathematics (for junior and senior batches), biology, chemistry, astronomy and junior science (April- June 2015);
- Pre-Departure Training Camps for international Olympiad teams: European Girls Mathematical Olympiad and International Mathematical Olympiad, International Chemistry Olympiad, International Biology Olympiad, International Astronomy Olympiad (April- July 2015);
- Workshops on 'the issue of waste' for high school students (Shivaji Nagar, Govandi, April 14-24, 2015);
- Summer camp for students of Nutan Vidya Mandir (HBCSE, May 2015);
- NIUS project camp (HBCSE, June-July 2015);
- Research scholar orientation programme for batch of 2015 (HBCSE, August 10-19, 2015);
- Effective use of activities and experiments with the 'Phirti prayog shala' from Konkan – (HBCSE, August 12, 2015);
- Workshop on 'Learning angles' for BMC school students (October 15-31, 2015);
- Workshop on 'Integers' with students from Kendriya Vidyalaya (October 19-30, 2015);
- Workshop on “Mathematics laboratory”, TIFR open day (November 1, 2015);
- NIUS Biology camp Batch XII: Camp XII.1 (November 2-6, 2015);
- Workshop on design and technology for students from Class 8-9 (HBCSE, November 21-22, 2015);
- Pre-Departure Training Camps for junior science international Olympiad (HBCSE, November- December, 2015);
- Pre-conference (epiSTEME 6) workshop on “Mapping data and knowledge for citizen science” (HBCSE, December 7-11, 2015);
- Workshop on “Problem solving in mathematics”, for NTS students (December 8, 2015);
- Workshop on “No solution is also a solution in mathematics”, for Shishuvan School Students (December 21, 2015);
- NIUS Chemistry project camp Batch XII: Camp XII.1 (December 23-31, 2015);
- Workshop on “Understanding area through geometry”, for Shishuvan School Students (December 23, 2015);
- Nurture Programme for NTS Scholars, Secondary and Higher Secondary students (HBCSE, January 4-8, 2016);
- Workshop on “Exploring theorem of Pick”, for NTS students (January 8, 2016);
- One day workshop for class 9 students from Nutan Vidya Mandir' School (January 30, 2016);

- Workshop on “Trigonometry through puzzles”, for St. Aloysius High School Students from Jalgaon (HBCSE, February 3, 2016);
- Workshop on “Tree-mapping”, for 80 students, Nalanda Public School (Mulund, February 20, 2016);
- Workshop on “Efficient cut for understanding area”, for NMMC students, RAINBOW programme (IWSA, Vashi, March 3, 2016);
- Workshop on “Algebraic patterns”, for NMMC students, RAINBOW programme (IWSA, Vashi, March 3, 2016);
- Workshop on D&T activities, Adhbut Vigyan, Thakkar organization (Bhiwandi, March 6, 2016);
- Workshop on “Hands-on-minds-on in mathematics”, Thakker Education Society (Bhiwandi, March 6, 2016)

Collaborative Undergraduate Biology Education (CUBE) Workshops

- CUBE Summer workshops (Batch I & Batch II) on “Introducing simple model systems to address sophisticated questions” (HBCSE, April 17 to June 3, 2015);
- Citizen Science workshop on Tree mapping and phenology mapping –Seasonomics (Mapusa, Goa, May 2015);
- Workshop conducted at KBP College, Vashi and at RD National College (Bandra, June 2015);
- CUBE Mumbai Summer Meet 2015 (HBCSE, July 5, 2015);
- CUBE Mid-Semester Meet (HBCSE, September 26, 2015);
- Workshop on Tree-mapping for students for Universe Simplified, Science Resource Center (Andheri, Mumbai, November 21, 2015);
- CUBE workshops outside HBCSE for students (Dhempe College, Mushtifund School, Panjim, Goa, November 14, 2015; Acharya Narendra Dev College, Delhi, December 29 to January 2, 2016);
- Visit and workshop at CHM College (Ulhasnagar, December 15, 2015);
- Workshop on “Various biological systems” at Ruia College (Mumbai, January 6, 2016); Deonar Colony Municipal School, Mumbai for grade 5 to 7 students (December 4 to February 25, 2016);
- Regional meet at Delhi for students (January 27, 2016);
- Workshop at CHM College, for undergraduate and post-graduate students (Ulhasnagar, February 9, 2016)

Workshops for Pre / In-Service Teachers

- Train the trainers workshop on digital literacy (SM Shetty College, April 20-22, 2015);
- Resource Generation Camp (RGC) in Junior Sciences (April 25- 26, 2015; July 18-19, 2015; August 22-23, 2015; October 31- November 1, 2015; February 6-7, 12-13, 2016);
- Junior Science Exposure Camp for teachers (Swami Narayan School, Vapi, June 7, 9, 2015; Kutch University, June 15, 17, 2015; Pal, Jalgaon, June 23-28, 2015; Majhihira National Basic Educational Institute, Purulia, September 8-10, 2015; Dombivili, September 25-27, 2015; Guwahati, October 8-10, 2015; Atomic Energy Central School, Tarapur, January 21- 23, 2016);
- Rayat Education Society’s elementary teacher workshop (June 8-12, 2015);
- Half-day mathematics laboratory workshop (in collaboration with Zonal Institute of Educational Training, Kendriya Vidyalaya Sangathan) for teachers (June 9, 2015);
- One-day mathematics education workshop for in-service teachers from Anand shala (Khopoli Khalapur, June 10, 2015);

- DSERT Karnataka physics teachers workshop (June 22-26, 2015);
 - One-day mathematics education workshop with Vissanji Academy (HBCSE, July 11, 2015);
 - Workshop on Science and Innovation Activity Centres (SIAC) for teachers (HBCSE, July 13-15, 2015);
 - Pilot testing workshop conducted for the course "Invitation to Connected Learning Initiative (CLIX)" for teachers and students (Hyderabad, July 24-28, 2015);
 - Pandharpur's school teachers workshop (Lotus School Pandharpur, July 29-31, 2015);
 - Workshop on 'Application of light' organized jointly by HBCSE and Bombay Association for Science Education (HBCSE, August 8, 2015);
 - Junior science teacher training workshop organized in collaboration with Janakalyan Samiti (HBCSE, August 10-13, 2015);
 - One-day workshop on "Inquiry based science teaching", with science teachers (grades 1-10) (Diamond Jubilee High school, Mumbai August 14, 2015);
 - Orientation to field officers of the CLIX project on "Invitation to CLIX" (HBCSE, August 21-22, 2015);
 - Rayat Education Society's High School and Junior College Science Teacher's workshop – Science education and introduction to science Olympiads (August 24-28, 2015);
 - One day workshop on 'Introduction to chemistry Olympiad' for teachers (August 26, 2015);
 - HBCSE and Royal Society of Chemistry collaborative programme: Level three training camp for Teachers Developers (August 31-September 4, 2015);
 - Resource Generation Camp (RGC) in Cell and Molecular Biology (September 3-4, 2015); Plant Sciences and Ecology (September 3-4, 2015); Animal Sciences (September 14-15, 2015); Ethology (November 26-27, 2015); Genetics (December 7-8, 2015);
 - 14 workshops for YCMOU-PGRP, batch of academic year 2015-16 (September 13, 2015; October 18, 2015; November 1 and 29, 2015; December 20, 2015; January 10, 2016; February 7, 2016 and March 20, 2016);
 - Resource Generation Camp for Chemistry Olympiad (September 30-October 3, 2015);
 - Resource Generation Camp (Physics) for Olympiad session 2015-16 (October 1-3, 2015);
 - Rayat Education Society's High School and Junior College Science Teachers' workshop –Science Education, Science Project and INSPIRE Programme (October 5- 9, 2015);
 - Workshop on Polyhedra- material preparation and development (HBCSE, October 9, 2015);
 - Biology Olympiad Exposure Camp for teachers (October 14-16, 2015);
 - Chemistry Exposure Camp for teachers (November 16-18, 2015);
 - Workshop for teachers on "Project-Based Learning" (KV-ZIET Mumbai, November 18-20, 2015);
 - Workshops on "Area-perimeter", "Specialized content knowledge for teaching area", "Specialized content knowledge for teaching Algebra" for Secondary School Teachers (November 11, November 24, December 30, 2015);
 - Workshop on problem solving in mathematics, for St. Xavier's Pre-service Teachers (Mumbai, December 4-5, 2015);
 - Workshop on "Learning to teach mathematics using videos", for Secondary School Teachers in collaboration with CEQUE (December 12, 2015);
 - Hands on workshop on 'Managing school laboratory' organized jointly by HBCSE and Bombay Association for Science Education (HBCSE, December 18-19, 2015);
 - Workshop for "Developing lesson plans", for Secondary School Teachers in collaboration with CEQUE (December 30, 2015; January 5, 2016);
 - Workshop on "Studying lesson plans", for secondary school teachers (December 30, 2015);
 - Workshop on designing laboratory sessions for meaningful learning in undergraduate Chemistry Laboratory, for 45 teachers from various universities in Maharashtra (SP college Pune, January 4-5, 2016);
 - Workshop on 'Exposure to mathematics education', for Primary teachers of Nashik Education Society in collaboration with Hemendra Kothari Foundation (January 6-7, 2016);
 - Two-day workshop for biology teachers on "Biology teaching-the missing link", organized along with Department of Microbiology, St. Ann's college for women, Santoshnagar Colony, Mehdiapatnam, Hyderabad and Asian Association for Biology Education (January 7-8, 2016);
 - Workshop on developing mathematical activities for D.Ed. students from Rayat Education Society, Rurki (January 11, 2016);
 - Teacher Professional Development workshop of Chiplun Taluka Vidnyan Mandal, Taluka-Chiplun, District Ratnagiri (HBCSE, January 11, 2016);
 - Workshop for D.Ed students from Shahu Maharaj college, on "Students conception" (HBCSE, January 11-12, 2016);
 - Workshop on "Collective lesson planning", for secondary school teachers (January 16, 2016);
 - Workshop on "Science learning", as part of the 3rd Rayat Vidnyan parishad, organised jointly by Rayat Shikshan Sanstha, Satara and HBCSE, for 600 science teachers (Sandhana Sankul Hadapsar, Pune, January 23-25, 2016);
 - Workshops by Kelly Butler on Process Oriented Guided Inquiry Learning -POGIL (Abasaheb Garware College, Pune, KET V. G. Vaze College, Mumbai, January 25, 28, 2016; Ruia College, Mumbai, February, 2, 3, 5, 6, 29, 2016; New Arts, Commerce and Science College, Parner, Ahmednagar, March 5, 2016);
 - Workshop on "Digital literacy" (Project of NUSSD, TISS) (Rajahmundry, Andhra Pradesh, January 23-25, 2016; February 1-3, 2016);
 - Workshop for teachers I2C, Pilot, CLIX (Mizoram and Rajasthan, February 3-9, 2016; February 12-17, 2016);
 - Teacher Training Programme for Science and Maths Teachers (Meghalaya, March 1-7, 2016);
 - Workshop on "Understanding student errors", for NMMC teachers in RAINBOW programme (IWSA, Vashi, March 3, 2016);
 - Workshop on Tech-Knowledge Teacher, for teachers (March 16, 2016);
 - Workshop on preparation for experience based holistic learning environment, for teachers (March 28, 2016)
- Workshops for Resource Persons/ Trainers/ Teacher Trainers**
- One day workshop on the role of students' questioning in learning Science (HBCSE, April 10, 2015);
 - Workshop on "Designing constructivist learning environment" organized by Shri Shivaji Shikshan Sanstha, Amravati and HBCSE, Jijamata Science and Arts College, Buldhana, (December 21-23, 2015);
 - Kumar Vishwakosh workshops (November 16-20, 2015; January 18-22, 2016; February 8-12, 2016)
 - Process Oriented Guided Inquiry Learning (POGIL) workshops by Prof Kelly Butler (February 4, 2016);
 - Four day Do-It-Yourself Biolab workshop by Yashash Shetty, Shreyasi Kar and Tejas Rode (HBCSE, February 17-20, 2016)

Non-DAE Research Projects

S. Chandrasekharan

The cognitive mechanisms underlying model-based discovery and learning, DST Cognitive Science Research Initiative (Category: Exploring Higher Mental Functions), October 2013 to September 2016

S. Chandrasekharan (in collaboration with Alexandra Mazulek [P.I.], Georgia Institute of Technology, Atlanta, USA) Getting a grip on the numerical world: Kinesthetic interaction

with simulations to support collaborative discovery in systems biology, National Science Foundation, USA, September 2013 to 2016

Jyotsna Vijapurkar (with A. Msimanga, University of Witwatersrand (P. I.) and other collaborators)

A multidisciplinary approach to language issues in science education in multilingual contexts.



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National Centre for Biological Sciences , Bengaluru

Biochemistry, Biophysics and Bioinformatics

How do proteins fold, unfold and misfold?

Dr Udgaonkar's laboratory focuses on two aspects of protein folding: how cooperative are the reactions, and how folding begins. Using hydrogen exchange-mass spectrometry, the laboratory has demonstrated that secondary structure change in protein folding and unfolding reactions can occur diffusely and not modularly. Using microsecond mixing methods in conjunction with multiple structural probes, it has shown that multiple structural rearrangements of the polypeptide chain lead to the first structured molten globule intermediate. The laboratory has also been studying the mechanism of misfolding of the prion protein which leads to neurodegenerative disease. Using multiple pathogenic mutations, the laboratory has demonstrated that an early step in misfolding is the destabilization/unraveling of helix 1 away from the rest of the structured part of the protein, after which the rest of structured region undergoes conformational conversion. Using a mutational approach, the laboratory has identified several of the key intramolecular interactions that must be perturbed before misfolding can occur. [Jayant Udgaonkar, Jogender Singh - till 04/06/2015, Neha Nandwani, Sabareesan A.T, Rama Reddy Goluguri, Prashantkumar Navalbhai Jethva, Harish Kumar, Sreemantee Sen, Vishal Bhardwaj- till Aug. 2014, Roumita Moulick, Pooja Malhotra 06/06/2016, Pratibha Kumari till July 2014, Sandhya Bhatia, Rubby Abdullah till July 2014, Abhijeet Ghode till Dec 2014, Nilesh Aghera till April 2014, Ishita Sengupta, Vishal Bhardwaj-till 18/02/2015, Pooja Malhotra 6/06/2016].

Root Responses to Drought and Salinity

Salinity and drought adversely affect rice production globally. We have investigated the responses of different rice varieties, including Pokkali and BI-33, to salinity and drought. We find that tolerant varieties grow long roots to mine water from subsurface sources. Deeper layers of soil have limited oxygen, so the tolerant varieties form aerenchyma in the roots to transport oxygen from the shoots to distal portions of the root. Oxygen loss to the surroundings is limited by building a

waxy coat to the root. Waxy barriers within the roots are reorganised in a manner to either optimise fluid flow (under drought) or to minimise entry of external fluid directly into the xylem stream (under salinity). These adaptations appear to make a large contribution to the plant's ability to survive the applied stress. [Rukaya Amin, in collaboration with Prof. HE Shashidhar, University of Agricultural Sciences, GKVK Bangalore]

Computational Approaches to Protein Science

Genome sequencing projects provide a large amount of data on sequence information of genes in various model organisms. Our laboratory is interested in enabling functional characterization of gene products and to perform in-depth studies of mechanism of action of enzymes through structural analysis. Mathematical models of aligned set of sequences of protein families and computational algorithms have been used to search for biomedically important domains like RNA-binding domains in the human genome (Ghosh and Sowdhamini, 2016) and for S-ribosylhomocysteineases in bacterial genomes (Rao et al., 2016). In the plant genomes, we continue to be interested in the upregulation of genes to stress and we recently observed for combined stresses (Barah et al., 2016). We chose to study *Tulsi* to provide the draft genome and also in order to recognise key gene products that harbour enzymes involved in the synthesis of medicinally relevant secondary metabolites (Upadhyay et al., 2015). [R. Sowdhamini, Atul Kumar Upadhyay - till 31/07/2015, Mahita Jarjapu, Snehal Dilip Karpe, Pritha Ghosh, Iyer Meenakshi Shankar- from 20/01/2015, Banhita Maitra - from 31/07/2014, Gandhimathi, K.Harini till 30/11/2015, Rithvik S. Vinekar till 14/09/2015, Prashant Narendra Shingate till 30/06/2015, Joshi Adwait Govind, Shaik Naseer Pasha, Anshul Sukhwal, Naveen Kumar N, Oommen K.M., Nitish Sathyanarayanan, Nithin Ravooru till 29/06/2015, Narmada Sampaturu- till 13/07/2015]

Evolving genomes and gene expression states

Bacteria adapt to their environments often by changing their genetic material in small steps. These include adaptation to a variety of stresses including long-term starvation and antibiotic exposure. We have used microbiology and next-generation sequencing to study adaptation of the bacterium *E. coli* to long-term starvation in the laboratory. We have found that the genetic diversity of the population increases with time, in a manner that cannot be explained by non-adaptive neutral drift. Many of the genetic changes affected proteins that decide which proteins to produce when, thus reiterating the interplay between genotypic adaptation and gene expression states. Bacteria might also use specific mechanisms to make certain regions of its DNA more mutable. We have used bioinformatics to show that the pathogen that causes cholera might use a DNA modification called methylation to effect changes that might influence virulence. [Aswin Sai Narain Seshasayee, Aalap Bhalchandra Mogre, Iyer Meenakshi Shankar, Avantika Lal till 25/03/2016, Savita Chib, Revathy Krishnamurthy, Supriya M Khedkar, Parul Singh, Rajalakshmi S, Reshma T.V]

Investigating the role of post-translational modifications in host-pathogen interactions

More than ninety percent of adults have been infected with at least one of the eight known herpes viruses and a latent form of the virus remains in most people. Herpes virus factors hijack the host machineries to their own advantage. For example, the multi-functional ubiquitin ligase ICP0 encoded by the Herpes Simplex Virus (HSV) can use the ubiquitin-proteasome machinery to degrade host immune responses. ICP0 also regulates the host's cell-cycle progression to promote viral replication. Despite extensive research, the molecular details of

ICP0 function in HSV replication is currently lacking. Our lab was focused to investigate the role of ubiquitin-proteasome pathway in the life cycle of Herpes simplex virus. Our work in the last year has shown how the ICP0 can target cellular anti-viral responses like for destruction. The molecular details obtained from our research are expected to yield new therapeutic targets for Herpes Simplex virus prevention and cure. [Ranabir Das, Kiran Sankar Chatterjee, Priyesh Mohanty, Hitendra Negi, Parag Surana, Dambarudhar S S Hembram]

Insight into the mechanism of plant miRNA biogenesis

Plant miRNAs are processed from stem-loop structure containing precursors that are recognized and cleaved by Dicer like 1 (DCL1) with the help of dsRNA binding protein Hyponastic leaves 1 (HYL1) and a zinc finger protein named Serrate. It is not known what determines biogenesis and abundance of miRNAs, beyond a ubiquitous requirement for a stem-loop structure. We have recently shown that miRNA-miRNA* loop length determines abundance of miRNAs (Jagtap and Shivaprasad, 2014). In addition, we have observed unusually high GC content and specific sequence signatures among plant miRNAs. A specific GC signature is maintained across plant miRNAs by having position specificity for G or C. We show that RNA binding domain 1 of HYL1, a dsRNA partner of DCL1, is responsible for the observed GC signature among miRNAs. In support of this observation, *hyl1* mutants lack precise processing ability and accumulate miRNAs at much lower levels. [P. V. Shivaprasad, Rahul Raj Singh till 31/05/2015, Anushree, Sruthi S, Unnatiben Rajeshbhai Patel till 19/07/2014, Soumita Das, Supriyo Basak till 20/04/2015, Sagarika Mishra]

Structure to Signaling

Understanding biological roles and mechanisms of non-coding RNAs in bacteria.

RNAs perform a variety of cellular functions. This is especially evident in bacteria, where ligand-sensing riboswitches and RNA-protein complexes control important processes such as growth, metabolism and adaptation to changing environments. A hallmark of regulatory RNAs is their ability to undergo a ligand/protein induced structural change that is crucial for their function. Combining X-ray crystallography with RNA biochemistry and biophysics, we aim to understand how these regulatory RNAs function in bacteria. To this end, we have identified a widespread RNA-

binding domain called ANTAR, which coordinates with a ligand-sensing riboswitch and a small RNA to control bacterial metabolism. We have computationally predicted over 2500 examples of the small RNA in diverse bacterial species including many pathogenic bacteria, suggesting a role for ANTAR regulation in bacterial pathogenesis which we are exploring. We have successfully crystallized the complex of the ANTAR protein with RNA, setting the stage for structural elucidation in future. [Aarati Ramesh, Chaithanya Kotyada till 31/12/2015, Tushar Raskar till 02/06/2015]

Cellular Organization and Signalling

Nucleating a biomedical and viral diseases ecosystem

Our long standing interest has been in understanding the progression of human cervical cancers, a major malignancy in India. We have recently characterized a sub-set of CD66+ cells that drive these tumors with distinctive properties in terms of migration, metastasis, self renewal etc. The five year DBT glue grant we had with St. John's medical college ends this year and younger faculty hired by them will continue to develop that program. The program led us to build several useful platforms in hematology around gene editing and HLA data base creation using novel sequencing (NGS) approaches. Our other major effort in recent times has been to the creation of a enabling environment for younger investigators to develop strong research themes in virology with a focus on flaviviruses. Using NGS we have characterized a number of viral outbreaks across the country. This work feeds into vaccine design, viral epidemiology etc. [Sudhir Krishna, Calvin Steve Rodrigues, Aswathy A.K. till 23/05/2016, Leanna Rose Joy, Krithika Badarinath, B.S. Srinag till 31/03/2016, Deepak Arya till 27/09/2016, Lokendra Yadav till 20/11/2015, P. Annapurna till 31/03/2016, Sasikala P Sachithanandan till 30/11/2015, P Chitra till 30/06/2016, Aswathy A.K]

Notch signaling in T-regulatory cells

Cells can recycle damaged organelles to regenerate building blocks and use this to conserve resources, particularly during periods of nutrient stress. Our experiments show that this process, termed Autophagy, can be controlled by the short-range signaling regulator Notch1, in cells of the mammalian immune system. We have studied the Notch1-Autophagy interaction and consequences to immunity in T-regulatory cell maturation and function. More specifically, our experiments suggest that Notch-induced autophagy is a mechanism of quality control of mitochondrial organization and function (Marcel & Sarin, eLife, 2016). The regulation of Notch1 activity itself and the mechanisms by which changes in nutrient status are sensed in these cells are areas of ongoing investigation. [Apurva Sarin, Neetu, Nimi Marcel till 30/04/2016, Sanjay Kumar Shukla till 31/05/2016, Shambhavi Naik till 31/12/2015, Nimi Marcel]

Active organization of cell surface proteins

The laterally structured plasma membrane defines interactions between the cell and outer environment. We had previously shown that actin juxtaposed to the plasma membrane regulates lateral

heterogeneities by actively clustering cell surface proteins like GPI-anchored proteins. On probing the interactions of outer leaflet GPI-anchored proteins with cortical actin, we found a general mechanism of transbilayer coupling with long saturated acyl-chains of inner leaflet phosphatidyl serine and GPI-anchored proteins is essential to generate cholesterol dependent and actin mediated nanodomains. Consistent with the predictions of an active actin composite cell surface, we established that the diffusion of GPI-anchored proteins and actin associated transmembrane proteins is driven by active fluctuations of dynamic cortical actin filaments in addition to thermal fluctuations. We also reconstituted this active composite membrane *in vitro*, comprising of synthetic fluid lipid bilayer, purified membrane actin binder, actin filaments and myosin motors, and evaluated the phase space of different actin configurations. This system allowed us to illustrate the active remodeling configuration which indeed drives the active fluctuations of associated membrane components resembling those observed in cells. Towards probing the functional relevance of membrane organization, we uncovered the mechanism by which nano-scale organization of dually lipidated Hedgehog (Hh), a secreted morphogen involved in short and long range signalling in *Drosophila* wing imaginal disc, is essential for its endocytosis and ESCRT dependent secretion as exovesicles to initiate long range signalling. [Satyajit Mayor, Anupama H.L, Anup Ashok Prachure un 19/05/2016, Mugdha Sathe, Joseph Jose Thottacherry, Joseph Mathew, Chaitra P, Kabir Bazmi Husain, Abrar Ahmed Bhat, Suvrajit Saha till 02/03/2016, Parijat Sil, Shree Krishnamoorthy 31/07/2015, Gayatri Muthukrishnan 31/10/2015, Darius Vasco Koster, Marcus Taylor, Bini Ramachandran, Suvrajit Saha, 03/03/2016 to 30/06/2016, Garima Singhal till 31/07/2016, Anupama Ambika, Rumamol C]

Architecture of phosphoinositide signalling

Our long term scientific interest is the analysis of cellular signalling mediated by lipid molecules generated during phosphoinositide metabolism. Phosphoinositide signals provide molecular control for key sub-cellular processes such as membrane remodelling, cytoskeletal function, transcription and translation. Through these processes, this signalling pathway orchestrates basic cellular behaviours such as cell division, shape changes, polarized movement and cell death. Therefore, this pathway plays a key role in a number of physiological processes including early embryogenesis, lymphocyte development and function as well as neuronal activity. The overall goal of our work is to

understand how the architecture of this signalling cascade is designed to optimally deliver physiological outputs. We use *Drosophila* as our model system; the goal is to discover key principles of signal transduction that are likely to be conserved during evolution but are experimentally more tractable in *Drosophila*. It is hoped that in the medium term, our analysis in *Drosophila* will inform studies of equivalent signalling pathways in mammalian models with more immediate biomedical relevance. [Raghu Padinjat, Shweta, Sruthi S Balakrishnan, Avishek Ghosh, Bishal Basak, Aastha Kumari, Urbashi Basu, Kuldeep, Sanjeev Mahadeva Sharma, Sourav Kolay, Sudipta Ashe, Swarna Mathre, Aniruddha Panda, Rajan Surendra Thakur, Suhail Muzaffar, Ishtapran saho, Pramod Kumar Singh, Vishnu Janardan]

Modulation of host trafficking pathways by intracellular pathogens

My lab works on host-pathogen interactions, specifically on how fundamental host cellular pathways such as endocytosis and autophagy are modulated by intracellular infections. We focus on

two distinct pathogens, *M. tuberculosis* that causes tuberculosis and the liver stage of *Plasmodium* spp, that cause malaria. Our results show that both pathogens cause global alterations in the organization and dynamics of the host cell endocytic network. These alterations include sub-cellular redistribution of specific endosomal pools and an increase in the number and content of distinct endosomal populations specifically in the infected cells. In some cases, abrogation of these alterations by chemical treatment results in killing of the pathogen, suggesting the importance of these changes in pathogenesis mechanisms. In conclusion, our results suggest that intracellular pathogens cause extensive re-wiring of the host endocytosis machinery and exploit its plasticity for their benefit and provide further support for host directed therapeutics against infectious diseases. [Vardharajan Sundaramuthy, Debakshi Mullick, Kuldeep, Devaiah M.K. till Dec. 2014, Ashima Singla till 06/07/2015, Ashutosh Kumar till May 2015.]

Neurobiology

In Vitro and In Vivo Disease Models

My group has been looking at the interactions of clinically used antipsychotics and the serotonin 2A receptor. We have genetically engineered a strain of mice to lack the receptor. Using the wild type and modified strains of mice we showed that the sedative effect of the atypical antipsychotic clozapine is dependent on the novelty of the environment the mice are placed in. This was not true for the typical antipsychotic Haloperidol. We have also used these and other specialized strains of mice to identify regions of the brain that get activated by different antipsychotics. These animal models should help us design new drugs and understand how antipsychotics work in humans. We have also generated human induced pluripotent stem cells (hiPSCs) from patients that have Late Onset Alzheimer's Disease, in collaboration with physicians/researchers from NIMHANS, Bengaluru. The APOE gene of these cells has been modified by gene editing to determine the contribution of various APOE alleles present in these patients. [Thangaselvam, Radhika Sudhir Joshi, Shishu Pal Singh, Shuchita Arun Soman, Odity Mukherjee, Anup Parchure From 19/05/2016, J Joe Anand Kumar, Megha P.B, Ashaq Hussain Najar, Amit Sangwan till April 2015, M.M Panicker]

The Bhalla laboratory at NCBS works on sequential activity in the brain, and its correlates in learning and memory. Speech, music, dance, and thought all

involve sequential activity of ensembles of neurons, and the capability for recursion is likely to be a key aspect of the organization of such sequences. We have developed a detailed computer simulation of the function of a key early brain region for smell sensory processing, the olfactory bulb. (Gilra and Bhalla, PloS One, May 2015). This model accounts for many observations in the literature and makes specific predictions about the mechanism for important olfactory processing operations. We have also reported how rats are able to use air-borne odor guided cues to navigate (Bhattacharyya and Bhalla, eNeuro, Dec 2015). We find that they follow a particular tracking strategy that trades off error and speed. This is interesting as an example of strategies that the brain can adopt to best exploit its environment. [Upinder S. Bhalla, Sahil Moza, Soumya Bhattacharjee, Dilawar Singh, Aditya Asopa, Urvashi Raheja- till -03/06/2016, Priyanka Gupta, Aanchal Jitendrakumar Bhatia, Kambadur Gundu Ananthamurthy, Jens Oliver Muthmann – till -31/08/2016, Ekaterina Brocke, Banhita Maitra, G.V. Harsha Rani - till 05/02/2015, Anu G Nair, Aviral Goel - 18/12/2015, Shriya Palchaudhuri]

Physics, Neurobiology and Ecophysiology of insect flight

Recent work in my laboratory has focused on the biomechanical and neural basis of flight in insects from a comparative perspective. We aim to specifically understand how diverse flight-related

reflexes distributed over the body are neurally synchronized to generate well-coordinated movements of various body parts. In previous years, we extensively studied the antennal positioning reflex in flying hawkmoths. The methodology developed for this purpose can now be applied to study various other reflexes in flying insects. In addition to neural mechanisms of coordination, we had also studied the biomechanical mechanisms of wing-wing and wing-haltere coordination in flies and argued that the wing hinge of a fly must consist of a mechanical clutch, in addition to a gear-box like structure, which allows independent control of each wing. We have continued delving deeper into the wing hinge mechanics using sophisticated X-Ray imaging techniques. We are also studying the multimodal integration of visual and mechanosensory inputs by descending interneurons using electrophysiological methods, airflow sensing by antennal and cephalic mechanosensors, the imaging and quantification of wing movements during aerial maneuvers using high-speed videography etc.. Together, these investigations will throw light on fundamental aspects of how insects generate stable flight through rapid responses to multisensory stimuli. In addition, we continue the task of cataloguing moth biodiversity, documenting the life cycles of various species of hawkmoths, and filming their flight and migratory behavior in the wild. [Sanjay Sane, Umesh Mohan, Abin Ghosh V C, Payel Chatterjee, Nitesh Saxena, Taruni Roy till 31/07/2016, Tanvi Deora till 29/07/2015, Dinesh Natesan, Harshada Hemant Sant, Karthikeyan C, Ajinkya S Dahake - till July 2014, Amritansh Vats till 31/08/2016, Deepak C.K. till 31/08/2015, Kumarvardhanam Daga, M. Maitri]

Neural Circuits and Development Lab

Our lab is focused on understanding how animals generate co-ordinated movements in response to environmental stimuli. Towards this end, we study the role of Purkinje neurons in the cerebellum and how they contribute to movement. Last year, we showed for the first time that Purkinje neurons are bistable, i.e., they exist in one of two membrane potential states, up and down. Interestingly, the same synaptic inputs can cause distinct outputs depending on whether the neuron is in the up or down state.

Thus, the output of Purkinje neurons is a function of its internal state and incoming synaptic inputs. We further showed that whenever movement is initiated, Purkinje neurons toggle to up states, primarily due to strong excitation from the inferior olive. Purkinje neurons exhibit bistability soon after acquiring their identity, even though at these stages the inferior olivary inputs are very weak, thus throwing open questions regarding the developmental regulation of mechanisms causing bistability. [Vatsala Thirumalai, Mohini Sengupta, Lena Mareike Josefine Robra, Urvashi Jha, Sriram Narayanan, Bhavika Mam, Vandana Agarwal, Sahana Sitaraman, Igor Kondrychyn (CDF), Mohan Raghavan till July 2014, Gnaneshwar V Yadav till 17/11/2016, Bhavika Mam till 31/07/2014, Sriram Narayanan till June 2014, Shreya ParthaDas Sharma till July 2014, Shaista Jabeen, Anubhab Khan till July 2014, Sriram Narayanan till 31/07/2015]

Cell molecular mechanisms in the adult brain

Our laboratory aims to understand the functioning of the adult brain at a cell molecular level under three broad themes: 1) Adult neurogenesis, a process by which new neurons are continuously generated in the adult brain, influencing learning, memory and cognition. Our work in the past year has identified a gene that seems critical for adult neurogenesis. We are now trying to understand the mechanistic aspect of this action. 2) Neuronal maintenance: How mature neurons maintain their dendritic organization and functional integrity throughout a lifespan is poorly understood. We have preliminary evidence suggesting that the maintenance of mature neurons is governed by a proactive genetic-program. Through inducible gene deletion studies, we are now identifying the molecular machinery underlying the maintenance of long-living neurons. 3) Neuro-immune interactions: We are studying microglia, the brain-resident immune cells, and its regulation in a healthy brain, and that during infection, injury or aging. Overall, our investigations will provide deeper insights into the basic biology of the adult brain, enabling informed therapeutic targeting for a range of neurodegenerative and psychiatric disorders. [Hiyaa Ghosh]

Genetics And Development

Intracellular calcium signaling in neurons

Calcium entry through non-excitatory channels is thought to primarily regulate calcium homeostasis in neurons. Subsequent to identification of Orai as the channel to refill cellular calcium stores in non-excitatory cells, investigation of Orai function in neurons demonstrated a requirement for it in

Drosophila flight. By analysis of an *Orai* mutant and by controlled expression of a *Drosophila Orai* transgene that prevents Orai function, we showed that Orai-mediated calcium entry is required in dopaminergic interneurons of the developing flight circuit (1). The loss of Orai-mediated calcium entry alters gene expression of dopaminergic neurons

leading to reduced levels of the enzyme Tyrosine Hydroxylase, which is essential for dopamine synthesis. These studies suggested that modulation of calcium entry through Orai serve as a novel mechanism for restoring dopamine levels in dopaminergic neurons and is significant in the context of Parkinson disease where dopamine neurons undergo neuro-degeneration. [Pathak, T., Agrawal, T., Richhariya, S., Sadaf, S. and Hasan G.] Store-operated calcium entry through Orai is

required for transcriptional maturation of the flight circuit in *Drosophila* (2015). *J. Neurosci*, **35**, 13784-13799. [Bipan Kumar Deb – Onrolls, Tarjani Agrawal, Shlesha Rajesh Richhariya, Preethi Ravi, Steffy B Manjila, Megha Mohammed Bin Abu Baker till 30/04/2015, Sufia Sadaf till 30/06/2016, Trayambak Pathak 31/10/2016, K Dhanya, Trayambak Pathak till 10/07/2016, Siddharth Jaykumar, Sreeja Kumari Dhanya]

Theory And Modeling Of Biological System

Dynamics of Biological Systems across Scales

At the molecular level, we have examined, using a combination of experiments and mathematical models, the dynamics of different mechanisms of protein regulation and their role in feedback loops. At the cellular level, we have focussed on mechanisms of communication between cells, for example, we have shown how the nature of public goods secreted by bacteria would influence the optimal regulation of quorum sensing systems that regulate the production of these public goods. Finally, at an ecosystem level, we have been studying phage-bacteria communities, and have proposed a new role for the bacteriophage defence mechanisms that use restriction-modification enzymes, as well as a connection between the expected maximal diversity of bacterial strains in such an ecosystem and the burst size of the bacteriophage. [Sandeep Krishna, Rohit Chandrakant Suratekar, Vishaka Datta]

Evolutionary cell biology

We use the membrane traffic system of eukaryotic cells as a window to study the evolution of cellular complexity. The research has three elements. First, we use sequence-based techniques to reconstruct the cell biology of ancient cells. For example, we have recently reported the deepest reconstruction of mitochondrial endosymbiosis (Purkanti & Thattai, PNAS, 2015), and probed the archaeal ancestor of eukaryotes (Dey, Thattai & Baum, Trends in Cell Biology 2016). Second, we use mathematical models to understand the form, function and evolution of the traffic system. Using such models, we have shown that the Golgi apparatus arose as a by-product of physical rather than evolutionary

processes (Mani & Thattai, eLife2016). Third, we use cell-biological experiments to track evolution on laboratory timescales. We are presently testing the hypothesis that cellular hybridization can lead to dramatic changes in the membrane traffic network. [Mukund Thattai, Ramya Purkanti till 07/01/2016, Somya Mani, Anjali Jaiman, Neha Wadia - till 30/06/2015, Venkatakrishnan Ramaswamy, Ramya Purkanti 08/01/2016 to 07/01/2017]

Computational protein folding and design

The amino-acid sequence of a protein includes residues which are important for function and defines an energy landscape on which both protein folding and functional dynamics occur. Thus, both functional residues and functional dynamics leave footprints on the folding landscape of the protein. In the last year, my group continued to use computational tools to understand the folding energy landscapes of natural and designed proteins. We found that functional residues are the cause of domain-swapping in the protease inhibitor protein stefin-B. Domain-swapping is important because it is the first step in the disease-causing aggregation of several proteins. We also studied the folding landscape of the designed protein Three Foil and found that the origins of its kinetic stability lie in its complex topology. Understanding kinetic stability is of great practical importance for ensuring that a protein remains folded under a variety of harsh conditions.[Shachi Gosavi, Hemanth Giri Rao Vantharam.V-till 31/07/2015, Vishram Terse Onrolls, Nahren Manuel Mascarenhas, Shilpa SiddappaYadahalli, Hitesh Kumar Rafalia, Venkata Ramana till 30/06/2016]

Ecology And Evolution

India has a population of over a billion people, with only 4% of its area protected as wildlands. Yet the Indian subcontinent harbours incredible biodiversity. Do we know what this diversity is?

How has this diversity come to be? How are we impacting this diversity? Over the past several years, we have conducted research that has helped identify cryptic species and genera of birds and mammals,

enhancing our knowledge of India's natural capital. We have studied the biogeographic origins of species in the Indian subcontinent, with particular attention to biodiversity hotspots. Our research on conservation genetics and landscape genetics helps identify vulnerable and isolated tiger populations, investigate connectivity in the Central Indian landscape and develop novel conservation genomics methods. In order to answer these questions, we conduct fieldwork to sample behavioral, ecological and genomic data from these wild populations. We analyze these data in population genetic and phylogenetic contexts to better understand the evolution, population ecology and conservation of populations. [Uma Ramakrishnan, Krishnapriya Tamma - till 14/05/2015, Jyothi Venugopal, Prachi Srikanth Thatte, Anubhab, Amruta Varudkar, Robin V Vijayan, S.P. Vijayakumar till 30/11/2015, Ishan Agrawal - till 30/10/2015, Vivek Ramachandran till 03/12/2015, Varad B Giri , Atul Kumar Upadhyay till 10/08/2016, Krishnapriya Tamma 18/06/2015 to 17/06/2016, Priyadarshini Gurung, Tanushree Srivastava till 31/03/2016, Nishma Dahal, Meghna Natesh]

Terrestrial ecosystems and community ecology

Can our ecosystems cope with the challenges of ever-expanding human activities? We work on understanding the dynamics of grasslands, forests and mixed tree-grass ecosystems, their responses to changing climates, and what this means for their future distribution and functioning. Our group has established long term experimental and monitoring programs in forests that span a rainfall gradient in peninsular India to address fundamental questions about how these forests are structured, and how they are responding to changes in climate and other directional environmental drivers. Using both empirical data from our sites, as well as simulation studies using data from a range of forest sites across the globe, we have shown that the loss of large-bodied seed dispersers from plots can have effects that cascade through the system, influencing both tree community composition, as well as the ability of forests to sequester carbon in the future (Osuri et al. 2016 *Nature Communications*). However, responses differ across continents, largely as a result of floristic differences and distinct dispersal mode, seed size, adult size combinations on different continents. We are currently evaluating the causes underlying these contrasting responses across continents to get a more nuanced understanding of defaunation effects globally. We also have established research sites in grassland ecosystems in India that address fundamental questions on the role of resource versus consumer control of vegetation structure and function. Specifically, we are investigating how top-down and bottom-up

ecological forces influence plant functional diversity in these ecosystems, and how this in turn mediates the potential responses of these ecosystems to future changes in climate.[Mahesh Sankaran, Amritendu Mukhopadhyay- till 31/01/2016, Varun Varma- till 30/06/2016, Yadugiri V T, Lalitha Krishnan, Chandan Kumar Pandey -31/07/2016, Ayesha Elizabeth Prasad 31/10/2014, Joyshree Chanam, Varun Varma, Dharmendra Lamsal till 31/07/2016, Atul Joshi Anusree A.S., Dina - till 30/06/2016, Siddharth Bharath Iyengar- 14/08/2014, Mayank Kohli - till 31/07/2014, Harinandan P.V- till 15/02/2016, Nandita Nataraj, Chengappa S.K.M Arockia Catherin, Siddarth Jude Machado 31/07/2016, Amol Ramesh Kulavmode 31/07/2016]

Speciation, Adaptation and Morphological Diversification in Tropical Regions

Diversity is the cornerstone of life on earth. We study how new species are formed, and how organisms diversify to adapt to their abiotic and social environments, which has given rise to the spectacular biodiversity. In the last year we particularly focused on understanding how sexual dimorphism evolves in relation to natural and sexual selection, as well as speciation and biogeographic isolation, using a molecular phylogeny of *Papilio* /swallowtail butterflies. This provided unparalleled insights into how diversity has evolved in the complex landscape of the Oriental Region. We further investigated the genetic mechanisms that control sexual dimorphism. After discovering that */doublesex/*, a highly conserved gene in the sexual differentiation pathway, has been co-opted to control female polymorphism in the mimetic butterfly */Papilio polytes/*, my lab focused on studying how */doublesex /* and other key genes regulate sexual development and polymorphism during pupal development.[Krushnamegh Kunte, Riddhi Deshmukh, Saurav Baral, Jahnvi Joshi, Vivek Sarkar till 31/07/2015, Dipendra Nath Basu till 31/03/2016, Vaishali Bhaumik till 31/03/2016, Kiran Marathe till 31/07/2015, Rohit Ravindran, Samita Jha- till 31/10/2014].

Research on Honeybee Biology

Two studies were finished and published in international journals. (1) A. *Structural and temporal dynamics of the bee curtain in the open-nesting honeybee species, Apis florea*. *Apidologie* (2016). doi:10.1007/s13592-016-0428-8. The study described for the first time the temporal dynamics of worker behavioral maturation in the Asian honeybee *Apis florea*. We found that the maturation is strongly delayed compared to the Western honeybee, *Apis mellifera*, which suggest differences in hormonal regulation and aging.[Bhagavan, H.,

Muthmann, O. & Brockmann] (2) In collaboration with German colleagues we investigated the peptide inventory of the corpora cardiaca (CC) of *Apis mellifera* workers by direct tissue profiling using MALDI-TOF MS combined with proteomic approaches focusing on cysteine-containing peptides. The study led to the identification of a new candidate neuropeptide, the agatoxin-like peptide (ALP). [Sturm, S., Ramesh, D., Brockmann, A., Neupert, S., & Predel, R. (2016)]. *Agatoxin-like peptides in the neuroendocrine system of the honeybee and other insects*. Journal of Proteomics, 132(C), 774. DOI: 10.1016/j.jprot.2015.11.021. [Axel Brockmann, Divya R, Ebi Antony George, Asem, Surindro Singh till 31/10/2015, Arpita Sarkar 17/07/2015, Hemalatha B, Saud Saldulkar - till 31/07/2013, Bunindro Singh- till 31/07/2014, Arumoy Chatterji, Rikesh R. Jain - till 31/08/2016, Abhishek Anand - till 30/06/2016].

Naturalist-Inspired Chemical Ecology

The fundamental task for any living organism is to identify objects in the world around them. Understanding how small networks like insect brains perform object identification can uncover basic principles of sensory processing as well as provide opportunities to generate better pest and pollination management strategies. To understand insect object identification, The NICE group performs research across species, mountains, and continents. This past year witnessed the first full year of the lab. During this period, we have established a unique visual-olfactory virtual reality for insects, identified specific neural pathways coding changes in object recognition for invasive species, have performed a series of field-to-lab analyses to uncover the mechanisms underlying coffee white stem borer preference for coffee in India, assessed a bio fumigant molecule from aerial parts of a native Indian plant broadly detected and repellent for all tested insect orders, and used multivariate analysis across continents to predict the optimal floral signature for hoverflies searching for pollination sites across climates (Figure 1). We also organized the first International Collaborations in Chemical Ecology workshop here in India. On our work on developing ecological methods to control coffee pests: <http://www.deccanherald.com/content/570011/bitter-coffee-this.html>. On our recent international workshop to develop chemical ecology in India: <https://indiabioscience.org/news/2016/fostering-collaborations-and-creating-a-roadmap-for-indian-chemical-ecology> [Shannon Olsson, Srishti Batra, Suhrid Sundar Ghosh -12/10/2015, V.S. Pragadheesh]



Figure 1: Hoverflies (*Episyrphus sp.*) across latitudes, altitudes, and continents.

Chemical Ecology of Plant-Insect Interactions:

Plant-insect interaction is a dynamic system with constant variations. Our group aims to understand these interactions spanning from biochemistry to ecosystem level. When attacked, plants exhibit biochemical changes resulting in defence responses. Our laboratory focusses on studying the variation and regulation of such plant defence responses. We characterize various secondary metabolites as well as volatile emission and extrafloral nectar secretion, which serve as indirect defence responses. Since plants seldom utilize defences singularly, we are investigating the spatiotemporal variation and interactions among these defences asking how plants optimally manage to partition their resources. Further we study the evolution of plant defence strategies using the ancient ferns as model systems investigating the fern defences as well as their geographic variation. Insects, on the other hand have strategies to detoxify plant defences. We also study such detox mechanisms by feeding assays using lab synthesized plant secondary metabolites. [Radhika Venkadesan]

Evolutionary ecology of adaptation and genome evolution

We use bacterial and insect model systems to understand the evolutionary and ecological processes underlying adaptive evolution. Silent mutations are thought to be inconsequential since they do not alter the protein sequence. However, we showed that such mutations could be extremely deleterious or highly beneficial for a bacterium. Contrary to current hypotheses, this is not explained by their resemblance to regulatory motifs. Instead, the evolution of regulatory motifs is itself governed by many factors including GC content and genome organization, highlighting the pitfalls of ascribing pattern to selection. In another project, we analyzed the evolution of insect immunity. We showed that age, sex and mating all determine the response to bacterial infection. Intriguingly, beetles exhibit a poorly understood form of immune memory (immune priming). We found substantial stage- and population-specific variation in flour beetles, suggesting that priming may be an evolved response to bacterial infection.

[Mrudula Sunil Sane, Kruttika Anirudha Phalnikar, Saurabh Kishor Mahajan, Vrinda Ravi Kumar, Aparna Agarwal, Alefiyah Habibullah till 31/08/2015, Mihir Umarani till June 2014, Gaurav Diwan, Nachiket Shankar till July 2014, Swastika Issar till 31/01/2016, Ashwin Kumar Nair, Arun Prakash, Ashwin Kumar Nair till June 2014, Swastika Issar till June 2014, Imroze Khan, Laasya Samitha, Deepa Agashe].

Members

Satyajit Mayor, Upinder S. Bhalla, Sumantra Chattarji, Gaiti Hasan, Sandeep Krishna, Sudhir Krishna, M.K. Mathew, Raghu Padijat, M.M. Panicker, Sanjay P. Sane, Mahesh Sankaran, Apurva Sarin, R. Sowdhamini, Jayant B. Udgaonkar, K. VijayRaghavan, Shannon B Olsson, Ranabir Das, Shachi S. Gosavi, Krushnamegh Kunte, Uma Ramakrishnan, Aarti Ramesh, P.V. Shivaprasad, Varadharajan Sundaramurthy, Mukund Thattai, Vatsala Thirumalai, Radhika Venkatesan, Aswin Sai Narain Seshasayee, Hiyaa S. Ghosh (from 17/8/15), Deepa Agashe, Axel Brockmann, Yamuna Krishnan (from 31/7/15), Deepak T. Nair (from 30/6/15)

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U.B. Poornima, H Krishnamurthy, Ravindra Munshi, H S Venkataramana, P V Narayana Rao, Suresh Kumar A, H M Basavaraja, Savitha K S, Natarajan T, Basavaraj Jalihal, M Anand Prakash, Sidhartha S Swain, Vipin V, Rakshith H Komalan, D Mohandas, Praveena Gadagoli, Chandrashekara K S, Avinash D Chinchure, G H Mohan, P C Gautam, Awadhesh Pandit, Prasanta K Baruah, K S Rajshekar, P P Ranjith, Umashashi S, G Ashwatha Narayana, Allwyn V R, Jayaprakash R, Devakumar S

Ph.D.

Jogender Singh - Until 04/06/2015, Neha Nandwani, Sabareesan A.T, Rama Reddy Goluguri, Pashantkumar Navalbhai Jethva, Harish Kumar, Sreemantee Sen, Sahil Lall, Kiran Sankar Chatterjee, Atul Kumar Upadhyay - Until 31/07/2015, Mahita Jarjapu, Snehal Dilip Karpe, Pritha Ghosh, Iyer Meenakshi Shankar- from 20/01/2015, Gandhimathi, K.Harini (Bridging) - Until 30/11/2015, Rithvik S. Vinekar (Bridging) - Until 14/09/2015, Prashant Narendra Shingate - Until 30/06/2015, Joshi Adwait Govind, Shaik Naseer Pasha, Anshul Sukhwal, Naveen Kumar N, Oommen K.M., Nitish Sathyanarayanan, Nithin Ravooru - Until 29/06/2015, Narmada Sampaturu - - Until 13/07/2015, Calvin Steve Rodrigues, Neetu, Anupama H.L, Ashok Prachure - Untill 19/05/2016, Mugdha, Joseph Jose Thottacherry, Joseph Mathew, Chaitra P, Kabir Bazmi Husain, Abrar Ahmed Bhat, Shree Krishnamoorthy 31/07/2015, Urbashi, Kuldeep, Sanjeev Mahadeva Sharma, Debakshi Mullick, Kuldeep, Thangaselvam, Sahil Moza, Soumya Bhattacharjee, Dilawar Singh, Aditya Asopa, Jesvin Singh Madan, Umesh Mohan, Abin Ghosh V C, Mohini Sengupta, Lena Mareike Josefina Robra, Urvashi Jha (External Registration), Sriram Narayanan, Bhavika Mam, Gunage Rajesh Dattaram - Until 03/03/2015, Durafshan Sakeena Syed - Until 19/07/2016, Bipan Kumar Deb – Onrolls, Rohit Chandrakant Suratekar – Onrolls, Vishaka Datta – Onrolls, Ramya Purkanti - Until 07/01/2016, Somya Mani, Anjali Jaiman, Hemanth Giri Rao Vantharam V - Until 31/07/2015, Vishram Terse Onrolls, Krishnapriya Tamma - Until 14/05/2015, Jyothi Venugopal Nair, Prachi Srikanth Thatte, Anubhab Khan, Amritendu Mukhopadhyay - Until 31/01/2016, Varun Varma - Until 30/06/2016, Yadugiri V T, Riddhi Deshmukh, Saurav Baral, Divya R, Ebi Antony George, Srishti Batra, Mrudula Sunil Sane, Kruttika Anirudha Phalnikar, Saurabh Kishor Mahajan, Vrinda Ravi Kumar.

PhD(Eurospin)

Jens Oliver Muthmann – Until -31/08/2016, Ekaterina Brocke, Banhita Maitra, Dinesh Natesan,

Integrated PhD

Vishal Bhardwaj - Until Aug. 2014, Roumita Moulick, Pooja Malhotra 06/06/2016, Sandhya Bhatia, Anirban Baral - Until 31/07/2015, Priyesh Mohanty, Aswathy A.K. - Until 23/05/2016, Leanna Rose Joy, Krithika Badarinath, Suvrajit Saha - Until, 02/03/2016, Parijat Sil, Shweta, Sruthi S Balakrishnan, Avishek Ghosh, Bishal Basak, Aastha Kumari, Radhika Sudhir Joshi, Shishu Pal Singh, Shuchita Arun Soman, Urvashi Raheja - Until -03/06/2016, Priyanka Gupta, Aanchal Jitendrakumar Bhatia, Kambadur Gundu Ananthamurthy, Farhana Yasmin, Mohammed Mustafizur Rahman - Until 31/07/2015, Giselle Maria Fernandez, Prabahan Chakraborty, Saptarnab Naskar, Ashutosh Shukla, Payel Chatterjee, Nitesh Saxena, Taruni Roy - Until 31/07/2016, Tanvi Deora - Until 29/07/2015, Vandana Agarwal, Sahana Sitaraman, Ankita Prakash Chodankar, Ali Asgar Bohra, Tarjani Agrawal - Onrolls, Shlesha Rajesh Richhariya - Onrolls, Preethi Ravi - Onrolls, Steffy B Manjila, Amruta Varudkar, Lalitha Krishnan, Chandan Kumar Pandey - Until 31/07/2016, Aparna Agarwal,

Junior Research Fellow

Rubby Abdullah - Until July 2014, Abhijeet Ghode - Until Dec 2014, Sam Kuruvilla - Until- 29/01/2016, Rukaya Amin Chowdery, Hitendra Negi, Rahul Raj Singh - Until 31/05/2015, Anushree, Sruthi S, B.S. Srina - Until 31/03/2016, Deepak Arya - Until 27/09/2016, Lokendra Yadav - Until 20/11/2015, P. Annapurna - Until 31/03/2016, Nimi Marcel - Until 30/04/2016, Sanjay Kumar Shukla - Until 31/05/2016, Garima Singhal (Regd. For PhD elsewhere)- Until 31/07/2016, Anupama Ambika, A. (Regd. For PhD elsewhere), Rumamol C (Regd. For PhD elsewhere), Sourav Kolay, Sudipta Ashe, Swarna Mathre, Aniruddha Panda, Rajan Surendra Thakur, J Joe Anand Kumar(Regd. For PhD elsewhere), Megha P.B (Regd. For PhD elsewhere), Ashaq Hussain Najar, Amit Sangwan - Until April 2015, G.V. Harsha Rani - Until 05/02/2015, Anu G Nair, Aviral Goel, 18/12/2015, Shriya Palchaudhuri, Sumantra Chattarji, Shobha Anil Kumar(Regd. For PhD elsewhere), InStem JRF - Shreya ParthaDas Sharma, InStem JRF - Deepika Patel, Harshada Hemant Sant (Regd. For PhD elsewhere), Karthikeyan C (Regd. For PhD elsewhere), Ajinkya S Dahake - Until July 2014, Deepak C.K. - Until 31/08/2015, Kumarvardhanam Daga, M. Maitri, Shaista Jabeen, Anubhab Khan - Until July 2014, Sriram Narayanan - Until 31/07/2015, M Umashankar, Swetha B. M(Regd. For PhD elsewhere), Nagaraju Dhanyasi(Regd. For PhD elsewhere) - Until 31/03/2016, Madhumala K.S. (Regd. For PhD elsewhere), Aman Agarwal(Regd. For PhD elsewhere), Indulekha P S(Regd. For PhD elsewhere, K Dhanya (Regd. For PhD elsewhere), Trayambak Pathak(Regd. For PhD elsewhere) - Until 10/07/2016, Siddharth Jaykumar(Regd. For PhD elsewhere), Sreeja Kumari Dhanya, Shilpa SiddappaYadahalli (Regd. For PhD elsewhere),

Hitesh Kumar Rafalia (Regd. For PhD elsewhere), Venkata Ramana - Until 30/06/2016, Priyadarshini Gurung (Regd. For PhD elsewhere), Tanushree Srivastava (Regd. For PhD elsewhere) - Until 31/03/2016, Nishma Dahal (Regd. For PhD elsewhere), Meghna Natesh, Dharmendra Lamsal - Until 31/07/2016, Atul Joshi (Regd. For PhD elsewhere), Anusree A.S. (Regd. For PhD elsewhere), Dina - Until 30/06/2016, Siddharth Bharath Iyengar- 14/08/2014, Mayank Kohli - Until 31/07/2014, Harinandanan P.V- Until 15/02/2016, Nandita Nataraj, Chengappa S.K, M Arockia Catherin, Siddarth Jude Machado till 31/07/2016, Amol Ramesh Kulavmode - Until 31/07/2016, Vivek Sarkar - Until 31/07/2015, Dipendra Nath Basu - Until 31/03/2016, Vaishali Bhaumik - Until 31/03/2016, Kiran Marathe - Until 31/07/2015, Bunindro Singh - Until 31/07/2014, Arumoy Chatterji, Rikesh R. Jain - Until 31/08/2016, Abhishek Anand - Until 30/06/2016, Alefiyah Habibullah - Until 31/08/2015, Mihir Umarani - Until June 2014, Gaurav Diwan, Nachiket Shankar - Until July 2014, Swastika Issar - Until 31/01/2016, Ashwin Kumar Nair, Arun Prakash

Postdoc

Nilesh Aghera (PI grant) - Until April 2014, Ishita Sengupta, Vishal Bhardwaj - Until 18/02/2015, Jogender Singh Bridging [04/06/2015 03/06/2016], Pooja Malhotra (06/06/2016 onrolls), M. Snigdha, Ashvini Kumar Dubey- Until 30/09/2015, Parag Surana, Dambarudhar S S Hembram, Soumita Das (DBT_RA), Supriyo Basak - Until 20/04/2015, Sagarika Mishra (DBT_RA), Sasikala P Sachithanandan - Until 30/11/2015, P Chitra (DBT_RA) - Until 30/06/2016, Aswathy A.K (Bridging), Shambhavi Naik (Bridging) - Until 31/12/2015, Nimi Marcel (Instem Bridging), Gayatri Muthukrishnan 31/10/2015, Darius Vasco Koster, Marcus Taylor, Bini Ramachandran, Suvrajit Saha(Bridging) 03/03/2016 to 30/06/2016, Suhail Muzaffar, Ishtapran saho, Pramod Kumar Singh, Vishnu Janardan, Ashutosh Kumar (Bridging) - Until May 2015, Odity Mukherjee , Anup Parchure, From 19/05/2016 , Kapil Saxena - Until 31/12/2014, Daniel Brian Weatherhill - Until July 2017, Debarati Mukherjee - Until - 08/05/2015, Bhaktee Dongaonkar, Mohammed Mustafizur Rahman (Bridging) (20/09/2015 -20/09/2016), Sonal Kedia - Until 30/11/2015, InStem Postdoc - Amita Sneh (PI grant) - Until 10/01/2016, InStem Postdoc - Sailaja A Goda (PI grant) - Until 09/01/2016, Igor Kondrychyn (CDF), Mohan Raghavan - Until July 2014, Gnaneshwar V Yadav (Bridging) - Until 17/11/2016, Pushkar D Paranje - Until 12/02/2015, Rudra Nayan Das - Until 30/09/2015, O. Venkateshwara Reddy - Until 21/10/2014, Rajesh Dattaram (Bridging)- Until 03/03/2016, Durafshan Sakeena Syed(Bridging) w.e.f (20/07/2016 19/07/2017), Megha, Mohammed Bin Abu Baker (Bridging) - Until 30/04/2015, Sufia Sadaf - Until 30/06/2016, Trayambak Pathak (Bridging till 31/10/2016), Neha Wadia - Until 30/06/2015, Venkatakrishnan Ramaswamy, Ramya Purkanti (Bridging) 08/01/2016 to 07/01/2017, Nahren Manuel Mascarenhas, Robin V Vijayan, S.P. Vijayakumar - Until 30/11/2015, Ishan Agrawal - Until 30/10/2015, Vivek Ramachandran - Until 03/12/2015, Varad B Giri, Atul Kumar Upadhyay(Bridging) - Until 10/08/2016, Krishnapriya Tamma (Bridging) 18/06/2015 to 17/06/2016, Ayesha Elizabeth Prasad 31/10/2014, Joysree Chanam, Varun Varma(Bridging), Jahnvi Joshi, Asem, Surindro Singh - Until 31/10/2015, Arpita Sarkar (DBT_RA) 17/07/2015, V.S. Pragadheesh, Imroze Khan (Own grant), Laasya Samitha (Career Development Fellowship)

M.Sc. in Wild Life and Conservation

Rohit Ravindran

Graduate Trainee

Hemalatha B (Regd. For PhD elsewhere), Suhrid Sundar Ghosh -12/10/2015

Administrative/Auxilliary Staff

K V Ramanathan, N N Shanthakumary, S Ashok Rao, P V Suryarao, Shaju Varghese, Srinidhi V, K S Vishalakshi, S B Saraswathi, C Prashanth Murthy, Maithly Ramesh, Prashanth K, A Anandraj, N Ramprasad, R N Nagaraj, Seetharam Naik, Lakshmi Priya P, Nirmala K S, Sujatha N, Indu Bala, Karthika G, Thanuja S, Pradip Pyne On Lien, H R Uma on lien, Vinodh Kumar V on lien

Research Facilities

H. Krishnamurthy

National and International Involvement

Jayant Udgaonkar: Member, Editorial Board of Protein Engineering, Design and Selection (2013- date); Member, Editorial Advisory Board of Biochemistry (2013- 2015); Associate Editor of *Biochemistry* (2015-); Guest Editor, Section on Folding and Binding, *Curr. Opin. Struct Biol.* (2013, 2016); Member, DBT Task Force on Basic Biology (2014-present); Convenor, Section on General Biology, Indian Academy of Sciences (2013-2015). **M.K. Mathew:** Member, Scientific Advisory Committee, National Institute for Interdisciplinary Science, Thiruvananthapuram (2011- date); Member, Scientific Advisory Committee, CDFD (2010-date); Visiting Professor, IISER Thiruvananthapuram (2014-ongoing) ; DBT nominee on IBSC of Monsanto; Serving on IBSC of 5 other institutions; Serving on Academic Council of Cotton College State University, Guwahati 2014 ongoing; Serving on Senate of IISER Thiruvananthapuram 2014 ongoing. **R. Sowdhamini:** Editorial Board of Bioinformatics, PLoS ONE, BMC Bioinformatics , Biology Direct, Journal of Biomolecular Structure and Dynamics; Member of Bioinformatics Taskforce (since 2014). **Aswin Sai Narain Seshasayee:** Biosafety committee member for Indian Institute of Science and Novozymes, Bangalore. **Ranabir Das:** Nature Structural and Molecular Biology, Nature Communications, Biochemistry, Journal of Molecular Biology, Applied Physics Letters, Journal of Proteome Research, FEBS Letters; Editorial Board, *Matters*; Reviewed four EMR grant proposals for DST. **P.V Shivaprasad :** Member of Cambridge RNA club; Cambridge Epigenetics Club. **Shachi Gosavi:** Journal Reviewer (Journal of Physical Chemistry B; Journal of Chemical Physics, PLOS Computational Biology, PLOS One, etc.); Guide for summer internship programs: Indian Academy of Sciences, National Network of Mathematical and Computational Biology. **Satyajit Mayor:** Editor, Biochemical and Biophysical Research Communications (2014- date); Editorial Board, Cell (2008- date); Editorial Board, Journal of Cell Science (2011- date); Editorial Board, Biochimica Biophysica Acta (2008- date); Editorial Board, The Biochemical Journal (2011- date); Editorial Board of Reviewers, Molecular Biology of the Cell (2004- date); Invited Fellow, Royal Society of Chemistry (2014) Foreign Fellow, US National Academy of Sciences (2015) . **Sudhir Krishna:** Member, Research

Advisory Council, All India Institute of Medical Sciences (2014- date); Member, Scientific advisory committee, Bose Institute, Kolkata (2015- date); Member, Science and engineering research board, Department of Science and Technology, Govt of India: Program advisory committee of biophysics, biochemistry, molecular biology and microbiology (2012-2015). **Gaiti Hasan:** DBT Recombinant DNA Advisory Committee (Jan 2016 till date); DBT Task Force on genome editing technologies (July 2014- date); Member Intermediate and Senior Fellowships Committee, Wellcome-DBT Alliance (2011-2015); Scientific Advisory Committee for the National Institute for Biomedical Genomics, Kalyani, West Bengal. (March 2013 date); Intermediate and Senior Fellowships Committee for the Wellcome-DBT India Alliance, (2011- datedate). **Raghu Padinjat:** Member, Genome Engineering Task Force. Department of Biotechnology, Government of India. (2014-present). **K. VijayRaghavan:** Member, Science Advisory Council of the Cabinet (2012- date). **Sumantra Chatterji:** Editorial Boards: IBRO Reports, Journal of Neuroscience Methods, Journal of Neurophysiology, Molecular Brain, Neural Plasticity, Journal of Psychiatry & Neuroscience; Associate Editor, Frontiers in Behavioral Neuroscience. **Upinder S. Bhalla:** Editorial Boards: Journal of Computational Neuroscience, Neuroinformatics, Frontiers in Neuroscience, eNeuro- Board of Reviewing Editors, eLife- Board of Reviewing Editors; India representative to the International Neuroinformatics Coordination Facility (2009- date); Board Member, International Society for Systems Biology(2009 - date); Society for Neuroscience (1991- date); Indian Neuroscience Association (1999- date) Faculty member, Erasmus Mundus (EUROSPIN) program in neuroinformatics (involving KTH Sweden, Univ. of Edinburgh, Univ. of Freiburg, NCBS); Member, Scientific Advisory Committee, National Brain Research Centre (2012- date); Chair, Neurosciences Task Force, Department of Biotechnology (2009-2014); Member of the Council of the Indian National Science Academy (2015); Member, Programme Advisory Committee on Animal Sciences, Science and Engineering Research Board (2015-); Member, NeuroML Board of Editors (2015-); Member, Governing Board, International Neuroinformatics Coordination Facility (2010-2015). **Sanjay Sane:** Editorial Boards: Journal of Bionic engineering, Biology Letters, Journal Of Neurophysiology; Review editor: Frontiers in neural circuits Society of Integrative and Comparative Biology (1996- date); Society of Experimental Biology (2005- date); International Society of Neuroethology (2007- date). **Vatsala Thirumalai:** Member, Society for Neuroscience, Washington DC (2002- date); Member, Board of Studies, Faculty of Technology, Anna University, Chennai; Editorial Board, Journal of Neurophysiology (2014-date); Reviewing Editor, Frontiers in Neural Circuits (2015-) **Hiyaa Ghosh:** Editorial board of Science Matters; Reviewed research papers for Biochemical Journal, Journal of the American Aging Association, Aging Cell, Journal of Immunology, Blood, American Cancer Society, British Journal of Nutrition, FEBS Journal. **Shannon B Olsson:** Review Editor, Frontiers in Integrative Neuroscience, Frontiers in Physiology, Halteres; Coffee Board of India Steering Committee Member; IBSD Imphal Prioritization of Animal Bioresources Res. Areas: Fish and Insectexpert committee; Nazareth College Scientific Advisory Board Member; Chemical Ecology Master's Program and Schools; NCBS; Peer Reviewer, *Journals:* Nature Publishing Group, J. Exp. Biol., J. Chemical Ecology, IEEE Sensors, J. Insect Science, Chemical Senses, Animal Behaviour, Current Science; *Peer Reviewer, Grants:* National Science Foundation, German-Israeli Foundation for Scientific Research and Development. **Mahesh Sankaran:** Subject Editor Biotropica (2014 date). **Krushnamegh Kunte:** Editorial Board: Journal of Threatened Taxa, Journal of Research on the Lepidoptera, Current Science; Manuscripts reviewed for Proceedings of the Royal Society B, Journal of Theoretical Biology, PLoS ONE, Current Science, Journal of Insect Physiology, Behavioral Ecology and Sociobiology, Ecology and Evolution, Journal of Biosciences, Systematics and Biodiversity, Journal of Threatened Taxa, Journal of Research on the Lepidoptera, Journal of the Lepidopterists Society, and Journal of the Bombay Natural History Society. ; Research funding proposals reviewed for the British Ecological Society, the United States; Department of Agriculture (USDA), the National Geographic Society, the Rufford Small Grants Foundation, and the Lepidoptera Research Foundation. **Deepa Agashe:** Editorial Board, *Matters* (May 2016 present); Associate Editor, *Molecular Biology and Evolution* (Oct 2015-present); Guest Editor, *Current Science* special section on Evolutionary biology (May 2015); Reviewed manuscripts for Ecology, Current Science, American Naturalist (2), Evolution, BMC Genomics, Nucleic Acids Research; Reviewed grant proposals for DBT. **Mukund Thattai:** Editorial Board Member, Journal of Experimental Zoology B (2013 date) Joint Faculty Member, International Centre for Theoretical Sciences (2010 date) Asia Committee; Academic Editor, PLoS ONE (2007 date); Wellcome Trust-funded TheatreScience workshop. **Sandeep Krishna:** Reviewed manuscripts for Mol. Biosyst., PLOS one, PLOS Comput. Biol. Eur Phys J, Nuc. Acids Res., J. Theoret. Biol., J. Mol. Biol., BMC Syst. Biol; DBT nominee on Biosafety committee of TheraIndx company, Neelamangala, Bangalore.

Visits

M.M. Panicker: Achucarro - Basque Center for Neuroscience, Bilbao, Spain. (July 2015); Max Delbruck Center for Molecular Medicine, Berlin, Germany. (July 2015); Indian Institute of Science, Bangalore. (Nov 2015). **M.K Mathew:** Cotton College State University, Guwahati, (Aug 2015); NUS IISER Thiruvananthapuram Symposium (sept 2015); St. Joseph's College (feb 2016); IISER Mohali (Mar 2016). **R. Sowdhamini:** SELECTBIO conference in Sheraton Bangalore Hotel (May 2015); 19th Conversation held in Albany University (June 2015); JNCASR, Bangalore (sept 2015); ICMR Puducherry (Nov 2015); University of Kerala (Jan 2016); SBCADD'2016 in Alagappa University, Karaikudi (Feb 2016); Indo-French workshop in Indian Institute of Science (Mar 2016); Workshop on advanced Techniques in Protein Design and Engineering in IISER Mohali (Mar 2016); RMRC, Port Blair (Mar 2016). **P.V Shivaprasad:** Attended C4 initiative, New Delhi (Apr 2015). ICAR sponsored Summer School on "RNAi in Crop Plants" at NRCPB, Delhi (May 2015). Biannual meeting of the Indian Society for Developmental Biologists, CCMB, Hyderabad (July 2015). NexGen Genomics & Bioinformatics Technologies, NGBT Conference, Hyderabad, India (oct 2015). CIMAP-CSIR, Bangalore, (Sept 2015). Athanasios College For Advanced Studies (MACFAST) Tiruvalla, Kerala (Dec 2015). Genotypic technologies, Bangalore (Jan 2016). Savithribhai Phule University, Pune (Feb 2016). 8th RNA Group Meet, CCMB, Hyderabad (Jan 2016). University of Agricultural Sciences, Bangalore, (Feb 2016). School of Biotechnology, Madurai Kamaraj University, (May 2016). "De-coding the Non-coding" workshop, Central University, Kasargod, Kerala. (Feb 2016). Attended UGC SAP programme, University of Madras, (Mar 2016). **Arati Ramesh:** Biofilms Conference, SASTRA University, Tanjore (Jan 2016); Gordon Research Conference: Microbial Adhesion and Signal transduction Mount Holyoke, RI, USA (July 2015). **Ranabir Das:** Invited talk at RCB-Delhi (Feb 2016). NMR Symposium, IIT Kharagpur, (feb 2016). Visited Bose Einstein-Kolkata, (Mar 2016). **Aswin:** Indian Academy of Sciences Annual Meeting at IISER Pune (November 2015); Workshop at ISCB, Singapore (November 2015); Bacterial Expressions II, NCBS (December 2015). **Gaiti Hasan:** Brandeis University, Waltham, USA (July 2015); Dept of Biological Sciences, TIFR, Mumbai (Oct 2015); Annual meeting of the Current Science Editorial Board, Bangalore. (Nov 2015); International Neuropeptide. Society meeting, NISER, Bhubhaneshwar. (Dec 2015); Biennial meeting of Indian Drosophila, Biologists, IIT, Kanpur. (Dec 2015). **Sudhir Krishna:** IFOM, Milan, Italy, (July 2015); AOGIN India, CMC, Vellore, (Aug 2015). ; 11th Indo-Australian biotechnology conference, Sydney, Australia, (Sept 2015); DAPCON- 2016, University of Delhi, (Feb 2016); International cancer workshop for SAARC nations, Delhi, (March 2016). **Apurva Sarin:** All

India Cell Biology Conference, Thiruvanthapuram, India (Dec 2015). **Varadharajan Sundramurthy**: Bangalore Bioinnovation Cluster (Aug 2015); TIFR, Mumbai (Oct 2015); Sastra Univeristy, Thanjavur (Jan 2016); CDRI, Lucknow (Feb 2016); University of Wuerzburg (Mar 2016); MPI-IB, Berlin (Mar 2016); MSU, Baroda FOR teaching a course; International TB vaccines meeting, NIRT, Chennai meeting; Ramalingaswamy meeting (RCB, Dec, 2015). **Raghu Padinjat**: Indian Society for Developmental Biology Meeting, Hyderabad, India. September, 2016; Indian Society for Cell Biology, Trivandrum, India, December 2016; 6th International Lipid Meeting, Singapore, December 2016. **Sumantra Chattarji**: 54th Annual Meeting of the American College of Neuropsychopharmacology (ACNP), Hollywood, FL, USA (2015). Gordon Research Conference at MA, USA (2015). 9th World Congress, Rio De Janeiro, Brazil (2015). Center for Neural Science, New York University, New York, USA (2015). **Upinder S. Bhalla**: ICMF Nodes meeting, NENCKI Institute, Warsaw (Apr 2015). *Spikes Seminar Series*, Bangalore, CNS/IISc (June 2015). International Congress of Polish Neuroscience Society, Gdansk, Poland (sept 2015) NAMASEN meeting, NENSKI institute, Gdansk, Poland, (Sept 2015). Invited talk at Bangalore, ICTS (Jan 2016). Workshop on Computational Brain Research at IIT Chennai, Madras (Jan 2016). HHMI/eLife, eLife Editors general assembly. Maryland (Nov 2015); The First IBRO-APRC Global Advocacy Workshop. Neuroscience funding and research in India. TIFR/IBRO, Mumbai; Transylvania Experimental Neuroscience Summer School, Romania (June 2015). **Sanjay Sane**: Department of Zoology, University of Cambridge (Aprl 2016). University of Washington (Jan 2016). Centre for Bioystems Sciences and Engineering Department, Indian Institute of Science (Nov 2015). Kavli Frontiers in Science - Indo-American Symposium hosted by US National Academy of Sciences and Indo US Science and Technology forum, Irvine, USA (Aug 2015). Academia Sinica, Taipei, Taiwan (June 2015). Technical University of Denmark, Lyngby, Denmark (May, 2015). Lund University, Sweden (May 2015). Rothamsted Research, UK (Apr 2015). **Vatsala Thirumalai**: Mahabaleshwar Seminar on Imaging in Zebrafish, Alibaug, MH (2015); IBRO School in Neuroscience, BHU, Varanasi. (2015). **Hiyaa Ghosh**: IICB, Kolkata (Sept 2015). **Axel Brockmann**: Second Meeting of the Indian Subcontinent branch of the International Neuropeptide Society / Society for Biologically Active Peptides NISER, Bhubaneswar (Dec.2015). Institute of Advanced Study in Science and Technology, Guwahati, India (Oct. 2015). Indian Bee Course, Department of Animal Science, Central University of Kerala, Nileshtar, Kerala (Aug 2015). International Conference on Biotechnological Advances in Environmental Health and Biodiversity Conservation (EHBC), Imphal Manipur, India (May 2015). IBRO-APRC-NBRC School (March 2016). 3rd M K Chandrashekar Memorial Meeting, JNCASR, Bangalore (Feb 2016). **Shannon Olsson**: Keynote Speaker, Founders Day, Indian Inst. for Integrative Medicine, Jammu (Dec 2015); Int. Congress Comp. Phys and Biochem. Krakow, Poland (Aug 2015); IIT Madras Biofest, Chennai (Mar 2015). International Society for Chemical Ecology, Brazil (July 2015). India International Coffee Festival, Mumbai (Jan 2016). Central Drug Research Institute, Lucknow (Jan 2016). **Uma Ramakrishnan**: National University of Singapore: Conservation genetics; Field Museum of Natural, History, Chicago, U.S.A. **Mahesh Sankaran**: "ToichNutNet German Centre for Integrative Biodiversity Research (iDiv), Halle-Jena-Leipzig, Germany (Jan 2016); Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES), Thematic assessment on Land Degradation and Restoration, Bonn, Germany (Sept 2015). **Krushnamegh Kunte**: University of Wzrburg, Germany (Dec 2015); Ludwig-Maximilians-University, Munich, Germany (Dec 2015); Natural History Museum, London, UK (Dec 2015); Imperial College London, Silwood Park campus, UK (Dec 2015). **Deepa Agashe**: Attended meeting at Austin, USA (June 2016); Indian conference on Behavior, Ecology and Evolution, Uttarakhand, India (Mar 2016); National Seminar on Frontiers in Biotechnology, Bharathiyar University, Coimbatore, India (Feb 2016); Undergraduate Lab research talk, IISc, Bangalore (Feb 2016); ICTS School on Population Genetics and Evolution, Bangalore, India (Jan 2016); Jawaharlal Nehru University (JNU), New Delhi, India (Nov 2015); National Conference on Ethology and Evolution, IISER Mohali, India (Oct 2015); J Craig Venter Institute, La Jolla, USA (Aug 2015); Department of Ecology and Evolutionary Biology, University of Minneapolis, USA (Aug 2015); Department of Microbiology, Michigan State University, USA (Aug 2015); Department of Organismic and Evolutionary Biology, Harvard University, USA (Aug 2015). **Radhika Venkadesan**: International Conference on Recent Trends in Analytical Chemistry (ICORTC-2015), University of Madras, (Dec 2015); Indo-German Workshop on Novel Approaches to Investigate Signals and Defences in Plant-Biotic Interactions, National Institute of Plant Genome Research, NewDelhi (Dec 2015); Bangalore SCCS, IISc (Sept 2015); Round Table on Semiochemicals, National Institute of Agriculturally Imporant Insect Resources, Bangalore, India. (Aug 2015); St. Aloysius College, Mangalore. (Feb 2015); International Conference on Recent Trends in Analytical Chemistry (ICORTC-2015), University of Madras (Dec 2015). **Mukund Thattai**: RIKEN, Tokyo, Japan (Apr 2015); Evolutionary Cell Biology Program. Kavli Institute for Theoretical Physics. (Aug 2015). **Sandeep Krishna**: Ecology and Evolution Conference, Uttarakhand (Mar 2016). 3rd Indian Statistical Physics Community meeting, ICTS, Bangalore (Feb 2016). Diversity in bacteria-virus ecosystems is facilitated by weak defences against viruses. Complex System Approach to Self-Organization meeting, IIT Chennai (Feb 2016). Entrainment and Phase-Locking of Biological Oscillators, Transitions in Biological Systems meeting at NCBS, Bangalore (Jan 2016). Growth phase dependent regulation of the E. coli RNA polymerase by 6S RNA and Rsd, International Conference on Systems Biology, Singapore (Nov 2015). Restriction-modification systems as engines of diversity in bacteria-virus ecosystems, Models of Life conference, Krogerup, Denmark. (Aug 2015). Excursions in Complexity meeting, Niels Bohr Institute, Copenhagen (Jun 2015). R Models of Life conference, Krogerup, Denmark (Aug 2015). Niels Bohr Institute, Copenhagen (Jun 2015). NNMCB meeting on Mathematical Modelling of Biological Systems, Univ. of Kashmir, Srinagar (Apr 2015). **Shachi Gosavi**: National Symposium on Biophysics, Jamia Milia Islamia, Delhi (Feb 2015). Molecular Graphics and Modeling Society conference on Exploring Mechanisms in Biology: Theory and Experiment, Singapore (Nov 2015). Biophysical Society Meeting, Los Angeles, USA (Feb 2016). Gordon Research Conference on Protein Transport Across Cell Membranes, Galveston, USA, (Mar 2016). **Parijat Sil**: Corsiga, France to present poster at Qbio 2015 conference (28th sept- 3rd oct, 2015). **Prabhakara Chaitva**: Corsiga, France to present poster at Qbio 2015 conference (28th sept- 3rd oct, 2015). **Priyadarshini Gurang**: University of Cambridge, UK to attend the Student Conference on Conservation Science (SCCS) and attend a short course before conference (19th -24th march). **Atul Joshi**: University of Cambridge, UK to attend the Student Conference on Conservation Science (22-24 mar' 2016). **Jahnavi Joshi**: Attending a workshop organised by Transmitting science at Piera Barcelona (14-17 March 2016). **Savita Chib**: Santa Barbara, USA to attend 2015 Summer course of cellular Evolution : A laboratory course on cellular evolution (3 aug-5 sept 2015). **Ramya Purkanti**: UCSB, Santa Barbara, USA to attend 2015 Summer course of cellular Evolution : A laboratory course on cellular evolution (3rd aug-5th sept 2015). **Mughda Sathe**: San Diego, USA to attend Annual Meeting of ASCB-2015 (12th -16th dec' 2015). **Surujit Saha**: San Diego, USA to attend Annual Meeting of ASCB-2015 (12th -16th dec' 2015) and, to visit the lab of Prof. Orion Weiner, University of California, USA (17th -22nd dec'2015). **Dipendra Nath Basu**: Natural History Museum, London for PhD dissertation Program (1nov- 20dec 2015). **M. Sankaranarayanan**: Trinity College, Dublin to attend Science Foundation Ireland Meeting (9th -20th nov 2015). **Baskar B**: Trinity College, Dublin to attend Science Foundation Ireland Meeting (9th -20th nov 2015); **Jyothi C. Nair**: Berlin to present a

poster at the 10th International Conference on Behaviour, Physiology and Genetics of Wildlife 2015 (28th sept-10th oct 2015). **Darius Koester:** IISER Pune to participate in Indo-French Frontiers in Cytoskeleton Research (25th -27th oct' 2015). **Amit Das:** University of Dundee, research collaboration at the University of Dundee, Scotland (21st sept- 10th oct 2015). **Sanjeev Sharma:** Robinson College, London to present poster at *Signalling 2015: Cellular Functions of Phosphoinositol and inositol phosphates* conference (1st -4th sept 2015). **Suhrid Ghosh:** Uppsala University, Sweden as part of collaborative project with Dr. Kain Nordstrom (20th July- 20th Aug 2015). **Krutika Phalnikar:** WoodsHole, Massachusetts, USA to attend workshop on *Strategies & Techniques for analysing microbial population structures* (5th -15th aug 2015). **Vrinda Ravi Kumar:** Maxplank Institute of Chemical Biology, Jena, Germany for a collaborative research project (30th July- 20th Aug 2015). **Radhika Sudhir Joshi:** Hongkong University of Science and technology, China to attend conference on GRC-modulation of neural Circuit behaviour (21st -26th June 2015). **Kabir Hussain:** University of colorado, USA to attend 4-week scientific workshop on Soft matter in and out equilibrium(1st -31st July 2015); **Hemanth Giri Rao:** Barcelona, Spain to attend the 29th Annual symposium of protein society 2015. **Rajesh D.:**Tuscanny, Italy and Syockholm, Sweden to attend the Gorden Research Conference and International Society of Stem Cell Research (ISSCR2015) Annual Meeting. (24th -27th June 2015). **Anand M. Osuri:** University of Oxford, United Kingdom on a collaborative project (15th june -31st aug' 2015). **Joseph Mathew K.:**Marine Biology Laboratory (MBL), University of Chicago to participate in the Integrin project (June 14th -Aug 4th , 2015). **Awasthy AK:** Stockholm Sweden to attend ISSCR conference (24th-27th june 2015). **Avantika Lal:** Vermont, USA to attend a conference on Mechanism and Regulation of prokaryotic tenascription(21st-26th june 2015). **Pooja Malhotra:** Barcelona, Spain to attend 29th Annual Symposium of Protein Society (22nd-25th july 2015). **Prachi Thatte:** Montpellier, France to attend International Congress for Conservation Biology (2nd-6th ag 2015). **Meghna Natesh:** Montpellier, France to attend International Congress for Conservation Biology (2nd-6th ag 2015). **Antony George:** University of Wurzburg on a collaborative project with Dr. Ricar Scheiner under the 'DAAD', a new passage to India program (june-july 2015)

Invited Talks

M.M. Panicker

1. Lipid Bodies associated with the Primed Pluripotent Stem Cell State - A novel endogenous marker. At the Achucarro - Basque Center for Neuroscience, Bilbao, Spain. (July 2015)
2. Pluripotency sings the Blues. At the Bader Laboratory, Max Delbruck Center for Molecular Medicine, Berlin, Germany. (July 2015)
3. Human Induced Pluripotent Stem Cells based modelling of Late Onset Alzheimer Disease (LOAD) genetics in an Indian cohort. Conference on Neurodegenerative Diseases: Pathogenesis to Therapy Centre for Brain Research, Indian Institute of Science, Bangalore. (Nov 2015)

M.K Mathew

1. The Root of the Matter: How Rice Copes with Drought and Salt at: Botany Department Colloquium, Cotton College State University, Guwahati, (Aug 2015).
2. Endocytosis in Plants, with a Pinch of Salt at: Institute for Advanced Studies in Science and Technology, Guwahati (Aug 2015).
3. Vesicle Trafficking Across Layers of the *Arabidopsis* Root: Remodeling by Salt at: Scales in Biology: From Genes to Ecosystems. NUS IISER Thiruvananthapuram Symposium (sept 2015).
4. How Rice Copes with Drought and Salt: a Root Story. St. Joseph's College (feb 2016).
5. Vesicle Trafficking and Endomembrane Compartments with a Pinch of Salt Arabidopsis Meeting, IISER Mohali (Mar 2016).

R. Sowdhamini

1. Bioinformatics genome-wide survey of myosins in Genomics and Proteomics Research . SELECTBIO conference in Sheraton Bangalore Hotel (May 2015).
2. Computational Analysis and Prediction of Proteins that undergo domain swapping. Albany 2015: The 19th Conversation held in Albany University (June 2015).
3. Cardiomyopathies and energetics calculations of myosin coiled-coils. JNCASR-NNMCB Program on Mathematical Biology JNCASR (sept 2015).
4. Sequence and Structural Analysis of Odorant Binding Proteins in three Mosquito Genomes. Genomics & Proteomics of Disease Vectors and Pathogens VCRC, ICMR Puducherry (Nov 2015).

5. Genome sequencing of 'Tulsi - a herbal plant. International Symposium Bioinformatica Indica University of Kerala (Jan 2016).
6. Analysis and Prediction of Domain Swapping in Proteins. SBCADD'2016 in Alagappa University, Karaikudi (Feb 2016).
7. Genome Sequencing of 'Tulsi. Indo-French workshop on 'Exploring the scope of collaborations in marine biology and biotechnology between France and India' in Indian Institute of Science (Mar 2016).
8. Protein domain swapping. Workshop on Advanced Techniques in Protein Design and Engineering in IISER Mohali (Mar 2016).
9. Three-dimensional modeling of protein-ligand interactions : implications in drug design". Bioinformatics - recent advances in genomics RMRC, Port Blair (Mar 2016).

P.V Shivaprasad

1. Plant small RNAs and epigenetics. Photosynthetic enhancement to boost yield", International Rice Research Institute, C4 initiative, New Delhi (Apr 2015).
2. Insight into small RNA biogenesis and their functions in plants. IISER, Trivandrum (May 2015).
3. Two lectures titled 'Small RNAs and Epigenetics: The dark matter of genomes' and 'Insight into small RNA biogenesis and their functions in plants ICAR sponsored Summer School on "RNAi in Crop Plants" at NRCPB, Delhi (May 2015).
4. Insight into Small RNA biogenesis and their functions in plants. Biannual meeting of the Indian Society for Developmental Biologists, CCMB, Hyderabad (July 2015).
5. Biogenesis and functions of Plant miRNAs. NexGen Genomics & Bioinformatics Technologies, NGBT Conference, Hyderabad, India (oct 2015).
6. Plant small RNAs and Epigenetics, Foundation Day lecture, CIMAP-CSIR, Bangalore, (Sept 2015).
7. Small RNAs and epigenetics. Mar Athanasios College For Advanced Studies (MACFAST) Tiruvalla, Kerala (Dec 2015).
8. Epigenetics and transcriptional silencing. Genotypic technologies, Bangalore, Bangalore (Jan 2016).
9. Insight into small RNA biogenesis and their functions in plants. National Seminar. Current Trends in Epigenetics: From Genotype to Phenotype, Savithribhai Phule University, Pune (Feb 2016).
10. Insight into small RNA biogenesis and their functions in plants. 8th RNA Group Meet, CCMB, Hyderabad (Jan 2016).
11. Involvement of Epigenetics and transcriptional silencing in stress responses. University of Agricultural Sciences, Bangalore, (Feb 2016).

12. Cascade silencing initiator miRNAs regulate phenylpropanoid pathways in diverse plant species. School of Biotechnology, Madurai Kamaraj University, (May 2016).

13. Biogenesis and functions of plant small silencing RNAs. "De-coding the Non-coding" workshop, Central University, Kasargod, Kerala. (Feb 2016).

14. Small RNAs and epigenetics, the dark matter of genomes" UGC SAP programme, University of Madras, (Mar 2016).

Arati Ramesh

Biofilms Conference, SASTRA University, Tanjore (Jan 2016)

Ranabir Das

1. Investigating an Ubiquitin Ligase encoded by the Herpes Simplex Virus-1, RCB-Delhi (Feb 2016).

2. Studying the activity of a Ubiquitin Ligase encoded by the Herpes Simplex Virus -1, IIT Kharagpur, (Feb 2016)

3. Studying the activity of a Ubiquitin Ligase encoded by the Herpes Simplex Virus -1, Bose Einstein-Kolkata, (Mar 2016).

Gaiti Hasan

1. Encouraging flight: a calcium-dopamine nexus. Brandeis University, Waltham, USA (July 2015)

2. Encouraging flight: a calcium-dopamine nexus. Dept of Biological Sciences, TIFR, Mumbai (Oct 2015)

3. Invertebrate models of human disease. Annual meeting of the Current Science Editorial Board, Bangalore. (Nov 2015)

4. A neural circuit for adaptation to nutritional stress. International Neuropeptide Society meeting, NISER, Bhubhaneshwar. (Dec 2015)

5. A neural circuit for adaptation to nutritional stress. Biennial meeting of Indian Drosophila Biologists, IIT, Kanpur. (Dec 2015)

Sudhir Krishna

1. IFOM, Milan, Italy, (July 2015)

2. AOGIN India, CMC, Vellore, (Aug 2015).

3. 11th Indo-Australian biotechnology conference, Sydney, Australia, (Sept 2015)

4. DAPCON- 2016, University of Delhi, (Feb 2016)

5. International cancer workshop for SAARC nations, Delhi, (March 2016).

Apurna Sarin

Notch activity in T-cells and consequences to immune homeostasis. All India Cell Biology Conference, Thiruvanthapuram. India (Dec 2015)

Varudharajan Sundramurthy

1. Mining host-pathogen interaction networks for drugs and drug targets against infectious diseases, Bangalore Bioinnovation Cluster (Aug 2015).

2. Rewiring of host trafficking pathways by intracellular pathogens, TIFR, Mumbai (Oct 2015).

3. Bioimage informatics : a primer, Sastra Univeristy, Thanjavur (Jan 2016).

4. Targetting host pathways to fight intracellular pathogenes, CDRI, Lucknow (Feb 2016).

5. Combating host cellular pathways to fight intracellular pathogens, University of Wuerzburg (Mar 2016).

6. Combating host cellular pathways to fight Mtb, MPI-IB, Berlin (Mar 2016).

Sumantra Chatterji

1. 54th Annual Meeting of the American College of Neuropsychopharmacology (ACNP), Hollywood, FL, USA (2015).

2. Gordon Research Conference on the Amygdala in Health and Disease Easton, MA, USA (2015).

3. International Brain Research Organization, 9th World Congress, Rio De Janeiro, Brazil (2015).

4. Center for Neural Science, New York University, New York, USA (2015).

Upinder S. Bhalla

1. Activities of the Indian National Node for Neuroinformatics. INCF Nodes meeting, NENCKI Institute, Warsaw (Apr 2015).

2. Olfactory bulb coding of odors, mixtures and sniffs is a linear sum of odor time profiles. Spikes Seminar Series , Bangalore, CNS/IISc (June 2015).

3. Where, what and how much: The code in your nose. Cambridge/Mass MIT (Nov 2015)

4. Optical control of network context in hippocampal synaptic plasticity. International Congress of Polish Neuroscience Society, Gdansk, Poland (sept 2015)

5. Space and plasticity: a multiscale modeling study. NAMASEN meeting, NENSKI institute, Gdansk, Poland, (Sept 2015)

6. Many ways to lose your mind: Dimensions of robustness in noisy chemical bistable circuits. Information Processing in Biological Systems, Bangalore, ICTS (Jan 2016)

7. Neuroscience at The Bangalore Biocluster. Workshop on Computational Brain Research at IIT Chennai, Madras (Jan 2016)

Sanjay Sane

1. Synching the wing beat. Department of Zoology, University of Cambridge (April 2016).

2. Behavioral coordination in flying insects. University of Washington (Jan 2016).

3. Airflow sensing in flying insects. Centre for Bioystems Sciences and Engineering Department, Indian Institute of Science (Nov 2015).

4. Biomechanics of animal behavior. Kavli Frontiers in Science - Indo-American Symposium hosted by US National Academy of Sciences and Indo US Science and Technology forum, Irvine, USA (Aug 2015).

5. Fast, small yet still in control: how flying insects balance speed and accuracy. Academia Sinica, Taipei, Taiwan (June 2015).

6. Fast yet Balanced: how flying insects deal with the challenge of miniaturization Technical, University of Denmark, Lyngby, Denmark (May, 2015).

7. Biomechanics of wing and haltere coordination in flying insects. Lund University, Sweden (May 2015) .

8. Airflow sensing in flying insects. Rothamsted Research, UK (Apr 2015).

Hijaa Ghosh

Cellular Mechanisms in the adult brain Prof B K Bachhawat Memorial Lecture Hall, IICB, Kolkata (Sept 2015)

Axel Brockmann

1. Studies on the behavioural function of neuropeptides in honeybees. Second Meeting of the Indian Subcontinent branch of the International Neuropeptide Society / Society for Biologically Active Peptides NISER, Bhubaneswar (Dec.2015).

2. Honeybees and the mechanisms of animal behaviour. Institute of Advanced Study in Science and Technology, Guwahati, India (Oct. 2015).

3. Neuro and molecular biology of honeybee behaviour. Indian Bee Course, Department of Animal Science, Central University of Kerala, Nileshevar, Kerala (Aug 2015).

4. Honeybees and the mechanisms of animal behaviour. International Conference on Biotechnological Advances in Environmental Health and Biodiversity Conservation (EHBC), Imphal Manipur, India (May 2015).

5. Honeybees and the mechanisms of animal behaviour. IBRO-APRC-NBRC School Development and Functions of Brain Circuits: From Molecules to Behaviour. (March 2016).

6. Studies on the dance communication in honeybees. 3rd M K Chandrashekar Memorial Meeting, JNCASR, Bangalore (Feb 2016).

Shannon Olsson

1. Naturalist-inspired chemical ecology. Keynote Speaker, Founders Day, Indian Inst. for Integrative Medicine, Jammu (Dec 2015)
2. Naturalist-inspired chemical ecology. Symposium Speaker, August 2015, Int. Congress Comp. Phys and Biochem. Krakow, Poland (Aug 2015).
3. Biosynthetic infochemical communication. IIT Madras Biofest, Chennai (Mar 2015).
4. Targeting the objects of insects affections across species and continents. International Society for Chemical Ecology, Brazil (July 2015).
5. How animals wake up and smell the coffee. India International Coffee Festival, Mumbai (Jan 2016).
6. Chemical Ecology: inspiration for natural products chemistry. Central Drug Research Institute, Lucknow (Jan 2016).

Uma Ramakrishnan

Courses Taught : National University of Singapore: Conservation genetics

Krushnamegh Kunte

1. Speciation and Morphological Diversification in *Papilio* Swallowtail Butterflies. University of Würzburg, Germany (Dec 2015)
2. Speciation and Morphological Diversification in *Papilio* Swallowtail Butterflies. Ludwig-Maximilians-University, Munich, Germany (Dec 2015)
3. Speciation and Morphological Diversification in *Papilio* Swallowtail Butterflies. Natural History Museum, London, UK (Dec 2015)
4. Speciation and Morphological Diversification in *Papilio* Swallowtail Butterflies. Imperial College London, Silwood Park campus, UK (Dec 2015)

Deepa Agashe

1. Food over sex: Resource competition underlies fitness effects of group sex ratio. Evolution meeting, Austin, USA (June 2016)
2. Female resource competition mediates fitness effects of group sex ratio. Indian conference on Behavior, Ecology and Evolution, Uttarakhand, India (Mar 2016)
3. Experimental approaches to understanding the evolution of bacterial genomes. National Seminar on Frontiers in Biotechnology, Bharathiyar University, Coimbatore, India (Feb 2016)
4. Evolution of insect-microbe symbioses. Undergraduate Lab research talk, IISc, Bangalore (Feb 2016)
5. Evolution of bacterial codon use. ICTS School on Population Genetics and Evolution, Bangalore, India (Jan 2016)
6. Determinants of bacterial codon use. Bacterial Expressions Conference, NCBS, Bangalore, India (Dec 2015)
7. Synonymous mutations mediate rapid bacterial adaptation. Jawaharlal Nehru University (JNU), New Delhi, India (Nov 2015)
8. Female interference competition mediates fitness consequences of group sex ratio in flour beetles. National Conference on Ethology and Evolution, IISER Mohali, India (Oct 2015)
9. Synonymous mutations mediate rapid bacterial adaptation. J Craig Venter Institute, La Jolla, USA (Aug 2015).
10. Synonymous mutations mediate rapid bacterial adaptation. Department of Ecology and Evolutionary Biology, University of Minneapolis, USA (Aug 2015)

11. Synonymous mutations mediate rapid bacterial adaptation. Department of Microbiology, Michigan State University, USA (Aug 2015)

12. Food over sex: resource competition underlies fitness effects of sex ratio. Department of Organismic and Evolutionary Biology, Harvard University, USA (Aug 2015)

Radhika Venkadesan

1. Chemical Ecology. International Conference on Recent Trends in Analytical Chemistry (ICORTC-2015), University of Madras, (Dec 2015)
2. Trick with mimics: role of cytokinins in *Rhodococcus fascians*-plant interactions. Indo-German Workshop on Novel Approaches to Investigate Signals and Defences in Plant-Biotic Interactions, National Institute of Plant Genome Research, New Delhi (Dec 2015)
3. Semiochemicals. Bangalore SCCS, IISc, (Sept 2015)
4. Chemical Ecology of Plant-insect interactions. Round Table on Semiochemicals, National Institute of Agriculturally Important Insect Resources, Bangalore, India. (Aug 2015)
5. *Courses Taught* : Cellular Microbiology course (Lecturer; GKVK)

Mukund Thattai

1. Hybridization as a source of novel organelles, RIKEN, Tokyo, Japan (Apr 2015)
2. From Ancient Proteins to Ancient Cells: The Story of the Primordial Mitochondrial Division Apparatus. Evolutionary Cell Biology Program. Kavli Institute for Theoretical Physics. (Aug 2015)

Sandeep Krishna

1. Diversity in bacteria-virus ecosystems is facilitated by weak defences against viruses' at the India Behaviour, Ecology and Evolution Conference, Uttarakhand (Mar 2016).
2. Mode-hopping in entrained biological oscillators. 3rd Indian Statistical Physics Community meeting, ICTS, Bangalore (Feb 2016).
3. Diversity in bacteria-virus ecosystems is facilitated by weak defences against viruses. Complex System Approach to Self-Organization meeting, IIT Chennai (Feb 2016).
4. Entrainment and Phase-Locking of Biological Oscillators. Transitions in Biological Systems meeting at NCBS, Bangalore (Jan 2016).
5. Growth phase dependent regulation of the *E. coli* RNA polymerase by 6S RNA and Rsd International Conference on Systems Biology, Singapore (Nov 2015).
6. Restriction-modification systems as engines of diversity in bacteria-virus ecosystems. Models of Life conference, Krogerup, Denmark. (Aug 2015).
7. Oscillations in NFκB, p53 and Wnt. Excursions in Complexity meeting, Niels Bohr Institute, Copenhagen (Jun 2015).
8. Restriction-modification systems as engines of diversity in bacteria-virus ecosystems. Models of Life conference, Krogerup, Denmark (Aug 2015).
9. Oscillations in NFκB, p53 and Wnt at the Excursions in Complexity meeting, Niels Bohr Institute, Copenhagen (Jun 2015).
10. Counting genomes: the lysis-lysogeny decision in temperate bacteriophage NNMCB meeting on Mathematical Modelling of Biological Systems, Univ. of Kashmir, Srinagar (Apr 2015).

Shashi Thutupalli

Complex Systems Approach to Self-organization, IIT Madras, India (2016)

Jahnavi Joshi

1. "Allopatry, reproductive isolation and systematics: defining speciation in the biogeographically complex Indo-Australian

Region” at Centre for Ecological Sciences, Indian Institute of Science, Bangalore, India to attend Molecular Phylogeny Workshop (Nov 2015)

2. Diversification in the tropical forests: A case study of Papilio butterflies at India- Behavior, Ecology and Evolution (I-BEE) meeting, Corbett, India (Mar 2016)

3. “Allopatry, reproductive isolation and systematics: defining speciation in the biogeographically complex Indo-Australian Region at 8th Young Investigator’s Meeting (YIM), Delhi (Feb 2016)

4. “Assessing evolutionary assembly of the butterfly mimetic communities in the Western Ghats at National Ethology and Evolution meeting, Indian Institute of Science, Education and Research, Mohali, India (Oct 2015)

5. “Integrative taxonomy: Species delimitation in multi-disciplinary framework at University of Agricultural Sciences, Bangalore, India (Feb 2016)

Darius Koester

1. “Actomyosin Dependent Clustering and Segregation of Cell Surface Molecules at Multiple Scales” Biophysical Society Meeting, Los Angeles, USA (Feb 27-Mar 2, 2016)

2. “Actomyosin Dependent Clustering and Segregation of Cell Surface Molecules at Multiple Scales” Spring meeting of German Physical Society, Regensburg, Germany (Mar 10, 2016)

Nishma Dabal

“Impacts of climatic fluctuation on Himalayan pikas at 5th World Lagomorph conference at Turlock, USA

Dinesh Nateson

“Airflow mediated antennal positioning in flying hawk moths at Society for Integrative and Comparative Biology (SICB) Portland, Oregon (3-7 Jan 2016)

Kamlesh Kumari

“Phosphatidylinositol 5-phosphatase a novel regulator of membrane trafficking in *Drosophila melanogaster*” Annual Meeting of ASCB-2015, San Diego, USA (12-16 Dec 2015)

Trayambak Pithak

“Oral function and SOCE is required in dopaminergic neurons in *Drosophila* fly circuit” meeting organised by

society of neuroscience, Chicago, USA

Shweta

“RDGB functions of membrane contact site in *Drosophila* photoreceptors” meeting on Organelle Crosstalk in Membrane Dynamics and Cell Signaling organised by Biochemical Society, Edinburgh, London (26-29 Oct 2016)

Thangaselvam M.

“Metabolic Implication of Retenoid Sequestering lipids Bodies” GSCN meeting, Frankfurt Germany (9-11th Sept 2015)

Surujit Saha

“Spatial Patterning and diffusion of cell surface molecules in a n active-composite cell membrane at Qbio 2015 conference, Corsica, France (28th Sept- 3rd Oct, 2015)

Joseph Jose Thottacherry

“Coupled feedback loop between clathrin independent endocytic pathway and membrane tension maintains membrane homeostasis” at 14th EMBO Endocytosis Meeting, Mandelieu-la-Naule, France (27 Sept-2nd Oct 2015)

Pilot Dovich

“Genome sequencing of a herb Tulsi unravels key genes behind its strong medicinal properties at Plant Genome Evolution conference, Netherlands, Amsterdam (6-8th Sept 2015)

Atul Kumar Upadhyay

“Assessment Conservation status of bats in India and the impact of bats on public health at University of Sarawak, Malaysia (14-17 Aug 2015)

Mahita Jarjapu

“Identification of novel inhibitors of TLR-4 signalling Pathways, at a conference organised by the International Society for computational Biology, Dublin, Ireland. (10th -14th July 2015)

Conferences Organized By the Centre

1. EMBO-DBT workshop (2nd Feb 2016). NCBS hosted the EMBO-DBT workshop to celebrate the 30 years of DBT. The centre was chosen as a venue by the EMBO-DBT as part of their pan-India effort to educate researchers on the upcoming schemes of EMBO, targeted to fund Indian researchers. In addition to the team from EMBO, the campus hosted four eminent scientists including Nobel Laureate Christiane Nusslein-Volhard, Stephen Cohen, James Briscoe and Matthew Freeman. This event was supported by the DBT.

2. Conference on Ubiquitin and Ubiquitin like Modifications. Mechanisms and Implications for Human Diseases (27th -28th Jan 2016) The event involved participation from graduate students, postdoctoral fellows and faculty members from various institutes across India. *Organiser: Ranabir Das*

3. Glycobiology Course [25th-29th Jan 2016]. The course involves participation from students who should have graduate level exposure to molecular and cellular biology and is meant to educate on the various aspects of glycobiology. *Organisers: Mukund Thattai, Ajit Varke* NCBS

4. Annual Talks - Coming of Age: Transitions in Biological Systems (11th-13th Jan 2016). The event organised annually is meant to showcase NCBS science to the world. Workshop on Advanced Hierarchical Modelling in Ecology (8th-12th Dec 2015) *Organisers: Ullas Karanth, Ajit Kumar*

5. Bacterial Expression II (1st-5th Dec 2015). The meeting was intended to bring together well recognised international/national researchers who use range of techniques to understand gene expression and adaptation in bacteria. *Organisers: Aswin Sheshasayee, Sandeep Krishna*

6. CoE Workshop on Biomolecular Interactions (25th -27th Nov 2015). The workshop was a part of Centre of Excellence, funded by DBT, on techniques like imaging, cryoelectron microscopy, crystallography and bioinformatics tools for probing biomolecular interactions. *Organisers: R. Sowdhamini (NCBS), Satyajit Mayor (NCBS), N. Srinivasan (IISc), Nagasuma Chandra (IISc)*

7. The 7th Bangalore Microscopy Course (20th -27th Sept 2015). The annual, weeklong intense program designed to help attendees develop an appreciation of various techniques

in microscopy, was hosted during 20-27th September 2015. *Organisers: Satyajit Mayor, Krishnamurthy H, and Manoj Mathew.*

8. Computational Approaches to Memory and Plasticity (CAMP, June 27-12th July 2015). This 15 day intense program, a first of its kind in India was organized during 1-16th July, 2015. *Organisers: Upinder Bhalla (NCBS), Rishikesh Narayanan (IISc) and, Arvind Kumar (KTH, Stockholm).*

9. Physics of Life, NCBS-Simons Annual Monsoon School (21st -27th June 2015). Aimed at imparting integrative scientific training to researchers, this 6-day innovative program, extending from 21st to 27th June 2015 was intended to expose and groom engineers and researchers with mathematical/ physics background to biology. This workshop was organized under the scope of the Simons Centre for the Study of Living Machines at NCBS. *Organisers: Madan Rao, Mukund Thattai, Sandeep Krishna and Shachi Gosavi*

10. 5th Science Journalism Workshop (8th-20th June 2015). The two-week long, annual course aimed at imparting basic skills necessary for communicating science to the lay person via the written word will be organized in June 2015. *Organiser: Anil Ananthaswamy: consultant, New Scientist magazine and Peter*

Aldbous (An award-winning veteran science journalist and former bureau chief, New Scientist magazine, San Francisco)

11. The BBRC Symposium on Trends in Biochemistry and Biophysics (18 May 2015). The symposium was meant to highlight the recent advances in the broad areas of protein and nucleic acid science offering first rate presentations by internationally recognized leaders in these fields. *Organisers: Wolfgang Baumeister (Germany), Ernesto Carafoli (Italy), Satyajit Mayor (NCBS), Dolors Alsina (Netherlands)*

12. Mechanical manipulations and responses at the scale of the cell and beyond (24 Apr-6 May 2015). This two week intensive program which is a joint venture of ICTS with NCBS and RRI, Bangalore was held during April 24-May 6, 2015. *Organisers: Satyajit Mayor, Darius Koestar*

13. Bodystorming workshop (Apr 25-May 2, 2015). The campus hosted a 10-day intensive workshop on bodystorming- an initiative led by Professor Carl Flink in collaboration with Professor David Odde (Department of Biomedical Engineering), both from the University of Minnesota. The program was supported by a Public Engagement Award to NCBS from the WTDBT India Alliance, among other sources *Organisers: Aparna U. Banerjee Darius Koestar*

Non-DAE Research Projects

Investigator: K VijayRaghavan
Title: J.C. Bose
Funding Agency: DST
Duration: June 2006 to July 2017

Investigator: K VijayRaghavan
Title: Collective migration in the fly nervous system
Funding Agency: IFCPAR
Duration: Apr 2012- Jan 2016
Investigator: Satyajit Mayor
Title: J.C. Bose fellowship
Funding Agency: DST
Duration: Aug 2006 to Jul 2016

Investigator: Raghu Padinjat
Title: Coordination and control of the phosphoinositide cycle during cell signaling
Funding Agency: Welcome Trust DBT
Duration: March 2015 to Feb.2020

Investigator: Satyajit Mayor
Title: Using CREB over expression to track systems consolidation of an allocated memory trace
Funding Agency: HFSP
Duration: Sept 2012 to Aug 2015

Investigator: Satyajit Mayor
Title: Mechanisms and functional consequences of compositional regulation at the local and global scale in membranes of living cells
Funding Agency: India Alliance
Duration: Mar 2016-Mar 2021

Investigator: Satyajit Mayor
Title: A Joint Centre for Cancer Biology & Therapeutics
Funding Agency: DBT
Duration: Mar 2016-Mar 2019

Investigator: Satyajit Mayor
Title: Computational knockouts and functional validation by RNAi and single site mutation analyses for select protein domains in endocytosis and signal transduction
Funding Agency: DBT
Duration: Jan 13 to July 2016

Investigator: Satyajit Mayor
Title: India Bio Science
Funding Agency: DBT
Duration: Nov 2013 to Nov 2016

Investigator: Director NCBS
Title: IndiaBioscience - Scheme Pandit Madan Mohan Malavlya National Mission on Teachers and Teaching (PMMMNTT)
Funding Agency: MHRD
Duration: Mar 2016- Mar 2017

Investigator: Jayant B Udgaonkar
Title: JC Bose fellowship
Funding Agency: DST
Duration: July 2007 to July 2017
Investigator: Jayant B Udgaonkar
Title: Understanding the mechanism of protein misfolding in neurodegenerative disease
Funding Agency: DBT
Duration: Sept 2015 to Oct 2020

Investigator: Uma Ramakrishnan
Title: Ramanujam fellowship
Funding Agency: DST
Duration: Jul 2010 to Jul 2015

Investigator: Uma Ramakrishnan
Title: Biogeography of the Indian Sub continent
Funding Agency: DAE

Duration: Jul 2012 to Jul 2017

Investigator: Uma Ramakrishnan
Title: Genetic mating system & its evolutionary consequences in a harem forming promiscuous bat cynopterus sphinx
Funding Agency: DST (SERB)
Duration: Dec 2012 to Dec 2015

Investigator: Uma Ramakrishnan
Title: Metapopulation dynamics of tigers in the malenad Mysore landscape of Karnataka
Duration: Jan 2012- Jan 2017

Investigator: Uma Ramakrishnan
Title: Chemical ecology of the North East Region (NER) of India: A collaborative programme linking NER and Bangalore researchers
Funding Agency: DST
Duration: Mar 2015-Mar 2020

Investigator: Uma Ramakrishnan
Title: Developing a protocol for SNP typing from fecal samples to monitor individual tigers and population connectivity
Funding Agency: Wild life conversation trust
Duration: Mar 2016-Dec 2016

Investigator: Sumantra Chattarji
Title: mGluR-Dependent Synaptic Plasticity: Parallels and Distinction between the Hippocampus and Amygdala and Implications for Fragile X Syndrome
Funding Agency: WT-DBT Fellowship to Debarati Mukherjee
Duration: May 2013 to May 2015

Investigator: Sumantra Chattarji

Title: Characterization and reversal of the contrasting patterns of stress-induced changes in synaptic connectivity and its molecular mediators in amygdala, hippocampus and medial prefrontal cortex

Funding Agency: DBT

Duration: Feb 2013 to Feb 2016

Investigator: Sumantra Chattarji

Title: National Mouse Research Resource (NAMOR)

Funding Agency: DBT

Duration: Sep 2013 to Mar 2018

Investigator: Vatsala Thirumalai

Title: Investigating the role of gap junctions at an identified glutamatergic synapse in a developing vertebrate

Funding Agency: DBT

Duration: May 2013 to May 2018

Investigator: Ajith Kumar

Title: Research on wildlife biology & conservation by students of masters course in NCBS

Funding Agency: DST

Duration: Jul 2012 to Dec 2015

Investigator: Gaiti Hasan

Title: A Longitudinal study of molecular and cellular changes in intracellular calcium signaling with neurological correlates in a SCAI cohort in southern India

Funding Agency: DBT

Duration: Aug 2012 to Aug 2018

Investigator: Gaiti Hasan

Title: Molecular genetics of intracellular calcium signaling in neurons with application to neurodegeneration and lipid metabolism in humans

Funding Agency: DBT

Duration: Sep 2013 to Aug 2018

Investigator: Gaiti Hasan

Title: Olfactory modulation of Insect flight

Funding Agency: CFIPRA

Duration: Apr 2014 to Apr 2017

Investigator: Sudhir Krishna

Title: Notch signaling & human cancer stem like cells: Molecular mechanisms and development of a translational initiative programme

Funding Agency: DBT

Duration: Sep 2011 to Mar 2017

Investigator: R. Sowdhamini

Title: Centre of excellence on computational & system biology

Funding Agency: DBT

Duration: Oct 2009 to July 2016

Investigator: R. Sowdhamini

Title: Phylogenetic analysis, computer modelling and Biochemical

characterisation of Protein in Phenylacetic Acid Hybrid pathway

Funding Agency: CSIR

Duration: Feb 2014 to Feb 2017

Investigator: Odity Mukherjee

Title: Innovative young biotechnologist award -2009 (IYBA)

Funding Agency: DBT

Duration: May 2009 to May 2015

Investigator: Odity Mukherjee

Title: Molecular characterisation of fronto temporal lobar degeneration and related disorders in India

Funding Agency: ICMR

Duration: Sept. 2013 to Sep. 2016

Investigator: Mahesh Sankaran and Ajith Kumar

Title: Programme support for technological innovations & ecological research for the sustainable use of bioresources in the Sikkim Himalaya

Funding Agency: DBT

Duration: May 2009 to Mar 2016

Investigator: Mahesh Sankaran

Title: Biodiversity ecosystem function stability relationship

Funding Agency: DBT

Duration: Aug 2010-Aug 2015

Investigator: Mahesh Sankaran

Title: Hydrologic and carbon services in the western ghats: Response of forests and agro ecosystems to extreme rainfall events

Funding Agency: ATREE

Duration: Jan 2012 to July 2017

Investigator: Mahesh Sankaran

Title: Linking plant functional traits to ecosystem services across tropical forest communities in the western ghats

Funding Agency: DST

Duration: Aug 2013 - Aug 2016

Investigator: Sanjay P Sane

Title: From swarm intelligence to living buildings. Novel concepts of managing internal climates

Funding Agency: HFSP,

Duration: Dec 12 to Nov 16

Investigator: Mukund Thattai

Title: Computational cell biology: Exploring the organizing principles of transcriptional regulatory networks and intracellular traffic networks

Funding Agency: WT-DBT

Duration: July 2010 to June 2016

Investigator: Mukund Thattai

Title: Simons centre for study of living machines

Funding Agency: SFMPS

Duration: Jul 2013 to Jun 2018

Investigator: M.M. Panicker

Title: programme support on targeted generation and interrogation of cellular models and networks in neuro-psychiatric disorders using candidate genes

Funding Agency: DBT

Duration: Mar 2012 to Mar 2017

Investigator: Aswin Sai Narain

Seshasayee

Title: Ramanujan Fellowship

Funding Agency: DST

Duration: Jul 2011 to June 2016

Investigator: Aswin Sai Narain

Seshasayee

Title: Exploring stationary phase genome dynamics in coli using next generation sequencing

Funding Agency: DBT

Duration: June 2013 to June 2016

Investigator: Aswin Sai Narain

Seshasayee

Title: Genomic analysis of dosage dependent silencing of horizontally-acquired genes by the nucleoid-associated protein H-NS in E.Coli,

Funding Agency: DST

Duration: May 2013 to May 2016

Investigator: Aswin Sai Narain S

Title: Genome-scale analysis of differential propensities of different chromosomal domains for horizontal gene insertion in Escherichia coli

Funding Agency: IFCPAR

Duration: April 2014 to Apr 2017

Investigator: Aswin Sai Narain S

Title: Establishing State-of-the-Art Next-Generation Sequencing Facility

Funding Agency: DBT

Duration: Mar 2013 to Feb 2018

Investigator: Raghu Padinjat

Title: The role of Phospholipase D in regulating neuronal vesicular transport

Funding Agency: DBT

Duration: Aug 2013 to Jan 2017

Investigator: Krushnamegh Kunte

Title: Ramanujan fellowship

Duration: Jan 2012 to Dec 2017

Investigator: Krushnamegh Kunte

Title: PEER-NATIONAL ACADEMY OF SCIENCE

Duration: Aug 2013 to Jul 2015

Investigator: Krushnamegh Kunte

Title: Evolution, Diversification and Biogeography of Cicadas (Insecta: Hemiptera: Cicadidae) on the Indian Subcontinent

Funding Agency: NSF

Duration: Aug 2013 to Dec 2015

Investigator: Nahren Manuel Mascarenhas

Title: Investigating the folding and domain swapping mechanisms in cystatin like folds with structure based modules
Funding Agency: DST
Duration: May 2013 to May 2016

Investigator: Imroze Khan
Title: An evolutionary ecological approach to the immunological memory and immunosenescence in invertebrates
Funding Agency: DST
Duration: Nov 2013 to Oct 2016

Investigator: Daniel Weatherill
Title: Using CREB overexpression to track systems consolidation of an allocated memory trace
Funding Agency: WT DBT
Duration: Aug 2012 to July 2017

Investigator: Marcus Taylor
Title: Examining the Nano and Meso-scale organisation of the T-Cell receptor during immunological synapse formation
Funding Agency: AXA
Duration: Dec.2012 to Sept 2017

Investigator: Debarati Mukherjee
Title: MGlur-Dependent Synaptic Plasticity : parallels and Distinctions between the Hippocampus and Amygdala and Implications for Fragile X Syndrome
Funding Agency: WT DBT
Duration: May 2013 to April 2017

Investigator: Thomas van Zanten
Title: Dissecting the role of actin in organizing plasma membrane components at the nanoscale and how it assists in self-organization upon receptor activation
Funding Agency: EMBO
Duration: June 2014 to June 2016

Investigator: Megha
Title: Early Career Award
Funding Agency: WT DBT
Duration: April 2013 to March 2017

Investigator: T.V.Ramakrishnan
Title: Year of Science Professorship
Funding Agency: DST
Duration: May 2013 to April 2018

Investigator: Padubidri Shivaprasad
Title: Ramanujan Fellowship
Duration: July 2013 to June 2018

Investigator: . Rakesh Khatri
Title: Characterisation of chronic myeloid leukemia stemcells in terms of novel biomarkers and therapeutic targets
Funding Agency: DST
Duration: Sept 2013 to July 2018

Investigator: Deepa Agashe
Title: Inspire Award
Funding Agency: DST

Duration: Nov. 2013 to Aug 2015

Investigator: Deepa Agashe
Title: The long-term evolutionary causes and consequences of biased codon use in bacteria
Funding Agency: DST
Duration: Aug 2013 to July 2018

Investigator: Mahesh sankaran
Title: carbon flux measurements in island Rainforest ecosystems
Funding Agency: UGC-UKEIRIE
Duration: July 2014 to July 2016

Investigator: Mahesh sankaran
Title: Shaping savanna landscapes: the long-term influence of large herbivores on the spatial organization of savanna ecosystems
Funding Agency: National Geographic Society
Duration: Feb 2016

Investigator: Ajith Kumar
Title: MSc programme in wildlife ,
Funding Agency: Jamshatjee Tata trust
Duration: Nov.2014 to Oct. 2019

Investigator: Aswin Seshasayee
Title: Complex combinatorial control of the balance between two bacterial lifestyles: Planctonic and biofilm under India-Japan S &T cooperation
Funding Agency: DST
Duration: Jan 2014 to Jan 2016

Investigator: Raghu Padinjat
Title: Regulation of drosophila larval growth and TOR signaling- a novel phosphoinositide kinase-
Funding Agency: DBT
Duration: Oct 2014 to Oct h2017

Investigator: Deepa Agashe
Title: Functional characterization of GUT microbial Communities and their fitness effects during dietary switches in butterflies
Funding Agency: ICGEB
Duration: Jan.2015 to Dec.2017

Investigator: Ishita Sengupta
Title: IYBA AWARD
Funding Agency: DBT
Duration: Sep.2014 to Aug.2017

Investigator: Jahnvi
Title: Adaptive radiation in papilio swallowtail butterflies of the Indo Australian region
Funding Agency: DBT
Duration: June 2014 to June 2017

Investigator: Arati Ramesh
Title: Structural Mechanisms of mRNAs-Mediated gene regulation in Bacteria
Funding Agency: Welcome Trust DBT
Duration: March 2015 to Feb.2020

Investigator: Shannon Olsson
Title: Multi modal factors that attract hoverflies for pollination
Funding Agency: Uppsala University
Duration: Feb 2015 to Feb 2017

Investigator: Varadharajan Sundaramurthy
Title: Quantitative analysis of host determinants intracellular myco bacterial infectiondbt01/01/201531/12/2020Ramalingaswami fellowship
Duration: Jan.2015 to Dec.2019

Investigator: Ranbir Das
Title: Investigating the nucleon mechanism of homologous recombination in DNA repair
Funding Agency: Ramalingaswami Fellowship
Duration: Dec.2014 to Nov.2019DBT01/12/201430/11/2019

Investigator: Upinder Singh Bhalla
Title: Computational Metric Approach to olfaction
Funding Agency: UGC
Duration: Oct. 2014 to Sep.2017

Investigator: Raghu Padinjat
Title: Coordination and control of the phosphoinositide cycle during cell signaling
Funding Agency: Welcome Trust DBT
Duration: March 2015 to Feb.2020

Investigator: Upinder Singh Bhalla
Title: Memory implications of circuit rewiring by activity-dependent long range molecular gradients
Funding Agency: DST
Duration: July 2015 to July 2018

Investigator: Deepa Agashe
Title: Evolutionary consequences of Altering tRNA gene copy number
Funding Agency: CSIR
Duration: Aug 2014 to Aug 2017

Investigator: Varadharajan Sundaramurthy
Title: Assay development for P. vivax infected hepatocytes in MTCC plates
Funding Agency: MMV
Duration: May 2015 to Dec 2016

Investigator: Aswin Seshasayee
Title: Elucidating the link between stemness and carcinogenesis - Through the lens of an oncogenic virus
Funding Agency: DBT
Duration: May 2015 to May 2019

Investigator: Reety Arora
Title: Elucidating the link between stemness and carcinogenesis - Through the lens of an oncogenic virus
Funding Agency: India Alliance
Duration: July 2015 to June 2020

Investigator: Laasya Samhita
Title: Stress-dependent evolution of new traits in bacteria through manipulation of RNA levels
Funding Agency: India Alliance
Duration: July 2015 to June 2020

Investigator: Prachi Tatte
Title: Connectivity of Jungle cat populations in the Kanha- Pench-Tadoba landscape
Funding Agency: DeFries-Bajpai Foundation
Duration: Aug 2015 to Aug 2016

Investigator: Shannon Olsson
Title: Coffee White Stem Borer: Understanding its Ecology and Ethology
Funding Agency: Central Coffee Research Institute, Chikmagalur District Coffee Research
Duration: Sep 2015 to Sept 2017

Investigator: Jayant Udgaonkar
Title: Understanding the mechanism of protein misfolding in neurodegenerative disease
Funding Agency: DBT
Duration: Sep 2015 to Sept 2020

Investigator: Vivek Ramachandran
Title: Non-volant small mammal communities of the Western Himalayas: exploring drivers of elevational richness and community composition
Funding Agency: SERB
Duration: Nov 2015 to Nov 2018

Investigator: Gnaneshwar Yadav
Title: Unravelling the role played by neuronal gap junction protein Connexin 35 (Cx35) in zebrafish
Funding Agency: SERB
Duration: Nov 2015 to Nov 2018

Investigator: Radhika Venkadesan
Title: Ramanujan Fellowship
Funding Agency: DST
Duration: Dec 2015 to Dec 2020

Investigator: Shannon Olsson
Title: Ramanujan Fellowship
Funding Agency: DST
Duration: Dec 2015 to Dec 2020

Investigator: Raghu Padinjat
Title: Accelerating the application of stem cell technology in human diseases (ASHD)
Funding Agency: DBT
Duration: Dec 2015 to Dec 2020

Investigator: Varadharajan Sundaramurthy
Title: Quantitative analysis of the modulation of host trafficking pathways by intracellular mycobacteria
Funding Agency: DST
Duration: Dec 2015 to Dec 2018

Investigator: Bhaskar B
Title: Dissecting endogenous and pathogenic mechanisms of Atx2 prion-domain
Funding Agency: SERB
Duration: Dec 2015-2018

Investigator: Satyajit Mayor
Title: philanthropic grant - DBNS support
Funding Agency: Pratiksha Trust (Kris Gopalakrishnan)
Duration: Jan 2016 to Jan 2017

Investigator: Dimple Notani
Title: Understanding the Enhancer-Code used by IFN γ in the Activation/Repression of Target Genes during Inflammation
Funding Agency: India Alliance
Duration: Mar 2016 to Mar 2021

Investigator: Hiyaa Ghosh
Title: Ramanujan Fellowship
Funding Agency: SERB
Duration: Feb 2016 to Feb 2021



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National Centre for Radio Astrophysics, Pune

Sun and Heliosphere

Interplanetary Consequences of Coronal Mass Ejection Events occurred during 18–25 June 2015:

In this paper, we review the preliminary results on the propagation effects and interplanetary consequences of fast and wide coronal mass ejection (CME) events, occurred during 18–25 June 2015, in the Sun-Earth distance range. The interplanetary scintillation (IPS) images reveal that the large-scale structures of CME-driven disturbances filled nearly the entire inner heliosphere with a range of speeds, ~ 300 – 1000 km/s. The comparison of speed data sets, from IPS

technique results in the inner heliosphere and *in-situ* measurements at 1 AU, indicates that the drag force imposed by the low-speed wind dominated heliosphere on the propagation of CMEs may not be effective (refer to Figure 1). The arrival of shocks at 1 AU suggests that a shock can be driven in the interplanetary medium by the central part of the moving CME and also by a different part away from its centre. The increased flux of proton at energies 10 MeV is consistent with the acceleration of particles by the shock ahead of the CME. [P.K. Manoharan (NCRA), D. Maia (University of Porto, Portugal), A. Jobri (NCRA), and M.S. Induja [NCRA]]

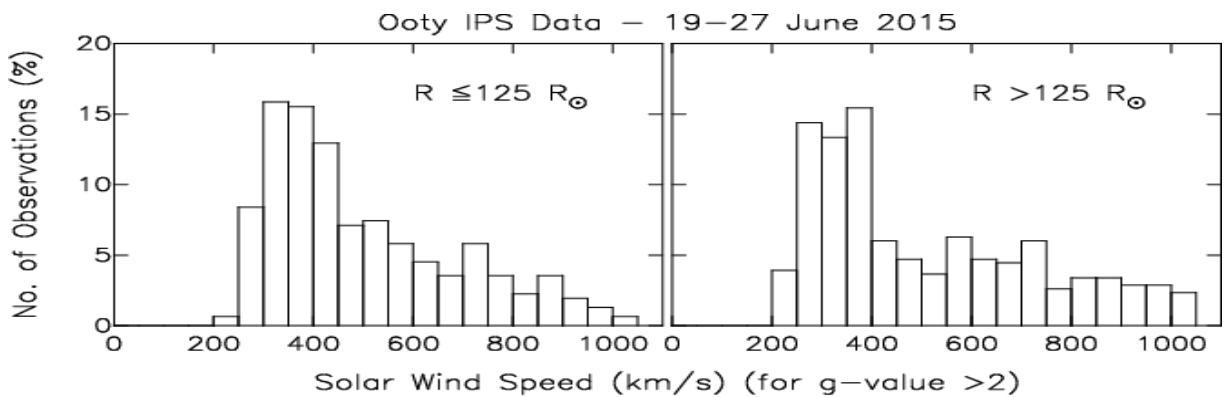


Fig 1: Histograms of solar wind speed estimates obtained from the Ooty IPS measurements at distances, respectively, $\leq 125 R_{\text{sun}}$ (left plot) and $> 125 R_{\text{sun}}$ (right plot). The y-axis marks the percentage of number of observations in each speed bin normalized by the total number of observations considered. These plots include speed data from sources for which the measured g-values are ≥ 2 and this criterion would allow only the enhanced level of scintillation caused by the propagating CME disturbances to be taken into account. It is evident in these plots that during the passage of CMEs, the interplanetary medium is filled with a range of speeds, ~ 300 – 1000 km/s. However, as seen in the above plots, the evolution of highspeed wind (i.e., > 500 km/s) between these two regions of the inner heliosphere (i.e., with respect to the midway between the Sun and Earth) is not significant

An Intense Flare–CME Event in 2015: Propagation and Interaction Effects Between the Sun and Earth’s Orbit:

We report the interplanetary effects of a fast coronal mass ejection (CME) associated with the intense X2.7 flare that occurred on 05 May 2015. The near-Sun signatures of the CME at low-coronal heights [$< 2 R_{\text{sun}}$] are obtained from the EUV images at 171 \AA and metric radio observations. The intensity and duration of the CME-driven radio bursts in the near-Sun and interplanetary medium indicate this CME event to be an energetic one. The interplanetary-scintillation data, along with the low-frequency radio spectrum, played a crucial role in understanding the radial evolution of the speed and expansion of the CME in the inner heliosphere as

well as its interaction with a preceding slow CME. Ooty IPS images are shown in Figure 2.

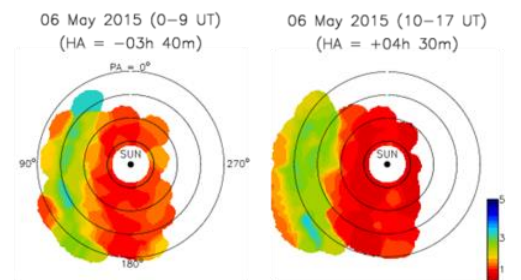


Fig 2: Interplanetary-scintillation images observed with the ORT on 06 May 2015. In these “position angle–distance” diagrams, Sun is at the centre and concentric circles are of radii 50, 100, 150, 200 R_{sun} . The colour scales show the normalised scintillation index. Time increases from the right-hand side of the image to the left-hand side of the

image. The indicated hour angle [HA] positions correspond to the ORT pointing directions. The position angles [PAs] 0° , 90° , 180° , and 270° , respectively, correspond to North, East, South, and West of the Sun. The disturbance associated with the CME has expanded considerably in the IPS field of view and the comparison between these images clearly shows the propagation of the CME in the eastern direction with respect to the Sun.

The estimation of the speed of the CME at several points along the Sun to 1 AU trajectory shows that: i) the CME went through a rapid acceleration as well as expansion up to a height of $\approx 6 R_\odot$, and ii)

the CME continued to propagate at speed ≥ 800 km/s between the Sun and 1 AU. These results show that the CME likely overcame the drag exerted by the ambient/background solar wind with the support of its internal magnetic energy. When the CME interacted with a slow, preceding CME, the turbulence level associated with the CME-driven disturbance increased significantly. [*A. Jobri and P.K. Manoharan, NCRA*]

Murchison Widefield Array Observations of Anomalous Variability

A Serendipitous Night-time Detection of Interplanetary Scintillation :

This study presents observations of high-amplitude rapid (2s) variability towards two bright, compact extragalactic radio sources out of several hundred of the brightest radio sources in one of the $30^\circ \times 30^\circ$ Murchison Widefield Array (MWA) Epoch of Reionization fields using the MWA at 155 MHz. After rejecting intrinsic, instrumental, and ionospheric origins we consider the most likely explanation for this variability to be interplanetary scintillation (IPS), likely the result of a large coronal mass ejection propagating from the Sun. This is confirmed by roughly contemporaneous observations with the Ooty Radio Telescope. We see evidence for structure on spatial scales ranging from $<10^3$ to 10^6 km. The serendipitous night-time nature of these detections illustrates the new regime that the MWA has opened for IPS studies with sensitive night-time, wide-field, low-frequency observations. This regime complements traditional dedicated strategies for observing IPS and can be utilized in real-time to facilitate dedicated follow-up observations. At the same time, it allows large-scale surveys for compact (arcsec) structures in low-frequency radio sources despite the $2'$ resolution of the array [*D.L. Kaplan (University of Wisconsin-Milwaukee), S.J. Tingay (Curtin University of Technology, Australia), P.K. Manoharan (NCRA), et al.*]

Low Frequency Radio Experiment (LORE) - A Baseline Design Study :

In this paper, we present a case study of Low Frequency Radio Experiment (LORE) payload to probe the corona and the solar disturbances at solar offsets greater than 2 solar radii, i.e., at frequencies below 30 MHz. The LORE can be complimentary to the planned Indian solar mission, "Aditya-L1" and its other payloads as well as synergistic to ground-based interplanetary scintillation (IPS) observations, which are routinely carried out by the Ooty Radio Telescope. We discuss the baseline design and technical details of the proposed LORE and its particular suitability for providing

measurements on the detailed time and frequency structure of fast drifting type-III and slow drifting type-II radio bursts with unprecedented time and frequency resolutions. We also brief the goniopolarimetry, which is possible with better-designed antennas and state-of-the-art electronics, employing FPGAs and an intelligent data management system. These would enable us to make a wide range of studies, such as nonlinear plasma processes in the Sun-Earth distance, *in-situ* radio emission from coronal mass ejections (CMEs), interplanetary CME driven shocks, nature of ICMEs driving decelerating IP shocks and space weather effects of solar wind interaction regions. [*P.K. Manoharan (NCRA), A. Naidu (NCRA), B.C. Joshi (NCRA), Jayashree Roy (NCRA), G. Kate, K. Pethe (College of Engineering, Pune), S. Galande (College of Engineering, Pune), S. Jamadar (College of Engineering, Pune), S.P. Mahajan (College of Engineering, Pune), and R.A. Patil (College of Engineering, Pune)*]

Satellite Mission Concepts Developed at the Alpbach 2013 Summer School on Space Weather

This journal volume (Space Weather and Space Climate vol. 5, 2015) was edited by P.K. Manoharan. It contains articles on four mission concepts. A brief background: Sixty young, highly qualified European science and engineering students converge annually for stimulating 10 days of work in the Austrian Alps. In the above summer school, four teams were formed, each of which designed a space mission and was then judged by a jury of experts. Students learned how to approach the design of a satellite mission and explored new and startling ideas supported by experts. The Summer School Alpbach enjoys more than 30 years of tradition in providing in-depth teaching on different topics of space science and space technology, featuring lectures and concentrated working sessions on mission studies in self-organised working groups. The Summer School is organised by the Austrian Research Promotion Agency (FFG) and co-sponsored by the European Space Agency (ESA), the International Space Science Institute (ISSI), and the national space authorities of its

member and cooperating states. [P.K. Manoharan, NCRA]

Our Galaxy

Orbital and super-orbital variability of LS I +61 303 at low radio frequencies with GMRT and LOFAR:

LS I +61 303 is a gamma-ray binary that exhibits an outburst at GHz frequencies each orbital cycle of 26.5 d and a super-orbital modulation with a period of 4.6 yr. We have performed a detailed study of the low-frequency radio emission of LS I +61 303 by analysing all the archival Giant Metrewave Radio Telescope data at 150, 235 and 610 MHz, and conducting regular LOW Frequency ARray observations at 150 MHz. We have detected the source for the first time at 150 MHz, which is also the first detection of a gamma-ray binary at such a low frequency. We have obtained the light curves of the source at 150, 235 and 610 MHz, all of them showing orbital modulation and the light curves at 235 and 610 MHz also show the existence of super-orbital variability. A comparison with contemporaneous 15-GHz data shows remarkable differences with these light curves. The light curve at 235 MHz seems to be anti-correlated with the one at 610 MHz, implying a shift of about 0.5 orbital phases in the maxima. We model the shifts between the maxima at different frequencies as due to the expansion of a one-zone emitting region assuming either free-free absorption or synchrotron

self-absorption with two different magnetic field dependencies [B. Marcote, M. Ribo, J. M. Paredes, C. H. Ishwara-Chandra and 22 authors]

Supernovae and supernovae remnants:

We have discovered a shell type TeV supernova remnant SNR G353.6-0.7 in the GMRT 325 MHz band. The SNR shows the shell structure, however the maximum radio emission site is opposite to the TeV emission site. We are further studying this source. We carried out GMRT observations of three core collapse supernovae to look for their circumstellar interaction. In none of the cases, we found significant interaction. However, one of the cases is extreme absorption case which we are following with other telescopes in multiwaveband [Poonam Chandra with A. J. Nayana (NCRA), Subhasis Roy (NCRA), Alexandre Marcorith & Matthieu Renaud (Laboratoire de Physique Theorique et Astroparticules, Universite Montpellier 2, CNRS, France), Marianne Lemoine-Goumard (Chemin du Solarium, CS 10120, 33170 GRADIGNAN CEDEX, France), Tatischeff Vincent (Centre de Spectrométrie Nucléaire et de Spectrométrie de Masse, IN2P3/CNRS and Univ Paris-Sud, 91405 Orsay, France), Sanjay Bhatnagar (NRAO, Socorro, USA)]

Stars and Pulsars

The GMRT High Resolution Southern Sky Survey [GHRSS]:

We conducted a survey for pulsars and transients using the GMRT viz., the GMRT High Resolution Southern Sky (GHRSS) survey. With 35% of the survey completed we reported the discovery of 10 pulsars, 1 of which is a millisecond pulsar (MSP), which is among the highest pulsar per square degree discovery rates for any off-Galactic plane survey. We re-detected 23 known in-beam pulsars. Utilising the imaging capability of the GMRT, we also localised four of the GHRSS pulsars (including the MSP) in the gated image plane within ± 10 arc seconds. We demonstrated rapid convergence in pulsar timing with a more precise position than is possible with single-dish discoveries. We also showed that we can localise the brightest transient sources with simultaneously obtained lower time resolution imaging data, demonstrating a technique that may have applications in the Square Kilometre Array [Bhattacharyya, B.; Cooper, S.; Malenta, M.; Roy, J.; Chengalur, J.; Keith, M.; Kudale, S.; McLaughlin, M.; Ransom, S. M.; Ray, P. S.; Stappers, B. W.]

Fermi millisecond pulsars (MSPs) :

From the timing follow-up of the Fermi millisecond pulsars (MSPs) discovered with the GMRT, we got detections of gamma-ray pulsations for three of these pulsars. Sensitive Pass 8 spectral analysis for PSR J0248+4230, J1207-5050 and J1536-4948 using the radio timing ephemerides derived from the GMRT observations, gave significant LAT detections. PSR J1536-4948 is found to be a bright LAT source allowing detailed study of radio-gamma-ray profile for probing the pulsar emission geometry [Bhaswati Bhattacharyya (University of Manchester), Jayanta Roy (University of Manchester, NCRA), Paul Ray (Naval Research Laboratory), Yashwant Gupta (NCRA), Dipankar Bhattacharya (IUCAA) and members of Fermi Pulsar Search Consortium]

Magnetism in massive stars:

We observed and analysed 36 hours of VLA data for 18 magnetic stars above 8 solar masses to look for radio emission from these. We detected four stars. Two of them are O stars and 2 of them are B

stars. Three stars seem to have non-thermal radio emission, which may arise due to magnetic field of binary interactions. We are carrying out a detailed study of these stars [Poonam Chandra with Sushma Kurapati (NCRA), Gregg Wade (RMC, Kingston, Canada), Jason Grunhut (ESO, Garching bei München), Dinya Oberoi (NCRA), Asif ud-Doula (Penn State Worthington Scranton 120 Ridge View Drive Dunmore, PA), Mary Oksala (Astronomical Institute ASCR, Czech Republic), Veronique Petit (Florida Institute of Technology, Melbourne, FL)]

Search for pulsed radio emission from SWIFT J174540.7-290015:

To probe the possible magnetar nature of the transient X-ray source SWIFT J174540.7-290015, we conducted radio observations at 1390 MHz and 327 MHz, using the GMRT and the ORT, respectively. The source was observed at the two frequencies for 2.7 and 3.5 hours respectively. SWIFT J174540.7-290015 was detected as a transient X-ray source on February 6, 2016 (ATEL #8649). We observed the source using the ORT on February 10, 2016 at 327 MHz with 4 ms sampling time and 1024 frequency channels across the 16 MHz bandwidth. Our search for any periodic or transient emission from the source in the DM range of 0--3000 pc/cc did not result in any significant detection. The 5-sigma flux density upper limits for the periodic and transient radio signals from the source at 327 MHz are 4.5 mJy and 15 Jy, respectively. For computing these limits, we have assumed 10 percent pulse duty cycle for the periodic signal, and a pulse-width of 10 ms for the transient signal. Observations at 1390 MHz were conducted on February 15, 2016, using 15 dishes of the GMRT in phased-array mode, with a time resolution of 0.12 ms and 512 channels across a bandwidth of 33 MHz. Search for any periodic or transient signals in the DM range 0--3000 pc/cc from these data also did not result in any significant detection. Using these data, we constrain the 5-sigma periodic and transient flux densities of the source at 1390 MHz to 70 μ Jy and 0.2 Jy, respectively. Our radio observations suggests a "radio quiet" magnetar with high magnetic field (Rea et al. 2012). Our observations do not rule out a transient accreting neutron star [Yogesh Maan, Mayuresh Surnis, M.A. Krishnakumar, Bhal Chandra Joshi, P K Manoharan]

Upper limits on the pulsed radio emission from SGR candidate SGR 0755-2933:

SGR J0755-2933 was discovered through a sharp, soft burst on March 16, 2016 at 22:41:24 UT by the Swift Burst Alert Telescope (BAT) instrument. While the X-ray flux has been reported to decline by a factor of 16 in subsequent Swift observations, no X-ray pulsations were detected (ATEL #8868). We

performed radio observations with the ORT at 327 MHz and the GMRT at 1390 MHz. The observations at the ORT were performed on March 17, 2016 with 8 ms sampling over a band of 16 MHz, spread over 1024 channels. The observations at the GMRT were performed on March 25, 2016, wherein, the data were recorded simultaneously in imaging and phased array mode, over a bandwidth of 33 MHz, spread over 512 channels. The GMRT PA and ORT data were searched for periodic and transient signals over a dispersion measure range of 0--2000 pc/cc. We did not detect any significant pulsation with 8-sigma upper limits on flux density of 0.89 mJy and 0.12 mJy (assuming a 10 percent duty cycle) for periodic signals at 327 and 1390 MHz, respectively. The 8-sigma upper flux density limits for any transient signal are 2.8 Jy and 220 mJy (assuming 10 ms burst duration) at 327 and 1390 MHz, respectively. The 3-sigma upper limit on the continuum flux density from the imaging data at 1390 MHz is 0.3 mJy. [Mayuresh Surnis, Yogesh Maan, Bhal Chandra Joshi, P K Manoharan]

Radio Pulsation Search and Imaging Study of SGR J1935+2154:

The Swift burst alert telescope (BAT) detected an X-ray burst of SGR J1935+2154 on July 5, 2014. The duration of the burst was \sim 0.1 s with a double peaked structure (Cummings et al. 2014). Following the trigger given by the above BAT detection, the Swift X-ray telescope (XRT) observations localized the source, which lies very close to the geometric center of the supernova remnant (SNR) G57.2+0.8. Subsequent Chandra and XMM-Newton observations revealed coherent pulsations from this source with a period of 3.2 s and confirmed its magnetar nature with a diffuse X-ray emission extending upto 1' around the magnetar, which could be a dust scattered halo or pulsar wind nebula (PWN).

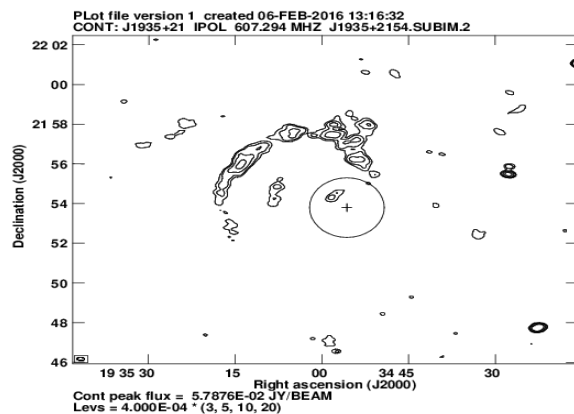


Fig 3: High resolution GMRT Image of SNR G57.2+0.8 at 610 MHz. The RMS noise in the map is 0.4 mJy. The contour levels are at 3, 5, 10, and 20 Σ . The cross indicates the position of SGR J1935+2154 with the size of the cross indicating 10 Σ position uncertainty. The solid circle represents the extent of diffuse X-ray emission reported by Israel et al. 2016

We carried out imaging observations and search for radio pulsations with the GMRT and the ORT towards the magnetar SGR J1935+2154 immediately after the burst was reported. Imaging observations, with the GMRT on July 14, 2014 at 610 MHz with 33 MHz band spread across 512 channels, resulted in the first high resolution radio image (Figure 3) of the positionally associated SNR G57.2+0.8. A pulsational search was carried out on time-series data taken with the GMRT and the ORT. We did not detect significant periodic radio pulsations from the magnetar, with 8 sigma upper limits on its flux density of 0.4, and 0.2 mJy at 326.5, and 610 MHz, respectively, for an assumed duty cycle of 10 percent. The corresponding 6 sigma upper limits at the two frequencies for any burst emission with an assumed width of 10 ms are 0.5 Jy, and 63 mJy, respectively. No continuum radio point source was detected at the position of SGR J1935+2154 with a 3 sigma upper limit of 1.2 mJy. We also did not detect significant diffuse radio emission in a radius of 70 arc seconds in coincidence with the diffuse X-ray emission reported recently, with a 3 sigma upper limit of 4.5 mJy. Using the archival HI spectra, we estimated a more reliable distance of SNR G57.2+0.8 to be 11.7(3) kpc. Based on measured HI column density along this line of sight, we argue that the magnetar could be physically associated with SNR G57.2+0.8. Based on present data, we can not rule out either a pulsar wind nebula or a dust scattering halo origin for the diffuse X-ray emission seen around the magnetar [Mayuresh. P. Surnis, Bhal Chandra Joshi, Yogesh Maan, M. A. Krishnakumar, P. K. Manoharan, Arun Naidu]

Multi-Frequency observations for measuring scatter-broadening parameters of pulsars with GMRT:

Motivated by pulse scatter-broadening measurements of 124 pulsars with the ORT two years back, we conducted low frequency follow up

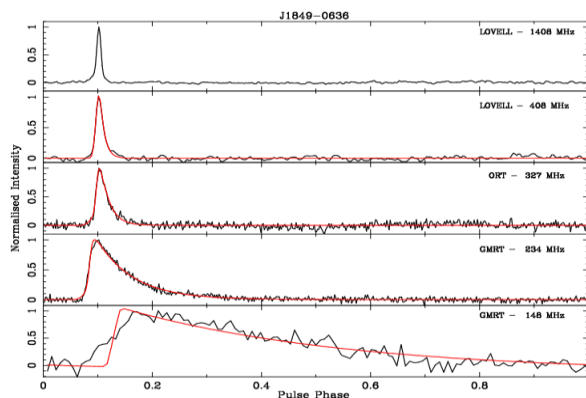


Fig 4: The plot shows the frequency evolution of pulse scatter broadening as a function of observing frequency for PSR J1849-0636. The profiles at 1420 and 408 MHz were taken from archival data

(Gould and Lyne 1998) whereas those at 327, 234 and 148 MHz were obtained from our observations. The black curves represent the observed profile and the red curves show the best fit model from which an estimate of τ_{sc} is obtained.

observations at 148, 234 and 610 MHz using the GMRT last year with a view to significantly enhance the currently known sample (about 60) of measurements of frequency scaling index α for pulsars in our ORT study. Observations of 45 pulsars were carried out using the GMRT between July 9 to August 1, 2015 with a phased array of at least 15 antennas. We used 256 spectral channels across 16 MHz bandwidth at 148 and 234 MHz and across 32 MHz at 610 MHz. Evolution of pulse scatter-broadening as a function of frequency for PSR J1849-0636, observed using the GMRT and the ORT is shown in the adjoining figure. The analysis of these data has yielded 26, 42 and 5 new measurements at 148, 234 and 610 MHz respectively. Using all available data at multiple frequencies, this has enabled us to determine 40 measurements of the frequency scaling index α , 33 of which are new, significantly increasing the sample of such measurements. Further analysis and interpretation of these measurements is in progress [M.A. Krishnakumar, B.C. Joshi and P.K. Manoharan]

A Pilot Pulsar Timing Array experiment with the ORT and the GMRT:

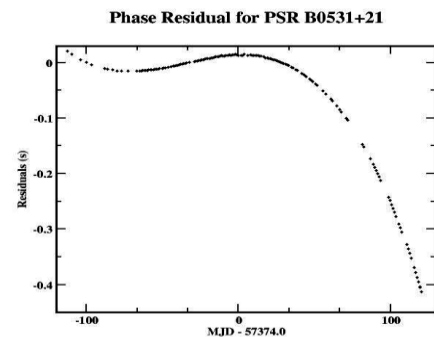


Fig 5: The plot shows the phase connected timing residuals for PSR B0531+21 using the observations with the ORT between October 2015 and March 2016. The residuals were obtained after subtracting a timing model, obtained from a fit to pulse arrival times. The timing model was calculated for December 18, 2015. The wander of the pulseperiod, called timing noise, is evident from the residuals.

Pulsar Timing arrays use an ensemble of pulsars to detect small time varying changes in the proper separation between two points in space-time caused by a passing gravitational wave, which introduces a shift in frequency of their pulsed radiation. Last year, we started an experiment utilizing simultaneous observations with the ORT at 326.5 MHz and with the GMRT at 1300 MHz of a sample of 9 millisecond pulsars, currently being monitored by International Pulsar Timing Array experiments. The main objectives of the

experiment are to build timing solutions for these pulsars, characterize the precision of pulse time of arrivals and measure variation in the dispersion measures of these pulsars, thereby contributing to the international efforts. Observations were carried out for 10 observing epochs so far using coherent dispersion to achieve pulse time of arrivals with micro-second precision and preliminary results indicate dispersion measure variations in at least two of these pulsars. These observations are continuing [Bhal Chandra Joshi, A. Gopakumar, Manjari Bagchi, P K Manoharan, M.A. Krishnakumar, Yogesh Maan, Arun Naidu]

Simultaneous Observations of Crab pulsar with the GMRT, the ORT and the ASTROSAT:

Soon after the launch of Astrosat last year, observations of Crab Pulsar (PSR B0531+21) were carried out using the GMRT at 1280 MHz, the ORT at 326.5 MHz and ASTROSAT using its CZT instrument on board. The main objective of these observations was to calibrate the relative as well as

absolute timing offset of time series data from these instruments upto 10 us precision with a view to validate capability for future radio high energy co-observations. The radio data has been used to obtain latest timing solution maintaining phase continuity over the last six months and to provide upto date ephemeris for folding high energy data, obtained with the CZT, every 15 days. Figure 5 shows a phase connected solution for the pulsar, which is known for its large timing noise. The random variation in its pulse period due to the timing noise, evident in Figure 5, makes accurate prediction of its period at an epoch for folding high energy data challenging and our 15 day ephemeris is useful for this. In addition, these data are currently being used to calibrate relative offsets between high energy and radio data. The radio data also consists of a statistical complete sample of giant pulses and work is in progress to examine its correlation with high energy emission [Sachindra Naik, A. R. Rao, Dipankar Bhattacharya, Biswajit Paul, Santosh Vadawale, Bhal Chandra Joshi]

Extra Galactic Astronomy and Cosmology

Radio-Far-infrared Correlation in “Blue Cloud” Galaxies with $0 < z < 1.2$:

We studied the radio-far-infrared (FIR) correlation in “blue cloud” galaxies chosen from the PRISM Multiobject Survey up to redshift (z) of 1.2 in the XMM-LSS field. We used rest-frame emission at 1.4 GHz in the radio and both monochromatic (at 70 μm) and bolometric (between 8 and 1000 μm) emission in the FIR. To probe the nature of the correlation up to $z \sim 1.2$, where direct detection of blue star-forming galaxies is impossible with current technology, we employ the technique of image stacking at 0.325 and 1.4 GHz in the radio and in six infrared bands, 24, 70, 160, 250, 350, and 500 μm . The stacking analysis allows us to probe the radio-FIR correlation for galaxies that are up to two orders of magnitude fainter than the ones detected directly. The k correction in the infrared wavebands is obtained by fitting the observed spectral energy distribution with a composite mid-IR power law and a single temperature graybody model. We find that the radio luminosity at 1.4 GHz is strongly correlated with monochromatic FIR luminosity at 70 μm having slope 1.09 ± 0.05 and with bolometric luminosity having slope 1.11 ± 0.04 . Within the uncertainties of our measurement and the limitations of our flux-limited and color-selected sample, we do not find any evolution of the radio-FIR correlation with redshift. [Yogesh Wadadekar with Aritra Basu (MPI/R, Germany), Alexandre Beelen (LAS,

France), Veeresh Singh (UKZN, South Africa), K. N. Archana (M. G. University); Sandeep Sirothia, C. H. Ishwara-Chandra]

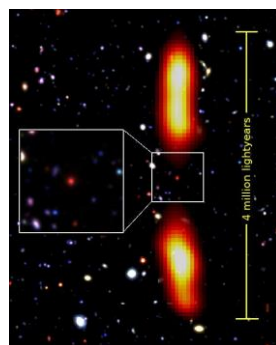


Fig 6: This is an optical image with radio lobes (in yellow-red). The supermassive black hole in the red galaxy at the centre (zoo-med in inset) has led to the formation of the giant radio lobes.

A dying, giant radio galaxy in the distant Universe:

We have discovered a relic Giant Radio Galaxy (GRG) J021659-044920 at redshift $z \sim 1.3$ that exhibits large-scale extended, nearly co-spatial, radio and X-ray emission from radio lobes, but no detection of Active Galactic Nuclei core, jets and hotspots. The total angular extent of the GRG at the observed frame 0.325 GHz, using Giant Metrewave Radio Telescope observations is found to be ~ 2.4 arcmin, that corresponds to a total

projected linear size of ~ 1.2 Mpc. The integrated radio spectrum between 0.240 and 1.4 GHz shows high spectral curvature with sharp steepening above 0.325 GHz, consistent with relic radio emission that is $\sim 8 \times 10^6$ yr old. The extended X-ray emission favours inverse-Compton scattering of the Cosmic Microwave Background (ICMB) photons as the plausible origin. Using both X-ray and radio fluxes under the assumption of ICMB we estimate the magnetic field in the lobes to be $3.3 \mu\text{G}$. The magnetic field estimate based on energy equipartition is $\sim 3.5 \mu\text{G}$. Our work presents an extremely rare example of a GRG caught in a dying phase in the distant Universe [Yogesh Wadadekar with Prathamesh Tambane (IISER-Pune), Aritra Basu (MPIfR, Germany), Veeresh Singh (UKZN, South Africa), C. H. Ishwara-Chandra, Alexandre Beelen (LAS, France), Sandeep Sirothia]

Discovery of rare double-lobe radio galaxies hosted in spiral galaxies:

Double-lobe radio galaxies in the local Universe have traditionally been found to be hosted in elliptical or lenticular galaxies. We have discovered four spiral-host double-lobe radio galaxies (J0836+0532, J1159+5820, J1352+3126, and J1649+2635) by cross-matching a large sample of ~ 187000 spiral galaxies from SDSS DR7 (Sloan Digital Sky Survey Data Release 7) to the full catalogues of FIRST (Faint Images of the Radio Sky at Twenty-cm) and NVSS (NRAO VLA Sky Survey). The host galaxies are forming stars at an average rate of 1.7-10 solar masses per year and possess supermassive black holes (SMBHs) with masses of a few times 10^8 solar masses. Their radio morphologies are similar to Fanaroff-Riley type II radio galaxies with total projected linear sizes ranging from 86 to 420 kpc. We proposed that the formation of spiral-host double-lobe radio galaxies can be attributed to more than one factor, such as the occurrence of strong interactions, mergers, and the presence of unusually massive SMBHs, such that the spiral structures are not destroyed. [Yogesh Wadadekar with Veeresh Singh (UKZN, South Africa), C. H. Ishwara-Chandra, Jonathan Sievers (UKZN), Matt Hilton (UKZN), Alexandre Beelen (LAS, France)]

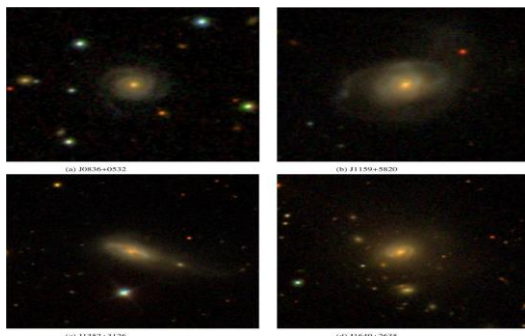


Fig 7: Optical images of the 4 newly discovered and extremely rare spiral galaxies, each of which hosts a large, double-lobed radio galaxy. From the 187,000 spiral galaxies searched, only these 4 galaxies were found to host FR-II type AGN

Cosmic reionization after Planck:

Cosmic reionization holds the key to understand structure formation in the Universe, and can inform us about the properties of the first sources. By combining the recent release of Planck electron scattering optical depth data with observations of high-redshift quasar absorption spectra, we obtained strong constraints on viable reionization histories. We show that inclusion of Planck data favours a reionization scenario with a single stellar population. The mean neutral fraction drops from 0.8 at $z = 10.6$ to 0.0001 at $z = 5.8$, which indicates a significant reduction in contributions to reionization from high-redshift sources. We were able to put independent constraints on the escape fraction of ionizing photons by incorporating the high-redshift galaxy luminosity function data into our analysis. We obtained a non-evolving escape fraction of about 0.1 at $6 < z < 9$. [Sourav Mitra (University of the Western Cape, South Africa), T. Roy Choudhury (NCRA), Andrea Ferrara (SNS, Pisa, Italy)]

Photon number conserving models of ionized bubbles during reionization:

Traditional excursion set based models of ionized bubble growth during the epoch of reionization are known to violate photon number conservation, in the sense that the mass fraction in ionized bubbles in these models does not equal the ratio of the number of ionizing photons produced by sources and the number of hydrogen atoms in the intergalactic medium. We demonstrated that this problem arises from a fundamental conceptual shortcoming of the excursion set approach which only tracks average mass fractions instead of the exact, stochastic source counts. With this insight, we built an approximately photon number conserving Monte Carlo model of bubble growth based on partitioning regions of dark matter into halos. Our model shows dramatic improvements in photon number conservation, as well as substantial differences in the bubble size distribution, as compared to traditional models. Along the way, we clarified some misconceptions regarding this problem that have appeared in the literature [Aseem Paranjape (IUCAA, Pune), T. Roy Choudhury (NCRA), Hamsa Padmanabhan (IUCAA, Pune)]

Modelling the cosmic neutral hydrogen from DLAs and 21 cm observations:

There exist different analytical prescriptions in the literature to model the 21-cm (emission line surveys/intensity mapping experiments) and Damped Lyman-Alpha (DLA) observations of neutral hydrogen (HI) in the post-reionization

universe. We attempted to reconcile the approaches towards a consistent model of the distribution and evolution of HI across redshifts. We found that a physically motivated prescription provides a good fit to the majority of the available data, but predicts a bias parameter for the DLAs which is in tension with the recent estimates from the clustering of DLA systems at $z \sim 2.3$. Our findings have significant consequences for the characteristic host halo masses of the DLAs and the power spectrum of 21-cm intensity fluctuations [Hamsa Padmanabhan (IUCAA, Pune), T. Roy Choudhury (NCRA), A. Refregier (ETH, Zurich, Switzerland)]

Cold Gas in Faint Dwarf Galaxies:

We presented the results of a study of the amount and distribution of cold atomic gas, as well its correlation with recent star formation in a sample of extremely faint dwarf irregular galaxies. Our sample was drawn from the Faint Irregular Galaxy GMRT Survey (FIGGS) and its extension, FIGGS2. We used two different methods to identify cold atomic gas. In the first method, HI spectra were decomposed into multiple Gaussian components and narrow Gaussian components were identified as cold HI. In the second method, the brightness temperature (TB) is used as a tracer of cold HI. We find that the amount of cold gas identified using the TB method is significantly larger than the amount of gas identified using Gaussian decomposition. We found that the star formation rate density has a power-law dependence on the cold HI column density, but that the slope of this power law is significantly flatter than that of the canonical Kennicutt-Schmidt relation [Patra, Narendra Nath; Chengalur, Jayaram N.; Karachentsev, Igor D.; Kaisin, Serafim S.; Begum, Ayesha]

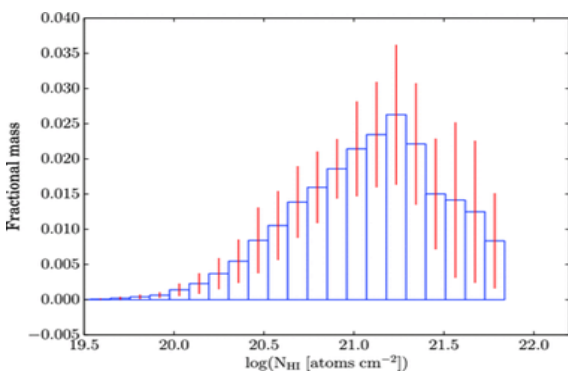


Fig 8: The fractional HI mass in the cold phase of the atomic ISM as a function of to HI column density. Above $\log(N_{\text{HI}}) \sim 21.8$ cold HI fraction drops to zero, consistent with the expected threshold column density for conversion of low metallicity ($Z \sim 0.1$) gas into the molecular phase. From Patra et al., MNRAS, 456, 2467 (2016).

The extremely gas rich Dwarf Galaxy And IV:

HST and GMRT observations are of the isolated dwarf irregular galaxy And IV allowed us to determine the galaxy distance of 7.17 ± 0.31 Mpc

using the Tip of Red Giant Branch method and show that the galaxy is extremely gas rich. The galaxy has a total blue absolute magnitude of -12.81 mag, linear Holmberg diameter of 1.88 kpc, and an HI-disk extending to 8.4 times the optical Holmberg radius. The HI mass-to-blue luminosity ratio for And IV amounts 12.9 in solar units. From the GMRT data we derived the rotation curve for the HI and fit it with different mass models. We found that the data are significantly better fit with an iso-thermal dark matter halo, than by an NFW halo. We also found that the MOND rotation curve provides a very poor fit to the data. The fact that the iso-thermal dark matter halo provides the best fit to the data supports models in which star formation feedback results in the formation of a dark matter core in dwarf galaxies. The total mass-to-blue luminosity ratio of 162 (in solar units) makes And IV among the darkest dIrr galaxies known. However, its baryonic-to-dark mass ratio is close to the average cosmic baryon fraction [Karachentsev, I. D.; Chengalur, J. N.; Tully, R. B.; Makarova, L. N.; Sharina, M. E.; Begum, A.; Rizzi, L.]

HI Emission from a low redshift sub-DLA:

We presented HI 21 cm emission observations of the $z \sim 0.00632$ subdamped Lyman- α absorber (sub-DLA) towards PG 1216+069 made using the Arecibo Telescope and the Very Large Array (VLA). The Arecibo HI 21cm spectrum corresponds to an H I mass of $\sim 3.2 M_{\odot} 10^7 M_{\text{sun}}$, two orders of magnitude smaller than that of a typical spiral galaxy. This is surprising since in the local Universe the cross-section for absorption at high H I column densities is expected to be dominated by spirals. The HI 21cm emission detected in the VLA spectral cube has a low signal-to-noise ratio, and represents only half the total flux seen at Arecibo. Emission from three other sources is detected in the VLA observations, with only one of these sources having an optical counterpart. This group of HI sources appears to be part of complex 'W', believed to lie in the background of the Virgo cluster. While several HI cloud complexes have been found in and around the Virgo cluster, it is unclear whether the ram pressure and galaxy harassment processes that are believed to be responsible for the creation of such clouds in a cluster environment are relevant at the location of this cloud complex. The extremely low metallicity of the gas, $\sim 1/40$ solar, also makes it unlikely that the sub-DLA consists of material that has been stripped from a galaxy. Thus, while our results have significantly improved our understanding of the host of this sub-DLA, the origin of the gas cloud remains a mystery [Chengalur, Jayaram N.; Ghosh, T.; Salter, C. J.; Kanekar, N.; Momjian, E.; Keeney, B. A.; Stocke, J. T.]

The spatially resolved K-S relation in atomic gas dominated regions:

We studied the Kennicutt-Schmidt (K-S) relation between average star formation rate (SFR) and average cold gas surface density in the HI-dominated ISM of nearby spiral and dwarf irregular galaxies. We divided galaxies into grid cells varying from sub-kpc to tens of kpc in size. Grid-cell measurements of low SFRs using H α emission can be biased and scatter may be introduced because of non-uniform sampling of the IMF or because of stochastically varying star formation. In order to alleviate these issues, we use far-ultraviolet emission to trace SFR, and we summed up the fluxes from different bins with the same gas surface density to calculate the average Σ_{SFR} at a given value of Σ_{gas} . We studied the resulting Kennicutt-Schmidt relation in 400 pc, 1 kpc and 10 kpc scale grids in nearby massive spirals and in 400 pc scale grids in nearby faint dwarf irregulars. We found a relation with a power-law slope of 1.5 in the HI-dominated regions for both kinds of galaxies. The relation is offset towards longer gas consumption time-scales compared to the molecular-hydrogen dominated centres of spirals, but the offset is an order of magnitude less than that quoted by earlier studies. Our results lead to the surprising conclusion that conversion of gas to stars is independent of metallicity in the HI-dominated regions of star-forming galaxies. Our observed relations are better fit by a model of star formation based on thermal and hydrostatic equilibrium in the ISM, in which stellar heating and supernova feedback set the thermal and turbulent pressure [Roychowdhury, Sambit; Huang, Mei-Ling; Kauffmann, Guinevere; Wang, Jing; Chengalur, Jayaram N.]

Merging gas rich void galaxies:

We presented a detailed study of the extremely isolated Sdm galaxy UGC 4722 (MB = -17.4) located in the nearby Lynx-Cancer void. UGC 4722 is a member of the Catalogue of Isolated Galaxies, and has also been identified as one of the most isolated galaxies in the Local Supercluster. Optical images of the galaxy however showed that it has a peculiar morphology with an elongated ~ 14 kpc-long plume. New observations with the Russian 6-m telescope (BTA) and the GMRT of the ionised and neutral gas in UGC 4722 revealed the second component responsible for the disturbed morphology of the system. This is a small, almost completely destroyed, very gas-rich dwarf. We estimated the oxygen abundance for both galaxies to be two to three times lower than what is expected from the luminosity-metallicity relation for similar galaxies in denser environments. The colours of the plume stars were found to be consistent with a simple stellar population with a post starburst age

of 0.45-0.5 Gyr. This system hence appears to be the first known case of a minor merger with a prominent tidal feature consisting of a young stellar population [Chengalur, J. N.; Pustilnik, S. A.; Makarov, D. I.; Perepelitsyna, Y. A.; Safonova, E. S.; Karachentsev, I. D.]

Deep radio surveys at 325 MHz of legacy fields with GMRT: Search for High-redshift Radio Galaxies revisited :

We have carried out deep radio survey of legacy deep fields like DEEP2, VIMOS4, VLACOSMOS and LBDS at 325 MHz with GMRT. The primary aim of these observations are to search for steep spectrum radio sources, which are strong candidates for high-redshift radio galaxies. We have catalogued about 1000 sources with flux density > 1 mJy at 325 MHz, from one of the fields. The GMRT 325 MHz sources were matched with FIRST, NVSS, SDSS and DEEP2 optical data. In this field, about 120 sources have spectral index steeper than 1 and majority remain un-identified with SDSS. The steep spectrum radio sources without optical counterparts are strong candidates for HzRGs and will be followed up in optical and IR for redshift estimates. One of the steep spectrum source, un-identified in SDSS, show clear FR II morphology in FIRST. Using FRI/FRII break luminosity, its redshift is expected to be > 2 . This deep radio data at 325 MHz will also be used to study evolution of low power radio sources, along with available deep multi-band data. (Ishwara-Chandra C.H)

J1216+0709: A Radio Galaxy with Three Episodes of AGN Jet Activity :

We report the discovery of a “triple-double radio galaxy,” J1216+0709, detected in deep low-frequency Giant Metrewave Radio Telescope (GMRT) observations. J1216+0709 is only the third radio galaxy, after B0925+420 and Spica, with three pairs of lobes resulting from three different episodes of active galactic nucleus (AGN) jet activity. The 610 MHz GMRT image clearly displays an inner pair of lobes, a nearly coaxial middle pair of lobes, and a pair of outer lobes that is bent with respect to the axis of the inner pair of lobes. The total end-to-end projected sizes of the inner, middle, and outer lobes are 40" (~ 95 kpc), 1.65 (~ 235 kpc), and 5.7 (~ 814 kpc), respectively. The host galaxy is a bright elliptical with blackhole mass of $4 \times 10^9 M_{\text{sun}}$ and a star formation rate of 4.66 M_{sun}/yr . The host galaxy resides in a small group of three galaxies and is possibly going through an interaction with faint dwarf galaxies in the neighborhood, which may have triggered the recent episodes of AGN activity [Singh, V., Ishwara-

Chandra, C. H., Kharb, Preeti, Srivastava, Shweta, Janardhan, P.]

A study of Seyfert galaxies with strong Forbidden High-Ionization Lines:

We studied the radio properties at 1.4 GHz of Seyfert galaxies with strong forbidden high-ionization lines, selected from the Sloan Digital Sky Survey - a large-sized sample containing nearly equal proportion of diverse range of Seyfert galaxies showing similar redshift distributions using the Very Large Array survey images. The radio detection rate is low, 49%, which is lower than the detection rate of several other known Seyfert galaxy samples. These galaxies show low star formation rates and the radio emission is dominated by the active nucleus with $< 10\%$ contribution from thermal emission, and possibly, none show evidence for relativistic beaming. The radio detection rate, distributions of radio power, and correlations between radio power and line luminosities or X-ray luminosity for NLS1, Seyfert 1 and Seyfert 2 galaxies are consistent with the predictions of the unified scheme hypothesis. Using correlation between radio and [O III] 5000 Angstrom luminosities, we show that $\sim 8\%$ sample sources are radio-intermediate and the remaining are radio-quiet. There is possibly an ionization stratification associated with clouds on scales of 0.1-1.0 kpc, which have large optical depths at 1.4 GHz, and it seems these clouds are responsible for free-free absorption of radio emission from the core; hence, leading to low radio detection rate for these FHIL-emitting Seyfert galaxies [Dharam V. Lal]

Atacama Large Millimeter Array (ALMA) detections of CO emission in intermediate-redshift damped Lyman-alpha absorbers:

We have used the Atacama Large Millimeter Array (ALMA) to detect CO emission from five damped Lyman-alpha systems (DLAs) at $z \sim 0.1-0.8$, the first ever detections of molecular gas in DLAs. The inferred molecular gas masses are far larger than in typical spiral galaxies, with the molecular gas mass in one of the DLAs (at $z=0.101$) more than two times larger than the upper limit on its atomic gas HI mass. We have used the CO data on the latter DLA to obtain its rotation curve, and find that the damped absorption is likely to arise from the circumgalactic medium, and not from the host galaxy itself. For another DLA, at $z=0.7156$ towards J1323-0021, we also used the Very Large Telescope to detect H-alpha and OII emission, measuring its star formation rate, and thus allowing us to infer its star formation efficiency [Kanekar N, with J. X. Prochaska (University of California, Santa Cruz, USA), M. Neeleman (University of California, Santa Cruz, USA), M. Zwaan (European Southern Observatory,

Germany), P. MOLLER (European Southern Observatory, Germany), L. Christensen (Dark Cosmology Centre, Denmark)]

ALMA detection of ionized carbon emission in high-redshift damped Lyman-alpha absorbers:

We have used ALMA to detect ionized carbon CII-158micron emission from two DLAs at $z \sim 4$, allowing us to identify the host galaxy of the two DLAs. These are the highest redshifts at which any line emission has been detected from a DLA host. They are also the first detections of CII-158micron emission from DLAs, opening a new window to probe the nature of the host galaxies. Our ALMA data also detected rest-frame 160-GHz continuum emission from the two DLAs, allowing an estimate of their star formation rates (SFRs); we obtain SFRs of 25-110 solar masses per year, far higher than typical of high- z DLAs. The CII-158micron line luminosities are also far higher than expected from the measured SFRs and the local correlation between line luminosity and SFR. Clear signatures of rotation were found in both DLAs, implying that these are massive rotating disks at high redshifts [Kanekar N, with J. X. Prochaska (University of California, Santa Cruz, USA), M. Neeleman (University of California, Santa Cruz, USA), M. Rafelski (NASA-Goddard Space Flight Center, Maryland, USA)]

The gas mass and star formation rate of DLAs, and the neutral gas content of the Universe:

We have completed a Hubble Space Telescope (HST) archival survey for low-redshift DLAs and find that the neutral gas content of the Universe at $z \sim 1$ is significantly lower than obtained from earlier, biased estimates. We also used the Arecibo telescope to carry out a search for redshifted HI-21cm emission from the HST sample of DLAs, and detected HI-21cm emission in seven systems, significantly increasing the number of systems with gas mass measurements. We obtained low atomic gas masses in all DLAs towards quasars, consistent with their low gas-phase metallicities, while one of the DLAs detected towards a bright galaxy was found to have a high atomic gas mass. Finally, we have used the Giant Metrewave Radio Telescope (GMRT) to map the HI-21cm emission from three of the DLAs detected with the Arecibo telescope, measuring the size of the DLA host galaxy and its rotation curve. We have also used the Canada-France-Hawaii Telescope (CFHT) to detect H-alpha emission from two of the DLAs detected in HI-21cm emission with the Arecibo telescope, and have used these data to determine their SFRs and hence the star formation efficiency [Kanekar N, with J. X. Prochaska (University of California, Santa Cruz, USA), M. Neeleman (University of California, Santa Cruz, USA), J. Ribando (Utica College, New York,

USA), Chengalur, Jayaram N. (NCRA-TIFR, Pune, India), W-H. Wang (Academia Sinica Institute of Astronomy and Astrophysics, Taiwan), and Tapasi Ghosh (Arecibo Observatory, USA)]

Neutral gas associated with active galactic nuclei:

We have continued a large project searching for "associated" HI-21cm absorption from a sample of compact flat spectrum radio sources at $z=0.3-3.6$ with the Giant Metrewave Radio Telescope (GMRT). The data on all sources have been analysed and HI-21cm absorption has so far been detected in five of them. We find statistically-significant evidence of redshift evolution in the HI-21cm optical depths of neutral gas associated with active galactic nuclei (AGNs) in this uniformly-selected sample, with lower detection rates of absorption as well as lower HI-21cm optical depths at high redshifts, $z>0.76$. However, the data are also consistent with an alternative hypothesis, that the decline in the strength of HI-21cm absorption at high redshifts is because the AGNs in the high- z sample have higher ultraviolet luminosities. We have also obtained the first detection of redshifted HI-21cm absorption in an AGN with a high ultraviolet luminosity, demonstrating that a literature model arguing that neutral gas cannot survive in the presence of an ultraluminous AGN is incorrect. We have also obtained the first two high- z detections of redshifted HI-21cm absorption in gigahertz-peaked-spectrum sources, at $z\sim 1.2$. [Kanekar N. with J.N.H.S. Aditya (NCRA-TIFR, Pune, India) and S. Kurapati (NCRA-TIFR, Pune, India)]

A blind millimetre-wave survey for high-redshift molecular absorption:

We have carried out a large "blind" survey for redshifted molecular absorption at redshifts $z>0.85$ towards 188 sources using the 30-50 GHz receiver of the Australia Telescope Compact Array (ATCA). When combined with our earlier Very Large Array survey, this will yield by far the largest-ever survey for redshifted molecular absorption, with a redshift path of ~ 230 , nearly ten times larger than the best earlier such survey. The ATCA data have now been analysed and we have obtained 27 candidate detections of redshifted radio molecular

absorption, which will be followed up with deeper ATCA observations to confirm these tentative detections. There is not a single known radio molecular absorber at $z>0.9$, so confirming even a few of these detections would have huge implications for studies of molecular gas and fundamental constant evolution at high redshifts [Kanekar N. with A. J. Nayana (NCRA-TIFR, Pune, India), C. L. Carilli (NRAO-Socorro, USA), and K. M.Menten (Max-Planck-Institut fur Radioastronomie, Bonn, Germany)]

Fast Radio Bursts with the GMRT:

We carried out study of four FRBs with the GMRT, which were detected with Parkes. In one of the FRB 150418, a potential afterglow has been found. The afterglow associates it with $z=0.49$ redshift galaxy. More work is being done to confirm or reject this association [Poonam Chadra with Ramesh Bhat and Shivani Bhandari and Emily Petroff (Centre for Astrophysics/ & Supercomputing Swinburne University of Technology Hawthorn, Victoria 3122, Australia), Evan Keane (Jodrell Bank Centre for Astrophysics, Alan Turing Building, Oxford Road, Manchester, M13 9PL, United Kingdom) et al.]

Prospects of detecting the 21-cm signature of the first sources with the SKA:

Several low-frequency experiments are being planned to study the nature of the first stars using the redshifted 21-cm signal from the cosmic dawn and epoch of reionization. We modelled the 21-cm signal pattern around these first sources using a one-dimensional radiative transfer simulation and worked out the detectability of these sources using a telescope like the SKA1-low. We found that, upon integrating the visibility around a typical source over all baselines and over a frequency interval of 16 MHz, it should be possible to make a 9-sigma detection of the isolated sources at redshifts around 15 with the SKA1-low in 1000 hours. The exact value of the signal to noise ratio (SNR) will depend on the source properties. The predicted SNR decreases with increasing redshift. These calculations will be useful in planning 21-cm observations to detect the first sources [Raghunath Ghara, T. Roy Choudhury (NCRA), Kanan Datta (Presidency University, Kolkata)]

Square Kilometer Array

NCRA leads Indian participation in the international SKA project :

The Square Kilometre Array (SKA) is the most ambitious international radio astronomy project attempted to date. It aims to build a telescope with 1 million square metres of collecting area, covering

a large frequency range from about 50 MHz to 10 GHz, in a radio quiet region of the globe. This will result in an instrument that is 50 times more sensitive than the best today, capable of cutting edge science in several aspects of astronomy and astrophysics. As of today, eleven of the major radio

astronomy practicing nations are collaborating in this project, which entered the design phase from November 2013 onwards, expected to last till end of 2017. Construction of the telescope will then begin in 2018, with early science expected by 2021-22. India (represented by NCRA) is now an active participant in the SKA, with NCRA having become a Full Member of the SKA Organisation in August 2014. This was transferred to a Full Membership of India, with a formal signing ceremony with the SKA Organisation, held at the Offices of the Department of Atomic Energy in Mumbai on the 5th of October 2015. The SKA India Steering Committee, a high level committee to provide guidance and monitoring of the overall SKA activities in India, was set-up in July 2015 by the Department of Atomic Energy, and had its first meeting on 7th September 2015 at TIFR, Mumbai. The SKA India Consortium (SKAIC), created in February 2015, to bring together under one umbrella all organisations in India interested in SKA activities and coordinate the SKA related activities across the country, has started functioning regularly. In addition to the main Executive Council of the SKAIC, two sub-committees have been formed by the SKAIC : one to coordinate all the science related activities and another to coordinate all the technical activities. Meanwhile, Indian involvement in the design phase activities of the SKA continued, with NCRA leading a collaboration of members from 7 different SKA member countries for the work on the design of the Telescope Manager – a sophisticated monitor & control system for the SKA, which will be like the

brain and central nervous system of the observatory. The Telescope Manager consortium has successfully completed the Preliminary Design Review phase of the work, and is now well into the Detailed Design phase that will lead to the Critical Design Review by middle of 2017. NCRA also continues to be involved to a smaller extent in the Central Signal Processing and Signal & Data Transport work packages. Many of these SKA activities are being carried out in active collaboration with partners from Indian industry. Alongwith the above, science activities related to the SKA continue to gain momentum in India. SKA India Science Working Groups, formed in March 2014, have been working on developing the science case and the potential user base within the country. Their activities include carrying out theoretical studies and modelling, as well as using the existing facilities like the GMRT to conduct research and investigations that will prepare the scientific community to make the best use of the SKA when it is ready. Many of these science working groups have been meeting regularly and working on science case documents, in addition to increasing their participation in the International Science Working Groups of the SKA [Yashwant Gupta, Y. Wadadekar, N.M. Ramannujam, T. R. Choudhury, Chengalur, Jayaram N., S.K. Ghosh, J.P. Kodilkar and B. Ajithkumar, (NCRA-TIFR) working with partners from TRDDC, TCS, PSL and NVIDIA in India, and colleagues from many other Indian institutions as well as from SKA members in South Africa, U.K., Australia, Canada, Italy and Portugal]

Instrument and Facilities

Upgrade of the GMRT Electronics Systems :

The GMRT is undergoing a major upgrade which includes broad band seamless frequency coverage from 50 to 1500 MHz with improved sensitivity and maximum instantaneous bandwidth of 400 MHz. This is accompanied by other upgrades such as a next generation monitor & control system, a modern antenna servo system, improvements to the mechanical systems of the antennas, enhancements in data storage and computing resources, alongwith matching improvements in infrastructure facilities relating to civil and electrical systems. The upgrade requires several improvements to the front-end and back-end electronics systems of the telescope, including the fibre-optic system that connects these two systems. Many of these upgrade activities have crossed important implementation milestones, leading to the first major release of the upgraded GMRT systems to the user community. Highlights of some these upgrade activities during this year are as follows :

Upgrades of the GMRT front-end and fibre-optic systems:

The main changes being carried out to the front-end systems are the design and implementation of new, broadband feeds; matching RF front-end electronics systems with improved dynamic range; and associated improvements in the support electronics. For the fibre-optic system, there is a new scheme for transfer of broadband signals from each antenna to the central receiver room, while maintaining the availability of the existing system for transfer of narrow band signals with IF carriers.

For the GMRT feeds and front-end receivers, the following has been achieved :

(a) For the 130-260 MHz band, the dual Kildal ring feed designed and installed on 4 antennas, has been found to have very good performance around 150 MHz, but needs some improvement of performance at the 235 MHz end of the band. The final version of the new front-end system has passed prototyping and is ready for mass production. It has a wireline based quadrature hybrid, a significantly improved low noise amplifier and narrowly

tuned notch filters to block interfering signals from commercial TV and wireless systems. [Bhandari Hanumanth Rao, Ramesh S, Bhalerao Vilas B, Prajapati A, Vavhal A, Sureshkumar S]

(b) For the 250-500 MHz band, the cone-dipole feed has been installed on 22 of the 30 antennas, and the remaining feeds are available for installation. This is now accompanied by the final version of the front-end system, which features an improved low noise amplifier with 20 Kelvin noise temperature, notch filters and meta-material based switched sub-band filters. [Bhandari Hanumanth Rao, Ramesh S, Raut Anil N, Temkar Vishal B, Chatterjee, S, Parikh G P, Prajapati A]

(c) For the 550-900 MHz range, the final design of feed plus low noise front-end electronics was arrived at : a cone-dipole feed with a special front-end box very close to it containing the polarizer, low noise amplifier and calibration noise injection circuitry. The system uses in house developed low cost switched sub-band filter and special notch filters for rejecting TV and Mobile signals. This is now in mass production phase, and 4 antennas have been equipped with this system [Bhandari Hanumanth Rao, Ramesh S, Bhalerao V B, Khan I, Prajapati A, Kumbhar G C, Sureshkumar S]

(d) An upgraded high dynamic range version of the common box electronics that comes after the front-end systems has been finalized and entered into mass production. It has a much better dynamic range (1 dB compression and IP3 points) and is better in handling broadband signals without saturation. [Temkar Vishal B, Kumbhar Ganesh C.]

Highlights from the Signal Transport and Fiber-Optics Systems are as follows :

The RF over fiber system using Dense Wavelength Division Multiplexing (DWDM) to bring back the wideband signals from the upgraded systems (while continuing to support the existing narrow-band IF systems) and including a 1 Gbe bi-directional ethernet link, has now been successfully installed in all the 30 antennas, and is working reliably. Furthermore, work on equipping the fiber optic system at the central electronics building with RF frontend signal monitoring and in-line optical power monitoring, reached an advanced stage and installation for 16 antennas was completed. [Sureshkumar S., Raybole Pravin, Lokhande Satish, Rai Sanjeet, Prajapati Ankur, Gopinathan M.]

Upgrades of the GMRT back-end systems :

As part of the GMRT upgrade, new back-end systems are being implemented to achieve the specifications for the upgrade like increased bandwidth of 400 MHz, direct processing of RF signals, increased dynamic range, improved channel resolution in the digital back-ends etc. A significant feature of the new system is the reduction in electronics at the remote antenna sites and shifting of most of the complex signal processing operations to the Central Electronics Building (CEB) which will reduce the down time of antennas in case of problems. Some of the main developments in this year have been as follows.

Analog Back-end System :

The complete Analog Backend system for 30 antennas has been completed and released for use, and is

functioning well. The released system has improved dynamic range, facility for variable gain, selectable signal bandwidth and individual LO signal for each antenna. Other features like power equalisation, signal monitoring and system health monitoring tools have been implemented and released during this year. All these new facilities are widely used and help in quickly setting up of the telescope for observations, as well as in quick trouble shooting of problems in the system. An RF filter bank at the input of the Analog Backend system has been developed and prototype units tested successfully with the system. When completed for all 30 antennas, this will improve the signal to noise ratio at the output of the Analog Backend system. The team is in the advanced stages of implementing a Active Hydrogen Maser based Time and Frequency standard at GMRT and RAC Ooty, which will help improve the VLBI capability to these Telescopes. [Ajithkumar B., Shinde Navnath, Gupta Shweta, Nanavare D.K., Ganla Atul, Dhende Abhijeet, Phakatkar Sudhir, Hande P.J., Vishwakarma Ajay]

Digital Back-end Systems :

A 16-antenna, dual polarization version of the GPU-based hybrid correlator and beamformer (with incoherent and coherent modes and a pulsar preprocessor) was completed, and released for user in September 2015. It has Atmel dual ADC boards for digitisation of the baseband signals, Casper FPGA boards for data packetisation & transfer to the computer nodes, which are high-end DELL machines having NVIDIA K20 GPUs, and 40 Gbit infiniband connectivity between the nodes for data transfer. This system can currently process 100/200/400 MHz bandwidth signals, with upto 16 K spectral channels, and includes support for a full Stokes mode. Currently work is in progress to develop the next version of this back-end system which will support upto 32 antennas, dual polarisation signals with 400 MHz bandwidth, 16 K frequency channels and wide range of integration times. [Reddy S. Harshvardhan, Kudale Sanjay, Shelton G.J., Halagali I.M., Bbonde I.S., Ajithkumar B., Gupta Yashwanth]

A scheme for improving the cross talk performance of the receiver, using phase modulation of the RF signal at each antenna with different Walsh Patterns and matching demodulation in the back-end system, is being developed. The scheme for demodulation in the back-end has been implemented and tested, and the prototype has been demonstrated to be working satisfactorily. The final system and implementation for all antennas, will be taken up shortly, in the next version of the back-end. [Sandeep C Chaudhari, Sweta Gupta, Ajithkumar B., Yashwant Gupta]

A scheme for digitising the signals directly at the antenna site and bringing the digital data to CEB through optical fibre links, that could have some advantages over the current analog system, is being developed for trial implementation in 5 antennas, and initial work in this direction has started. [Sandeep C. Chaudhari, Aniket Hendre, N.D. Shinde, Sweta Gupta, Ajithkumar B]

A scheme for detection and filtering of Radio Frequency Interference (RFI) signals in the digital back-ends, based

on statistical properties of the desired signal and RFI, has been developed and is in advanced stages of testing and implementation in different stages of the back-end receiver system. Schemes are being developed for both narrow band and broadband interfering signals, including for the beamformer data. [Kauschal D Buch, Kishor D. Naik, Aditya Chowdhury, Yashwant Gupta]

New Monitor & Control System for the upgraded GMRT

To control and coordinate the upgraded GMRT systems for performing astronomical observations, efforts are on to develop a next generation Monitor and Control (M&C) system. This includes modern hardware and software architectural features compared to the existing GMRT control system, including futuristic developments that could be of relevance to next generation radio telescopes such as the SKA. Some of the highlights are as follows. [Kodilkar Jitendra, Uprade Raj, Kanade Charudatta, Bhor Rahul, Misal Mahadev, Sateesh C., Rajendran B., Katore Santaji, Bhong Deepak, Sherkar Sachin, Nayak S., Kantharia Nimisha, Gupta Yashwant]

New M&C modules :

New Monitor and Control Modules (MCM) developed based on Rabbit RCM 4300 micro-controller, which had completed mass production last year, underwent significant software and firmware developments to implement control of various GMRT sub-systems at antenna base and in the Central building. Installation and testing of these MCM cards was completed for the Sentinel, Optical Fiber and FPS sub-systems at antenna base. For simultaneously updating the firmware on multiple MCM cards over the Ethernet interface, a Remote Firmware Update application has been developed and tested. To update the firmware, a web-interface is provided. The application will be used to update/maintain the firmware running on rabbit MCMs for all 30 antennas

Next Generation M&C Software System :

NCRA is actively involved in the development of a next generation M&C system applicable for large systems (including radio telescopes like the GMRT and the SKA), in collaboration with the TRDDC research laboratory and partners from software industry. As a first step of this effort, a modern M&C system software is being developed for the GMRT, which can be used as a demonstrator for SKA and can help evaluate and test various kind of prototypes required in the SKA design. The development of Phase-1 of this system was completed, wherein the basic M&C operations for 3 remotely controlled GMRT antennas were tested successfully using Ethernet interface from the new Central M&C system. The core M&C system functionality consists of sending control commands to the Servo and receiver sub-systems at antenna base, receiving monitoring data, event/alarms from the sub-systems, python based scripting environment, user-friendly GUI and automatically archiving of the M&C system data. The software architecture of the new M&C system is based on the TANGO open source software framework, and supports features like data driven configuration, scalability, and facility to evolve. The

software architecture of the new M&C system is thus more aligned with the requirements of the Telescope Manager functionality planned in SKA1, and is expected to have direct relevance and feedback into this SKA design work, that is led by India. The GMRT M&C system development work is being carried out by the GMRT Operations Group, in close collaboration with industry partners TCS Pune.

Web-based Absentee Observing and Monitoring System for the GMRT :

A new system has been developed and released to help astronomers using the GMRT for astronomical observations, and for GMRT engineers to monitor data and perform statistical tests on several parameters such as antenna pointing, temperature, wind speeds etc. This web-based system is designed so that radio astronomers can prepare their observing files before their observations, monitor antenna control data and astronomical data quality during their observations and download their data after observations. Basic statistical tools to allow a detailed study of several antenna parameters over time are also provided. The system consists of a combination of newly developed tools and existing desktop tools that have been made web-compatible, and will further facilitate absentee observing that is being supported at the GMRT since 2014. Users have begun to use this facility regularly now, and since the website (<http://gmrt.ncra.tifr.res.in/~astrosupp/>) was officially released on 15 June 2015, there have been about 8000 visitors.

Security System for High Lift Platform (HLP) :

An integrated security system for the special High Lift Platform vehicles used at the GMRT has been developed in house. It provides alarm and SMS alert facility on detection of over temperature, smoke and vehicle door lock status. Installation and testing has been completed on one HLP vehicle.

GMRT Servo system Upgrades :

The major upgrade of the GMRT servo system consists of the mass commissioning of new Brush-less DC (BLDC) motors and drives to replace the aging Permanent Magnet DC motors and mass commissioning of PC/104 based digital position loop controller to replace obsolete 8086-based controller. The mass commissioning of PC/104 based digital position loop controller was completed in all 30 antennas last year, which was a major milestone. These controller remove obsolescence and impart greater flexibility for implementing new control algorithms to improve tracking accuracy of the system. The mass commissioning of BLDC systems is also nearing completion with 25 antennas having been retrofitted with these systems. This has considerably brought down the antenna down time as the motors do not need to be serviced every 6 months as was the case earlier. Such service required a two day antenna downtime apart from the cost of service. The new system is also more reliable, which has resulted in number of intermittent problems having reduced significantly. It is expected to complete this mass commissioning in all antenna by October

2016. Another component being upgraded from last year is the feed positioning system. New backlash free gearboxes were tried both in the laboratory and the antennas and their performance was found to be repeatable. Commissioning these gearboxes on all antenna is likely to reduce the extra time required for determining the elevation offsets. As a next step, work is underway to design a new feed position controller for tryout next year. If found suitable, a mass commissioning is planned in the subsequent years [Suresh Sabbapathy, Shailendra Bagade, Amit Kumar, B. Thyagaraj, T Haokip, Samir Gadekar, Abhishek Pawar, Priyanka Desai, Sandeep Malu, and B C Joshi with BARC reactor control division]

Release of the first phase of the upgraded GMRT :

The good progress achieved in the upgrade activities described above resulted in the first phase of the upgraded GMRT (uGMRT) being released to the user community. In October 2015, a 16 antenna uGMRT system supporting wideband observations of upto 400 MHz bandwidth in 2 of the 4 uGMRT bands (Band 5 : 1000 to 1450 and Band 3 : 250-500) was released for internal use by NCRA members for early science verification experiments. This was followed by an announcement in December 2015 of a shared risk release of this system to the world-wide astronomy community, from GMRT observing cycle #30 that starts in April 2016 . This would mark the first formal release of the uGMRT, and is eagerly awaited by the global community.

Multi-frequency multi subarray observations using the upgraded-GMRT:

Recent upgrade of GMRT included a new GMRT Wideband backend (GWB), which allows observations with 400 MHz bandwidth using several combination of spectral channels. GWB also provides two beam output for time-series observations, which are useful for pulsar studies. Together with legacy GMRT Software Backend (GSB), this provides a capability for simultaneous 4 frequency pulsar observations. GWB can be used with the recently commissioned wide-band feeds (250-500 MHz and 1000-1400 MHz). These two new features of GMRT provide a unique capability to the GMRT to simultaneously observe pulsars from 150 to 1400 MHz, which would be very important for investigations into spectra of pulsars as well as a variety of propagation effects in the Inter-stellar medium, such as pulse scatter broadening and dispersion. In response to a call for proposal for a shared risk release of this backend, we put

a proposal to test and validate this multi-frequency multi subarray capability of uGMRT as well as open up GWB for wideband pulsar observations. A total of 3 observing sessions were conducted in December and January 2015, with each of the sessions utilizing 24 (out of 30) GMRT dishes divided into 4 subarrays. The 4 subarrays were used at 150 MHz (once in legacy mode with 16 or 32 MHz bandwidth, and twice with the wideband system), 300--500 MHz (i.e. the wideband system), 610 MHz (in legacy mode with 33 MHz bandwidth), and L-band (once with the 200 MHz wideband system, and twice in legacy mode with 33 MHz bandwidth). The wideband observations utilized a bandwidth of 200 MHz with 4096 channels, while the legacy system observations used 512 channels across the (typically) bandwidth of 33 MHz. We observed calibrator sources as well as a select group of pulsars to estimated values of G/T_{sys} (Figure 9). Our conclusion was that the G/T_{sys} from the calibrator source 3C273 are comparable with those from the legacy system, while they were marginally smaller for other calibrators, particularly at lower frequencies, possibly due to presence of radio frequency interference (RFI). Data from observations of 10 pulsars were analyzed to determine the typical percentage of RFI-free data one gets and these indicate that for the 300--500 MHz and 1300--1500 MHz bands, typical percentage of data contaminated by RFI is 5--10 percent. However, this fraction can reach to 30--40 percent during peak RFI times. Overall, we could validate the multi-frequency multi subarray mode of GWB and generate feedback to the observatory for improvement. Currently, the science data analysis is in progress [Yogesh Maan and Bhal Chandra Joshi]

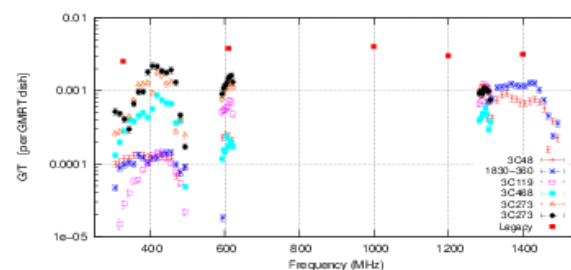


Fig 9: G/T_{sys} measurements as a function of frequency, using the sources 3C48, 3C119, 3C468.1, 1830S-3360 and 3C273 (2 measurements), along with the earlier measurements available from the GMRT website (marked as "Legacy" in the list of legends) are shown together.

Radio Physics Laboratory

Activities of Radio Physics Laboratory:

The Radio Physics Laboratory (RPL) hosted the fourth "Pulsar Observatory for students (POS)" program at Ooty Radio Telescope. The first leg of the program with lectures on pulsar astronomy was held between October 22-25, 2015, which was attended by 27 students, where they were exposed to details of pulsar astronomy (Figure 5). A new feature from this year was introduction to pulsar timing technique and its use in detection of gravitational waves. The students were also introduced to Fourier analysis and techniques to find new pulsars. The

students then came in three batches till June 2016 to conduct live pulsar observations with ORT, where the participants were introduced to pulsar data analysis. At the end of the year, RPL hosted eighth radio astronomy winter school for College and University students (RAWSC-15) between December 15 to 24, 2015. The school was attended by 32 students drawn from all over India and seems to have become an exposure summer school of choice for the undergraduate science students. In this year's program, a new component of simple physics experiments was conducted in collaboration with

IISER, Pune for two days apart from hands-on radio astronomy experiments and exposure lectures. RPL also put up a stall at the Annual Science day exposition at the GMRT and also participated in local astronomy outreach events. RPL also undertook an expansion of its facilities with procurement of laboratory equipment, antenna design software and radio astronomy receivers. A new experiment for two element interferometer was

developed and a new 5-m antenna is currently being commissioned. Facilities at ORT were also upgraded by procurement of time standards and disks for POS archive and new pulsar analysis software was installed [B. C. Joshi with Subbasis Roy, A. Gopakumar, J. Bagchi, N. Gupta K. Krishnakumar, P. K. Manoharan, A. Jesu Raja, T. R. Joshy, Ashok Kumar, D J Saikia, D Bhattacharya]

Radio Astronomy from Space

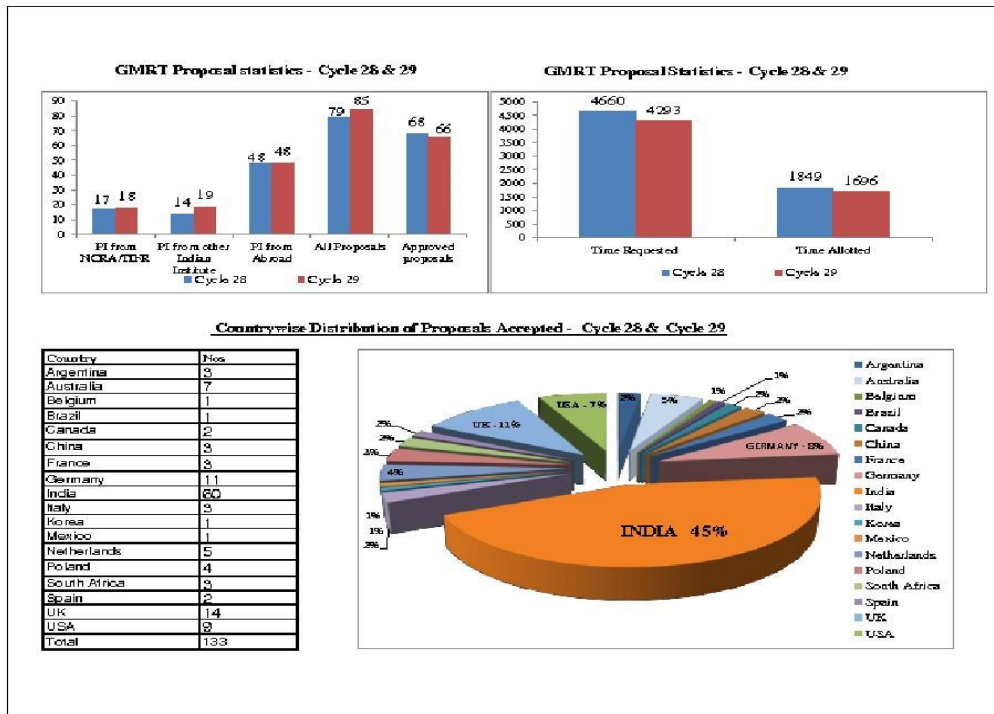
In the 12th plan, a new project to develop capability for radio astronomy from space was initiated. As part of this project, NCRA has undertaken the development of a solar radio astronomy payload called Low Frequency Radio Astronomy Experiment (LORE), which will be useful for observations of Type II and Type III bursts associated with solar energetic phenomena, such as Coronal Mass Ejections (CME) at 0 to 30 MHz, where ionosphere is opaque to radio waves necessitating space based astronomy. Last year, we developed an antenna system, consisting of three mutually orthogonal antennas after extensive simulations with antenna design software, CAD-FEKO. We also developed a preamplifier for these systems. A scaled version of these antennas at 70 MHz was validated in antenna radiation tests between Kollaripetta and Radio Astronomy Centre, Ooty last year. Implementation of signal processing in digital hardware was initiated last year and is currently in progress [Bhal

Chandra Joshi, P K Manoharan, Jayashree Roy, Gopinath Kate, Kainalya Pethe, Shridhar Galande, Sachin Jamadar S. P. Mahajan, R.A.Patil]



Fig 10: The 70 MHz monopole antenna configuration with a ground-plane, ready for experiments at the test range at the Radio Astronomy Centre, Udhagamandalam

GMRT Time Allocation Committee (GTAC)



Members

Chandra P, Chengalur J. N., Ghosh S. K., Gupta Y, Ishwara Chandra C H, Joshi B. C., Kanekar N., Kantharia N. G., Lal D.V., Mitra D., Oberoi D, Roy Choudhury T, Roy J., Roy S, Saikia D. J., Sirothia S. K., Visweshwar Ram M.R., Wadadekar Y.G.,

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National and International Involvement

Chandra, Poonam: *Member*, International Astronomical Union (IAU). **Chandra, Ishwara C. H :** *Councilor*, Executive Council, Astronomical Society of India, during 2013 to 2016; *Member* Scientific Organizing Committee and Local Organising Committee, international meeting Extragalactic Relativistic Jets: Cause and Effect, ICTS, Bangalore during October 2015. **Chengalur, Jayaram N.** *Member* National Committee of the IAU; AIRIES Scientific Advisory Committee; SKA Science Working Group; JoAA editorial board; Sectional Committee of the Indian Academy of Science. **Choudhury, T. R.:** *Member* International Science Working Group on Cosmology for the SKA; International Science Working Group on Cosmic Dawn / Epoch of Reionization for the SKA; *Chair* Science Sub-Committee of the SKA-India Consortium. **Dharam V. Lal:** *Coordinator* SKA India Continuum Survey Science Working Group; *Member* SKA Extragalactic Continuum (galaxies/AGN, galaxy clusters) Science Working Group; SKA India Consortium; *Nominated* Scientific Organising Committee of Science with uGMRT workshop. **Gupta, Y.:** *Member* Steering Board of CASPER (Collaboration for Astronomy Signal Processing and Electronics Research, based out of University of California, Berkeley); (Representing India) Board of the International Square Kilometre Array Organisation, from 2011 onwards; Governing Council of the Indian Institute of Astrophysics (IIA), Bengaluru, since January 2016.; Advisory Committee for the Shanti Swarup Bhatnagar Prize in Physical Sciences, 2015; *Science Director* from India on the SKA Board, since 2014; *Leader*, Telescope Manager Consortium -- an international collaboration for work on the design of the Telescope Manager system for the SKA, led by NCRA, October 2013 onwards; *Chair* of the TMT-India Software Work Packages Monitoring Committee overseeing the overall development of software packages in India, for the Thirty Metre Telescope International Project; March 2015 onwards. **Joshi, B.C.:** *Member* Panel on Education, COSPAR; RadioAstron International Science Committee. **Kanekar N.:** *Referee* Journals Monthly Notices of the Royal Astronomical Society, Astronomy and Astrophysics, and Astrophysical Journal, for funding proposals to the European Research Council, and for proposals for observing time on the Giant Metrewave Radio Telescope and the Shanghai-Tianma 65m telescope, *Member* Science Working Group "Time Domain, Cosmology, and Physics" for the Very Large Array – 2020, Scientific Organizing Committee for the conference SKA in Seoul – 2015, South Korea, November 2015, Co-organized the Radio Astronomy School, NCRA-TIFR, Pune, September 2015. **Manoharan P.K. :** *Vice-President* IAU Division E Commission 49 Interplanetary Plasma & Heliosphere, *Editor* Solar and Terrestrial Sciences Section of *Geosciences Letters*, official journal of the Asia Oceania Geosciences Society (AOGS). Journal of Space Weather and Space Climate, *National Coordinator*, International Space Weather Initiatives (ISWI) Programme in India, *Co-PI*, Aditya-L1 Space Solar Coronagraph Project, ISRO, India, *Membership* in International Union and Societies, *Member* Nomination committee, Axford Medal of Asia Oceania Geosciences Society (AOGS), Astronomical Society of India (ASI), Asia Oceania Geosciences Society (AOGS), International Astronomical Union (IAU), Community of European Solar Radio Astronomers (CESRA)

Visits

Chandra, Poonam: *Visited*- Bern, Switzerland, June 2015; Sweden, August 24-27, 2015; IISER Mohali, 2015 December 14-18, 2015; TIFR Mumbai, January, 2016. **Chandra, Ishwara C. H** *Visited* -University of Barcelona, Spain, October 2015; INAF-Bologna, Italy, October 2015. **Chengalur, Jayaram N.** *Visited* Seoul, South Korea, Nov 2-4, 2015, KASI, South Korea, Nov 5-6, 2015, Albuquerque, NM, USA, Dec 2-4, 2015. **Dharam, V. Lal** *Visited* Kruger National Park in South Africa, July 1-3, 2015; Wenner-Gren Center, Stockholm, Sweden, August 24 - 27, 2015; ICTS-TIFR campus, Bangalore, October 12 to 20, 2015; TIFR, Mumbai, January 20 to 23, 2016. **Gupta, Y.** *Visited* SKA Consortium Work Package Leaders meeting, Jodrell Bank, UK, April 9-10, 2015; IIST, Trivandrum, April 9-10, 2015; CSP Consortium and the Work Package Leaders group meeting, Edingburgh, UK, April 9-10, 2015; Meeting for the constitution of the Inter-Governmental Organisation for future governance of the SKA project Rome, Italy, October 14-16, 2015; Pondicherry, ,PhD viva-voce examination, October 26-27, 2015; Annual SKA Engineering Meeting, Penticton, Canada, November 8-14, 2015; University of Toronto, Canada, Canadian Institute of Theoretical Astrophysics, November 16-17, 2015; SKA Board and the SKA Strategy Committee meeting, Jodrell Bank, UK, November 18-20, 2015; Science at Low Frequencies conference, Albuquerque, USA, December 2-4, 2015; 2nd meeting for the constitution of the Inter-Governmental Organisation for future governance of the SKA project Rome, Italy; January 26-29, 2016; Bologna, Italy, colloquium, January 26-29, 2016; Telescope Manager consortium of the SKA project meeting, Capetown, South Africa to February 1-5, 2016; IIA, Bangalore, February 8-9, 2016; IIT Indore, technical discussions and delivering an invited talk, March 28-29, 2016. **Joshi, B.C.** *Visited* Aryabhatta Research Institute of Observational Sciences, Nainital, India, May 6 - 8, 2015, Radio Astron International Science Council, Max-Planck Institute for Radio Astronomy, Bonn, Germany, June 15 - 16, 2015, Workshop on Young Rotation Powered Pulsars, Tata Institute of Fundamental Research, Mumbai, India, August 13, 2015, SKA Key Science Workshop, Stockholm, Sweden, August 24 - 27, 2015, 2nd URSI Regional Conference on Radio Science, Jawaharlal Nehru University, New Delhi, India, November 16 - 19, 2015, Neutron Star Pedagogic School, NCRA, Pune, India, January 6 - 13, 2016, Neutron Star Workshop, NCRA, Pune, India, January 14 - 15, 2016. **Kanekar, N.** *Visited* Arecibo Observatory, Puerto Rico, USA.; April 2015. Columbia University, New York, USA.; April 2015. University of California, Santa Cruz, USA.; April 2015. The National Radio Astronomy Observatory, Socorro, New Mexico, USA; May 2015. The National Central University, Taiwan; June 2015. The Raman Research Institute, Bengaluru; June 2015. The Korea Astronomy and Space Science Institute, Daejeon, Korea; November 2015. Esalen Institute, Big Sur, California, USA; February 2016. University of California, Santa Cruz, USA.; February 2016. **Manoharan, P.K.** *Visited* Solar-Terrestrial Environment Lab., Nagoya University, Japan, during March, 7–12 2015. Center for Geo-Space Science Research, Faculty of Sciences, University of Porto, Portugal, during October 09–16, 2015. University of Mauritius, Mauritius, during September 25–26, 2015. **Wadadekar, Y.** *Visited* South African Astronomical Observatory, Cape Town, 4-18 July 2015.

Invited Talks

Chandra, Poonam

1. Gamma ray burst jets and their environments, Jet triggering Mechanisms, *TIFR Mumbai*, Jan 20-23, 2016
2. Evolution of explosions and their environments, NCRA Colloquium, *NCRA-TIFR, Pune*, Feb 26, 2016
3. Electromagnetic Counterparts of Gravitational Wave sources, International Conference on Gravitation and Cosmology, *IISER-Mohali*, December 14-18, 2015
4. Supernova SN 2010jl: An extraordinary evolution of the circumstellar interaction, Richard McCray Symposium, *Bern, Switzerland*, June 22-26, 2015

Chengalur, Jayaram N.

1. HI at intermediate Redshifts, SKA in Seoul Conference, *Seoul, South Korea*, Nov 2-4, 2015.
2. The Ooty Wide Field Array, Science at Low Frequencies II, *Albuquerque, NM, USA* Dec 2-4, 2015.
3. HI at intermediate and high Redshifts, Large Scale Structure Conference, *IUCAA, Pune*, Feb.1-12, 2016.

Choudhury T. Roy

1. Reionization, Saha Theory Workshop: Cosmology, Interface, *Saha Institute of Nuclear Physics, Kolkata, India*, January 2015
2. Observational Constraints on Cosmological Reionization, Advanced Workshop on Cosmological Structures from Reionization to Galaxies: Combining efforts from analytical and numerical methods, *ICTP, Trieste, Italy*, May 2015
3. Invited Review, Observational Constraints on Reionization: Do we need 21 cm experiments?, National Workshop: Cosmology with the HI 21-cm Line, *Raman Research Institute, Bangalore, India*, June 2015.
4. Probing the Universe with Cosmic Neutral Hydrogen, Advances in Astroparticle Physics and Cosmology (AAPCOS), *Saha Institute of Nuclear Physics, Kolkata, India*, October 2015

Gupta, Y.

1. Probing the Universe at Radio Wavelengths: From the GMRT to the SKA, (Colloquium) *Tata Institute of Fundamental Research, Mumbai*, September 16, 2015.
2. The upgraded GMRT : Current Status and Future Prospects, (Colloquium), *CITA, Toronto, Canada*, November 17, 2015.
3. Science at Low Frequencies (Conference), Update from the GMRT : towards the next decade, *Albuquerque, USA*, December 2, 2015.
4. Probing the Universe at Radio Wavelengths : From the GMRT to the SKA, *Tata Research Design and Development Centre, Pune*, January 18, 2016.
5. Update from India : the upgraded GMRT, (Colloquium), *INAF, Bologna, Italy*, January 29, 2016.
6. The Universe at Radio Wavelengths, (Colloquium), *IIT, Indore*, March 28, 2016.

Joshi, B.C.

1. Pulsars and their environments, Recent trends in study of compact objects (RETCO-II) Conference, *Nainital, India*, May 7, 2015
2. Radio emission from Young RPPS, Young Rotation Powered Pulsars workshop *TIFR, Mumbai, India*, August 13, 2015
3. Pulsars and their environments, Radio Pulsars - Data Analysis techniques, Neutron Star Pedagogic School, *NCRA, Pune, India*, January 8 and 13, 2016
4. Pulsars science with SKA, Neutron Star Workshop, *NCRA, Pune, India*, January 15, 2016

Kanekar, N.

1. HI in High-Redshift Galaxies, workshop on 21cm Cosmology, *Bengaluru, India*, June 2015
2. The Gas Mass of Star-forming Galaxies at $z \sim 1.3$ ", conference IMPS takes Esalen, *Esalen Institute, Big Sur, California, USA*; February 2016

Manoharan, P.K.

1. Current State of Reduced Solar Activity and Solar Wind Conditions, ST04-14-30 Session, Asia Oceania Geosciences Society (AOGS), 12th Annual Conference, *Singapore*, August 5, 2015
2. IPS Observations from Ooty Radio Telescope – Space Weather Studies", ST07-11 Session, Asia Oceania Geosciences Society (AOGS), 12th Annual Conference, *Singapore*, August 6, 2015
3. Invited presentations on
 - a. Radial evolution of coronal mass ejections in the inner heliosphere,
 - b. Ooty studies on three-dimensional evolution of solar wind during solar cycles 22–24, Coimbra Solar Physics Meeting 2015: Ground-based Solar Observations in the Space Instrumentation Era, *Coimbra, Portugal*, October 05–09, 2015.
4. Colloquium, Ooty Radio Telescope – Space Weather Studies, *University of Mauritius, Mauritius*, September 25, 2015.

Wadadekar, Y.

1. A deep low frequency galaxy survey with the GMRT, SPARCS 2015, *Kruger National Park, South Africa*, 1 July 2015
2. The radio-FIR correlation in blue-cloud galaxies with $z < 1$, *University of Western Cape, South Africa*, 15 July 2015 and
3. The radio-FIR correlation in blue-cloud galaxies with $z < 1$, *ACRU University of Kwazulu-Natal, South Africa*, 23 July 2015
4. A dying, giant radio galaxy in the distant Universe" at the NCRA Academic Day, *NCRA-TIFR, Pune, India* 2015 on 26 November 2015

Conferences Organized by the Centre

1. First "Camp for Hands-on Experience in Radio Astronomy (CHERA)" was held at RAC-NCRA-TIFR, during 1–14 July 2015. This decade has seen an unprecedented increase in the radio astronomy initiatives and related developmental activities across the world as well as in India. The CHERA was initiated to train the next generation of radio astronomers and instrumentation developers. The focus of the camp was to provide hands-on

experience with instrumentation/ observation/ measurement/analysis, thus distinct from the other initiatives that were already in place. In addition to the hands-on component, the 2-week camp introduced under-graduate and masters students to radio astronomy, basic concepts and advance topics/techniques. The first camp included 11 students (3 from IITs, 2 from IISERs, 3 from Universities, 2 from other colleges, and 1 from

IIST) plus 4 our own students and engineer trainees. The first CHERA at RAC was conducted in collaboration with the Raman Research Institute, Bangalore.

2. Organized a mini workshop at RAC, on "*Science with Upgraded ORT*" during 14–22 June 2015. In this workshop, 14 researchers/students from several institutions participated. I am happy to put in the record that the upgraded ORT has attracted more number of researchers, from different institutions within the country as well as from other countries, to make use of the ORT for challenging and advanced astrophysical research problems.

3. Fourth Workshop on *Pulsar Observatory for Students (POS)* was organized at RAC, during 22–25 October 2015. The POS workshop mainly aims to motivate undergraduate students to the methodology of pulsar astronomy in particular and radio astronomy in general. Each POS program consists of two legs: (1) a four-day workshop that introduces participants to basics of radio astronomy and pulsars (for the POS-2015, it took

place during 22–25 October 2015); and (2) second leg of the program involves four-day live ORT observations of pulsars by the participants during their various academic breaks in the year. One observing session of POS-2015 was carried for the students during 27–30 December, 2015, and the second observing session will be held during 24–27 June 2016. In the POS-2015 programme nearly 25 students participated. For the POS programme the following members provide support in the organizational matters: Dr B.C.~Joshi (NCRA, TIFR) and Dr A. Gopakumar (DAA, TIFR). We have already started to see the fruits of the past-POS programmes. For example, some of the POS-trained students have joined the graduate school programmes of the NCRA and other astrophysical institutions.

4. One-week training programme at RAC for ~50 students of the first- and second-year bachelor science/engineering studnets. This programme includes lectures on astrophysical and engineering aspects of radio astronomy and visits to RAC facilities.

Non-DAE Research Projects

P.K. Manoharan

1. *Principle Investigator*

Sun-Earth Connection and Space Weather Studies in the Three-dimensional Heliosphere, CAWSES-India Phase 2 Programme, ISRO Project (extended up to 2015).

2. *Co-Principle Investigator*

Pulsar Monitoring observations program with the upgraded Ooty Radio Telescope, DST SERB, New Delhi



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International Centre for Theoretical Sciences, Bangalore

Astrophysical Relativity

- i) Formulated a method to test General Relativity using an observed gravitational signal from a binary black hole system, and implemented this in the LIGO data analysis pipelines. [LIGO Scientific Collaboration and Virgo Collaboration]
- ii) Direct contribution to the data analysis aimed to decipher the discovery of gravitational waves by LIGO. The analysis described above was used to establish the consistency of the observed signal with a binary black hole system predicted by General Relativity. The results are reported in the LIGO discovery paper as well as a companion paper describing the tests of General Relativity performed using this event. Also contributed an analysis used to infer the mass and spin of the final black hole (merger remnant) making use of fits to numerical-relativity simulations. [LIGO Scientific Collaboration and Virgo Collaboration]

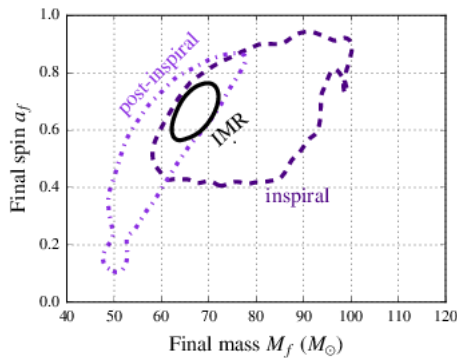


Fig: The joint posterior distributions (90% credible regions) for the mass and dimensionless spin of the final compact object as determined from the inspiral (dark violet, dashed) and post-inspiral (violet, dot-dashed) signals of the LIGO gravitational wave observation GW150914. Note that the two estimated posteriors are consistent with each other, as well as the estimate from a full inspiral-merger-ringdown analysis (black).

Complex Systems

- i) **Quantum Magnetism** :The controlled description and experimental signatures of unconventional quantum paramagnets including quantum spin liquids were studied in a variety of systems both in two and three spatial dimensions. [1. Subhro Bhattacharjee, S. Erfanifam, E.L. Green, M. Naumann, Zhaosheng Wang, S. Granovsky, M.

Doerr, J. Wosnitza, A.A. Zvyagin, R. Moessner, A. Maljuk, S. Wurmehl, B. Buchner, S. Zherlitsyn; 2. A. Banerjee, Subhro Bhattacharjee, C. A. Bridges, J.-Q. Yan, A. A. Aczel, L. Li, M. B. Stone, G. E. Granroth, M. D. Lumsden, Y. Yiu, J. Knolle, D. L. Kovrizhin, R. Moessner, D. A. Tennant, D. G. Mandrus, S. E. Nagler; 3. Subhro Bhattacharjee , G. J. Sreejith, R. Moessner; 4. Yin-Chen He, Subhro Bhattacharjee, Frank Pollmann, R. Moessner; 5. Subhro Bhattacharjee , Eoin Quinn, and Roderich Moessner]

- ii) **Topological Phases of Bosons:** Interacting bosons can stabilize a wide array of topological phases. In the two works, a symmetry protected topological phase and a long ranged quantum entangled topological phase are studied. [1. Subhro Bhattacharjee , R. Moessner, and Frank Pollmann; 2. Krishanu Roychowdhury, Subhro Bhattacharjee , and Frank Pollmann]

- iii) **Holography in condensed matter:** The applicability of recent conjectures of gauge-gravity correspondence in condensed matter systems is investigated for a system of bosons by trying to explicitly construct the bulk theory. The resultant phases– Mott insulator and superfluid are obtained in the bulk theory and their signatures in the bulk theory are characterized for a system of $U(N)$ bosons. [Peter Lunts, Subhro Bhattacharjee , Jonah Miller, Erik Schnetter, Yong Baek Kim, Sung-Sik Lee]

- iv) **Master equation descriptions of open quantum systems:** A comparison was made between two approaches of studying open quantum systems, namely the Redfield and Lindblad quantum master equation descriptions. For systems with few degrees of freedom, it was shown that the Redfield approach gives results which agree with exact analytical results for steady state properties and with exact numerics for time-dependent properties, over a wide range of parameters. In comparison, the Lindblad equations, usually derivable from Redfield after further approximations, have a limited domain of validity in non-equilibrium. We thereby concluded that it is indeed justified to use microscopically derived

Redfield equations to go beyond the limitations of Lindblad in out-of-equilibrium systems. Closed form analytical results were obtained for out-of-equilibrium time dynamics of two-point correlation functions. These results explicitly show approach to steady state and thermalization. These results are experimentally relevant for cold atoms, cavity QED and far-from-equilibrium quantum dot experiments. [Archak Purkayastha , Abhishek Dhar and Manas Kulkarni (Princeton University)]

v) **Energy current fluctuations in harmonic chains:** Recently a remarkable connection has been proposed between the fluctuating hydrodynamic equations of a one-dimensional fluid and the Kardar-Parizi-Zhang (KPZ) equation for interface growth. Earlier work used this connection to relate equilibrium correlation functions of the fluid to KPZ correlation functions. This connection has now been used to compute the exact cumulant generating function for energy current in the fluid system. This leads to exact expressions for all cumulants and in particular to universal results for certain combinations of the cumulants. As examples, two different systems, expected to be in different universality classes were considered, namely a hard particle gas with Hamiltonian dynamics and a harmonic chain with momentum conserving stochastic dynamics. Simulations provided excellent confirmation of the theory. [Abhishek Dhar and Keiji Saito (Keio University, Japan)]

vi) **Thermalization and equilibrium correlations in integrable models:** Integrable models are Hamiltonian systems which have a large number of conserved quantities. An interesting problem is to understand as to how they differ from typical (non-integrable) systems in their ability to thermalize and in the form of space-time correlation functions, which contain important information on transport properties. This problem was addressed by examining two integrable systems, the quantum transverse field Ising model and the classical Toda lattice. In the quantum case it was shown that even the integrable model shows the so-called eigenstate thermalization hypothesis (differences in details with non-integrable models were pointed out). In the classical Toda case, it was shown that space-time correlation functions have scaling forms that are completely different from the non-integrable cases. [Aritra Kundu , Abhishek Dhar , Sourav Nandy (IACS, Kolkata), Arnab Das (IACS, Kolkata), Arnab Sen (IACS, Kolkata)]

vii) **Driven inelastic Maxwell gas in one dimension:** A mechanically vibrated system of granular particles is in some ways similar to a gas of

molecules in thermal equilibrium. But they are known to exhibit very different statistical properties, for example the velocity of thermal molecules always follows a Boltzmann distribution while the granular particles do not. An open problem is to characterize the non-equilibrium steady state of driven granular systems. We examined a simple one-dimensional lattice model of a driven granular gas and obtained some exact results on the form of velocity distribution and space-time correlation functions. [Abhishek Dhar , V. V. Prasad (IMSc, Chennai), Sanjib Sabhapandit (RRI, Bangalore), Onuttom Narayan (UC Santa Cruz, US)]

viii) Patterns forming in reaction-diffusion systems have an intrinsic length-scale set by kinetic parameters. As such, they do not scale with the system size. However, many biological patterns governed by reaction-diffusion mechanisms are known to scale with the domain size. We studied how the deformation dynamics of the underlying domain couples to the transport equations for the reactant molecules, and showed that with a proper covariant coupling and in the presence of an expanded molecule (akin to the ‘dilaton’ field in gravitational physics), the resultant patterns are scale invariant for a wide class of systems. [Pallab Basu , Madan Rao (NCBS), K. Vijay Kumar], manuscript under preparation

ix) The cellular cytoskeleton is a disordered meshwork of filamentous proteins and molecular motors, and is responsible for most mechanical deformations of cells and tissues. The ATP consuming activity of molecular motors generates net contractile forces on this network at the large scale, which leads to flows that have a chiral component. The mechanisms by which a net contraction is favoured were elucidated recently and were attributed to the nonlinear elastic behavior protein filaments. We asked why a net chiral flow emerges from a disordered network, and have shown that the same asymmetry between contraction and extension that leads to contractility leads to net chiral flows in the presence of a twist-stretch coupling in the elasticity of the filaments. [Debajit Goswami , Madan Rao (NCBS), K Vijay Kumar], manuscript under preparation.

x) **NESS in locally driven single file motion:** Motion of a locally driven particle traveling in a crowded environment is ubiquitous in physics and biology. Recent experimental techniques like active microrheology, microfluidics has generated a lot of interests in determining the statistical properties of the driven particle’s motion as well as its effect on other particles. We have investigated the non-

equilibrium properties of a specific interacting particle system in one dimension where particles perform random average process. We looked at the factorization properties of the joint distribution of the gaps between successive particles on a ring in presence of a locally driven tracer. When the drive is zero, we found various universal features of joint gap distribution. On the other hand, in presence of drive we found that the NESS is characterized by long range correlation which has well defined scaling with respect to the ring size. We computed such scaling functions exactly. [J. Cividini (Weizmann Institute of Science, Israel), Anupam Kundu, S. N. Majumdar (CNRS, France), D. Mukamel (Weizmann Institute of Science, Israel)]

xi) Long range correlations in stochastic energy transport: We studied a one dimensional boundary driven stochastic model of energy transport in which the bulk dynamics conserves both total energy and momentum. Presence of both conservation laws demands ‘3- particle’ interaction in the bulk dynamics. In the infinite length limit, we found that the steady state is described locally by an equilibrium Gibbs state. However there are finite size corrections to this local equilibrium state. We analyzed these finite size corrections by calculating the on-site fluctuations of the momentum and the two point correlation of the momentum and energy. These correlations are long ranged and have proper scaling forms which we computed explicitly. We also introduced a multi-lane variant of the model in which correlations vanish in the steady state. For this variant model we calculated the deviation from local equilibrium in terms of the on-site momentum fluctuations in the large length limit. [Anupam Kundu, O. Hirschberg (Technion, Israel), D. Mukamel (Weizmann Institute of Science, Israel)]

xii) Effect of Inertia on Model Flocks in a Turbulent Environment: We studied the swarming of self-propelled, interacting microorganisms in a turbulent flow by combining ideas from the world of turbulent transport of inertial particles and the popular Vicsek model for flocking. Given the competing interactions of self-propulsion and the carrier turbulent flow, as is typical in nature, we showed that including the effect of inertia was essential for the stability of flocks. We examined this problem from the point of view of global as well as local order and the statistics of the velocity of the microorganisms as a function of the inertia, the interaction radius, the level of self-propulsion as well as noise. [Samriddhi Sankar Ray, A. Choudhary and D. Venkataraman]

xiii) Abrupt growth of large aggregates by correlated coalescences in turbulent flow: For several years Smoluchowski’s equation for the kinetics of coagulation have been shown to hold true in a variety of systems. We however showed that such an approach fails when the coalescing species are dilute and transported by a turbulent flow. Our extensive calculations clearly showed that the intermittent Lagrangian motion involves correlated violent events which lead to an unexpected rapid occurrence of the larger drops. We quantified this new phenomenon in terms of the anomalous scaling of turbulent three-point motion, leading to significant corrections in macroscopic processes that are critically sensitive to the early-stage emergence of large embryonic aggregates, as in planet formation or rain precipitation. [Samriddhi Sankar Ray, J. Bec (CNRS, France), E.W. Saw (CNRS, France), and H. Homann (CNRS, France)]

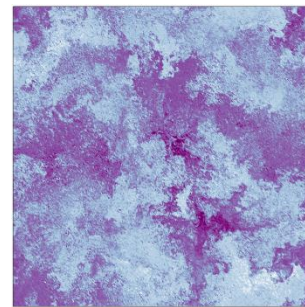


Fig: Distance traveled by fluid elements in a 3D turbulent flow during a large-eddy turnover time. Long distances (in white) and short (in purple), represented here as a function of the final position in a 2D slice, define an intricate landscape with fronts where particles coming from far apart meet together. Reference: *Abrupt growth of large aggregates by correlated coalescences in turbulent flow*, J. Bec, Samriddhi Sankar Ray, E.-W. Saw and H. Homann. *Physical Review E (Rapid)*, 93031102(R) (2016).]

xiv) Intermittency in Fractal Fourier Hydrodynamics: Lessons from the Burgers Equation: We obtained theoretical and numerical results for the one-dimensional stochastically forced Burgers equation decimated on a fractal Fourier set of dimension D . We investigated the robustness of the energy transfer mechanism 1 and of the small-scale statistical fluctuations on reducing the fractal dimension D . As a result of our theoretical and numerical studies, we were able to show that a very small percentage of mode-reduction ($D \leq 1$) was enough to destroy most of the characteristics of the original non-decimated equation. We obtained strong evidence of a suppression of intermittent fluctuations for $D < 1$ and a quasi-singular transition from the fully intermittent ($D = 1$) to the non-intermittent case for $D \leq 1$. Our calculations showed that the existence of strong localized structures (shocks) in the one-dimensional Burgers equation is the

possible result of highly entangled correlations amongst all Fourier modes. [Samriddhi Sankar Ray, M. Buzzicotti (University of Rome), L. Biferale (University of Rome), and U. Frisch (CNRS, France)]

xv) **Elastic turbulence in a shell model of polymer solution:** We showed that, at low inertia and large elasticity, shell models of viscoelastic fluids develop a chaotic behavior with properties similar to those of elastic turbulence. The low dimensionality of shell models allowed us to explore a wide range both in polymer concentration and in Weissenberg number. Our results demonstrated that the physical mechanisms at the origin of elastic turbulence do not rely on the boundary conditions or on the geometry of the mean flow. [Samriddhi Sankar Ray, D. Vincenzi (CNRS, France)]

xvi) **How Violent are the Collisions of Different Sized Droplets in a Turbulent Flow?** : We studied the typical collisional velocities in a polydisperse suspension of droplets in two and three-dimensional turbulent flow and obtained precise theoretical estimates of the dependence of the impact velocity of particles-pairs on their relative sizes. We validated our analytical results against data from our direct numerical simulations. We were able to show that the impact velocity saturates exponentially with the inverse of the particle-size ratios. Our results are important to model coalescence or fragmentation (depending on the impact velocities) and will be crucial, for example, in obtaining precise coalescence kernels to describe the growth of water droplets which trigger rain in warm clouds. [Samriddhi Sankar Ray, M. James (Goettingen)]

xvii) **Enhanced droplet collision rates in turbulent flows: The effect of poly-dispersity and transient phases:** We compared the collision rates amongst droplets of different sizes in a polydisperse suspension advected by a two-dimensional turbulent flow and showed that the collision rate is enhanced in the transient phase for droplets for which the size-ratios between the colliding pairs is large. Our results suggest that an explanation of the rapid growth of droplets, e.g., in warm clouds, may well lie in the dynamics of particles in transient phases where increased collision rates between large and small particles could result in runaway process and the sudden and accelerated growth of super large droplets. [Samriddhi Sankar Ray, M. James (Goettingen)]

Interdisciplinary Mathematics

i) The work was multi-faceted theoretical investigations of nonlinear filtering, for highly nonlinear, high dimensional, chaotic dynamical systems. This included proving convergence results in the case of observational noise going to zero. [Amit Apte, Madhuresh, S. Vadlamani (TIFR-CAM)]

ii) Proving convergence of Kalman filter covariances onto unstable subspace of the dynamics. [Amit Apte, K.S. Gurumoorthy (Amazon), C. Grudzien, A. Carrassi (NERSC), C.K.R.T. Jones (U. North Carolina), M. Bocquet (EPNC Paris)]

iii) Proving arbitrary rates of convergence for observers for compressible Navier-Stokes equations. [Amit Apte, D. Auroux (U.Nice), M. Ramaswamy (TIFR-CAM)]

iv) Ongoing investigations of hybrid filters for Lagrangian data assimilation. [Amit Apte, L.C. Slivinski (NOAA), E.T. Spiller (Marquette U.)]

v) **Scattering:** Electromagnetic and acoustic scattering from various objects is of interest in many applications. Robust numerical algorithms for simulating the scattered field is of much interest in design and optimization. We will be constructing efficient, accurate, fast numerical and algorithmic tools, which will enable us to study scattering, shape reconstruction, and metamaterial cloaking. This requires identifying the ‘correct’ well-conditioned integral equation to begin with, followed by access to high precision quadratures and fast direct solvers. We will be exploring various aspects of this over the next decade. [Sivaram Ambikasaran]

vi) **Homogenization:** Homogenization is the study of elliptic PDE of the form with rapidly oscillating coefficients. These are highly important in the context of material science and engineering applications. One of the key problems in homogenization is to manufacture materials with anisotropic properties. More specifically, a problem of relevance to material scientists & engineers is that give an isotropic material and an isotropic intrusion, how do we manufacture anisotropic material? We plan to not only study these problems but also build accurate, fast algorithms for realtime design and simulation. [Sivaram Ambikasaran]

(vii) Some of Ramanujan’s identities have as left hand side functions which are related to height

functions of minimal surfaces. The most general local solution of the minimal surface equation is given by the Weierstrass-Enneper representation of minimal surfaces. Using these representations and some of Ramanujan's identities, we were able to obtain various non-trivial identities in one-complex variable. [Rukmini Dey]

(viii) A new proof of the singular Bolding problem for maximal surfaces was given and using this certain interpolating maximal surfaces between two special type of singular curves were obtained. [Rukmini Dey , Pradip Kumar (Shiv Nadar University) and Rahul Kumar Singh (HRI, Allahabad)]

(ix) The dimension of the Hilbert space of geometric quantisation of the vortex moduli space was calculated. [Rukmini Dey and Saibal Ganguli (HRI, Allahabad)]

(x) Dimensional reduction and geometry of generalised Seiberg-Witten equations were studied and geometric prequantization of the moduli space was carried out. [Rukmini Dey and Varun Thakre (HRI, Allahabad)].

xi) **Extensions to the Unified Transform Method:** The Unified Transform Method (UTM), developed by Fokas and collaborators, can be seen as an extension of Fourier analysis to boundary-value problems. It is also the application of ideas from integrable systems, such as Lax Pairs, to linear partial differential equations and boundary value problems. There is a lot of interest in adapting UTM to newer contexts. In particular, VV has showed how UTM may be extended to handle boundary value problems for degenerate partial differential equations (PDEs). A degenerate PDE is typically given as the product of two differential operators. The results obtained extend applications of UTM to problems arising in real physical problems, particularly those related to viscous water waves. [Vishal Vasani]

xii) **Observer models for PDEs :** An observer is a dynamical system which asymptotically converges in time to the solution of another dynamical system. Observer models can be used to attack certain inverse problems. In recent work, VV showed how one can obtain the variable diffusion coefficient of a material from a solution to the diffusion equation. This work was further extended to the wave equation in heterogeneous media. In parallel work, we showed how to resolve another class of observer problems. In these cases, one typically measures the solution to a PDE over a subset of the domain with the goal of recovering

the solution everywhere. These problems were placed in the context of interface problems. [Vishal Vasani , Mythily Ramaswamy (TIFR-CAM), Amit Apte]

xiii) **Gradient descent with nonlinear constraints:** One of the oldest and simplest algorithms for smooth optimization problems is gradient descent. Recently, VV developed a method for constrained optimization that follows the original spirit of unconstrained gradient descent, i.e. simply following a vector field pointing towards the optimal point. In this set-up nonlinear constraints are modeled as a manifold. By defining a vector field that exhibits first integrals of motion which are precisely the constraints and simultaneously minimizes the cost function, we achieved a gradient flow that automatically satisfied the constraints. The construction is achieved by considering a generalization of Nambu-Poisson differential equations. We also introduced a numerical method to integrate these differential equations and thus obtained a practical algorithm for optimization. [Vishal Vasani]

String Theory and Quantum Gravity

i) **String theory, AdS/CFT:** Applying AdS/CFT in time dependent solutions, studying phases of holographic black holes. [Pallab Basu , Chethan Krishnan, P. N. Bala Subramanian (IISc, Bengaluru)]

ii) **Understanding the underlying symmetries of string theory and their consequences.** Our aim here is to uncover and study the consequences of a very large unbroken symmetry at special points in string theory. We have called this structure the Higher Spin Square (HSS). We show that the HSS has a very interesting structure that governs the matter sector of the string theory in addition to the massless sector. [R. Gopakumar , M.R. Gaberdiel (ETH, Zurich)]

iii) Developing a new approach to effectively implementing the conformal bootstrap which aims to non-perturbatively solve the dynamics of conformal field theories (CFT) that hold the clue to many strongly interacting systems in nature. We have developed a novel calculation effective approach to implementing the so-called bootstrap conditions which constrain the dynamical information of a CFT. This approach appears to be promising in developing analytic control over our understanding of CFTs and their dual string theory description. [R. Gopakumar , A. Kaviraj (IISc,

Bangalore), K. Sen (IISc, Bangalore), A. Sinha (IISc, Bangalore)]

iv) **Anomalies out of equilibrium:** Another research being done is to understand using AdS/CFT how anomalies affect behavior away from equilibrium. This work had already given a way of computing, via AdS/CFT, universal contributions to black hole entropy from gravitational Chern-Simons (gCS) terms. In order to compare this against direct calculations on Black hole side, we had to come up with a covariant prescription for computing black hole entropy in the presence of gCS terms resolving various issues in the previous literature. In a subsequent work with Tatsuo Azeyanagi and Gim Seng Ng [arXiv:1505.02816], it was shown that for a class of black holes, this prescription gives a result that exactly matches the field theory predictions from Cardy-like formulae. This work, for the first time, has opened up a way to exactly compute at least some contributions to the entropy of high temperature black holes. In another paper again with Tatsuo Azeyanagi and Gim Seng Ng [arXiv:1507.02298], this work was extended to entanglement entropy due to Chern-Simons terms. [Tatsuo Azeyanagi (CNRS, France), Gim Seng Ng (IAS, Princeton), R. Loganayagam].

v) **Fluid dynamics from Schwinger-Keldysh:** Another research, involves formulating hydrodynamics as an effective field theory controlled by symmetries. The most general non-equilibrium dynamics of a microscopic quantum field theory is described by Schwinger Keldysh path integral which evolves the most general mixed state of the field theory under question. In this formalism, all microscopic fields (and their symmetries) are doubled and specific boundary conditions are imposed on the correlators of the two copies. On the other hand, the fundamental assumption implicit in all fluid dynamics is that, in an appropriate macroscopic regime, this doubled theory can be recast into dynamics of fluid fields. In a series of papers with Felix Haehl and Mukund Rangamani [arXiv:1510.02494, arXiv:1511.07809 and ongoing work soon to appear] we have been developing a formalism which clarifies the relation between these descriptions. [Felix Haehl (University of Durham, UK), R. Loganayagam, Mukund Rangamani (University of California, David, USA)]

vi) **Information paradox in the AdS/CFT conjecture :** In earlier work, Kyriakos Papadodimas and I succeeded in phrasing the problem precisely in the setting of the AdS/CFT conjecture and proposed a resolution that relied on subtle non-

local effects in gravity and a phenomenon called ‘state-dependence’. Over the past year, I have developed these themes further. We showed, how even in the absence of black holes, degrees of freedom in gravity defy a local characterization; degrees of freedom in a local region of spacetime are not independent of degrees of freedom in other regions. [Souvik Banerjee (University of Groningen, The Netherlands), Jan-Willem Bryan (University of Groningen, The Netherlands), Kyriakos Papadodimas (University of Groningen, The Netherlands, CERN), Suvrat Raju]

vii) In separate work, by means of some concrete calculations, I was able to resolve some puzzles that had arisen in our original resolution. We also examined an interesting phenomenon related to the breakdown of string perturbation theory when one considers a limit involving the scattering of a very large number of particles which, individually, have very small energy. We believe that this will also point us to interesting non-perturbative effects in string theory. [Sudip Ghosh, Suvrat Raju]

viii) **Chern-Simons matter theory:** Recent calculations of the S-matrix of Chern-Simons theory (in the large k and large N limit) have revealed novel features arising out of the fact that the CS interaction dresses the elementary bosons/fermions to become anyons. There are several other problems where these observations can have immediate implications and in particular for ABJ theory, which is dual to a higher spin theory and type IIA string theory depending on the ratio of the ranks of the gauge group. The non-relativistic limit of ABJ theory indicates the presence of the delta function in the forward scattering, which seems to have been missed in perturbative calculations of the S-matrix in (S. Minwalla and S. R. Wadia). A complete understanding of these effects would be desirable in the QFT calculation. The extension of these results to finite N and finite k is an interesting problem, which we are pursuing. [Sachin Jain (Cornell University USA), Mangesh Mandlik (TIFR, Mumbai), Shiraz Minwalla (TIFR, Mumbai), Tomohisa Takimi (Taiwan University, Taiwan), Spenta R. Wadia, Shuichi Yokoyama]

ix) **Black hole physics:** The black hole information puzzle has been a source of considerable discussion. We are exploring a physical and concrete approach, which could shed light on this problem: to find a precise CFT/AdS map between the degrees of freedom of the deconfined finite temperature phase of a non-abelian gauge theory (which we understand) and the interior of a black hole. [Spenta R. Wadia]

ICTS Programs

Higgs bundles

Organizers: V. Balaji, I. Biswas and A. Parameswaran
Dates: 21 March-1 April, 2016
Venue: ICTS-TIFR, Bangalore

Second Bangalore School on Population Genetics and Evolution

Organizers: Deepa Agashe, Kavita Jain
Dates: 25 January-6 February, 2016;
Venue: ICTS-TIFR, Bangalore

Modern Finance and Macroeconomics: A Multidisciplinary Approach

Organizers: Vishvesha Guttal, Srikanth Iyer and Srinivas Raghavendra; Dates: 22 December-2 January, 2015; Venue: ICTS-TIFR, Bangalore

Winter School on Quantitative Systems Biology 2015

Organizers: Antonio Celani, Sanjay Jain, Sandeep Krishna, Vijaykumar Krishnamurthy, Pankaj Mehta and Matthew Scott; Dates: 5-19 December, 2015
Venue: ICTS-TIFR, Bangalore

Neighborhood Astronomy Meeting

Organizers: Parameswaran Ajith
Dates: 28 March, 2016;
Venue: ICTS-TIFR, Bangalore

Indian Statistical Physics Community Meeting 2016

Organizers: Abhishek Dhar, Kavita Jain, Rahul Pandit, Samridhi Sankar Ray and Sanjib Sabhapandit;
Dates: 12-14 February, 2016
Venue: ICTS-TIFR, Bangalore

Modern Trends in Electron Transfer Chemistry: From Molecular Electronics to Devices

Organizers: Jyotishman Dasgupta, Ravindra Venkatramani;

Algebraic Surfaces and Related Topics

Organizers: Mario Chan, Jinwon Choi, R.V. Gurjar, Dong-Seon Hwang, JongHae Keum, Sagar Kolte and Ravi Rao
Dates: 21-30 November, 2015
Venue: ICTS-TIFR, Bangalore

Non-equilibrium statistical physics

Organizers: Cedric Bernardin, Abhishek Dhar, Joel Lebowitz, Stefano Olla, Sanjib Sabhapandit, Keiji Saito and Herbert Spohn;
Dates: 26 October-20 November, 2015; Venue: ICTS-TIFR, Bangalore

Extragalactic Relativistic Jets: Cause and Effect

Organizers: C. H. Ishwara-Chandra, Ajit Kembhavi, Preeti Kharb (Convener), Dharam Vir Lal, Anthony Readhead and C. S. Stalin;
Dates: 12-20 October, 2015; Venue: ICTS-TIFR, Bangalore

Bangalore school on statistical Physics - VI

Organizers: Abhishek Dhar, Sanjib Sabhapandit
Dates: 2-18 July, 2015;
Venue: Raman Research Institute,

Bangalore

Summer School on Gravitational-Wave Astronomy

Organizers: Parameswaran Ajith, K. G. Arun and Bala Iyer;
Dates: 29 June-10 July, 2015
Venue: ICTS-TIFR, IISc campus, Bangalore

Advanced Strings School 2015

Organizers: Justin David, Chethan Krishnan and Gautam Mandal;
Dates: 11-18 June, 2015
Venue: IISc, Bangalore

GdR Dynamo 2015

Organizers: Emmanuel Dormy, Stephan Fauve, Samridhi Sankar Ray, Binod Sreenivasan and Mahendra Verma; Dates: 1-12 June, 2015
Venue: ICTS-TIFR, IISc campus, Bangalore

Mechanical manipulations and responses at the scale of the cell and beyond

Organizers: Aurnab Ghose, Darius Koester, Roop Mallik, Satyajit Mayor, Thomas Pucadyil and Pramod Pullarkat
Dates: 24 April-7 May, 2015
Venue: NCBS and Raman Research Institute, Bangalore

Discussion Meetings

Dates: 28-29 January, 2016
Venue: ICTS-TIFR, Bangalore

Information processing in biological systems

Organizers: Vijay Balasubramanian, Pallab Basu, Sandeep Krishna, Vijaykumar Krishnamurthy and Mukund Thattai
Dates: 4-7 January, 2016
Venue: ICTS-TIFR, Bangalore

New questions in quantum field theory from condensed matter theory

Organizers: Subhro Bhattacharjee, Rajesh Gopakumar, Subroto Mukerjee and Aninda Sinha
Dates: 28 December-5 Jan, 2016

Venue: ICTS-TIFR, Bangalore

AEI-ICTS joint workshop on gravitational-wave astronomy

Organizers: Parameswaran Ajith, Bala Iyer and Bruce Allen;
Dates: 4-6 November, 2015
Venue: ICTS-TIFR, Bangalore

Nonlinear Physics of Disordered Systems: From Amorphous Solids to Complex Flows

Organizers: Samridhi Sankar Ray
Dates: 6-8 April, 2015
Venue: ICTS-TIFR, IISc campus, Bangalore

Lecture Series

Chandrasekhar lectures held - 2

Title: *Random Matrix Theory and the dynamics of nonequilibrium interfaces*
 Speaker: Herbert Spohn; Date: 27 October 2015
 Venue: ICTS-TIFR, Bangalore

Title: *The Nonlinear Physics of Disordered Systems: From Amorphous Solids to Complex Flows*
 Speaker: Itamar Procaccia; Date: 6 April 2015
 Venue: ICTS-TIFR, IISc campus, Bangalore

Ramanujan lectures held - 1

Title: *Understanding non-equilibrium: some recent advances and a challenge for the future*
 Speaker: Giovanni Jona-Lasinio; Date: 3 Nov 2015
 Venue: ICTS-TIFR, Bangalore

Distinguished lectures held - 5

Special Session: *100 Years of General Relativity*
 Speakers: François Bouchet, David Gross, Juan Maldacena, Peter Saulson and Edward Witten
 Date: 26 June 2015
 Venue: Faculty Hall, IISc, Bangalore

Turing lectures held - 1

1) *More perfect than we imagined: A physicist's view of life*
 2) *Statistical mechanics for real biological networks*
 3) *Optimization principles and information flow in biological networks*
 Speaker: William Bialek
 Dates: 4-6 January 2016
 Venue: ICTS-TIFR, Bangalore

Abdus Salam lectures held - 1

Title: *Brain Brawn and Behaviour*
 Speaker: K. VijayRaghavan;
 Date: 28 December, 2015
 Venue: ICTS-TIFR, Bangalore

Einstein lectures held - 11

Title: *Undreamt by Einstein: Discovery of gravitational waves*
 Speaker: Parameswaran Ajith
 Date: 19 February 2016
 Venue: Providence Women's College, Calicut, Kerala

Title: *Gravitational-wave astronomy: A new window to the Universe*
 Speaker: Parameswaran Ajith
 Date: 18 February 2016
 Venue: Regional Science Center and Planetarium, Calicut

Title: *Einstein's General Relativity: From Insight to Inspiration*
 Speaker: Bala Iyer; Date: 3 February 2016
 Venue: Sacred Heart College, Chalakudi, Kerala

Title: *LIGO-India: Beyond Gravitational Wave Detection to Gravitational Wave Astronomy*
 Speaker: Bala Iyer; Date: 2 February 2016
 Venue: Mahatma Gandhi University, Kottayam, Kerala

Title: *General Relativity: Beyond insight and elegance to observations and astronomy*
 Speaker: Bala Iyer; Date: 2 February 2016
 Venue: Mahatma Gandhi University, Kottayam, Kerala

Title: *LIGO-India: Beyond Gravitational Wave Detection to Gravitational Wave Astronomy*

Speaker: Bala Iyer; Date: 1 February 2016
 Venue: Cochin University of Science & Technology, Cochin, Kerala

Title: *General Relativity: Beyond insight and elegance to observations and astronomy*
 Speaker: Bala Iyer; Date: 1 February 2016
 Venue: Cochin University of Science & Technology, Cochin

Title: *String Theory and the Quest for Quantum Spacetime*
 Speaker: Rajesh Gopakumar; Date: 7 January 2016
 Venue: Jain College, Bangalore

Title: *LIGO-India: Beyond Gravitational Wave Detection to Gravitational Wave Astronomy*
 Speaker: Bala Iyer; Date: 15 November 2015
 Venue: Utkal University Auditorium

Title: *Einstein's General Relativity: From Insight to Inspiration*
 Speaker: Bala Iyer; Date: 14 November 2015
 Venue: Utkal University Auditorium

Title: *Einstein's legacy, and the search for gravitational waves*
 Speaker: Bruce Allen
 Date: 6 November 2015
 Venue: Faculty Hall, Indian Institute of Science, Bangalore

Members

P. Ajith (Astrophysical Relativity); Sivaram Ambikasaran (Fast Algorithms, data assimilation) Joined IISc, Bangalore; Amit Apte (Non-linear dynamics, data assimilation); Pallab Basu (String theory); Subhro Bhattacharjee (Condensed matter physics); Rukmini Dey (Mathematical physics and Geometry); Avinash Dhar (String Theory); Abhishek Dhar (Statistical Physics); Rajesh Gopakumar (Quantum Field theory, String Theory) is Director, ICTS; Vijay Kumar Krishnamurthy (Physical Biology); Anupam Kundu (Non-equilibrium statistical physics); R. Loganayagam (String Theory, Black Hole physics, Quantum Field theory); Suvrat Raju (String theory, Quantum Gravity); Samridhhi Sankar Ray, (Turbulence); Vishal Vasana (Partial Differential Equations, Nonlinear waves and Fluid Mechanics); Spenta Wadia (String theory) is Founding Director and Professor Emeritus

Research Scholars(Supervisor)

Soumyadeep Chaudhuri (R. Loganayagam); Avijit Das (Rukmini Dey); Santhosh Ganapa (Subhro Bhattacharjee); Abhirup Ghosh (P. Ajith); Sudip Ghosh (Suvrat Raju); Chandan Jana (Samridhhi Sankar Ray); Jaswin Kasi (R. Loganayagam); Aritra Kundu (Abhishek Dhar); Ajit Kumar Mehta (P, Ajith); Animesh Nanda (Anupam Kundu); Archak Purkayastha (Abhishek Dhar); Mukesh Raghav (Samridhhi Sankar Ray); Rajeev Ranjan (R. Loganayagam); Sumith Reddy (Amit Apte); Pushkal Shrivastava (Vijay Kumar Krishnamurthy); Rahul Singh (Vishal Vasana).

Visiting Fellows

Suman Acharyya (Nonlinear dynamics, chaos and dynamical systems); Sajini Anand P S (Nonlinear Dynamical Systems, Topological methods for Data Analysis, Signal Processing, Time series analysis); Deepak Bhat (Non-equilibrium statistical

physics and biological physics); Saurish Chakrabarty (Theory of the glass transition, Systems with competing interactions and frustration); Kusum Dhochak (Condensed Matter Physics, Strongly correlated systems, Topological Phases); Archisman Ghosh (Cosmology, Gravitational-wave physics) is Max Planck Prize Postdoctoral Scholar; Debajit Goswami (Theoretical Biological Physics); Nathan Johnson-McDaniel (Gravitational Wave physics) is Airbus Prize Postdoctoral Fellow; Sumit Kumar (Gravitational Waves, Cosmology); Chandrakant Mishra (Gravitational Waves); Nachiketa Mishra (Computational Mathematics and Numerical Analysis) is Airbus Prize Postdoctoral Fellow; Arunava Mukherjee; Prithvi Narayan (AdS/CFT correspondence & supersymmetric quantum field theories); Amin Ahmad Nizami (Conformal field theories, Entanglement and Black Holes); Souvik Roy (Inverse problems in fluid flows and medical Imaging, PDE framework for stochastic process and shape optimization); Vijay Prakash S (Nonlinear waves in fluids); Sambuddha Sanyal (Condensed matter physics); Abhiram Soori; Divya V. (Fluid mechanics, non-linear dynamics and inverse problems) is Airbus Prize Postdoctoral Fellow.

Associates

Shivani Agarwal, Sayantani Bhattacharyya, Subinoy Das, Nivedita Deo, Sidhartha Goyal, Gyan Bhanot, Kedar Damle, Justin David, Abhijit Gadde, Karthik Gurumoorthy, Shravan Hanasoge, Mark Hannam, Sascha Husa, Zubin Jacob, Kavita Jain, Sanjay Jain, Dileep Jatkar, Sandeep Krishna, Badri Krishnan, Swapna Mahapatra, Biman Nath, Surjeet Rajendran, Sumathi Rao, Madan Rao, Diptiman Sen, Anirvan Sengupta, Prajval Shastri, Ravi Sheth, Aninda Sinha, Shashi Thutupalli, Nisheeth Vishnoi.

Support Staff

Mukesh Dodain, Reena Chaudhary, Raghu DS, Abhijit De, Prashanth Kumar V, Jeeva M, Divya N, Ashwini P, Basavraj Patil, Suresh R, Akshaya Kumar Sahoo, Renu Singh, Madhulika Singh, Rajlakshmi Swaminathan, Mahindra V, Jenny Burtan, Deepak R, Gayatri N, Gangadhara U, Hamsa K, Mohan G, Mohammed Irshad, Muhammed Rayees, Parvathy Ramachandran, Shantaraj SK, Meenakshi, Veena S Yashwant, Parul Sehgal, Mayank Sharma, Manasi Shinde, Amresh Kumar Singh, Srinivasa R, Naveen LC, G Hemanta Kumar, Ananya Dasgupta.

National and International Involvement

Parameswaran Ajith: Associate of the Indian Academy of Sciences; Member of LIGO Scientific Collaboration, American Physical Society, International Astronomical Union, Indian Association of General Relativity & Gravitation, IndIGO consortium, Astronomical Society of India; Referee of Physical Review Letters, Physical Review D, Classical and Quantum Gravity, International Journal of Modern Physics D, Advances in Space Research. **Subhro Bhattacharjee:** Regular referee for American Physical society journals (Physical Review Letters and Physical Review B); Co-Organizer of Discussion meeting on 'New Questions in quantum field theory from condensed matter theory', held at ICTS, Bangalore (December 28, 2015 -January 5, 2016). **Abhishek Dhar:** Member of editorial board of Journal of Statistical Physics ; Member of editorial board of Pramana; **Rajesh Gopakumar:** Member, Editorial Board, Physical Review Letters; Member, Governing Council, INSA ; Member, Board of the NBHM (DAE); Member, SERC-THEP Planning Committee; Member, Sectional Committee (Physics), IAS; Member, IUPAP Commission on Mathematical Physics (C18); Member, LOC, Strings 2015, Bangalore. Member, International Advisory Committee, String-Math, Paris (2016); Member, Local Advisory Committee, Strings 2016, Beijing; Director, Spring School on String theory, ICTP, Trieste, Italy . **R. Loganayagam:** Member, program committee of the Asian Winter School to be held on Jan 2017 in China. **Samriddhi Sankar Ray:** Referees for the journals Physical Review Letters, Physical Review E, Europhysical Journal B, Physica D, Proceedings of the Royal Society, and Nonlinearity; Referee for extra mural grant proposals of DST (India). **Spenta Wadia:** Editor, Asian Journal of Mathematics, International Press, Boston 2016; Member, Science Council of Asia Pacific Centre for Theoretical Physics (APCTP), S. Korea, 2010; Member Advisory Board, Asia Pacific Mathematics Newsletter, World Scientific, 2010; Program Advisory Committee, IAS Nanyang Technological University, Singapore 2009-Steering Committee of the Asian Winter School on Strings, Particles and Cosmology, which is held in China, Japan, Korea and India every year by rotation; Fellow, TWAS (The World Academy of Science), elected 2006; Fellow, National Academy of Sciences, Allahabad, India, elected 2000; Fellow, New York Academy of Sciences, New York, USA, elected 1997; Fellow, Indian National Science Academy, Delhi, India, elected 1997; Fellow, Indian Academy of Sciences, Bangalore, India, elected 1992

Visits

Parameswaran Ajith visited 1) Max Planck Institute for Gravitational Physics (Albert Einstein Institute), Hannover, Germany, 5-10 September 2015. **Amit Apte** visited 1) NERSC, Bergen, Norway, March 2016; 2) IIT Madras, Chennai, India, February 2016; University of Nice, September 2015; University of Exeter, UK, September 2015; XIV Latin American Workshop on Nonlinear Phenomena (LAWNP), Cartagena, Colombia, September 2015. **Sivaram Ambikasaran** visited 1) Atlanta, USA, October 26-30, 2015. **Pallab Basu** visited 1) SINP, Kolkata, 27-31 July 2015; 2) Shiv Nadar University, 4 November 2015; 3) Tata Institute of Fundamental Research, Mumbai, 18 January 2016; 4) Bangkok for String theory Workshop, 19-23 January 2016. **Subhro Bhattacharjee** visited Max Planck Institute for the Physics of Complex systems, Dresden, Germany, May-September, 2015; MIT, Cambridge, USA, August, 2015; Theory and experiments: Magnetism meeting, Abingdon, UK, July 16-17, 2015; IISc, Chennai, November 10-14, 2015; Lecturer in the SERC school on topological condensed matter, SNBNCBS, Kolkata, November 23-December 12, 2015; Lecturer in School on condensed matter Physics, IOP, Bhubaneswar, February 24 - February 27, 2016. **Rukmini Dey** visited 1) IISc, Bangalore, February, 2016. **Abhishek Dhar** visited 1) Rutgers University, May 1-15, 2015; University of Nice, France, June 8-12, 2015; LPTMS in Universite Paris, Orsay, June 13-17, 2015; Yukawa Institute of Theoretical Physics (YITP), Japan, 20 July-22 August, 2015; Banaras Hindu University, November 26-November 30, 2015; KIIP, Santa Barbara, January 11-22, 2016; IISER Pune, February 28-March 1, 2016; IOP Bhubaneswar, March 22-23, 2016. **Rajesh Gopakumar** visited 1) NTU, Taiwan, July 2015; 2) Brandeis University, USA, July 2015; 3) Harvard University, USA (AndyFest), July-August 2015; 4) Chennai Mathematical Institute, Chennai, September 2015; 5) KIAS, Seoul, Korea, September 2015; 6) NTU, Singapore, November 2015; 7) IISER, Pune, November 2015; 8) ETH, Zurich, November 2015; 9) Indo-Israeli Meeting on String theory, Goa, December 2015; 10) OIST, Okinawa, Japan, January 2015; 11) Hebrew University Jerusalem, Israel, February 2015; 12) ICTP, Trieste, Italy, March 2015. **Vijay Kumar Krishnamurthy** visited 1) MPIPKS and BIOTEC, Dresden, Germany, May 2015, 2) MPIPKS and BIOTEC, Dresden, Germany, March 2016; 3) IOP Bhubaneswar, March 2016. **Anupam Kundu** visited 1)

IIT Gandhinagar, 27-30 May, 2015; SNBNCBS, Kolkata, 28th March - 1st April, 2016. **R. Loganayagam** visited 1) TIFR Centre For Applicable Mathematics, Bengaluru; 2) Indian Institute for Science Education and Research (IISER), Pune; 3) Tata Institute of Fundamental Research, Mumbai; 4) University of California Davis, USA; 5) Massachusetts Institute of Technology, Cambridge, USA; 6) Brandeis University, USA; 7) Chennai Mathematical Institute (CMI), Chennai; 8) The Institute of Mathematical Sciences (IMSc.), Chennai; 9) Laboratoire de Physique Thorique Ecole Normale Supérieure (LPTENS), Paris, France; 10) Universiteit van Amsterdam (UvA), Amsterdam, The Netherlands. **Suvrat Raju** visited 1) Harvard University, USA; 2) Brown University, USA; 3) Columbia University, USA; 4) Cornell University, USA; 5) Perimeter Institute for Theoretical Physics, USA; 6) Kavli Institute for Theoretical Physics, Santa Barbara, USA; 7) Tata Institute of Fundamental Research, Mumbai; 8) National Tsing Hua University, Taiwan; 9) University of Amsterdam, The Netherlands; 10) Birla Institute of Technology and Science, Pilani. **Samridhi Sankar Ray** visited 1) IIT, Chennai, India, 1- 5 February 2016; 2) IISER, Pune, India, 2- 4 January 2016; 3) JNCASR, Bangalore, India, 24-28 October 2015; 4) Delft, The Netherlands, 25-28 August 2015; 5) University of Rome Tor Vergata, Rome, France, May 2015; 6) Observatoire de la Côte d'Azur, CNRS, Nice, France, May 2015. **Vishal Vasan** visited 1) Seattle, USA, January 4-18, 2016; 2) State College, USA, January 20-31, 2016; 3) Santiniketan, West Bengal, India, February 19-21, 2016. **Spenta Wadia** visited 1) Yeosu, S. Korea 20-23 December 2015; 2) Hebrew University, Jerusalem, Israel, February 28-March 3, 2016.

Invited Talks

Parameswaran Ajith

1) *Title:* Testing General Relativity using golden black-hole binaries

Occasion: Astro-GR 2015 workshop

Venue: ICTP South American Institute for Fundamental Research, Sao Paulo, Brazil; *Date:* 14 August 2015

2) *Title:* Towards gravitational-wave astronomy

Occasion: XXVII IUPAP Conference on Computational Physics

Venue: IIT Guwahati, India; *Date:* 4 December 2015

3) *Title:* Towards gravitational-wave astronomy

Occasion: 8th International Conference on Gravitation and Cosmology

Venue: IISER Mohali, India; *Date:* 14 December 2015

4) *Title:* LIGO Observation of Gravitational Waves from a Binary Black Hole Merger

Occasion: RRI Colloquium

Venue: Raman Research Institute, Bangalore, India

Date: 25 February 2016

Amit Apte

1) *Title:* A simplified model for monsoon dynamics

Occasion: XIV Latin American Workshop on Nonlinear Phenomena (LAWNP)

Venue: Cartagena, Colombia; *Date:* September 2015

2) *Title:* Rank deficiency of Kalman filter and assimilation in unstable subspace

Occasion: Conference 'Dynamics days'

Venue: University of Exeter, UK

Date: September 2015

3) *Title:* A simplified model for monsoon dynamics

Occasion: Conference on 'Complex system approach to self-organization'

Venue: IIT Madras, Chennai, India,

Date: February 2016

4) *Title:* A tale of two data assimilation methods

Occasion: Discussion meeting 'Mathematics of sea-ice and data assimilation'

Venue: NERSC, Bergen, Norway;

Date: March 2016

Pallab Basu

1) *Title:* Holographic instability

Occasion: Invited seminar

Venue: Saha Institute of Nuclear Physics, Kolkata, India

Date: July 27, 2015

2) *Title:* Holographic instability

Occasion: Invited seminar

Venue: Shiv Nadar University, India

Date: November 4, 2015

3) *Title:* Holographic disorder and localization

Occasion: Invited seminar

Venue: Tata Institute of Fundamental Research, Mumbai, India; *Date:* January 18, 2016

4) *Title:* Instability of holographic spaces

Occasion: Bangkok String Theory Workshop

Venue: Chulalongkorn University, Thailand

Date: January 20, 2016

Subhro Bhattacharjee

1) *Title:* Topological phases and phase transitions in spin systems on a Kagome lattice

Occasion: Theory and experiments magnetism Meeting 2015; *Venue:* Abingdon, UK; *Date:* July 16-17, 2015

2) *Title:* Lattice Model for Bosonic Integer Quantum Hall Effect and Beyond

Occasion: MIT Seminar

Venue: Massachusetts Institute of Technology, Cambridge, USA; *Date:* August 11, 2015.

3) *Title:* Integer Quantum Hall Effect of Bosons on a Lattice

Occasion: Seminar

Venue: Institute of Mathematical Sciences, Chennai, India; *Date:* November 12, 2015.

4) *Title:* Lattice realization of quantum Hall effect of bosons

Occasion: Discussion Meeting on New questions in quantum field theory from condensed matter physics

Venue: ICTS-TIFR, Bangalore, India

Dates: December 28, 2015-January 5, 2016

Rukmini Dey

1) *Title:* Some Aspects of Minimal Surfaces

Occasion: Eigenfunctions Seminar

Venue: IISc, Bangalore; *Date:* February 2016

Abhishek Dhar

1) *Title:* Understanding anomalous transport in one-dimensional systems through fluctuating hydrodynamics.

- Occasion:* Rutgers statistical physics conference
Venue: Rutgers University; *Dates:* May 1-15, 2015
- 2) *Title:* Probability of a quantum particle to survive being detected
Occasion: Rutgers statistical physics conference
Venue: Rutgers University
Dates: May 1-15, 2015
- 3) *Title:* Understanding anomalous transport and current fluctuations in one-dimensional systems through fluctuating hydrodynamics
Occasion: Workshop on progress in Nonequilibrium Statistical Mechanics
Venue: University of Nice, France; *Date:* June 8-12, 2015
- 4) *Title:* Waiting time distributions for entropic fluctuations
Occasion: Invited Seminar; *Venue:* LPTMS in Universite Paris, Orsay; *Date:* June 13-17, 2015
- 5) *Title:* Tagged particle diffusion in single-file systems
Occasion: Frontiers in Nonequilibrium Physics
Venue: Yukawa Institute of Theoretical Physics (YITP), Japan; *Date:* July 20-August 22, 2015
- 6) *Title:* Understanding anomalous transport and current fluctuations in one-dimensional systems through fluctuating hydrodynamics
Occasion: Workshop on Statistical Physics of Soft Matter
Venue: Banaras Hindu University; *Date:* November 26-30, 2015
- 7) *Title:* Energy current fluctuations for one-dimensional equilibrium systems in ring geometries
Occasion: New Approaches to Non-equilibrium and Random Systems: KPZ Integrability, Universality, Applications and Experiments
Venue: KITP, Santa Barbara; *Date:* January 11-22, 2016
- 8) *Title:* Understanding anomalous transport and current fluctuations in one-dimensional systems through fluctuating hydrodynamics
Occasion: Invited Seminar
Venue: IISER, Pune, India; *Date:* February 29, 2016
- 9) *Title:* The first passage problem in quantum mechanics
Occasion: Seminar series in Complex Systems
Venue: IOP, Bhubaneswar, India
Dates: March 22-23, 2016
- Rajesh Gopakumar**
1) *Title:* The Higher Spin Square
Occasion: Black Holes, Holography and Strings, A celebration of the science of Andy Strominger
Venue: Harvard University, USA; *Date:* July 31, 2015
2) *Title:* The Higher Spin Square
Occasion: Workshop on Geometries in Gauge Theory and String Theory
Venue: KIAS, Seoul, South Korea; *Date:* September 18, 2015
3) *Title:* The Higher Spin Square
Occasion: International Workshop on Higher Spin Gauge Theories
Venue: NTU, Singapore; *Date:* November, 2015
4) *Title:* The Quantum Dynamics of General Relativity
Occasion: Symposium on 100 years of General Relativity, IAS meeting
Venue: IISER, Pune; *Date:* November, 2015
5) *Title:* The higher-spin/CFT duality
Occasion: Conference ‘All about AdS₃’
Venue: ETH, Zurich, Switzerland
Date: November, 2015
6) *Title:* String Theory as a Higher Spin Theory
Occasion: Quantum Field Theory, String Theory and Beyond
Venue: Hebrew University, Jerusalem, Israel
Date: March 3, 2016
- Vijay Kumar Krishnamurthy**
1) *Title:* Active Pulsatory Patterns
Occasion: Indian Statistical Physics Community Meeting
Venue: ICTS-TIFR; *Date:* 2015
2) *Title:* Cell polarity in *C. elegans* zygotes
Occasion: Mechanical Manipulations and Responses at the Scale of the Cell and Beyond
Venue: Raman Research Institute, Bangalore
Date: 2015
3) *Title:* Active mechanochemical patterns in developmental biology
Occasion: IOP Bhubaneswar seminar series on complex systems; *Venue:* IOP, Bhubaneswar ; *Date:* 2016
4) *Title:* Cell polarity in *C. elegans* zygotes
Occasion: Indian Statistical Physics Community Meeting
Venue: ICTS-TIFR; *Date:* 2016
- Anupam Kundu**
1) *Title:* Long range correlation in interacting particle systems
Occasion: Invited seminar
Venue: IIT, Gandhinagar, India; *Date:* May 2015
2) *Title:* Locally driven Random Average Process
Occasion: Invited seminar
Venue: S. N. Bose National Centre for Basic Sciences, Kolkata, India; *Date:* March 2016
- R. Loganayagam**
1) *Title:* A topological gauge theory for entropy current
Occasion: Strings 2015
Venue: ICTS-TIFR, Bangalore, India
Date: June, 2015
2) *Title:* a) The Fluid Manifesto: Schwinger Keldysh and the emergence of fluid dynamics
b) A topological gauge theory for entropy current: fluids and black holes
Occasion: APCTP focus program on holography
Venue: Asia Pacific Center for Theoretical Sciences (APCTP), Pohang, Korea
Date: August, 2015
3) *Title:* Topological sigma models & dissipative hydrodynamics
Occasion: National Strings Meeting, 2015
Venue: IISER Mohali, Mohali, India
Date: December, 2015
4) *Title:* Topological sigma models & dissipative hydrodynamics
Occasion: Fourth Indian-Israeli workshop on quantum field theory and string theory
Venue: Goa, India; *Date:* December, 2015
5) *Title:* Topological sigma models & dissipative hydrodynamics
Occasion: New questions in quantum field theory from condensed matter theory

Venue: ICTS-TIFR, Bangalore, India
Date: December, 2015-January, 2016

Suvrat Raju

1) *Title:* Comments on state dependent operators
Occasion: High Energy Theory seminar

Venue: Brown University, USA; *Date:* April, 2015

2) *Title:* A state-dependent description of the black hole interior
Occasion: Duality Seminar
Venue: Harvard University, USA; *Date:* April, 2015

3) *Title:* A state-dependent description of the black hole interior
Occasion: Theory seminar
Venue: Columbia University, USA; *Date:* April, 2015

4) *Title:* The information paradox and the black hole interior in AdS/CFT
Occasion: CMSA colloquium
Venue: Harvard University, USA; *Date:* April, 2015

5) *Title:* The information paradox and the black hole interior in AdS/CFT
Occasion: Invited seminar
Venue: Cornell University, USA; *Date:* April, 2015

6) *Title:* The information paradox and the black hole interior in AdS/CFT
Occasion: Invited seminar
Venue: Perimeter Institute for Theoretical Physics, Waterloo, Canada; *Date:* April, 2015

7) *Title:* A lightning review of state dependence
Occasion: Invited seminar
Venue: Kavli Institute for Theoretical Physics, Santa Barbara, USA; *Date:* June, 2015

8) *Title:* The information paradox and the black hole interior in AdS/CFT
Occasion: Discussion meeting on Quantum Information Processing; *Venue:* IISc, Bangalore, India; *Date:* June, 2015

9) *Title:* Local operators and state dependence in AdS/CFT
Occasion: Quantum Spacetime Seminar

Venue: Tata Institute of Fundamental Research, Mumbai, India; *Date:* October, 2015

10) *Title:* The information paradox and the black hole interior in AdS/CFT

Occasion: Department of Theoretical Physics colloquium

Venue: Tata Institute of Fundamental Research, Mumbai, India; *Date:* October, 2015

11) *Title:* Local operators and state-dependence in AdS/CFT

Occasion: Invited seminar

Venue: University of Amsterdam; *Date:* October 2015

12) *Title:* a) The information paradox and the black hole interior in AdS/CFT: Paradoxes

b) The information paradox and the black hole interior in AdS/CFT: Resolution

Occasion: 8th Taiwan String Workshop

Venue: NTU, Taiwan; *Date:* November, 2015

Samriddhi Sankar Ray

1) *Title:* Settling, Collisions, and Coalescences: Droplets in a Turbulent Flow

Occasion: Invited seminar

Venue: University of Rome, Tor Vergata, Rome, Italy

Date: May 2015

2) *Title:* Inertial Particles: Implication for Clouds

Occasion: Interdisciplinary Programme (IDP) in Climate Studies

Venue: Indian Institute of Technology Bombay, Mumbai, India

Date: August 2015

3) *Title:* Settling and Coalescences of Inertial Particles in Turbulence

Occasion: Invited seminar

Venue: Department of Physics, Indian Institute of Technology Bombay, Mumbai, India

Date: August 2015

4) *Title:* Bottlenecks in Turbulence: Signatures in Physical Space

Occasion: European Turbulence Conference 15

Venue: Delft, The Netherlands; *Date:* August 2015

5) *Title:* Enhanced Settling and Droplet Growth in Inertial Particles in a Turbulent Flow

Occasion: Invited seminar

Venue: Theoretical Sciences Unit, Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore, India; *Date:* September 2015.

6) *Title:* Abrupt growth of large aggregates by correlated coalescences in turbulent flow

Occasion: Growing Length Scale Phenomena in Condensed Matter Physics

Venue: Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore, India; *Date:* October 2015

7) *Title:* Abrupt Growth of Large Aggregates by Correlated Coalescences in a Turbulent Flow: Short Time Results; *Occasion:* CompFlu-2016

Venue: IISER, Pune; *Date:* January 2016

8) *Title:* Settling, collisions, coalescences of inertial particles in turbulent flows; *Occasion:* CSAS – 2016

Venue: IIT, Chennai; *Date:* February 2016

9) *Title:* Intermittency in Turbulent Flows: Time to Look in Fourier Space?

Occasion: Indian Statistical Physics Community Meeting 2016; *Venue:* ICTS-TIFR, Bangalore
Date: February 2016

Vishal Vasan

1) *Title:* Gradient descent with nonlinear constraints

Occasion: Joint Mathematics Meetings
Venue: Seattle; *Date:* 9 January 2016

2) *Title:* Growth rates for wind-driven surface gravity waves

Occasion: Joint Mathematics Meetings
Venue: Seattle; *Date:* 8 January 2016

3) *Title:* A model for wind-driven surface gravity waves

Occasion: Conference on Computational Mathematics and Nonlinear Dynamics

Venue: Santiniketan
Date: 19 February 2016

Spenta R. Wadia

1) *Title:* S-matrix of Chern-Simons theory with fundamental matter
Occasion: APCTP workshop on 'Frontiers of Physics'
Venue: Yeosu, Korea
Date: 20 Dec 2015

2) *Title:* S-matrix of Chern-Simons theory with fundamental matter
Occasion: Abdus Salam Memorial meeting
Venue: NTU, Singapore
Date: 27 Jan 2016

3) *Title:* S-matrix of Chern-Simons theory with fundamental matter
Occasion: Quantum Field Theory, String Theory and Beyond
Venue: Hebrew University, Jerusalem, Israel
Date: 28 February 2016

Conferences Organized by the Centre**Strings 2015**

Strings 2015 was hosted by ICTS from June 22-26, 2015. Strings 2015 was the latest in a sequence of annual conferences that bring the entire string theory community together. This large gathering allows researchers from different parts of the world to interact across subfields. The conference saw the participation of many of the most eminent theoretical physicists in the world and served as the site for the announcement of major discoveries in the field. The events were held in the various facilities of the Indian Institute of Science, Bengaluru and the new ICTS campus in Hesaraghatta.

Special Session: 100 Years of General Relativity

A Special Session celebrating 100 years of General Relativity was held at the Faculty Hall of the Indian Institute of Science on the afternoon of June 26, 2015. This special session was chaired by Prof. Gary Horowitz, University of California, Santa Barbara, and there were five distinguished lectures on Quantum Gravity, Cosmology and Gravitational Waves. The distinguished lectures were delivered by David Gross (KITP, Santa Barbara), Peter Saulson (Syracuse University), François Bouchet (Institut d'astrophysique de Paris), Edward Witten (Institute for Advanced Study, Princeton) and Juan Maldacena (Institute for Advanced Study, Princeton).

Particles, Gravity and Strings

A public outreach event Particles, Gravity and Strings was held at the Christ University Auditorium on June 27, 2015. This event was associated with Strings 2015, and the celebrations of 100 years of General Relativity. Nima Arkani-Hamed and Ashoke Sen engaged in a two-hour long interactive session with school and college students. The session started with a 20-minute long presentation by each of the speakers, followed by detailed interaction with students in the audience. This was followed by three public talks by Nathan Seiberg, Andrew Strominger and Cumrun Vafa.

Non-DAE Research Projects**Parameswaran Ajith**

i) *Title:* Gravitational wave astronomy using astrophysical black hole binaries; *Funding Agency:* SERB fast track grant; *Duration:* 2013-2016

ii) *Funding Agency:* Ramanujan fellowship from SERB
Duration: 2013-2018

iii) *Title:* Astrophysical Relativity and Gravitational-wave Astronomy; *Funding Agency:* Max Planck Partner Group (Max Planck Society and DST); *Duration:* 2015-2018

Investigator: Abhishek Dhar

i) *Title:* Heat Transport in Extended one-Dimensional Models (with Yonatan Dubi); *Funding Agency:* UGC-Israeli Science Foundation; *Duration:* 2014-2017

ii) *Title:* Energy diffusion in noisy Hamiltonian systems (with Cedric Bernardin, Francois Huvener, Milton Jara); *Funding Agency:* ANR, France; *Duration:* 2015-2019

iii) *Title:* Extreme events and large deviations in strongly correlated many-body systems (with Gregory Schehr,

Sanjib Sabhapandit, Anupam Kundu, Satya Majumdar, Cedric Bernardin, Kirone Mallick, Alberto Rosso)
Funding Agency: CEFIPRA; *Duration:* 2016-2019

Rajesh Gopakumar

i) *Title:* Unravelling String theory
Funding Agency: JC Bose Fellowship, DST
Duration: 2015-2020

Vijay Kumar Krishnamurthy

i) *Title:* Mechanobiological patterns in morphogenesis
Funding Agency: DBT Ramalingaswami re-entry fellowship;
Duration: February 2016 – February 2021

Suvrat Raju

i) *Title:* Amplitudes in Gauge Theory and Gravity
Funding Agency: Ramanujan Fellowship (DST)
Duration: October 1, 2010-September 30, 2015

ii) *Title:* Holography and its applications
Funding Agency: Indo-French Center for the Promotion of Advanced Research

Samriddhi Sankar Ray

i) *Title:* Collisions, Coalescences and Fragmentation of Droplets in Turbulent Flows: The Role of Turbulence in Triggering Rain; *Funding Agency:* Early Career Research grant, DST; *Duration:* 2016-2019

iii) *Title:* Theoretical and Numerical Studies of Turbulence in Fluids; *Funding Agency:* Co-PI and Member, Indo-French Centre for Applied Mathematics (IFCAM); *Duration:* 2014-2017

ii) *Title:* Mathematics of Complex Systems; *Funding Agency:* PI of Airbus Corporate Foundation - Tata Institute of Fundamental Research Partnership; *Duration:* 2014-2018

iv) *Title:* Flowing Matter – Cost Action” (COST MP1305); *Funding Agency:* European Cooperation in Science and Technology; *Duration:* 2014-2018



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TIFR Centre for Interdisciplinary Sciences, Hyderabad

In the current year, the group worked primarily in the field of developing solid-state nuclear magnetic resonance theory and methods. The following are the key points of the research work:

- A generalized theoretical framework to analyze the performance of any heteronuclear decoupling condition under magic-angle spinning (MAS).
- Interference of decoupling with R^3 conditions can be minimized by appropriate choice of rf fields in the fast MAS regime.
- Experimental demonstration of selective proton-proton distance restraints in fully protonated solids.

Dipolar coupling based polarization methods were shown to be superior compared to scalar coupling based methods at 90-100 kHz MAS frequency. (Agarwal Vipin)

A theoretical description of heteronuclear decoupling sequences

We have developed a generalized theoretical framework, that allows rapid analysis of residual couplings of arbitrary decoupling sequences in solid-state NMR under magic-angle spinning conditions. The generalization relies on the tri-modal Floquet theory, where three characteristic frequencies are used to describe the pulse sequence. This approach can be used to describe arbitrary periodic decoupling sequences that differ only in magnitude of the Fourier coefficients of the interaction-frame transformation. We have exemplified the usefulness of this framework by analyzing the performance of commonly used high-power and low-power decoupling sequences such as amplitude-modulated XiX and TPPM. The theory also rationalizes why some sequences are better offset compensated than others. (Vipin Agarwal with Kong O. Tan, Beat Meier and Matthias Ernst, ETH, Zurich)

Where to decouple in the fast MAS regime?

The performance of heteronuclear spin decoupling sequences severely degrades when the proton radiofrequency (RF) nutation frequencies

are close to or at multiples of MAS frequency, referred to as rotary-resonance recoupling conditions in literature. Recently, PISSARRO and rCW^{AiA} decoupling sequences have been shown to be less affected by the problem of MAS and RF interference, specifically at $n=2$ condition, in the fast MAS regime. We systematically evaluated the loss in intensity of several heteronuclear decoupling sequences at $n=1,2$ rotary resonance conditions compared to high-power decoupling in the fast-MAS regime. We have experimentally demonstrated that in the fast-MAS regime (above 40 kHz) the entire discussion about RF and MAS interference can be avoided by using appropriate low-power decoupling sequences which give comparable performance to decoupling sequences with 200kHz of 1H irradiation. (Vipin Agarwal, Kshama Sharma, P.K. Madhu, TCIS, TIFR, Hyderabad.)

1H - 1H distance restraints in immobile peptide and proteins at fast MAS

The structure determination of perdeuterated proteins by solid-state NMR has become routine using a large set of 1H - 1H distance restraints at fast magic angle spinning. However, not all proteins can be deuterated so the approach has limited applications. The progress in magic-angle spinning (MAS) technology now provides a possibility to record meaningfully resolved proton spectrum of fully protonated proteins. Fast MAS (~ 100 kHz) combined with high static fields has enabled proton-detected correlation spectroscopy in fully protonated samples with sufficient resolution, primarily for the purpose of assignment. Here, we propose a new experimental method to obtain long-range 1H - 1H contacts, in fully protonated proteins, at fast MAS using selective spin diffusion. The novel method demonstrates that 1H - 1H contacts on the order of 6-7 Å can be obtained in fully protonated proteins. A systematic comparison of the experimental 1H - 1H contacts was performed with the expected 1H - 1H contacts at a distance of 7 Å based on the X-ray structure. (Agarwal Vipin)

A quantitative comparison of J-coupling and dipolar-coupling-based polarization transfer methods

Spin identification in NMR is the first step to perform any further analysis. In case of biomolecules, spin identification is primarily achieved through assignment experiments. In solid-state, NMR assignments can be achieved by experiments that rely on dipolar or scaling based polarization transfer method. We compared experiments based on both polarization transfer method and showed that dipolar coupling based polarization transfer methods outperform scalar coupling transfer methods under most circumstances. Scalar coupling methods primarily work better where proton density is low or regions where biomolecules are highly mobile. (Vipin Agarwal, Beat Meier, Matthias Ernst, ETH, Zurich, Ago Samoson, University of Technology, Tallin, Estonia and Anja Bockmann, CNRS/Université de Lyon, France)

Fluctuation-dominated Order

In a class of nonequilibrium systems, fluctuations are anomalously strong but coexist with long-range order, leading to fluctuation-dominated phase ordering (FDPO). The signature of FDPO, a singularity in the scaled two-point function, was earlier observed in a variety of systems, ranging from models of active biological systems and granular media to experiments on vibrated rods. It has now been shown that a single order parameter does not suffice to characterize the order; a larger, infinite, set is required. This set is built from long-wavelength Fourier components of the density profile, and captures an essential aspect of the state, namely the continuous breakup and re-emergence of particle-rich regions. For a system of passive particles sliding on a fluctuating surface and for a related coarse-grained depth model, simulations revealed that each mode is populated for a finite fraction of time, in strong contrast to customary phase separation. The corresponding probability distributions remain broad in the thermodynamic limit and are described by simple scaling laws. Further, the temporal behavior of the principal mode shows an interesting property in some cases: the flatness, which is related to dynamical structure functions, was found to exhibit a divergence at a small argument, indicating that the behavior in time is intermittent. (M. Barma with R. Kapri (IISER, Mohali) and M. Bandyopadhyay (IIT Bhubaneswar))

An unusual calcium binding protein from *E. Histolytica* that binds and hydrolyzes guanosine triphosphate has been structurally characterized.

In an in-cell NMR study, differential accumulation and mobilization of starch or/and lipids in *Chlamydomonas reinhardtii* has been studied. In continuing the structural characterization of an UV inducible protein (UVI31+) from *C. reinhardtii*, the study uncovered first structural description of a plant chloroplast endonuclease that is regulated by UV-stress response in *C.reinhardtii* cells. (Chary KVR)

Structure, dynamics and interaction of Ca²⁺-binding proteins

The protozoan parasite *E. histolytica* encodes twenty-seven Ca²⁺-binding proteins (CaBPs) suggesting that the organism has an intricate and extensive Ca²⁺-signaling system. The structural and functional characterization of some of these CaBPs studied so far reveals their predominant role in phagocytosis and endocytosis. However, not all amoebic CaBPs are involved in phagocytosis and endocytosis. An unusual calcium binding protein from *E. Histolytica* that binds and hydrolyzes adenosine and guanosine triphosphates: A calcium binding protein (abbreviated as EhCaBP6) is mainly localized in the nucleus and present at the microtubule end and at the intercellular bridge with the microtubules during cytokinesis. Hence, it is supposed to be involved in cell division. In other organisms, calmodulin (CaM) plays a role of a major signal-transducing factor, through which Ca²⁺ concentrations are regulated during the cell cycles. In an attempt to understand the structural and functional similarity of EhCaBP6 with CaM, we have determined the 3D solution structure of EhCaBP6 using NMR. The protein EhCaBP6 has one unusual (EF-I), one canonical (EF-III) and two non-canonical (cryptic) (EF-II and EF-IV), EF-hands. The cryptic EF-II and EF-IV pair with Ca²⁺-binding EF-I and EF-III, respectively, to form a two-domain structure similar to CaM. The structural similarity between EhCaBP6 and CaM, despite their low sequence similarity, suggests towards their similar functions during the cell cycle. Intriguingly, the EhCaBP6 binds and hydrolyzes adenosine triphosphate. This is the first known instance of a CaBP that hydrolyzes guanosine triphosphate. (Deepshikha Verma, and A. Bhattacharya (JNU, New Delhi))

Biomolecular Interaction

Structure and Dynamics of a putative UV inducible protein (UVI31+) from *C. reinhardtii* that exhibits RNA and DNA endonuclease activity: *C. reinhardtii* is a single celled alga, which undergoes apoptosis in response to UV-irradiation. UVI31+ in *C. reinhardtii* exhibits DNA and RNA endonuclease activity, induced upon UV-stress.

UVI31+ that normally localizes to cell wall and pyrenoid regions gets redistributed into punctate foci within the whole chloroplast, away from the pyrenoid, upon UV-stress. The structure, dynamics and the putative function of UVI31+ have been studied. The 3D structure of UVI31+ has $\alpha_1\beta_1\beta_2\alpha_2\alpha_3\beta_3$ fold very similar to BOLA family of proteins, which in turn is similar to the well-described K-Homology Class-II (KH) domain that contains RNA and DNA binding motif. KH domains bind RNA or ssDNA, and are found in proteins associated with transcriptional and translational regulation, along with other cellular processes. Further, UVI31+ is found to recognize DNA primarily by its sheet domain with a dissociation constant of 52 nM. Point mutation at S114 of UVI31+ to Ala residue (S114A) reduced the endonuclease activity 10 fold. (Himanshu Singh, Sunita Patel, B.J. Rao (DBS))

Towards Tailoring Plant Protease Inhibitors for Control of the Crop Pest *Helicoverpa armigera*

Developing a peptide based eco-friendly insecticidal agents to control insect pests that adversely affect the agricultural production by destroying the crops or infesting the livestock is a major challenge. The most common Lepidoptera species, that cause damage to agriculture sector is *Helicoverpa*. Recently, it has been reported that peptide based protease inhibitors (PIs) from *Capsicum annuum* potently inhibit *H. armigera* gut proteases and also show a significant effect on its larval growth. However, very little information is currently available about the three-dimensional (3D) structure of these PIs or information about the residues that mediate their interaction with insect gut proteases. Recently, three recombinant PIs (IRD7, IRD9, IRD12) have been found to be very potent inhibitors with specific reference to their (i) stability in proteolytic environment (ii) proteinase inhibition specificities and (iii) inhibitory activity against insect proteinases. Thus, we set out to overexpress these three recombinant PIs, compare their activity *in-vitro* and *in-vivo*, and determine their 3D structure with a view to selecting the best candidate for future development as bioinsecticide proteases. As a prelude to the determination of 3D structures, we have carried out complete sequence specific ^1H , ^{13}C and ^{15}N resonance assignments for IRD7 and IRD12 and studied their dynamics using ^{15}N -relaxation data. The chemical shift index and the relaxation data show that IRD7 and IRD12 are well folded and highly stabilized with four disulphide bridges. (This project is being undertaken under DST-DIISRTE joint research project (Australia-India Strategic Research Fund

(AISRF)). (Janeka Gartia, Glenn King, The Queensland University, Brisbane, Australia and Dr. Ashok Giri, NCL Pune)

Differential accumulation and mobilization of starch and lipid in *Chlamydomonas reinhardtii*

Chlamydomonas reinhardtii has recently emerged as a viable alternative source of fossil fuel. However, the metabolic flow of carbon in *C. reinhardtii* for making the carbon reserve is not yet understood. In addressing this issue, we have grown the wild-type (cw15) and the starch deficient (sta6) strains of *C. reinhardtii* with a singly or doubly ^{13}C -labelled acetate as the sole source of carbon to monitor its assimilation by ^{13}C -NMR under nitrogen starvation and study the dynamics of starch and lipid reserves formed as dominant sinks of carbon. During such growth condition, the starch was found to accumulate and mobilize faster than TAG. This study describes different growth conditions for acetate carbon flow into formation of either starch or/and TAG and their remobilization during nitrogen replenishment condition, thus establishing a system for probing the cellular nitrogen sensing, uptake mediated changes in carbon flux. (Himanshu Singh, Manish Shukla, B.J. Rao (DBS))

Aggregation of proteins are involved in several neurodegenerative diseases such as Alzheimer's, Parkinson's diseases and type 2 diabetes. In the current year we have worked primarily on biophysical characterization of protein aggregation in presence and absence of indigenous proteins apolipoprotein E and chaperone protein Hsp70. We have observed that both these proteins strongly affect aggregation of amyloid proteins such as amyloid beta, alpha-synuclein and amylin. Additionally, we are exploring the possibility of application of our knowledge of protein self-assembly to prepare smart bionanomaterials such as peptide hydrogels. Important highlights of our work in the last year are listed below. (Garai Kanchan)

Development of a highly sensitive Fluorescence Correlation Spectrometer (FCS)

Last year, we built a fluorescence correlation spectroscopy (FCS) set up in house for characterization of protein dynamics and protein-protein interactions. However the sensitivity of the instrument was less than satisfactory. We identified several problems with different optical components mainly with the dichroic mirrors and one of the lenses. This year, we rectified those problems to build one of the most sensitive FCS instrument in the world. The counts per molecules

(CPM) obtained is about 400 kHz which is one of highest, reported in the literature. (Garai Kanchan)

Determination of solubility of amyloid peptides

We have established a new methodology for measurement of solubility of amyloid beta peptide using fluorescence of tetramethylrhodamine (TMR). We have found that amyloid fibrils are extremely insoluble in native buffer and their solubility is controlled by the folding-unfolding behaviour of the peptide monomers. (Garai Kanchan)

Characterization of interactions of apoE and Hsp70 with amyloid proteins

We have used FCS, ensemble fluorescence and atomic force microscopy (AFM) to establish that the proteins such as apoE and Hsp70 strongly influence amyloid aggregation. We are now collaborating with Prof. P K Madhu to understand the molecular basis of these interactions. (Garai Kanchan)

Understanding the structure-function differences between the apoE isoforms

We have used tryptophan fluorescence and secondary structure of the apoE proteins to find presence of intermediates in folding-unfolding pathway. We hypothesize that these intermediates may have strong functional consequences. We are currently collaborating with Dr. P Vallurupalli to characterize the structural properties of the intermediates. We are collaborating with Dr. J Mondal to identify the structural differences between apoE3 and apoE4. (Garai Kanchan)

Preparation of switchable peptide hydrogels

We have synthesized a new 18 residue peptide named MAX2 which forms hydrogel in native buffer and at physiological temperature 37 degree Celsius. The hydrogel formation can be reversed by altering the temperature and pH of the media. We think that this hydrogel can have useful applications in bionanotechnology. (Garai Kanchan)

Developing single molecule techniques for characterization of oligomers of amyloid proteins

We are working to setup a microfluidic based single molecule detection setup for quantitative characterization of the amyloid oligomers. Additionally, we are working to build a super resolution optical microscopy setup. Currently its sensitivity and the resolution are not good. We are working to improve it. This will be used for characterization of amyloid aggregates and their

interactions with proteins such as apolipoprotein E and the chaperones. (Garai Kanchan)

Particulate flows

Our studies on inertial particles in turbulent flows had revealed that caustics, i.e., regions of the flow where particle dynamics does not constitute a field, are an important contributor to clustering. We took this finding further to examine water droplets in a vertical flow, and showed that caustics droplets are far more likely to collide with other droplets repeatedly, coalesce, and grow much bigger than other droplets. This could mean that caustics droplets in clouds are far more likely to become rain drops. (Govindarajan Rama)

Flow of foam

We have shown that attractive interactions in the flow of foam change flow characteristics in a fundamental way. An unjamming driving force depends linearly on the attractive potential, and a stick-slip and a steady flow regime occur at higher forcing. (Govindarajan Rama)

Rotating flows

In a collaboration with Prof. Benoit Pier under an Indo-French grant, we have shown that flow past a rotating cylinder can be described a similarity flow which includes a wall-jet and a boundary layer. This has consequences for the stability of such a flow, which we are studying now. We have found several features in the transition to turbulence in a rotating channel. In particular, a non-monotonic response to rotation is found. Flow is far more likely to go into turbulence at moderate rotation rates than at low rotation rates, with coherent structures distributed very asymmetrically in the channel. At higher rotation rates, the stability operator becomes close to self-adjoint, leading to the strong suppression of algebraically growing perturbations. (Govindarajan Rama)

Rational design for the syntheses of N-Heterocyclic Carbene (NHC) coordinated 2-hydrophosphasilenes

Compounds with a heteroleptic multiple bond between heavier main-group elements, in particular those between group 14 and 15 elements, have attracted considerable attention, because of their unique reactivity and electronic properties. We have synthesised 2-hydrophosphasilene (**figure a**) stabilized by bulky terphenyl substituent along with N-Heterocyclic Carbene (NHC) and characterized by solution state NMR (^1H , ^{29}Si , ^{31}P) spectroscopy and single crystal x-ray diffraction study. (Jana Anukul)

Reversible coordination of NHC's with 2-hydrophosphasilenes

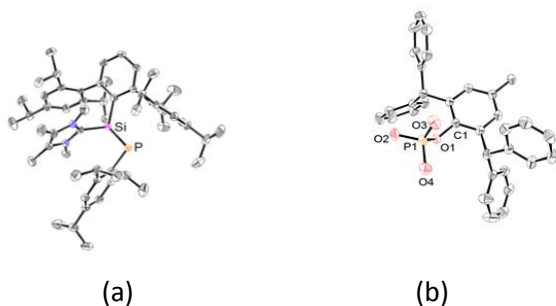
We have synthesized different NHC's substituted 2-hydrophosphasilenes and we have observed reversible coordination of NHC with it. (Jana Anukul)

Imidazolidine derived NHC-coordinated phosphorous trichloride for the syntheses of multiple bonded phosphorus compounds

We have synthesized imidazolidine derived N-heterocyclic carbene, SIDipp in modified way with better yield and successfully isolated its PCl_3 adduct. The purity of these adducts were characterized through solution state NMR. (Jana Anukul)

Syntheses of mono-aryl phosphates for the design of zwitterionic phosphates.

We have successfully prepared various phosphate monoesters of bulky aryl groups (**figure b**) and subsequently, we were able to form zwitterionic phosphates when these aryl groups react- with triethyl amine. (Jana Anukul)



Dynamics of Supercooled Liquids with Random Pinning

Extensive molecular dynamics simulations are performed to determine the phase diagram of two model glass forming liquids in the presence of external quenched disorder. The quenched disorder is introduced in the system by randomly choosing a fraction ρ_{pin} of particles from an equilibrium configuration of the supercooled liquids at temperature T and freezing them in space. The study of the dynamics of supercooled liquids with this type of quenched disorder has drawn a lot of attention in recent years due to theoretical predictions of the possibility of observing the ideal thermodynamic glass transition in such systems. In this Letter, we numerically examine this possibility by determining the phase diagram of the systems in the $\rho_{pin}T$ plane. We find that the phase diagram differs considerably from existing theoretical predictions and show that a rapid decrease in the kinetic fragility of the system

with increasing $\rho_{pin}T$ concentration is a probable reason for this difference. (Karmakar Smarajit)

The Static Length scale in the Glass Transition

The existence of a static length scale that grows in accordance with the dramatic slowing down observed at the glass transition, is a subject of intense interest. We showed how one can reach a typical length scale that grows in accordance with at least 15 orders of magnitude increase in the relaxation time, competing with the best experimental conditions. We also proposed a new susceptibility, "Pinning Susceptibility" which directly extract this static length scale and will be easily implementable in experiments. Possible correlation between static and dynamics length scales are also looked at, to understand some of the puzzling phenomena of glass transition. (Karmakar Smarajit)

Glass-Like Slow Dynamics in a Colloidal Solid with Multiple Ground States

We study the phase-ordering dynamics of a 2D model colloidal solid using molecular dynamics simulations. The colloid particles interact with each other with a Hamaker potential, modified by the presence of equatorial patches of attractive and repulsive regions. The total interaction potential between two such colloids is, therefore, strongly directional and has a 3-fold symmetry. Working in the canonical ensemble, we determine the phase diagram in the density temperature plane. We obtain three distinct crystalline ground states, viz., a low density honeycomb solid, a rectangular solid at intermediate density, and finally a high-density triangular structure. We show that when cooled rapidly from the liquid phase along iso-chores, the system undergoes a transition to a strong glass, while slow cooling gives rise to crystalline phases. We claim that geometrical frustration arising from the presence of many competing crystalline ground states causes glassy ordering and dynamics in this solid. Our results may be easily confirmed by suitable experiments on patchy colloids. (Karmakar Smarajit)

Short-Time Beta Relaxation in Glass-Forming Liquids Is Cooperative in Nature

Temporal relaxation of density fluctuations in supercooled liquids near the glass transition occurs in multiple steps. Using molecular dynamics simulations for three model glass-forming liquids, we show that the short-time β -relaxation is cooperative in nature. Using finite-size scaling analysis, we extract a growing length scale associated with beta relaxation from the observed

dependence of the beta relaxation time on the system size. We find, in qualitative agreement with the prediction of the inhomogeneous mode coupling theory, that the temperature dependence of this length scale is the same as that of the length scale, that describes the spatial heterogeneity of local dynamics in the long-time α -relaxation regime. (Karmakar Smarajit)

Elasto-plasticity in Amorphous Solids

The conditions which determine whether a material behaves in a brittle or ductile fashion on mechanical loading are still elusive and comprise a topic of active research among Materials physicists and engineers. In this study, we present the results of *in silico* mechanical deformation experiments from two very different model solids in two and three dimensions. The first consists of particles interacting with isotropic potentials and the other has strongly direction dependent interactions. We show that in both cases, the excess vibrational density of states is one of the fundamental quantities which characterizes the ductility of the material. Our results can be checked using careful experiments on colloidal solids. (Karmakar Smarajit)

Laser Installation

After overcoming all the technical related issues with the pump lasers etc, the new 7 fs, 1 kHz, 1.5 mJ laser system with Carrier Envelope Phase (CEP) control has been installed. The CEP stability of the amplifier was demonstrated to be <250 mrad over a period of 4 hours, testimony to the environmental stability in the laser cabin. Optical parametric amplified (TOPAS) is also installed and demonstrated to generate a combined Signal (S) + Idler (I) power of a maximum of 1.7 mJ at 1300 nm (S) +1700 nm (I). The wavelength spans from 1140 nm to 1640 nm (S) and 1560 nm to 2600 nm (I). A low dispersive pump probe set up for broad band wavelengths from 650 nm to 2600 nm and short pulse widths upto 7 fs, was set up and installed within the laser cabin to have environmental stability for the two arms of the pump probe and a resolution of 0.1 μm , allows ultra precise time resolution of ~ 1 fs over time delays of 1ns. (Ram Gopal, M. Anand and M. Krishnamurthy)

A new set up for high-density gas phase experiments

With the success of using CH₄ clusters in improving features of electron acceleration in 2014-15, the study of laser plasmas generated from a plume of clusters becomes imperative. We have designed and completed the set up of a new chamber to this end. The 6-way CF 150 cross

chamber is pumped by a 3200 L/s turbomolecular pump. The laser beam is focused at the centre of the chamber with a 150 mm focal length off-axis parabolic mirror. The cluster beam is presently generated by a pulsed commercial Parker Valve nozzle (series 90), which crosses the laser focus at the centre. The nozzle can be moved in vacuum using a UHV manipulator. In line with the requirement to have the set up to be mobile, an innovative mobile pumping station housing the turbo pump and a large bellow was designed and commissioned. The first set of experiments to characterize the cluster beam using Rayleigh scattering have been completed. A new nozzle with ~ 30 μm opening has been designed and is being fabricated presently. This nozzle will also be cryogenically cooled to 170-200 K, for generating large clusters. (Ram Gopal, M.Anand, Soubhik Sarkar and M. Krishnamurthy)

Ultra short electron pulses

An independent project was taken up to develop a source for generating ultrashort electron electron pulses. The rich collective physics of the generation of such electron beams apart, the possible application of electron pulses to study time resolved electron attachment processes or as a diagnostic probe for magnetic fields in plasmas etc. In collaboration with Dr Vandana Sharma and Ms Shilpa Rani (IITH) a chamber has been designed, fabricated and installed on the laser beam line to generate ultrashort electrons pulses from nanotips, using laser assisted field emission. Initial results showed the generation of ultrashort electron beams and developments to do pump probe experiments are designed.(Dr Vandana Sharma, Ms Shilpa Rani and Ram Gopal)

Hard X rays from mesoscopic particles

We had taken up to built an experiment, where in mesoscopic particles of any size, shape and composition can be used as an isolated, replenishable target for laser matter studies. Though we had success in developing the experiments, we had to redesign the experimental strategy to enhance the particle density and temporal stability. An innovative particle flux concentrator is designed to enhance the particle density at interaction region. Our first experiments with the microcrystalline boric acid particle exposed to 3 mJ 30 fs laser pulses (Intensity: $3e15$ W/cm²) showed electron temperatures greater than 25 keV as measured from bremsstrahlung X ray spectra obtained by a NaI (TI) detector. The maximum absorption of the laser as measured by the transmitted flux on a photodiode shows absorption of greater than 75%. We are pursuing to study the processes involved and the

responsible absorption mechanisms. Preliminary results indicate the effect of the carrier gas on the yield of the X-rays, which would suggest either self focussing in the gas to play a role, or additional heating of the plasma from background low energy electrons through ionization of carrier gas. (Ram Gopal, M. Anand, Rakesh Sharma, M. Krishnamurthy)

Notable advances have been made in developing methods in solid-state nuclear magnetic resonance and its applications to materials, especially, amyloid beta peptides. A unified theoretical and experimental understanding of heteronuclear spin decoupling in solid-state NMR has led to unifying many decoupling schemes under a single classification. Rotary-resonance recoupling leading to decoupling deterioration has been shown to be insignificant by working at very high radiofrequency regimes and slow magic-angle spinning conditions or vice-versa. Efficient recoupling methods have been introduced for geometry elucidation that are robust with respect to crystal orientations and experimental parameters which are also ideally suited for application in strongly coupled spin systems. Unique structural features have been observed in the transition of A β peptide from its oligomer stage to fibril stage. Insights have been obtained regarding the intramolecular antiparallel beta sheet transition to intermolecular parallel beta sheet arrangement during the conformation change from oligomers to fibrils. (Madhu P.K.)

Unification of heteronuclear dipolar decoupling schemes

Heteronuclear spin decoupling is very essential in magic-angle spinning solid-state NMR experiments for resolution and sensitivity enhancement. We have refined rCW^A decoupling method extensively by incorporating supercycling strategy. A unification of various schemes in vogue has been attempted under the general framework of phase and time modulation of radiofrequency pulses. This has clearly brought out common features among many schemes that were not obvious earlier. This has also pointed to several good decoupling conditions which are being currently exploited. (P. K. Madhu with Niels Nielsen and Asif Equbal, Univ. of Aarhus, Denmark.)

Theoretical understanding of heteronuclear dipolar decoupling schemes

Multi-mode Floquet theory has been used to obtain several key features of the rCW^A scheme, both in the non-supercycled and supercycled version. This has also established interesting

symmetry properties of the various spin operators and their role in achieving good decoupling. A Floquet analysis was also performed on the performance of the rCW^A scheme under fast magic-angle spinning conditions and low radiofrequency regime. This has clearly established the conditions under which the rCW^A decoupling scheme can be applied under these regimes for efficient performance. (P. K. Madhu with Niels Nielsen and Asif Equbal, Univ. of Aarhus, Denmark, Michal Leskes and Shimon Vega, Weizmann Institute of Science, Israel, and Vipin Agarwal, TCIS, TIFR, Hyderabad.)

Quenching of rotary-resonance conditions during decoupling

Rotary resonance recoupling, R3, leads to deterioration of decoupling efficiency when the radiofrequency field matches magic-angle spinning frequency. There has been some debate in the literature regarding design of schemes that can quench these conditions. We have suggested strategies to overcome the R3 conditions by performing experiments at high magic-angle spinning conditions and low radiofrequency regime. This completely avoids any discussion regarding R3 quenching and routine experiments can be performed without optimising yet another decoupling scheme. (P.K. Madhu, Kshama Sharma, Vipin Agarwal, TCIS, TIFR, Hyderabad.)

Recoupling pulse schemes and strategies

We have introduced non-linearly spaced pulses with regard to the rotor period for recoupling dipolar interactions under magic-angle spinning in rotational-echo double-resonance experiments. These experiments are useful to obtain distance constraints. The new strategy leads to a scaling of the dipolar coupling, however, it is independent of crystallite orientation dependence and other experimental parameters. The scaling factor is robust with regard to spinning frequency and radiofrequency amplitude. The scaling property will be useful in the measurement of strong dipolar couplings and this experiment is currently underway. Experiments to measure order parameter under very fast spinning are also underway. We have further improved our theoretical and experimental understanding in performing symmetry-based pulse schemes in an asynchronous way. Such a strategy has been extended to various symmetry-based schemes with higher efficiency in recoupling. (P. K. Madhu with Matthias Ernst, ETH, Zurich, and Mukul Jain, Kshama Sharma and Vipin Agarwal, TCIS, TIFR Hyderabad.)

Solid-state NMR spectroscopy of amyloid fibrils

A β peptide continues to be an interesting model for investigating different aspects of amyloid aggregation. The link between toxicity and size of Alzheimer's amyloid- β (A β) aggregates likely has a structural origin. However, the major structural features of A β peptide (dominated by β -sheets) appear to be conserved across sizes from small oligomers onwards, presenting an unsolved puzzle. We have probed A β aggregates of increasing size from the mesoscopic to the atomic scale with a combination of spectroscopic and imaging tools. We found that the apparently conserved beta sheet character hides a major secondary structure transition, where an intramolecular anti-parallel beta sheet structure (containing a beta turn) in the small oligomers evolves to a intermolecular in-register parallel beta sheet structure in the mature fibrils. At the atomic level, the salt bridge between D23 and K28, a key inter-residue contact in fibrillar A β which is frequently altered in early onset AD mutations, emerges in parallel. Our findings regarding the anti-parallel to parallel transition and the salt bridge are mirrored by molecular dynamics simulations. Notably, structural signatures for the soluble oligomers resemble the porin-like features of membrane bound oligomers. This suggests a mechanism of toxicity for the small soluble oligomers, and a reason why the mature aggregates may have lower toxicity. (P. K. Madhu with Baapaditya Chandra and Prof. Sudipta Maiti, TIFR, Mumbai, and Kaustubh Mote, TCIS, TIFR, Hyderabad.)

This year saw the start of Biological programmes at TCIS. In addition to recruiting students and setting up academic programmes, actual biological research has now taken off. Dr. Aprotim Mazumder investigates DNA damage responses in cells for its relevance to the emergence of cancers. To support such research, in addition to standard laboratory workspaces and equipment, a cell culture facility has been set up with incubators, biosafety cabinets, inspection microscopes, liquid nitrogen storage etc. Two widefield epifluorescence imaging systems with live-cell chambers have been set up, and a flow cytometer for evaluating high number statistics of fluorescence across large cell populations is operational too. Methods have been optimized for performing single molecule RNA fluorescence in situ hybridization in cells, steady-state anisotropy measurements and quantitative image analysis, and these tools are being applied to a variety of biological questions, most notably in the study of

cell-cycle dependent DNA damage responses. (Mazumder Aprotim)

Deciphering the binding and unbinding pathways of the ligand approach to protein by computer simulations. Delineating role of mutation in the drug resistance of kinase using computer simulation. Key insights on role of solvent and steric effects on hydrophobic cavity-ligand unbinding. Understanding role of osmolytes in conformations of hydrophobic polymer. (Mondal Jagannath)

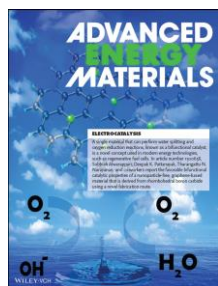
We were able to show that high resolution proton-detected NMR of proteins is possible under slow magic angle conditions and that these experiments can be very useful for a diverse range of samples such as nanoparticles. Solid state NMR was also used to understand the interaction of amyloid-beta oligomers with membranes and we were able to show, for the first time, the secondary structure of the amyloid-beta oligomers, interacting with the membranes. My research group works on understanding the metabolite transport across membranes. The current work focuses on the mitochondrial pyruvate carrier, which transports pyruvate from the cytoplasm into the mitochondria. This system is at the edge of what can be possibly studied by solid state NMR spectroscopy and as such, warrants the development of new techniques for its characterization. Towards this aim, I have developed several new techniques in solid state NMR over the past year, focusing on how these can be applied. This work has resulted in three high impact publications and has been highlighted in popular press as well.

High resolution ^1H detection at moderate MAS frequencies: One of the big challenges in solid state NMR is to achieve high resolution detection of protons. We used windowed ^1H detection with phase-modulated Lee-Goldberg homonuclear decoupling technique to obtain resolution in the ^1H dimension that is comparable to that achieved under much higher magic angle spinning frequencies. This method will be of tremendous use for cases where sample availability is not a limiting factor, particularly membrane proteins and fibrils. Together with Prof. V. Polshettiwar and Prof. P.K. Madhu, we used this method to look at catalytically active nitridated silicon nanoparticles in an effort to understand their catalytic activity as a base. We were able to determine, that the catalytic activity is primarily as result of primary amines. In collaboration with Prof. Sudipta Maiti and Pro. P.K. Madhu, we were able to determine that

amyloid-beta oligomers maintain a beta-sheet conformation when attached to membranes. Interestingly, we were also able to determine that the membrane bound species contains a beta-turn, which possibly indicates the presence of an antiparallel beta-sheet structure when bound to the membrane. This work received wide press coverage in Eureka Alert as well as popular press. (Mote Kaustubh R)

Synthesis and assembly of atomic layers

The discovery of atomically thin layers (also called 2-dimensional (2D) materials/layers) with a variety of intrinsic properties has spawned a new field of materials science research. Recent research on nanomaterials proved that new classes of engineered materials/solids can be designed by the combinatorial stacking or arrangements of various atomic layers. Hence, atomic layers are not only interesting in their pristine form, but are intriguing in their stacked form too. One of the main focus of the research is the study of interface induced properties in the stacked forms of atomic layers. This includes the controlled synthesis and systematic assembly of atomic layers, and probing their interface induced properties. Further, this research also includes theoretical understanding of the junction formation - from statistical to atomistic calculations, where we will try to model the system with potential in classical regime. Controlling and manipulating these junctions and assemblies can control the electronic, optical and electrochemical properties of resultant solids. The interfacial charge separation, heterogeneous electron transfer process etc. will also be studied. A chemical vapor deposition (CVD) set up is also developed at TCIS for the synthesis of individual atomic layers and layer by layer deposition of various layers. (T N Narayanan, Shubhadeep Pal, Ravi Kumar Biroju, Vineesh T V and Rahul Sharma)



Small molecule detection and development of bio-sensors

Biosensing is receiving enormous attention from the scientific community due to its importance in the development of point-of-care devices. Various platforms were used in the recent past for the detection of ppm/ppb levels of small molecules,

and electronic and electrochemical bio-sensing are important classes among them. In our present research, we are trying to develop engineered graphene based small molecules, such as ammonia, sensors. A first principle study on the interaction possibilities of graphene and ammonia is conducted using Density Functional Theory calculations. The bio-sensing possibilities of engineered graphene materials are also being studied experimentally. An impedance spectroscopy based electrochemical sensing possibilities are being explored. (T N Narayanan, Kiran Kumar Tadi, Shubhadeep Pal, Ravi Kumar Biroju, Ananth Puthirath)

Viscoelastic Studies on Self/forced assembled 3-dimensional structures

Controlled assembly of 1D or 2D nanomaterials to form macroscopic 3D structures is another intriguing field where these high surface area 3D structures can find applications in energy storage devices (3D batteries) and sensors (high diffusion electrodes). But the stable assembly of individual nanomaterials is a challenge. We are trying to make those controlled structures by solution self-assembly process and using external cross-linking agents. The interconnected structures need to have high mechanical strength for their further applications, and covalent linkage among nano blocks is highly demanding for ensuring the mechanical sturdiness of these 3D macroscopic structures. In my past studies it was revealed that microscopic characterization are not sufficient to prove the covalent linkage of individual nano blocks, and only a systematic viscoelastic measurement can render information about the covalent linkage. We are studying the viscoelastic properties of 3D graphene and 3D CNT assemblies to understand the fundamental mechanism underlying in the reinforcement of these 3D structures. (T N Narayanan, Sudeshna Patra)

Impact of the Peterlin approximation on polymer dynamics in turbulent flows

We study the impact of the Peterlin approximation on the statistics of the end-to-end separation of polymers in a turbulent flow. The finitely extensible nonlinear elastic (FENE) model and the FENE model with the Peterlin approximation (FENE-P) are numerically integrated along a large number of Lagrangian trajectories resulting from a direct numerical simulation of three-dimensional homogeneous isotropic turbulence. Although the FENE-P model yields results in qualitative agreement with those of the FENE model, quantitative differences emerge. The steady-state probability of large extensions is overestimated by

the FENE-P model. The alignment of polymers with the eigenvectors of the rate-of-strain tensor and with the direction of vorticity is weaker when the Peterlin approximation is used. At large Weissenberg numbers, the correlation times of both the extension and of the orientation of polymers are underestimated by the FENE-P model. (Perlekar Prasad)

Clustering of vertically constrained passive particles in homogeneous, isotropic turbulence.

We analyze the dynamics of small particles vertically confined, by means of a linear restoring force, to move within a horizontal fluid slab in a three-dimensional (3D) homogeneous isotropic turbulent velocity field. The model that we introduce and study is possibly the simplest description for the dynamics of small aquatic organisms that, due to swimming, active regulation of their buoyancy, or any other mechanism, maintain themselves in a shallow horizontal layer below the free surface of oceans or lakes. We have quantified the compressibility, the preferential concentration of the particles, and the correlation dimension by changing the strength of the restoring force. The main result is that there exists a particular value of the force constant, corresponding to a mean slab depth approximately equal to a few times the Kolmogorov length scale η , that maximizes the clustering of the particles. (Perlekar Prasad)

Inertial particle acceleration in strained turbulence

The dynamics of inertial particles in turbulence is modelled and investigated by means of direct numerical simulation of an axisymmetrically expanding homogeneous turbulent strained flow. This flow can mimic the dynamics of particles close to stagnation points. We report results relative to the acceleration variances and probability density functions for both passive and inertial particles. A high mean strain is found to have a significant effect on the acceleration variance both directly by an increase in the frequency of the turbulence and indirectly through the coupling of the fluctuating velocity and the mean flow field. The influence of the strain on the normalized particle acceleration probability distribution functions is more subtle. The magnitude changes in the inertial particle acceleration variance and the effect on the probability density function, are then discussed in a wider context for comparable flows, where the effects of the mean flow geometry and of the anisotropy at small scales are present. (Perlekar Prasad)

Thin film spintronics

An ultra high vacuum system was setup demonstrating the capability to grow thin films of ferromagnets and oxides with a sensitivity of less than 1 Angstrom per second. Capability to grow devices in-situ was also achieved for growing vertical junction devices. Further installations are ongoing to start performing research and produce new experimental findings. This unique system, which is still in its early stage of development, is expected to become a sophisticated world class tool to perform cutting edge experimental research in spintronic and nanoelectronics. (Raman Karthik V)

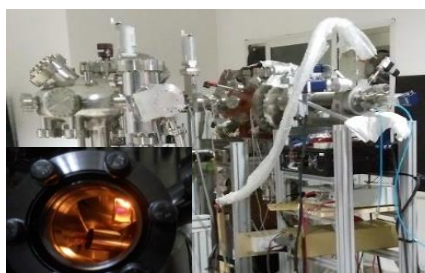


Figure: Setting up of a thin film cluster vacuum system with the capability evaporate ultra clean thin films of metal and oxides (As shown in the inset)

Silent Flocks: Constraints on Signal Propagation Across Biological Groups, Phys Rev Lett *114*, 218101 (2015), highlighted with a Physics Synopsis and selected as Editor's Choice. In collaboration with the group of A Cavagna (Rome), S Ramaswamy co-authored theoretical work showing that the collective dynamics of bird flocks was characterized by a long-wavelength regime displaying travelling density waves, and -- for large orientational inertia -- a short-wavelength regime with propagating spin waves. For large enough inertia they predicted the existence of a range of length scales over which neither density nor spin was propagative, compromising coherent information transfer and coordination for mid-sized flocks. This finding is of potential importance for flock size selection. (Ramaswamy Sriram)

A new perspective on lattice defects

Understanding plastic deformation is essential from both technological and fundamental viewpoints. In crystalline solids, deformation is mediated by lattice defects which begin to flow in response to stress when the solid yields. Yielding in disordered solids is much less understood and there is no universal language which can describe deformation in crystalline and disordered solids alike. In our group we have been working towards such a description. We have found that certain special displacements of atoms, called non-affine

displacements, are related to lattice defects. Indeed, in a crystal, dislocation pairs appear as lowest energy non-affine modes. Defect densities can be tailored by external fields which couple to non-affine displacements. Since non-affine displacements may be defined in both crystalline and disordered matter, our work raises the hope that a unified understanding of deformation may be possible. (Sengupta Surajit)

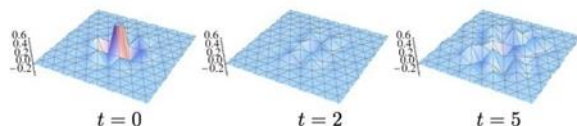


Figure: Decay of defect correlations with time t of a two dimensional triangular lattice in a non-affine field.

Using a combination of experimental and computational techniques, we have determined how the cavity mutant of the protein T4 lysozyme (T4L L99A/G113A/R119P) interconverts between two compact conformations. We find that the barrier is just $\sim 6 k_B T$. (Vallurupalli Pramodh)

The lab is now functional: a) The 700 MHz solution NMR spectrometer equipped with a cryoprobe has been installed successfully. b) The biochemistry/molecular biology wet lab has also been setup. (Vallurupalli Pramodh)

Using a combination of experimental and computational techniques, we have determined how the cavity mutant of the protein T4L interconverts between two compact conformations. We find that the barrier is just $\sim 5 k_B T$. (Vallurupalli Pramodh)

We have shown using NMR experiments that the activation energy required for the cavity mutant of T4L to interconvert between two compact subtle conformations is obtained due to interactions of the protein with the solvent water. (Anusha B Gopalan, Mukul Jain, Vallurupalli Pramodh)

Using a combination of computational (in collaboration with J. Mondal at TCIS) and experimental techniques, we have determined how T4 lysozyme L99A binds hydrophobic molecules like benzene in a buried cavity. (BR Dandekar, S Pandit, J Mondal, Vallurupalli Pramodh)

Members

Sriram Ramaswamy (till 28 Oct 2016), Surajit Sengupta, Smarajit Karmakar, Prasad Perlekar, Anukul Jana, Kanchan Garai, Pramodh Vallurupalli, T.N. Narayanan, Aprotim Mazumder, Karthik V Raman, Vipin Agarwal (from 5/5/15), Jagannath Mondal (from 30/6/15), Raghunathan Ramakrishnan (from 29/4/16), Kalyaneswar Mandal (from 25/5/16), Rama Govindarajan (till 1/7/16), Shubha Tewari (till 24/8/15), Rajat Varma (2/11/15 to 24/11/15), M Barma, N D Hari Dass, S Shenoy.

Research Scholars

Subhajit Dey, Mamta Jotkar, Sharath Jose, S Ravichandran, Sumit Birwa, S Ganga Prasath, Ritabrata Thakur, Rashmi Ramadugu, Debabrata Dhara, Debdeep Mandal, Timir Sil, Subhrajyoti Dolai, Shamasree Ghosh, Aslamuddin, Indrajit Tah, Rajshekhher Das, Bhanu Prasad Bhowmik, Kallol Paul, Ram Gopal, M . Anand, Shiv Narayan Dhuppar, Nikhita Pasnuri, Kesavan P.S., Shubhadeep Pal, Sudeshna Patra, Preethi S. Mathew, Narayan Kunchur, Anish H. Verma, Saurabh Chaudhary, Rayan Chatterjee, Rahul Chajwa, Lokrishi Prawar Dadhichi, Rahul Gupta

Visiting Fellows

Satya Prakash, Laxman Alakonda, Biswajit Santra, K. Praveen Kumar, C Neeraja, Bankanidhi Sahoo, Sitara Roy, Kiran Kumar Tadi, P. M. Sudeep, Santosh Bikarolla, Mathimalar, Sarada Seetharaman, Abhijeet Joshi

Project Staff

Karthik Menon, Arthi Appathurai, Avijit Maiti, Subrata Kuliya, Ramapada Dolai, Sourabh, Pappu Acharya, Rahul, Sambit, Mahopatra, Swapneel Pathak

Scientific Staff

G. Rajalakshmi, Krishna Rao

Visiting Students/Scientists and External Students/Visitors

Anil Palve (Mahatma Phule College, 2015, May-Nov), Sathyavathi Ravulapalli (Visiting Post-Doctoral Fellow, 2015 August-November), Agnish Dev Prusty (Visiting Student from IIT Bhubaneswar, Kapil K. Bhorkar Vineesh T V (CSIR-CECRI) Bharti Kumari (July-November 2015), Arpita Sundaria (October 2015-June 2016)

National and International Involvement

Agarwal Vipin: Member, National Magnetic Resonance Society, India. *Chary KVR*: Elected Council Member of The National Academy of Sciences, India (2016-2018). Member of Fellowship Scrutinizing Group of The National Academy of Sciences, India (2016). Elected as Treasurer and Steering Committee Member, Asian Biophysics Association (2013-present). Elected as Member, International Advisory Board, International Council on Magnetic Resonance in Biological Systems (ICMRBS), (2014-2016).

Member, IUPAB National Committee of INSA (2012-16). Executive Council Member (2008-present) and Advisor (2012-present), Royal Society of Chemistry, West India Section. Fellow of Royal Society in Chemistry (FRSC) (2004-present). Convenor, Indian Science Congress Association, Mumbai Chapter, Mumbai (2010-2015). Member, J.N. Tata Endowment Selection Committee, Mumbai (2005-Present). Member, Management Advisory Committee for the “National Facility for High Field NMR”, TIFR. Member, National Magnetic Resonance Society, India; Chemical Research Society of India, India; Indian Biophysical Society, India; Indian Chemical Society, India; and Member, Society of Biological Chemists. *Govindarajan Rama*: Editorial Board of Physical Review Fluids (from 2016 Jan). Editorial Advisory Board of the Physics of Fluids (till 2015 Dec). *Krishnamurthy M*: Elected as Secretary of the Asian committee on ultra intense laser (ACUIL), Busan Sept 2015. *Madhu P.K*: Convenor, MagRes academic advisory body (MRAAB), TIFR, Hyderabad. Head: Research, finance, and administration, TCIS, Hyderabad. Editorial board member of Journal of Magnetic Resonance. Editorial board member of Solid State Nuclear Magnetic Resonance. Editorial board member of Journal of Biomolecular NMR. International advisor, European School on Solid-State NMR. Member, MAC, National Facility for High-Field NMR, TIFR. Member, Board of Trustees of EUROMAR, European Magnetic Resonance Meeting. Scientific programme committee member, EUROMAR, Prague, July 1-5, 2015. Member, National Magnetic Resonance Society, India. *Narayanan T.N*: Associate Editor of Carbon-Based Materials – Frontiers in Materials (2015). National Organizing Committee member of 4th International Conference, COCHIN NANO-2016, to be held at Kochi during February 20-23, 2016. (International Program Committee Member of EMN Meeting on Electrocatalysis, Energy Materials Nanotechnology, February 15-19, 2016 Orlando, USA. *Raman Karthik V*: International Advisory member, SPIN-OS 2016. *Ramaswamy Sriram*: Member, Editorial Committee, Annual Review of Condensed Matter Physics, 2011-2015. Member, Editorial Board, Advances in Physics, since June 2007. Member, Editorial Board, European Physical Journal E, since Dec 2009. Member, Editorial Board, Journal of Statistical Mechanics: Theory and Experiment, since January 2004. Member, Editorial Advisory Board, Soft Matter, since May 2008. Member, Editorial Committee, Annual Review of Condensed Matter Physics, 2011-2015. Higgs Centre Associate, University of Edinburgh, 2012- present. J C Bose Fellowship of the Department of Science and Technology, India; Research grant: Rs 10,00,000 per year; 2007-2017 (renewed 2012). *Valurupalli Pramodh*: Reviewed articles for: Proceedings of the National Academy of Sciences (USA), Journal of Biomolecular NMR. *Jana Anukul*: Member of the Chemistry Subject Board of TIFR Mumbai. Member of infrastructure and services (space, electricity, AC, furniture, telecom, lab safety, security, maintenance) committee of the Narsingi campus of TCIS Hyderabad. Member of seminars and colloquia committee of TCIS Hyderabad. *Mondal Jagannath*: Reviewed manuscripts for Journal of Physical Chemistry, Journal of Chemical Physics, Journal of Molecular Liquids.

Visits

Agarwal Vipin: Monthly visits to TIFR Mumbai for experimental measurements. *Barma Mustansir*: Visited Rudolf Peierls Centre for Theoretical Physics, University of Oxford for a month (May 2015). *Chary KVR*: SP Pune University, Pune held on February 26, 2015 to deliver an invited talk; State Key Laboratory of Bio-organic and Natural Product Chemistry, Shanghai Institute of Organic Chemistry, Chinese Academy of Science on Friday, May 8, 2015 to deliver an invited talk; Hongzhou, China, from May 9-12, 2015 to attend Asian Biophysics Association Conference to deliver a talk and Chair a session; SGPGIMS, Lucknow, on June 23, 2015 to attend National Workshop on “NMR in Biological Systems”; University of Wisconsin, on August 4, 2015 to deliver an invited talk; Structural Biology Initiative CUNY Advanced Science Research Center (ASRC) Monday, August 10, 2015 to deliver an invited talk; National Institutes of Health, National Heart, Lung, and Blood Institute, Bethesda, Maryland, USA, on August 17, 2015 to deliver an invited talk; Nano Cell, University of Linz, Austria, on November 23, 2015 to deliver an invited talk; *Govindarajan Rama*: Kavli Institute of Theoretical Physics, Santa Barbara, University of Oregon, for discussions about the OMM project; *Jana Anukul*: Saarland University, Germany, 28th September - 09th October, 2015. *Madhu PK*: University of Leipzig, Leipzig, June 22-July 12, 2015; ENS, Lyon, France, October 26-29, 2015. EUROMAR, Prague, Czech Republic, July 5-10, 2015. Emerging NMR Methods, IISc, Bangalore, July 16-17, 2015. 1st Western Region Structural Biology Meet, IIT Bombay, Mumbai, India, August 1, 2015. ISMAR, Shanghai, China, August 16-21, 2015. Indo-German Workshop on Molecular Amplification, Tutzing, Munich, Germany, October 20-23, 2015. NMR Meets Biology, Kerala, India, January 14-19, 2016; *Mondal Jagannath*: Columbia University, USA (Collaboration with research group of Prof. Bruce J. Berne); University of California at Berkeley (Collaboration with research group of Prof. Niren Murthy). *Raman Karthik V*: PACIFICHEM Conference, USA December 2015. *Sengupta Surajit*: University of Dusseldorf, July 1 - July 11, 2015; Okinawa Institute of Science and Technology, April 25 - May 9, 2015; Institute of Industrial Science, University of Tokyo, May 8, 2015.

Invited Talks

Agarwal Vipin:

- Solid-State NMR as a tool for structural characterization of biomolecules and materials. 14th September 2015, DCS, TIFR Mumbai, India.
- Observation of long-range H^N-H^N contacts in non-deuterated proteins at 90 kHz MAS. NMR Meets Biology, 14th-19th January, Vayalar, Kerala, India. (2016)

Chary K.V.R.:

- Structure and Dynamics of Intrinsically Ordered and
- Disordered Proteins by NMR: The state-of-the-art.” at Indian Science Congress 2015, Kalina Campus, Mumbai University, on Monday, January 5, 2015
- Key-note address on, “Bioinformatics and NMR Spectroscopy”, at Lecture-Cum-Workshop on “Application of Bioinformatics in Drug Designing”, held at DY Patil University, on Thursday, January 22, 2015.

- “NMR At The Interface Of Physics, Chemistry And Biology/Biotechnology”, at Bio-Integration 2015 “Integrating Chemistry and Physics in Rediscovering Biotechnology” A National Seminar under Faculty QIP programme of SPPU, Pune held on Thursday, February 26, 2015.
- Structure and Dynamics of UV inducible protein (UVI31+) from *Chlamydomonas reinhardtii* that exhibits RNA and DNA endonuclease activity”, during the Asian Biophysics Association Conference, held at the Hongzhou, China, from May 9-12, 2015.
- Echoes in NMR”, at National Workshop on “NMR in Biological Systems”, held at SGPGIMS, Lucknow, on June 23, 2015.
- NMR of Nucleic Acids”, at National Workshop on “NMR in Biological Systems”, held at SGPGIMS, Lucknow, on June 25, 2015.

- Evolution through Structure”, at National Workshop on “NMR in Biological Systems”, held at SGP GIMS, Lucknow, on June 25, 2015
 - An unusual calcium binding protein from *Entamoeba histolytica*”, DCS Annual Talks, held at TIFR, on November 4, 2015.
 - Invited talk on, “ β -crystallins: Intrinsic Order & Disorder”, at the International Conference of FAOBAB, on Sunday, November 29, 2015.
- Garai Kanchan:**
- Invited speaker at Owls 2016 international conference.
- Govindarajan Rama:**
- Keynote lecture, IUTAM Symposium on Helicity, Structures and Singularity in Fluid and Plasma Dynamics, Venice, April 2016.
 - GEOFLO16: Two phase continuum models for geophysical particle-fluid flows, MPI-PKS Dresden, March 2016. (Two lectures)
 - Complex Systems Approach to Self-Organization (CSAS 2016), IIT Madras, Chennai, February 2016.
- Invited talks in Indian meetings:**
- Science Popularisation Programme, Madras Music Academy, Chennai, February 2016. The audience was about a 1000 people.
 - Subir Kar Plenary Lecture, 42nd National Fluid Mechanics and Fluid Power Conference, NITK Surathkal, December 2015.
- Jana Anukul:**
- Rational design for the syntheses of multiple bonded compounds involving heavier Group 14 elements and their reactivity" at Banaras Hindu University for DST-SERB, PAC meeting. May 2, 2015
 - Hydrocarbon Soluble Low-Valent Low-Coordinate Silicon Enriched Core: Elegant Approach Towards Syntheses of Heavier Group 14 Molecular Cluster" at INSA for INSPIRE interview. May 25, 2015
 - Functionalized Low-Valent Low-Coordinate Heavier Group-14 Chemistry" at Department of Chemical Sciences Annual Talks 2015, TIFR Mumbai.
- Karmakar Smarajit:**
- XXVII IUPAP Conference on Computational Physics CCP2015, Guwahati 2-4th Dec. 2015.
 - Compu-2016: Conference on Complex Fluids, IISER-Pune, 2-4th, January 2016.
 - Discussion Meeting on Glass Formers and Glasses, JNCASR, Bangalore, April 29 - 30 (2016), JNCASR.
- Krishnamurthy M:**
- Neutral atom acceleration, First Newton-Bhabha Workshop on High Field Science, March 1-3, 2016, Kerala, India.
 - Acceleration of neutral atoms, positive and negative ions with novel targets" at the International Conference on Extreme Light (ICEL) Bucharest, Romania 2015.
 - Ionisation and Recombination in NanoClusters for neutral atom acceleration, Invited talk at Gordon Research conference on Clusters and Nanostructures, Barcelona (2015).
 - Intense laser matter interaction, talk given at BITS Hyderabad on Science day, Hyderabad (2015).
- Madhu P.K:**
- Heteronuclear spin decoupling in solid-state NMR: Towards higher efficiency and unification, Emerging NMR methods, IISc, Bangalore, July 16-17, 2015
 - Structure, function, and dynamics of biomolecules with solid-state NMR, 1st western region structural biology meet, IIT Bombay, Mumbai, August 1, 2015
 - Heteronuclear spin decoupling in solid-state NMR: Towards higher efficiency and unification, ISMAR (International Society of Magnetic Resonance), Shanghai, China, August 16-21, 2015
 - Chemistry and biophysics of amyloid oligomers, Indo-German workshop on molecular amplification, Tutzing, Munich, Germany, October 20-23, 2015
 - Spin decoupling in NMR, NMR meets Biology, Kerala, India, January 14-19, 2016
 - Chair of a session, EUROMAR, Prague, Czech Republic, July 5-10, 2015
 - Chair of a session, ISMAR, Shanghai, China, August 16-21, 2015
- Mazumder Aprotim:**
- "Scientific talk in the Optics Within Life Sciences (OWLS) meeting, TIFR, Mumbai (March, 2016)
 - "Scientific seminar in Aurora College, Hyderabad, India (August, 2015)
 - "Scientific seminar in CDFD, Hyderabad, India (April, 2015)
- Mondal Jagannath:**
- How does a kinase inhibitor withstands gatekeeper residue Mutation", DCS annual talks, Tata Institute of Fundamental Research, Mumbai, 4-6 November, 2015.
 - "Role of osmolytes on conformational propensities of polymer", Soft Matter Young Investigators Meet, Pondicherry, 17-20 December, 2015.
- Narayanan T.N:**
- Recent Advances in Carbon Nanotechnology, T. N. Narayanan, St. Teresas College, Kochi, India, February 24th 2016
 - Tuning the Electrochemical and photophenomena of Atomic Layers – A *Mix and Match* Approach, T. N. Narayanan, 4th International Conference on Frontiers in Nanoscience and technology [Cochin Nano -2016] February 20-23, 2016, Kochi, India.
 - Engineering Atomic Layers for Efficient Sensors, NUCRET Boot Camp Hands-on Workshop Series Sensors: State-of-the-Art Science & Technology – Hands on Design of a Biosensor 2015, November 10-12, 2015, Northeastern University, Boston, USA
 - Recent Trends in Carbon Nanotechnology, National Conference on “Recent Developments in Physics”, NSS College, Ottapalam, Kerala, 19-20 October, 2015.
 - Department of Science and Technology “INSPIRE SCIENCE CAMP” lectures for XIth class students having their SSC score above 93.2% in board examination, Dayanand Science College, Latur, Maharashtra, India, September 18-22, 2015.
 - Engineering the Atomic Layers Interfaces for Novel Solids, Institute of Physics, Bhubaneswar, India, September 14, 2015.
 - New solids with novel interfaces with tunable properties, T. N. Narayanan, School of Chemical Sciences, Tata Institute of Fundamental Research, Mumbai, India, March 2, 2015.
 - New solids with novel interfaces for energy technology ,T. N. Narayanan, International Conference on Energy Harvesting, Storage and Conversion (IC-EEE), Kochi, India February 5-7, 2015.
 - New Trends in Energy and Water Technologies – A Nanotechnology Approach, T. N. Narayanan, National Seminar on Advanced Materials for Energy and Environment” (NSMEE-2015), Vimala College, Thrissur, February 9-10, 2015.
 - Fascinating Carbon Science”, T. N. Narayanan, Sri Vyasa NSS College, Wadakkanchery, Kerala February 4, 2015
- Perlekar Prasad:**
- Three and Two dimensional binary mixture turbulence IUPAP Conference on Computational Physics, IIT Guwahati, 25 December 2015
- Raman Karthik V:**
- Interface-assisted molecular spintronics, PAIFICHEM 2015, December 2015 (USA)
- Ramaswamy Sriram:**
- Invited speaker, SFB on Collective Behavior of Soft and Biological Matter, Hohegeiss, Germany, Nov 2015.
 - Invited speaker, Soft Matter Gordon Research Conference, 10-14 Aug 2015

- Invited speaker, Quantitative Biomedicine Symposium, Warwick Univ, May 2015
 - Invited speaker, (i) Active Matter Conference, Suzhou, China and (ii) Spring School on Active Matter, Beijing Computational Science Research Centre, May 2015
 - Invited lecture, Cell Mechanics Conference, Raman Research Institute, Bangalore, 24-26 April 2015
- Sengupta Surajit:**
From crystal to glass: relating plastic deformation to amorphization of a crystalline solid, Growing Length Scale Phenomena (GLSP) in Condensed Matter Physics, JNCASR, Bangalore October 8-10, 2015.

Vallurupalli Pramodh:

Invited talk at the NMR meets Biology Conference Jan 14-16, Kerala, India - Using NMR to Study Conformational Exchange Involving Transiently Populated (Invisible) Minor Conformers of Proteins.

Conferences Organized by the Centre

- National Poster Symposium on Advances in Chemical Sciences, jointly Organized by Royal Society of Chemistry – India Deccan Local Section, India & Tata Institute of Fundamental Research, Centre for Interdisciplinary Sciences, Hyderabad (December 12, 2015).
- XXVII IUPAP Conference on Computational Physics CCP2015, Guwahati 2 - 4th Dec. 2015
- Compu-2016: Conference on Complex Fluids, Hyderabad, 12-14th, December 2016, Session Organizer for Granular and Glassy systems
- Third Annual TCIS Summer Research Symposium, 1st July, 2016, TCIS, TIFR, Hyderabad.
- First Newton-Bhabha Workshop On High Field Science, March 1-3, 2016, Kerala, India.
- NMR Meets Biology, Alleppey, Kerala, January 14-19, 2016.
- Spinodal decomposition in the inverse cascade of two dimensional, binary fluid turbulence” European Turbulence Conference, TU Delft, The Netherlands 25-28 August 2015
- Two dimensional turbulence in symmetric binary mixtures, ICTS Discussion Meeting, Bangalore. 6-8 April 2015
- Co-organiser, Workshop on “Active Liquids”, 21 – 25 September 2015, Lorentz Center, University of Leiden, Netherlands (on critical issues in the statistical mechanics and dynamics of collections of self-driven particles)

Non-DAE Research Projects

Chary K.V.R.:

- The DST-DISRTI joint research project (Australia-India Strategic Res. Fund (AISRF)), DST, 2015-17.

Govindarajan Rama:

- Project Title : Rotating and Curved Boundary Layer Instabilities. Duration : 4 years (from 1.2.2013 to 31.1.2017), Indo-French grant.
- Project Title: Coupled Physical processes in the Bay of Bengal and Monsoon Air- Sea Interaction Duration : 3 years (from 4.4.2015 to 3.4.2018), OMM grant.

Jana Anukul :

- Project Title: Design and utility of appropriate anionic ligands for the syntheses and mutual conversion of multiple bond of heavier Group 14, AvH Foundation
- Project Title: Rational design for the syntheses of multiple bonded compounds involving heavier Group 14 elements and their reactivity, DST-SERB

- Project Title: Syntheses and Reactivities of Compounds Involving Formal Zero Oxidation State of Mono- and Di-Nuclear Group 14 Elements, CSIR

Madhu P.K.:

- Danish-Indian collaboration programme entitled “Solid-state NMR methods and applications”
- Indo-French IFCPAR/CEFIPRA project entitled “Novel nanocatalysts synthesis guided by DNP NMR”

Mondal Jagannath:

- Jagannath Mondal, 'Mechanistic Investigation anti microbial peptides in action using large-scale computer simulations', Extreme Science and Engineering Discovery Environment (XSEDE), USA for Computational allocation (allocation provided in San diego Supercomputer), 1 year (July 2015-June 2016)
- Jagannath Mondal, Ramanujan research grant, DST/SERB, 5 years.

Mote Kaustubh R.:

- Investigator: Kaustubh R. Mote Title: Structural and Mechanistic Characterization of the Mitochondrial Pyruvate Carrier Funding Agency: Department of Sciences and Technology, India (INSPIRE Faculty Award); Duration: 2015-2020

Narayanan T.N.:

- DST-Fast Track Young Scientist Research Grant - (2014-2017) Topic: “2-dimensional nanosheets based ultra-low density sponges for energy and environmental applications”.

Raman Karthik V.:

- Ramanujan Fellowship SERB, DST 2013-18
- MPI-DST Mobility grant 2015-18
- Ramaswamy Sriram: J C Bose Fellowship, DST, 2007-present (renewed 2012)

Surajit Sengupta:

- Surajit Sengupta and EU collaboration, DIONICOS: Dynamics of and in Complex Systems, European Commission, Feb 2014 to Feb 2017.





School of Technology and Computer Science

Visiting Students Research Program



School of Technology and Computer Science

Algorithms and Complexity

Coordination Complexity

In this work, a quantity called coordination complexity was studied. In a distributed optimization problem, the information defining a problem instance is distributed among n parties, who need to each choose an action, which jointly will form a solution to the optimization problem. The coordination complexity represents the minimal amount of information that a centralized coordinator, who has full knowledge of the problem instance, needs to broadcast in order to coordinate the n parties to ensure that they perform nearly optimally. Upper bounds were obtained on the coordination complexity of a problem imply the existence of good jointly differentially private algorithms for solving that problem, which in turn are known to upper bound the price of anarchy in certain games with dynamically changing populations. Also the coordination complexity for the problem of computing a many-to-one matching in a bipartite graph was fully characterized by giving almost matching lower and upper bounds. The upper bound, in fact, extends much more generally, to the problem of solving a linearly separable convex program. Using a different upper bound technique, we bound the coordination complexity of coordinating a Nash equilibrium in a routing game, and of computing a stable matching (R. Cummings, K. Ligett (California Institute of Technology, USA), J. Radhakrishnan (TIFR), A. Roth and Z. Steven (University of Pennsylvania, USA)).

Equilibrium Computation in Atomic Splittable Routing Games

In game theory, routing games are a popular class of games, widely used to model congestion in networks, such as road networks. Nonatomic routing games, where each user (or player) in the game is infinitesimal, are known to be potential games, and hence the equilibrium is

easily computable via convex programming. On the other hand, atomic splittable routing games, where some players control a large amount of traffic, are known to be much more complex. The goal of the project is to obtain efficient algorithms for computing the equilibria — stable states in the game, where each player simultaneously minimizes its delay. While previous work gives an algorithm for the case where congestion on each edge is a linear function of traffic, we extend this in a limited setting to quadratic functions. Our algorithm involves proving a number of new properties of equilibria in these games, which may be of independent interest (U. Bhaskar and P.R. Lolakapuri (TIFR)).

Hardness for Signaling in Bayesian Games

A Bayesian game is an incomplete information game, where the players are unsure of the payoff associated with each strategy. Typically, they are aware of a distribution over a set of payoffs, and play the game with the goal of minimizing their expected cost. Our work addresses the problem of selectively revealing information about the payoffs, in order to influence the players towards a desired outcome. The problem was earlier studied for the fundamental case of two-player zero-sum games, where the problem was shown to be hard on average ["On the Hardness of Signaling", FOCS 2014]. We give improved hardness results (NP-hardness, as compared to average-case hardness shown earlier) as well as good approximation algorithms for some cases of this problem. A significant contribution of our work is to use a linear programming perspective for this problem, which makes obtaining our hardness results simpler as compared to earlier approaches (Y. Cheng (University of Southern California, USA), Y.K. Ko (Princeton University, USA), C. Swamy (University of Waterloo, Canada) and U. Bhaskar (TIFR)).

Marton Bound with Common Message

Extending previous work, a stronger version of

the Marton Bound was derived in the classical setting of one sender and two receivers. This one-shot bound incorporates a common message that must be transmitted to both receivers (J. Radhakrishnan, P.G.D. Sen (TIFR) and N.A. Warsi (Oxford University, United Kingdom)).

On Polynomial Approximations to AC^0

We make progress on some questions related to polynomial approximations of AC^0 . It is known, by works of Tarui (*Theoret. Comput. Sci.* 1993) and Beigel, Reingold, and Spielman (*Proc. 6th CCC* 1991), that any AC^0 circuit of size s and depth d has an ϵ -error probabilistic polynomial over the reals of degree $(\log(s/\epsilon))^{O(d)}$. We improve this upper bound to $(\log s)^{O(d)} \cdot \log(1/\epsilon)$, which is much better for small values of ϵ . We give an application of this result by using it to resolve a question posed by Tal (ECCC 2014): we show that $(\log s)^{O(d)} \cdot \log(1/\epsilon)$ -wise independence fools AC^0 , improving on Tal’s strengthening of Braverman’s theorem (*J. ACM* 2010) that $(\log(s/\epsilon))^{O(d)}$ -wise independence fools AC^0 . Up to the constant implicit in the $O(d)$, our result is tight. As far as we know, this is the first PRG construction for AC^0 that achieves optimal dependence on the error ϵ .

We also prove lower bounds on the best polynomial approximations to AC^0 . We show that any polynomial approximating the OR function on n bits to a small constant error

must have degree at least $\tilde{\Omega}(\sqrt{\log n})$. This result improves exponentially on a recent lower bound demonstrated by Meka, Nguyen, and Vu (arXiv 2015) (S. Srinivasan (Indian Institute of Technology, Mumbai) and P. Harsha (TIFR)).

Partition Bound is Quadratically Tight for Product Distributions

Let $f : \{0,1\}^n \times \{0,1\}^n \rightarrow \{0,1\}$ be a 2-party function. For every product distribution μ on $\{0,1\}^n \times \{0,1\}^n$, we show that

$$CC_{0.49}^\mu(f) = O\left(\left(\log \text{prt}_{1/8}(f) \cdot \log \log \text{prt}_{1/8}(f)\right)^2\right),$$

where $CC_\epsilon^\mu(f)$ is the distributional communication complexity of f with error at most ϵ under the distribution μ and $\text{prt}_{1/8}(f)$ is the *partition bound* of f , as defined by Jain and Klauck [*Proc. 25th CCC*, 2010]. We also prove a similar bound in terms of $IC_{1/8}(f)$, the *information complexity* of f , namely,

$$CC_{0.49}^\mu(f) = O\left(\left(IC_{1/8}(f) \cdot \log IC_{1/8}(f)\right)^2\right)$$

The latter bound was recently and independently established by Kol [*Proc. 48th STOC*, 2016] using a different technique.

We show a similar result for query complexity under product distributions. Let $g : \{0,1\}^n \rightarrow \{0,1\}$ be a function. For every bit-wise product distribution μ on $\{0,1\}^n$, we show that

$$QC_{0.49}^\mu(g) = O\left(\left(\log \text{qprt}_{1/8}(g) \cdot \log \log \text{qprt}_{1/8}(g)\right)^2\right),$$

where $QC_\epsilon^\mu(g)$ is the distributional query complexity of f with error at most ϵ under the distribution μ and $\text{qprt}_{1/8}(g)$ is the *query partition bound* of the function g .

Partition bounds were introduced (in both communication complexity and query complexity models) to provide LP-based lower bounds for randomized communication complexity and randomized query complexity. Our results demonstrate that these lower bounds are polynomially tight for *product* distributions (R. Jain (National University of Singapore, Singapore), P. Harsha and J. Radhakrishnan (TIFR)).

Polynomial Approximations Over $\mathbb{Z}/p^k\mathbb{Z}$

We study approximation of Boolean functions by low-degree polynomials over the ring $\mathbb{Z}/p^k\mathbb{Z}$. More precisely, given a Boolean function $F : \{0,1\}^n \rightarrow \{0,1\}$, define its k -lift to be $F_k : \{0,1\}^n \rightarrow \{0, p^{k-1}\}$ by $F_k(x) = p^{k-F(x)} \text{ mod } p^k$. We consider the fractional agreement of F_k with degree d polynomials from $\mathbb{Z}/p^k\mathbb{Z}[x_1, \dots, x_n]$, which we call $\gamma_{d,k}(F)$.

Our results are the following:

- Power of this model: We observe that as k

increases, $\gamma_{d,k}(F)$ cannot decrease. We give two kinds of examples where $\gamma_{d,k}(F)$ actually increases. The first is an infinite family of functions F such that $\gamma_{2,2}(F) - \gamma_{2,1}(F) \geq \Omega(1)$. The second is an infinite family of functions F such that $\gamma_{d,1}(F) \leq \frac{1}{2} + o(1)$ — as small as possible — but $\gamma_{d,3}(F) \geq \frac{1}{2} + \Omega(1)$.

- Limitations of this model: We show that the Majority function Maj_n satisfies

$$\gamma_{d,k}(\text{Maj}_n) \leq \frac{1}{2} + \frac{O(d)}{\sqrt{n}}$$

irrespective of the value of k , strengthening classical results of Szegedy and Smolensky. Previous results only yielded

$$\gamma_{d,k}(\text{Maj}_n) \leq \frac{1}{2} + \frac{O(dp^k)}{\sqrt{n}} \text{ for } k > 1.$$

We observe that the model we study subsumes the model of *non-classical polynomials* and in particular, proving limitations on our model also proves upper bounds on the agreement of non-classical polynomials with Boolean functions. In particular, we can use our second result to show that no non-classical polynomial of degree d can agree with Maj_n on more than a $\frac{1}{2} + \frac{O(d)}{\sqrt{n}}$

fraction of its inputs, confirming a conjecture of Bhowmick and Lovett [*In Proc. 30th Computational Complexity Conf., pages 72-87, 2015*].

Our result also strengthens results about *weak representations* of the Majority function modulo large prime powers (A. Bhrushundi (Rutgers University, USA), S. Srinivasan (Indian Institute of Technology, Mumbai) and P. Harsha (TIFR)).

Popular Edges and Dominant Matchings

Given a bipartite graph G with strict preference lists and an edge e^* , we ask if there exists a popular matching in G that contains the edge e^* . This is called the *popular edge* problem. A matching M is popular if there is no matching M' such that the vertices that prefer M' to M outnumber those that prefer M to M' . It is known that every stable matching is popular; however G may have no stable matching with

the edge e^* . We identified another natural subclass of popular matchings called “dominant matchings” and showed that if there is a popular matching that contains the edge e^* , then there is either a stable matching that contains e^* or a dominant matching that contains e^* . This enables us to design a linear time algorithm for the popular edge problem. When all the preference lists are complete, we showed an $O(n^3)$ algorithm to find a popular matching containing a given set of edges or report that none exists, where n is the number of vertices in G (Á. Cseh (Technical University of Berlin, Germany) and T. Kavitha (TIFR)).

Popular Half-integral Matchings

We considered the *min-cost* popular matching in a bipartite graph G where there is a cost assigned to each edge in G . As before, every vertex ranks its neighbours in a strict order of preference. While there is a simple linear time algorithm to compute a maximum-size popular matching, no polynomial time algorithm is known for computing a min-cost popular matching in G . We considered the following generalization of a popular matching called a popular *half-integral* matching: this is a point $\vec{x} = (M_1 + M_2)/2$, where M_1 and M_2 are the 0-1 edge incidence vectors of matchings in G , such that \vec{x} satisfies popularity constraints. We show that every popular half-integral matching is equivalent to a stable matching in a larger graph G^* . This implies a polynomial time algorithm for the min-cost popular half-integral matching problem in G (T. Kavitha (TIFR)).

Rényi Information Complexity and an Information Theoretic Characterization of the Partition Bound

We introduce a new information-theoretic complexity measure for 2-party functions, called Rényi information complexity. It is a lower-bound on communication complexity, and has the two leading lower-bounds on communication complexity as its natural relaxations: (external) information complexity and logarithm of partition complexity. These two lower-bounds had so far appeared conceptually quite different from each other, but we show that they are both obtained from Rényi information complexity using two different, but natural relaxations. We also show that if both

the above relaxations are simultaneously applied to Rényi information complexity, we obtain a complexity measure that is lower-bounded by the (log of) relaxed partition complexity, a complexity measure introduced by Kerenidis et al. (FOCS 2012). We obtain a sharper connection between (external) information complexity and relaxed partition complexity than Kerenidis et al., using an arguably more direct proof. Further understanding Rényi information complexity (of various orders) might have consequences for important direct-sum problems in communication complexity, as it lies between communication complexity and information complexity. (M. Prabhakaran (University of Illinois at Urbana-Champaign, USA) and V. Prabhakaran (TIFR)).

Small Error Versus Unbounded Error Protocols in the NOF Model

Communication protocols that make use of random coins are fundamental objects of study in theoretical computer science. A basic question of interest is to understand the power of protocols as the requirements on their error probability is varied. The typical requirement, in general for randomized algorithms, is that the error probability be bounded away from $1/2$ (which is the error probability when guessing the answer to a boolean problem at random), say at most $1/3$. We know several natural problems for which this error requirement is still too strict in the sense that the parties involved in the protocol still need to communicate too many bits for solving a problem.

We investigate protocols where the error requirements are further relaxed. In particular, we compare two kinds of protocols: first class, called small error, where the error is at most $1/2 - \epsilon(n)$, where $\epsilon(n)$ is a small function of n , the size of the problem to be solved. $\epsilon(n)$ can be any function that is sub-exponentially small in n . In The second class of protocols are the most relaxed protocols called unbounded error, where $\epsilon(n)$ just needs to be greater than 0. Relatively recently (in 2007/08), two groups of researchers established that unbounded error protocols are strictly more powerful than small error ones in 2-party communication games. However many settings require a much larger number of parties. A very recent and involved work of Sherstov (2014) shows that unbounded error protocols remain more efficient than small error ones

when the number of communicating parties grows as a small function of n , i.e. at most $\log \log n$. In this work we show the first separation of powers when the number of parties grow as fast as $\log n$. Moreover our arguments are simpler and our bounds sharper than previous bounds, even when the number of players are as small as 3.

Finally, we derive some striking consequences of our analysis of multi-party communication protocols for small depth boolean circuits (this work is under submission and is a joint work of A. Chattopadhyay and N.S. Mande (TIFR)).

Towards Better Separation Between Deterministic and Randomized Query Complexity

We show that there exists a Boolean function F which gives the following separations among deterministic query complexity ($D(F)$), randomized zero error query complexity ($R_0(F)$) and randomized one-sided error query complexity ($R_1(F)$): $R_1(F) = \tilde{O}(\sqrt{D(F)})$ and $R_0(F) = \tilde{O}(D(F)^{3/4})$. This refutes the conjecture made by Saks and Wigderson that for any Boolean function f , $R_0(f) = \Omega(D(f)^{0.753\dots})$. This also shows widest separation between $R_1(f)$ and $D(f)$ for any Boolean function. The function F was defined by Göös, Pitassi and Watson who studied it for showing a separation between deterministic decision tree complexity and unambiguous non-deterministic decision tree complexity. Independently of us, Ambainis et al. proved that variants of the function F yield an optimal (quadratic) separation between $D(f)$ and $R_0(f)$, and polynomial separation between $R_0(f)$ and $R_1(f)$. Viewed as separation results, our results are subsumed by those of Ambainis et al. However, while the functions considered in the work of Ambainis et al are different variants of F , in this work we show that the original function F itself is sufficient to refute the Saks-Wigderson conjecture and obtain widest possible separation between the deterministic and one-sided error randomized query complexity.

We also show a lower bound of $\tilde{\Omega}(n^{3/4})$ on the

zero-error randomized query complexity of the *original* Göös, Pitassi and Watson pointer function on $\Theta(n \log n)$ bits; our lower bound is optimal up to a factor of poly $\log n$. This result completes our understanding of deterministic, bounded-error randomized, and zero-error randomized query complexities of this pointer-function (S. Mukhopadhyay, J. Radhakrishnan and S. Sanyal (TIFR)).

Applied Probability

Dynamic Portfolio Credit Risk Modeling

We considered a portfolio of credit risks and modeled their risk evolution as a function of time. Tail risk is the key concern in performance measurement of such portfolios. We conducted large deviations analysis to identify the key drivers of tail risk. In addition, we used the insights gained to develop provably efficient Monte Carlo based importance sampling techniques (S.K. Juneja (TIFR)).

Dynamic Spatial Birth and Death Processes - Exact Simulation and Large Deviations of Stationary Probabilities

We continued with our ongoing research on spatial birth and death processes. We extended our analysis to area interaction and Strauss processes. For these stochastic processes, we developed exact simulation techniques and conducted large deviations analysis of certain rare events (S.K. Juneja, S.B. Moka (TIFR) and M. Mandjes (University of Amsterdam, The Netherlands)).

To Lounge or to Queue up

We considered queueing systems with fixed number of customers as well as those where customers that arrive as an external stochastic process. Each customer's goal was to get served from a service facility. We assumed that customers first reside in a lounge area before strategically deciding to join the queue to the service facility. In this framework we identified the unique Nash equilibrium queue arrival strategy followed by the customers. We computed variety of structural properties of this equilibrium including the price of anarchy of the system (S.K. Juneja (TIFR) and D. Manjunath (Indian Institute of Technology, Mumbai)).

Information Theory and Cryptography

Secure Multiparty Computation

The goal of secure multiparty computation is to carry out computations on inputs distributed among two or more parties, so as to provide each of them with no more information than what the respective inputs and outputs reveal to each party. This models several practical settings where mutually distrusting parties need to collaborate, e.g., private auctions, privacy-preserving data mining, electronic voting, to name a few. The aim of this ongoing project is to derive optimal protocols for secure multiparty computations. Finding good lower bounds on communication and randomness requirements for secure computation is a long standing open problem. We derived new general lower bounds for three party secure computation using novel information theoretic techniques. Based on a generalization of the concept of common information (which is of broader interest), we developed state-of-the-art upper bounds on rate of secure two-party sampling from distributed sources and channels, and the best known upper bound on the rate of multiparty sampling from a setup using public discussion (B. Dey, M. Mishra (Indian Institute of Technology, Mumbai), S. Diggavi (University of California, Los Angeles, USA), M. Prabhakaran (University of Illinois at Urbana-Champaign, USA) and V. Prabhakaran, D. Data (TIFR)).

Verification of Concurrent Programs

Abstraction-driven Concolic Testing: Concolic testing is a promising method for generating test suites for large programs. However, it suffers from the path-explosion problem and often fails to find tests that cover difficult-to-reach parts of programs. In contrast, model checkers based on counterexample-guided abstraction refinement explore programs exhaustively, while failing to scale on large programs with precision. In this we, we developed a novel method that iteratively combines concolic testing and model checking to find a test suite for a given coverage criterion. If concolic testing fails to cover some test goals, then the model checker refines its program abstraction to prove more paths infeasible, which reduces the search space for concolic testing. We have implemented our method on top of the concolic-testing tool CREST and the model checker CpaChecker. We

evaluated our tool on a collection of programs and a category of SvComp benchmarks. In our experiments, we observed an improvement in branch coverage compared to CREST from 48% to 63% in the best case, and from 66% to 71% on average (A. Gupta (TIFR)).

Fence Synthesis Using Happens-before Formulas

Weak memory adds many behaviors in a concurrent program that are unexpected by the most programmers. The weak memory behaviors can be removed by placing memory fences in the programs. For performance, one should only add minimal number of fences such that there are no unwanted behaviors. In this paper, we present a novel method for synthesizing fences that disallow behaviors that are due to weak memory and violate a safety property of a straight line concurrent program. Our method constructs a formula that encodes all violating executions of the program under weak memory and iteratively constructs a happens-before formula over memory events that represents memory event orderings that leads to error for some inputs. Afterwards, our method searches for event cycles encoded in the formula and *optimally* introduces fences such that the cycles are removed from the program behavior. We have implemented the above method. Our tool supports TSO, PSO, and RMO memory models. We applied our tool on benchmarks, and compared the performance with other fence synthesis tools (A. Gupta (TIFR)).

Logic in Computer Science

Computability and Self-application

The class of functions computable by any programming framework is crucially dependent on the varieties of self application that are permitted by the programming primitives. Our analysis of the inter-relationships between notions of self-application and computability, with mechanisms for either enhancing or restricting self-application, leads to subtle variations in the kind of impossibility results that be derived in a basic programming model and also reveal limitations in its resultant expressive power (N. Raja (TIFR)).

Diagram Logic for Ambient Calculus

The Ambient Calculus serves as an analytical

model for the systematic investigation of prototypes of novel security protocols, and helps in uncovering weaknesses in security policies and their implementations. We have formalized a new diagram logic for reasoning in the ambient calculus, where the diagrammatic framework enhances the effectiveness of the underlying calculus in validating security policies and in simplifying the automation of verification proofs for complex protocols (N. Raja (TIFR)).

Separation Logic for Software Testing

The ideal goal of any Program Logic is to develop logically correct programs without the need for predominant debugging. Separation Logic is considered to be an effective Program Logic for proving programs that involve pointers. Reasoning with pointers becomes difficult especially due to the way they interfere with the modular style of program development. We extend Separation Logic and the notion of separating conjunction with an appropriate set of new axioms and assertions to deal with software testing of programs with pointer manipulating commands (A.K. Singh and N. Raja (TIFR)).

Quantum Information Theory

More on a Trace Inequality in Quantum Information Theory

It is known that for a completely positive and trace preserving (cptp) map N , $\text{Tr} \exp \{ \log \sigma + N^\dagger [\log N(\rho) - \log N(\sigma)] \} \leq \text{Tr} \rho$ when ρ , σ , $N(\rho)$, and $N(\sigma)$ are strictly positive. We state and prove a relevant version of this inequality for the hitherto unaddressed case of these matrices being nonnegative. Our treatment also provides an alternate proof for the strictly positive case (N. Sharma (TIFR)).

Random Coding Exponents Galore Via Decoupling

A missing piece in quantum information theory, with very few exceptions, has been to provide the random coding exponents for quantum information-processing protocols. We remedy the situation by providing these exponents for a variety of protocols including those at the top of the family tree of protocols. Our line of attack is to provide an exponential bound on the decoupling error for a restricted class of completely positive maps where a key term in

the exponent is in terms of a Rényi α - information-theoretic quantity for any $\alpha \in (1, 2]$. Among the protocols covered are fully quantum Slepian-Wolf, quantum state merging, quantum state redistribution, quantum/classical communication across channels with side information at the transmitter with or without entanglement assistance, and quantum communication across broadcast channels (N. Sharma (TIFR)).

Towards a Derandomised Construction of a Channel with Subadditive Minimum Output p - Renyi entropy

Information carrying capacity of classical communication channels is additive, that is, the capacity of two independent channels acting in parallel is exactly the sum of their individual capacities. This is a fundamental property of classical channels. The analogous question for the classical capacity of quantum channels was conjectured to be true for a long time. As an attempt towards resolving the conjecture, it was conjectured that the minimum output p -Renyi entropy of quantum channels was additive. In 2008, Hayden and Winter disproved the second conjecture. Their construction uses Haar random p unitary matrices, which are provably inefficient to implement as well as require a lot of random bits to describe. We have shown that the $n \times n$ Haar random unitary can be replaced by a $n \times n$ unitary from a finite set satisfying a special property called a t -design. Though our construction requires $t = n^{1/p}$ which is not known to be efficiently implementable, it nevertheless uses less random bits than a Haar random unitary. We achieve this by derandomising Milmans proof of Dvoretzkys theorem for the Schatten q -norm of matrices, $q > 2$ using unitary t -designs. Dvoretzkys theorem is a fundamental result in geometric functional analysis, and so the last result may be of independent interest (A. Nema and P.G.D. Sen (TIFR)).

Wireless Ad Hoc and Sensor Networks

Communication in the Presence of Jamming

We obtained capacity results for communication over state dependent channels in the presence of a jamming adversary. Such channels arise in information hiding (e.g., watermarking) and

communication in the presence of interference (A. Budkuley, B. Dey (Indian Institute of Technology, Mumbai) and V. Prabhakaran (TIFR)).

Online Algorithms for Basestation Allocation

We consider the design of online algorithms for assigning mobile users to basestations with the objective of maximizing the sum-rate, when all users associated to any one basestation equally share each basestation's resources. Each user on its arrival, reveals the rates it can obtain if connected to each of the basestations, and the problem is to assign each user to any one basestation irrevocably so that the sum-rate is maximized at the end of all user arrivals, without knowing the future user arrival or rate information or its statistics at each user arrival. In our work we have derived online algorithms with constant factor loss in comparison to online algorithms (that know both the future user arrival and user rates profile in advance). The proposed online algorithms are motivated from the famous online k -secretary problem and online maximum weight matching problem (R. Vaze (TIFR)).

Predicting Outages in Power Networks

We consider models for cascades on random networks where the cascade propagation at any node depends on the load at the failed neighbor, the degree of the neighbor as well as the load at that node. Each node in the network bears an initial load that is below the capacity of the node. The trigger for the cascade emanates at a single node or a small fraction of the nodes from some external shock. Upon failure, the load at the failed node gets divided randomly and added to the existing load at those neighboring nodes that have not yet failed. Subsequently, a neighboring node fails if its accumulated load exceeds its capacity. The failed node then plays no further part in the process. The cascade process stops as soon as the accumulated load at all nodes that have not yet failed is below their respective capacities. In our work, the model is shown to operate in two regimes, one in which the cascade terminates with only a finite number of node failures. In the other regime there is a positive probability that the cascade continues indefinitely. Bounds are obtained on the critical parameter where the phase transition occurs (R. Vaze (TIFR)).

Renewable Energy

Using renewable sources of energy for powering wireless communication systems has been proposed to increase lifetime of sensor networks, improve energy efficiency of low power devices, and also provide a means for green communication. Recent hardware progress has contributed towards realizing efficient practical design of small sized energy harvesting devices with sufficient power yield required for communication purposes. Harvesting energy from natural sources, however, makes the future available energy levels at the transmitters unpredictable and the transmitter has to adaptively choose the transmission power for maximizing its utility function. We are trying to derive an analytical framework for design of renewable energy sources powered wireless communication system. The objectives of the project are as follows:

1. Characterizing the fundamental limits such as capacity, reliability, coverage and connectivity, of wireless networks (e.g. ad hoc, relay assisted, overlaid heterogeneous, sensor etc.) when each node uses energy harvested from renewable energy source.
2. Develop a theoretical framework for the design of renewable energy sources powered wireless communication systems that is free of energy arrival distribution or allows arbitrary energy arrivals (R. Vaze (TIFR)).

Secure Communication Over Wireless Networks

A noisy channel between communicating parties can be exploited to achieve secure communication between collaborating parties without leaking information to adversarial parties. Wireless networks can be modelled using erasure channel models. We use such a model to develop the first information theoretically optimal schemes for communicating securely over networks with feedback. We obtain results for both one-hop and network settings. We also obtained the capacity of one-hop erasure networks to perform oblivious transfer, a secure computation primitive (L. Czap (Ecole Polytechnique Federale de Lausanne, Switzerland), S. Diggavi, C. Fragouli (University of California, Los Angeles, USA) and V. Prabhakaran (TIFR)).

Information System Development Group

The Information Systems Development Group (ISDG) of TIFR supports the institute by implementing software solutions required by various administrative processes. Almost all major data related to Accounts, Finance, Purchase, Stores and Establishment are digitized and their operations automated as part of the in-house developed ERP package TIIS (TIFR's Integrated Information System). Workflows like guesthouse booking, lecture room booking, vehicle requisition etc. are made available under the institute's intranet system named "Datanet". Some of the activities taken up by ISDG from April 2015 to March 2016 are given below. These are in addition to the regular maintenance and enhancements of existing packages as well as the generation of various reports required from time to time by DAE and/or data analysis.

Implementation Efforts at Centers

The major emphasis this year was to extend TIFR datanet and its modules comprising Purchase, Stores, Payroll, Establishment etc. to field stations and centers. Several training sessions were conducted to train staff members from centers for use of TIIS. Emphasis has been given to NCBS, TCIS and ICTS. Additions were made to the purchase and stores modules to incorporate changes related to processes followed at NCBS. The deployment model is centralized where a common HR database is shared with center wise databases for accounts, purchase and stores.

New release for Purchase and Stores

A new release of Purchase and Stores package of TIIS was developed. This version is web based and completely integrated with the TIFR datanet. Several enhancements were made in the system like PO Verification by Indenters for generating multiple accession numbers against a single line item, facility for single proprietary certificate etc.

Enhancements to Gate Pass, Transport and Guest House System

An online gatepass management system was released last year replacing the earlier paper based system. It allowed any regular staff member of the institute to create a gatepass by filling up the online form available on the

datanet. However, the system underwent some upgrades and features like packaging list and gate pass invalidation and mechanism for marking the material IN and OUT.

The existing transport requisition system was also modified to capture the user information in a more user friendly way and to ensure that the transport department gets all the desired information. Several fields were added in that process. SMS facility was also added so that staff members can be informed about their requisition status.

The Guest house software was also enhanced. Sub modules for occupancy chart and visitors idcard management was developed to depict the actual occupancy in the guest house, check-ins, check-outs. The idcard generation is integrated with the canteen wallet accounts for QR Codes. The bills can now be linked to the occupancy chart to enable online billing.

Employee Joining Flow

As per the guidelines of Govt. of India a service book has to be maintained for every event occurring in the official life of the staff. The new employee joiner flow was extremely disintegrated and time consuming at TIFR. This flow was re-engineered to enable all formalities

including medical check, idcard card generation, service book updation, email creation and datanet registration to be completed before the salary release.

Wallet Credits

The cashless canteen system has been running for the last two years. However, the amount of cash handled by canteen staff was still a lot more than what was desired. A wallet credit facility was therefore added to allow staff members to use the canteen in a post paid manner. Appropriate screens for wallet settlement, refunds etc were developed.

Salary and Pension

Re-fixation of salary for February and August promotion cases as per the government orders were done through the system. This also affected the pension fixation. Pension re-fixation was also done for pre 2006 pensioners. Other than that there were modifications from time to time like not allowing increments/promotions on the date where the staff member is on leave.

Miscellaneous: Some other miscellaneous development was taken up during this period like an online survey with a facility to generate a secured XML based output, online allotment meetings for non-academic staff etc.

Members

U. Bhaskar (from June 2015), A. Chattopadhyay, S.K. Ghosh (Up to July 2015), A. Gupta, M. Gopalkrishnan, P. Harsha, S.K. Juneja, T. Kavitha, P.K. Pandya, V. Prabhakaran, J. Radhakrishnan, N. Raja, P.G.D. Sen, N. Sharma and R. Vaze.

N. Bondale, N.S. Gawandi, R.J. Naik and K. Samudravijaya, P.N. Bhuwad and R.J. D'Mello (Up to January 2016).

Research Scholars

D.K. Data, A.A. Deo (from August 2015), M. Garg, K. Gajjar, R. Jain (from August 2015), G. Kumar (from August 2015), G.R. Kurri, N.S. Mande, S.B. Moka, T.M. Molli, S. Mukhopadhyay, V. Narayanan (from August 2015), A. Nema, S. Pandey (Up to November 2015), L.P. Raj, B. Roy (Up to July 2015), S. Sanyal (Up to September 2015), S. Sarawat, S. Sheriff, A.K.R. Singh, G. Sood, (Up to April 2015), A.G. Tengse (from August 2015), G. Thoppe (Up to July 2015), G. Varma (Up to September 2015), R. Venkat (Up to September 2015) and N.A. Warsi (Up to May 2015).

Visiting Fellows

R.M. Matteleckel (from February 2016), B. Roy (from August 2015 Up to January 2016) and M. Sharayu (Up to November 2015).

Junior Research Fellows

A.V. Deshpande and S.T. Hussain (Up to August 2015)

Information Systems Development Group

J.T. Barot, N. Goel, S. Patel, S. Rane, K.K. Shaw (from 15/05/2015) and S.K. Verma.

Project Staff

N.V. Narendrakumar (Up to March 2016), S. Sanyal (from October 2015) and R. Venkat (from October 2015).

Administration

J. Barretto, W.K. Gawade.

National and International Involvement

A. Chattopadhyay: Visiting Scientist, Simons Institute for Theory of Computing, Berkeley, USA, April, 2015; Program Committee Member, 56th Annual IEEE Symposium on Foundations of Computer Science (FOCS), Berkeley, USA, October 18-20, 2015; CNRS Researcher, Institut Henri Poincare, France, Paris, February 2016; Program Committee Member, 33rd International Symposium on Theoretical Aspects of Computer Science (STACS), Orleans, France, February 17-20, 2016. **A. Gupta:** Program Committee Member. FSTTCS, 2015; Principals of Programming Languages, 2016; 10th International Conference on Tests & Proofs (TAP), 2016. **P. Harsha:** Program Committee Chair, FSTTCS 2015; Program Committee Member, CCC 2016. **S.K. Juneja:** Associate Editor, Mathematics of Operations Research; Program Committee Member Applied Probability Society Conference 2015; Program Committee Member IFIP Performance 2015; Member, INFORMS: Institute for Operations Research and Management Sciences; Member, ORSI: Operations Research Society of India. **T. Kavitha:** Program Committee Member, 13th Workshop on Approximation and Online Algorithms (WAOA), 2015; Program Committee Member, 27th ACM-SIAM Symposium on Discrete Algorithms (SODA), 2016; Program Committee Member, 8th International Conference on FUN with Algorithms, 2016; Editorial Board Member, Journal of Combinatorial Optimization. **V. Prabhakaran:** Technical Programme Committee Member, IEEE International Symposium on Information Theory (ISIT), June 14-19, 2015; Technical Programme Committee Member, IEEE Information Theory Workshop, Jeju, October 11-15, 2015. **N. Raja:** Associate Editor-in-chief, International Journal of Computing Technology and Information Security, IJCTIS, Heber Publications (2015-16); Editorial Board Member, Logica Universalis, Journal published by Springer-Birkhauser (2015-16); Editorial Board Member, Scientific Issues of Jan Długosz University in Człuchów. Series Philosophy, Journal published by Akademia im. Jana Długosza w Człuchowie, Poland (2015-16); Editorial Board Member, ISTE International Journal of Computer Science and Engineering, ISTE Publications (2015-16); Member, Advisory Board, Cauvery Research Journal, Bharathidasan University (2015-16); Member, Programme Committee, Eleventh International Conference on Risks and Security of Internet and Systems, Roscoff, France (2016); Member, Programme Committee, Sixteenth International Conference on Innovations for Community Services, Vienna, Austria (2016); Member, Programme Committee, Symposium on Dependable Software Engineering, Beijing, China (2016); Member, Advisory Committee, Twelfth International Conference on Distributed Computing and Internet Technologies, India (2016); Principal Investigator, Centre for Formal Development and Verification of Software, Indian Institute of Technology, Mumbai, India (2015-16); **R. Vaze:** Editor of IEEE Journal on Selected Areas of Communications starting from April 2015.

Visits

U. Bhaskar: Dagstuhl Seminar "Dynamic Traffic Models in Transportation Science", Schloss Dagstuhl, Germany, October 4-9, 2015. Workshop on Algorithmic Game Theory at Hausdorff Institute of Mathematics, Bonn, Germany, December 14-17, 2015. Indian Statistical Institute, Kolkata, from March 28-29, 2016. **A. Chattopadhyay:** Visiting Scientist at Simons Institute for Theory of Computing, Berkeley, April 2015. Program Committee meeting of IEEE Annual Symposium on Foundations of Computer Science (FOCS), Carnegie Mellon University, Pittsburgh, USA, June, 2015. Summer School on Lower Bounds, Charles University, Prague, Czech Republic, June 28 - July 01, 2015. International Colloquium on Automata, Languages and Programming (ICALP), Kyoto, Japan, July 06-10, 2015. Stanford University, USA, October 2015. Santa-Fe Winter School on Complexity at IISER, Mohali, Chandigarh, December 08-12, 2015. Foundations of Software Technology and Theoretical Computer Science (FSTTCS), Indian Institute of Science, Bangalore, December 15-20, 2015. CNRS Researcher at Nexus of Information and Computation Theories at the Institute of Henri Poincare (IHP), France, Paris, February - March 2016. **A. Gupta:** National Centre for Biological Sciences, Bangalore, November 15-22, 2015. Intel, Bangalore, November 15-22, 2015. **P. Harsha:** Simons Institute for the Theory of Computing, Berkeley, USA, March 24 - April 24, 2015. Institute of Theoretical Computer Science and Communications. The Chinese University of Hong Kong, October 15-19, 2015. Weizmann Institute of Science, Israel, January 24 -February 12, 2016. Institute for Mathematical Science, National University of Singapore, Singapore, February 15-20, 2016. **S.K. Juneja:** Department of Applied Mathematics, Ecole Polytechnique, Palaiseau Cedex, France, May 23-30, 2015. Banff International Research Centre, Canada, May 31 - June 05, 2015. Department of Electrical and Computer Engineering, Ohio State University, USA, June 06-09, 2015. CAFRAL, RBI Mumbai (Centre for Advanced Financial Research and Learning), September 16 - December 31, 2015. Shanghai Centre for Mathematics, Fudan University, Shanghai, China. November 01-04, 2015. Eurandom, Eindhoven, The Netherlands, November 08-10, 2015. National University of Singapore, Singapore, December 14-18, 2015. **T. Kavitha:** Department of Computer Science and Engineering, IIT Delhi, January 25 - February 05, 2015. Department of Computer Science and Engineering, Chalmers University of Technology, Gothenburg, Sweden, April 19 - May 02, 2015. **J. Radhakrishnan:** Simons Institute for the Theory of Computing, Berkeley, USA, April 01 - May 16, 2015. Tokyo Institute of Technology, Japan, May 18 - July 16, 2015. **N. Raja:** International Center for Computational Logic, Dresden, Germany, September 2015. 35th International Conference on Foundations of Software Technology and Theoretical Computer Science, Indian Institute of Science, Bangalore, December 16-18, 2015 (A. Chattopadhyay, K. Gajjar, P. Harsha, T. Kavitha, N. Mande, T.M. Molli, S. Mukhopadhyay, J. Radhakrishnan, L.P. Raj, S. Sarswat, S. Sherif, A. Kr. Singh and R. Venkat). Formal Methods Update Meeting, Bangalore, July 2015 (N. Raja).

Invited Talks

U. Bhaskar:

1. "Optimal Signaling in Bayesian Games", Workshop on Game Theory and Mechanism Design, Indian Institute of Science, Bengaluru, January 12, 2016.
2. "Network Improvement for Equilibrium Routing",

International Conclave on Foundations of Decisions and Game Theory, IGIDR, Mumbai, March 17, 2016.

A. Chattopadhyay:

1. "Tribes is Hard in the Message-passing Model",

Workshop on Information Theory in Complexity Theory and Combinatorics, Simons Institute for Theory of Computing, Berkeley, USA, April 20-24, 2015.

2. "The Range of Topological Effects on Communication", 42nd International Colloquium on Automata, Languages and Programming (ICALP), Kyoto, Japan, July 06-10, 2015.
3. "Topology Matters in Communication", Stanford Theory Seminar, Stanford University, USA, October 08, 2015.
4. "Tribes is Hard in the Message-passing Model", Bombay Information Theory Seminar (BITS)", Indian Institute of Technology, Mumbai and TIFR, January 01-03, 2016.
5. "Topology Matters in Communication", Special Semester on Information and Computation Theories, Institut Henri Poincare, Paris, February 2016.
6. "A Little Advice can be very Helpful", Special Semester at Institut Henri Poincare, Paris, February 2016.

P. Harsha:

1. "Information Complexity in Parallel Repetition Theorems", Invited Session on Interactive Communication, 2015 IEEE Information Theory Workshop, Jeju Island, Korea, October 11-15, 2015.
2. "Old and New PCP Constructions: Towards the Sliding Scale Conjecture", CSE-ITCSC Joint Seminar, Institute of Theoretical Computer Science and Communications, The Chinese University of Hong Kong, October 19, 2015.
3. "Towards the Sliding Scale Conjecture: Old and New PCP Constructions", Workshop 3 on Approximation Algorithms, Program on Semidefinite and Matrix Methods for Optimization and Communication, IMS, NUS, Singapore, February 18, 2016.
4. "Partition Bound is Quadratically Tight for Product Distributions", IMSc, Chennai, 24 March 2016.

S.K. Juneja:

1. "Multi Armed Bandit Sampling in Nested Simulation for Financial Portfolio Risk Measurement", Keynote Speaker, 4th IIMA International Conference on Advanced Data Analysis, Business Analytics and Intelligence, Indian Institute of Management, Ahmedabad, April 11, 2015.
2. "Ordinal Optimization - Empirical Large Deviations Rate Estimators, and Multi-armed Bandit Methods", Seminaire Bachelier Paris, Henri Poincare Institute. Paris, May 29, 2015.
3. "Ordinal Optimization - Empirical Large Deviations Rate Estimators, and Multi-armed Bandit Methods", Workshop Applied Probability Frontiers: Computational and Modeling Challenges, Banff International Research Station, Canada, June 01, 2015.
4. "Ordinal Optimization and Multi-armed Bandits", and "Portfolio Risk Measurement Using Multiarmed Bandit Methods", NMI Conference on Non-convex Optimization for Machine Learning, Indian Institute of Technology, Mumbai, June 15-16, 2015.
5. "Large Deviations, Selecting the Best Population and Multi-armed Bandit Methods", Department of Mathematics, Indian Institute of Technology, Mumbai, October 4, 2015.
6. "Large Deviations, Selecting the Best Population and Multi-armed Bandit Methods", International Conference on Applied Probability and Computational Methods in Applied Sciences, Shanghai Centre for Mathematics, Fudan University. November 02, 2015.
7. "Strategic Arrivals to Queues", Keynote Speaker, XIX

Annual Conference of Society of Operations Management, Indian Institute of Management, Kolkata. December 12, 2015.

8. "Rest in Lounge or Wait in Queue", Workshop on Congestion Games, Institute for Mathematical Sciences, National University of Singapore, Singapore, December 16, 2015.

T. Kavitha:

1. "Popular Matchings", COST Action meeting on Computational Social Choice, University of Glasgow, Scotland, April 16, 2015.
2. "Popular Matchings with Two-Sided Preferences and One-Sided Ties", ICALP 2015, Kyoto, Japan, July 10, 2015.

V. Prabhakaran:

1. "Tension Bounds for Interactive Systems", IEEE Information Theory Workshop, Jerusalem, April 26 - May 1, 2015.
2. "Information Inequalities for Networks and Applications to Secure Computation", 53rd Annual Allerton Conference on Communication, Control, and Computing, University of Illinois, Urbana-Champaign, USA, September 29 - October 2, 2015.
3. "Lower Bounds for Interactive Function Computation", IEEE Information Theory Workshop, Jeju, October 11-15, 2015.
4. "Rényi information Complexity", Information Theory and Applications Workshop, University of California, San Diego, USA, January 31 - February 5, 2016.

J. Radhakrishnan:

1. "Set Membership with Two Bit-probes", Caltech, USA, May 01, 2015.
2. "Finding Duplicates in a Data Stream", The University of Electro-communications, Tokyo, Japan May 25, 2015
3. "Communication Assisted Agreement Distillation", Center for Exploring the Limits of Computation, Tokyo. Japan, July 02, 2015.
4. "Communication Assisted Agreement Distillation", Institute of Mathematical Sciences, Chennai. February 19, 2016.

N. Raja:

1. "Logic and Formal Reasoning in Computer Science", Silver Jubilee Conference of Assam Engineering College, Guwahati, 2015.
2. "The Ontology of Computer Programs", Conference on Scientific Objects and Digital Cosmopolitanism, Manipal, 2015.
3. "Varieties of Pluralism in Non-standard Logics", Conference on Pluralism in Mathematics, Kolkata, 2015.

R. Vaze:

1. "Achieving Non-Zero Information Velocity in Wireless Networks", Simons Conference on Networks and Stochastic Geometry, The University of Texas at Austin, USA, May 2015.
2. "Achieving Non-Zero Information Velocity in Wireless Networks", Telecom Paris Tech., Paris, July 2015.
3. "Optimal WiFi Sensing Via Dynamic Programming", Alcatel Lucent Bell Labs., Paris, July 2015.
4. "Achieving Non-Zero Information Velocity in Wireless Networks", IISc-DRDO Workshop on Models and Protocols for Mobile Ad-Hoc Networks. Indian Institute of Science, Bangalore, October 2015.

Conference/Workshop Organized by the School

Workshop on “Bombay Information Theory Seminar (BITS 2016)” jointly by IIT Mumbai and TIFR, January 01-03, 2016. (Organizers: P. Harsha, V.M. Prabhakaran and J. Radhakrishnan)

Non DAE Research Projects

V. Prabhakaran:

Uncoordinated, Secure and Energy Aware Access in Distributed Wireless Networks, DeiTy, Govt. of India, (Rs. 3 crore for 3 years across 4 institutes. Start date Jan 1st, 2014). *People: Prof. Bikash Dey, Dr. Sibi Pillai, IIT, Mumbai, Dr. Vinod Prabhakaran, TIFR, Mumbai, Dr. Sripati Acharya, NIT, Surathkal, Dr. Sumeet Kundu, NIT, Durgapur.*

R. Vaze:

1. Uncoordinated, Secure and Energy Aware Access in Distributed Wireless Networks, DeiTy, Govt. of India, (Rs. 3 crore for 3 years across 4 institutes. Start date Jan 1st, 2014). *People: Prof. Bikash Dey,*

Dr. Sibi Pillai, IIT, Mumbai, Dr. Vinod Prabhakaran, TIFR, Mumbai, Dr. Sripati Acharya, NIT, Surathkal, Dr. Sumeet Kundu, NIT, Durgapur.

2. Indian National Science Academy’s Young Scientist Award Grant: Design of Efficient Spatial Wireless Networks Using Stochastic Geometric Tools. Start Date: 1st June 2014- 3 years, (Rs. 15 Lakhs for 3 years).
3. CEFIPRA Indo-French joint program on D2D Communications for LTE-Advanced Cellular Networks. Start dated: 15th April 2015 for 3 years, (Rs. 10 Lacs for TIFR).



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General Facilities & Services

General Administration

The General Administration deals with allotment of Institute quarters for Academic and Non-Academic staff members, payment of security bills, common area maintenance and conservancy charges for TIFR colonies, issue of RFID cards to regular staff and ordinary ID cards to temporary staff and research scholars, distribution of uniforms, administering of group and graded insurance scheme, settlement of insurance claims of retired staff members and death cases, arrangement for Founder's Day celebration, sports activities assigned by DAE Sports & Cultural Meet, handled mailing and dispatch including , payment of property tax and municipal water bills, opening of files for import material, export, samples, equipment and general files to the tune of 650 files per year. Similarly GSLI claims for 55 persons inclusive of death claims worth Rs.36,62,980/- have been settled.

During the year the section allotted 60 flats to its staff members, including few flats to Guest House and Hostel and Off-Campus Accommodation. The work involves conducting DDQ meeting and allotment meeting manually under Non-Academic Pool and online for Academic Pool, preparing allotment orders obtaining concurrence DCSEM and preparing occupation, vacation, electricity meter transfer and issuing it to staff members. The section also coordinates with DCSEM the renovation of flats undertaken by DCSEM, provides transit flats for renovation and reimburses electricity bills to staff members towards electricity charges for flats during transit or in the custody of TIFR. During this year 52 flats were renovated (17 flats in Bhaskara, 20 flats in Parashara and 15 Flats in Panini) by DCSEM in Colaba Campus.

Under maintenance of quarters, TIFR reimburses security bills and also bills pertaining to cleanliness of premises. During the year General Administration has reimbursed bills to the tune of Rs. 51,83,780/- approx. to M/s. Tuff Security & Allied Services for providing security services at all

TIFR Colonies including TIFR seaside area and Cuffe Parade Water Tank. General Administration has also reimbursed bills pertaining to conservancy & common area maintenance of all TIFR colonies to respective Resident's Association upto Rs.6,04,198/- approx. Settlement of bills arising from maintenance of Nisargruna Biogas Plant upto Rs.3,67,440/-. Also renewed contracts for the above work and enhanced the rates as per minimum wages. We have made settlement of property tax bills approx. up to Rs.1,23,23,654/- and water bills approx. upto Rs.19,31,799/- to BMC. We also pay on monthly basis rent to the administrator of Mumbai Properties of the Indian Institute of Science for flats leased to TIFR. We also pay quarterly lease rent in respect of TIFR Hostel (E-1) to DCSEM Land Section.

The section also handles Mailing and Despatch. Mailing takes care of receipt of complete mail for TIFR. During the year mailing received 5500 (approx.) speed and 1200 (approx..) registered post letters/parcels and 5000 couriers/parcels. During the year approx.. 42000 outward mails was handled which included 18000 ordinary/registered post, 6000 speed post, 16100 Vichare Courier (only Mumbai) and 1900 Track-on & DTDC (all over India and international).

The General Administration installed RFID Card Preparation during the year. We have started in-house printing of RFID cards for regular staff members of TIFR, Centre's and Field Stations. We have prepared and issued RFID cards 447 to TIFR, 59 to HBCSE, 17 to CRL, Ooty, 33 to Balloon Facility and 60 to NCRA staff members, . We have also prepared and issued 800 ID cards to temporary staff and 43 to retired staff members during their probation. The complete record of all the applications received for ID cards, scrutiny of documents, data entry done, and the cards issued are maintained in registers and papers filed in respective files. [M.H. Jadhav (*till October 31, 2015*) T.J. Felix (*from November 1, 2015*)]

Computer Centre & Communication Facility

Upgradation of IT infrastructure:

- Computer Centre team upgraded the Virtual server environment, server, storage and software to

the latest available variants. All the critical equipment of the Computer Centre were migrated to IPV6. (Santosh Kyadari, Sagar Mungse).

- Old access control system is replaced with a new biometric enabled device with attendance recording feature for better management of entry of personnel inside CC premises for improved physical security of datacentre. (Shisheer Teli)
- Computer Centre team deployed open source Bulletin Board application for technical discussion among institute members. (Sagar Mungse)
- Computer Center team deployed Cloud Server Storage Services for data share and storing. (Sagar Mungse)
- Scientific software (Mathematica, Matlab, Labview, SigmaPlot, Solidworks, OriginLab, Intel compiler C++/Fortran OS X* and Autocad) were upgraded to the latest versions. (Anilkumar Naik)
- To help users Computer Centre team deployed an open source alternate webmail client - Roundcube for use by TIFR users. (Sagar Mungse, Kausalya S.)
- Purchased and deployed 250 Microsoft Windows license to meet the user requirement. (Santosh Kyadari, H. Raghavan)
- Implemented open source Games application software and written LoadLeveler scripts to run Games jobs in High Performance Cluster (HPC). (Anilkumar Naik)
- Bare Metal Recovery (BMR) tool was purchased and deployed for taking Operating System image of compute nodes and help in service restoration in the event of node failure in HPC. (Anilkumar Naik)
- All the computer and head nodes of HPC were upgraded to the latest version of GPFS file system. (Anilkumar Naik).

Software applications

- **Sign up Tool**
(<http://www.tifr.res.in/signup>)
- Server account signup tool with One Time Password (OTP) facility developed in-house to reduce the process time during joining. The LDAP integrated tool is developed keeping user

convenience in mind and record keeping of server accounts. (Siraj Momin, Kausalya).

TIFR Science News module:

(<https://www.tifr.res.in/admin/SN>)

- TIFR Science News (TSN) software module developed and deployed by in house engineers, is part of the TIFR website, which motivates budding young scientists on the research carried out in TIFR. It is categorized into research overviews, research highlights and research milestones. (Nishit Kotak)

Asset Management Tool

(<http://ccweb.tifr.res.in/~cccf/E-inventory>)

- Computer Centre team developed and deployed a software tool to track software and hardware assets of Computer Centre through their lifecycle. This tool has provision to send alerts on expiry of warranty service & Annual Maintenance Contract well in advance to enable planning. All the assets bought by Computer Centre will now be managed by this tool. The tool is intended to be a central repository of information and provides access to comprehensive documentation for all the assets purchased by Computer Center. (6 B.E. interns from Saboo Siddik college of Engineering, Byculla, Kausalya S.)

LDAP integrated Portal for CCCF use:

(<https://ccweb.tifr.res.in>)

- Computer Centre developed and deployed a portal for use by Computer Centre engineers where all applications and tools used by Computer Centre engineers are integrated with LDAP authentication and role profiling. This enabled Computer Centre to manage the services rendered to users in a systematic manner. A new Frequently Asked Question (FAQ) tool was developed for FAQ content management and delivery for CCCF website considering the fact that users use FAQ section very widely. (Nishit Kotak)

Members

Sri. H. Raghavan, Ms. Kausalya S., Sri. Vijay M. Naik, Sri Santosh K, Sri Rahul Auchare, Sri Anilkumar Naik, Sri. Shisheer G. Teli, Sri Sagar Mungse, Sri. Vinit Bhosle, Sri. Narayan Karle, Sri. Kiran Shirodkar, Sri. C. T. Chandrasekharan, Sri Vinod Lad, Sri Swapnil Malvankar.

Trainee Engineers: Sri Siraj K. Momin (till September 2015), Sri Nishit Kotak

Visits

Ms. Kausalya S, attended Nodal Officer Meet (ANUNET & ANUNET-S) 2015 on 19th August 2015, organized at ECIL, Hyderabad.

Sri Anilkumar Naik, attended National Knowledge Network (NKN) workshop conducted at Hyderabad from 21st and 22nd January 2016.

Sri. Shisheer G. Teli attended Regional Workshop on Institutional Digital Repository for National Digital Library (NDL) Project in, Vadodara, on 28th and 29th January 2016.

Conference Organized by the Section

Computer Centre team organised an Orientation programme for B.E. Student interns and TIFR staff on software technologies necessary for project implementation. As per following schedule : Linux, Vi editor, Bash Scripting : September 01, 2015, in D-405 (Vinit Bhosle, Sagar Mungse); Hadoop : September 01, 2015, in D-405 (Kausalya Srinivas); Understanding network traffic : September 01, 2015, in D-405 (Shisheer Teli); PHP, SQL & secure application programming, September 01, 2015 (Siraj Momin); Data analytics & graphing using R : September 01, 2015 (Siraj Momin); Linux basic training given to TIFR, Hyderabad members from 18th May to 22 May (Vinit Bhosle, Sagar Mungse, Anilkumar Naik)

Photography Section

This section caters to the needs of all Departments of TIFR for photographic coverage of (a) visits by dignitaries, (b) national and international conferences, (c) Public Lectures, (d) cultural and sports events of TIFR. The section also creates photographic prints, and creates digital images for theses and publications, etc.

In the last year, approximately 11378 digital photographs were taken. 12 Conferences organized at TIFR, 10 Public Lectures, 1 VIP visits, 3 ASET Colloquia, 1 School, and 50 other Institute events

were covered. Approximately 4452 digital prints were obtained in-house using computer-interfaced printers.

Besides the above, the Photography Section handles requests for photographs for Identity cards, Passports, and Visas. Approximately 4 documents or photos and 230 archival black & white and color film negatives and transparencies of different format [like 35mm and larger size] were scanned and 35 CDs and DVDs were recorded. [J.R. Acharya, V.M. Shinde]

Central Stores

The Central Stores is having total strength of 17 staff members and its functions have been distributed amongst the five sub-group. It is basically engaged in the activities of planning, procurement, provisioning and indenting of commonly used items required by various groups/section. The items received and distributed are of the nature of Capital, Furniture, Consumable and Lab Stores. The activities and functions covered by Central Stores are :-

- Forecasting regarding future requirements and also forecasting market and economic conditions and supply of available material and stock position.
- To keep the inventory as low as possible, consistent with institute and market conditions.
- Receipt and documentation of all material including consumable & capital items.
- Safe custody of materials (i.e.) storage, preservation and safety.
- Inspection & warehousing.
- Classification, codification, simplification, standardization, safety stock, analysis of value i.e. cost reduction techniques.
- Material handling including issue, distribution and accounting of materials.

- Assessment of surpluses scrap, obsolete and non-serviceable items and their disposal.
- Stock taking of inventories, stock adjustment, losses, physical verification of capital equipment, furniture & fixture items.
- Inventory management through RFID system.
- Clearance of material (consignment) received by rail/road/post/air.
- Hiring of transport and labour for the movement of materials wherever necessary.
- Repair and maintenance of equipments, furniture and other items through AMC and on requirement basis.
- Import and Export of materials, capital/consumables for research work/repair & replacement.

Receipts (Local/Import)

During the financial year 2015-2016 the Central Stores received 22351 items which constitute Capital Equipment's, Furniture/ consumables, stationery (Local & Import) and different types of gases for various groups/ sections.

Repair & Maintenance

In current financial year around 176 orders for AMC and 187 orders for repair & Maintenance were processed for various types of equipment and furniture items of different section/groups /labs. The introduction of Online Gate pass with the help of Head ISDG, the store can now track the Gate pass of the returnable from the date it went out to the date it arrived in the security gate.

Salvage and Disposal

The capital Equipment, Furniture and fabricated items received for disposal were disposed off through **M/s. MSTC Ltd.** The items which are obsolete/unwanted consumables, turning, and leftover metallic scrap, and garden waste were disposed off by inviting limited tenders to the competitive vendors. The online programme on Disposal is under progress which will be released in next financial year ie. 2016-17.

Stock Holding & Procurement

The physical verification of the stock is done every financial year, there are 627 stock items kept in the stores including stationery items. The stock items records are maintained on the bin cards while receiving and issuing to the respective users and report is generated for the stock position in the financial year. The statutory auditor check the stock report and the cutoff of capital, consumable, disposal, cash purchase, gate pass and Repairs and

maintenance voucher as on the financial year. The number of cash purchase made by various groups/section during the financial 2015-16 was for Rs.1,09,48,501/- and these purchase were properly recorded and accounted in the database. The online Cash Purchase programme has already started and user take the approval of the competent authority through the system.

Inventory

The Institute has introduced Radio Frequency Identification Devices (RFID) for tagging of capital item which is physically verified and tagged of each item lying in different location, presently around 85% tagging of the capital item is completed. Follow up is on with the end user to complete the task to tag all capital items. With the help of ISDG, all the item tagged of each user is shown in the datanet under the "Inventory" and this helped the user to transfer the capital item to other members of the Institute when necessary. Automated E mail alerts are sent to Inventory holder periodically from one year in advance of their retirement to remind them to transfer their inventory in time.

Transfer of Capital Equipments

Discarded items are being regularly collected from the various section/groups and essential repairs are carried out and reissued or disposed off. Accounts section is informed about the same for proper record keeping. [Bipin Kanchan; staff strength 17]

Security and Fire Section

The duties of Security and Fire Section involve administrative and physical work pertaining to securing the institute premises. The Security Section also takes care of Fire fighting and periodic maintenance of fire extinguishers, fire hydrants, fire hydrants hoses, etc. Addressable fire alarm system of M/S Essar, Honeywell has been working in serviceable condition which helps in early detection of fire within the institute premises.

Security section has been adopting modern day's technique of issuing gate pass by implementing Visitor Information System to keep record of visitors, daily wages, contractors etc. Security section meticulously eyes round o clock the institute premises and long shore line on the western side of TIFR using surveillance cameras (CCTV). The Security section is closely coordinating with various AMC agencies of CCTV and addressable fire alarm system for prompt clearance of defect. In addition to that the security section is also maintaining close liaison with

various departments and the firm dealing with contract workers working in TIFR for various projects regarding police verification certificate.

Security Section takes care of Transport and Telephone after office hours and on holidays. It assigns duties to drivers and takes care of all vehicle requisitions given by the transport section. Security section co-ordinates issue of Naval area passes to the colony residents. The section provides additional security during the International conferences, workshops and seminars which are held in the Auditorium. Section provides special security for institute staff travelling by staff bus during Band and strikes.

Security section periodically conducts mock fire drill in the Institute and also conducts training session in tandem with Civil Defence personnel for students and staff members on First aid and Fire fighting. [Bharat Bhushan Joshi; Staff Strength: 43]

Scientific Information Resource Centre

SIRC subscribed to **623** journals of which **352** journals are online only and majority of the remaining journals are Print or Print+Online. SIRC also subscribed **11** e-journals packages to access **3400+** journals. SIRC added **6** new electronic journals, converted **21** titles from Print+Online to Online only and upgraded **2** titles from Print to Print+Online only. It has discontinued **18** journals. A total of **1800** bound volumes and **38** journal CDs were added.

SIRC added to its collection **313** printed books, of which **297** were purchased and **16** were received as 'gratis'. A total of **61** Hindi books received from Hindi Section were processed. In addition to this, **18** books were procured for various groups / individuals.

Subscription to e-books published by Springer, European Mathematical Society (EMS) and Society for Industrial and Applied Mathematics (SIAM) was continued. Also SIRC subscribed to Annual Reviews Package, AIP Conference Proceedings and Elsevier e-books Series. In addition to this, **2** AMS e-book series back files acquired by TIFR-CAM, Bangalore are accessible.

Online access to some of the e-resources subscribed by SIRC was continued to all the Centres / Field Stations. Few online packages and online journals were subscribed for TCIS, Hyderabad and ICTS, Bangalore.

At the Circulation desks (both Books & Journals), approx. **5200** transactions took place. As a part of ILL arrangement, SIRC loaned **9** books to various libraries

and requested **1** book on ILL from other library. Similarly, SIRC sent out **63** articles and received **13** articles from others. About **3500** pages of photocopies were supplied to Institute members.

SIRC is in the process of implementation of RFID security systems for SIRC book collection and upgradation of SIRC server.

Exhibitions organized

SIRC had organized a Special Display of rare manuscripts, pencil sketches by Dr. Homi Bhabha, Constitution of India, books autographed by renowned scientists, mathematics books in Sanskrit, books / journals published in 19th century, etc. In addition to this, few newspaper clippings and documents regarding TIFR contribution in ASTROSAT launch were also displayed. The exhibition was inaugurated on the occasion of Founder's Day on 30th October 2015 by Prof. Sandip Trivedi, Director, TIFR.

SIRC had organized a small exhibition to commemorate the centenary of General Relativity with the collection of works of Einstein and works about him during 23 - 27 November, 2015. The exhibition included books, journals issues, newspaper clippings and photographs.

Lecture Organized

Librarian's Day and TIFR BOSLA Special Annual Lecture was jointly organized by SIRC, TIFR and Bombay Science Librarian's Association (BOSLA) on 8th August 2015 to commemorate the 123rd Birth Anniversary of Dr. S. R. Ranganathan.

Conferences and Workshops attended

- Varsha Phatak and Rekha Dabholkar attended "Thomson Innovation User Group Meeting 2015" organized by Thomson Reuters on 14th May 2015 at Trident Hotel, BKC, Mumbai.
- R. Prabakaran and Kasturi Gajendragadkar attended "Librarian Appreciation Day" organized by Royal Society of Chemistry on 14th August 2015 at Radisson Blue Hotel, Pune.
- Kasturi Gajendragadkar and Rekha Dabholkar attended Dr. Paul LeClerc's Talk on "Digitization, Openness and Remaking of the New York Public Library" organized by Columbia Global Centers South Asia and The Nehru Centre on 27th October 2015 at Hall of Harmony, Nehru Centre, Mumbai.
- R. Prabakaran attended 11th International Conference on 'Webometrics, Informetrics and Scientometrics & 16th COLLNET Meeting' organized by Society for Library Professionals in association with Asian Chapter, Special Libraries Association and Institute of Economic Growth during 26 - 28 November 2015 at New Delhi.

- Rekha Dabholkar and M.D. Mate attended a "First Aid Programme" conducted by Red Cross Society and sponsored by the Institute Staff Welfare Committee at TIFR during 4 - 5 January 2016.
 - Kasturi Gajendragadkar and H.B. Arya attended 5th lecture series of "KRM 2016 : digital contents, copyrights and Libraries" organized by Tata Memorial Hospital (TMH) and Health Science Library Association of India (HLAI) during 28 - 29 January 2016.
 - Rekha Dabholkar attended a "Workshop on Institutional Digital Repository for National Digital Library (NDL) project" organized by Library of Maharaja Sayajirao University of Baroda, vadodara and National Digital Library (NDL) project, IIT Kharagpur during 28 - 29 January 2016.
 - R. Prabakaran and S.K. Momin attended Workshop on Open Source Library Software (KOHA) and RFID Integration for DAE Libraries, jointly organized by The Institute of Mathematical Sciences, and Variable Energy Cyclotron Center held at Chennai, 17 - 18 March 2016.
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Invited Talks

R. Prabakaran

- Best Practices and Services in SIRC TIFR; *Librarians' Development Programme (LDP) – 2015 on Recent Trends in Librarianship*, KIIT University, Bhubaneswar, 5-6 June 2015.
- E-Book Collections and its use in TIFR; *Springer e-Books summit*, Bekal, Kerala, 3-5 August 2015.
- Copyright Compliance in Academic Libraries; *KRM 2016: Digital Contents, Copyrights and Libraries*, Tata Memorial Hospital, Mumbai, 28-29 January 2016.

Members

R. Prabakaran; H.B. Panchakshari (till 31/12/2015), Varsha Phatak, Kasturi Gajendragadkar, N.D. Raut, D.B. Ghoderao, Rekha Dabholkar, Swapna Kudapkar, S.K. Momin (from 18/09/2015), Pratibha Singh, G.S. Dhamdhere, H.B. Arya, Kalyani Pandit, Violet Prajith Kumar, M.D. Mate, C.S. Surve, A.S. Berde, Shilpa Kanchan, Sonal Kadam, A.V. Shinde.

Trainees:- Sumedha A. Mavlankar (from 01/12/2015) and Harshal B. Bhalero (from 01/03/2016).

Central Photocopying Facility

The facility caters to the photocopying needs of the Institute. It also provides multiple copying facility through GESTETNER machine for the conference papers, brochures and various forms required by the departments of the Institute. No. of Photocopies provided: approx. **40000** pages. No. of Multiple copies provided: approx. **7500** pages. [E.A. More]

Central Workshop

Central Workshop is constantly engaged in providing feasible solutions to complex mechanical engineering problems, which may include in-house product design and development. A wide range of high precision imported items have been developed indigenously. The Workshop also supports researchers in fabricating and modifying experimental setups. During 2014-15 Central Workshop has successfully completed **2840** Work Orders.

Auto Garage continues to provide maintenance services to all the vehicles of the Institute. During 2014-15 Auto Garage attended **174** breakdown requests from the Transport section along with preventive maintenance schedules of small and heavy vehicles. The Auto Garage section skillfully modified the CNG delivery system of CNG retrofitted buses to enhance efficiency.

Glass Blowing section has been fabricating customized glass, Pyrex, borosilicate and quartz, items such as special test tubes and flasks and making glass vacuum seals that help in observing reactions of various chemical reagents under various temperature and pressure conditions. During 2014-15 Glass Blowing has successfully completed **295** Work Orders.

Lecture theatre & Auditorium Facility provides audio visual services to all the lectures, public lectures, seminars, colloquia, conferences and

meetings. The section is responsible for maintaining the three lecture theatres, Conference rooms and Homi Bhabha Auditorium. The section also provides audio visual services to all the cultural events held in Auditorium and at other places in the Institute. In addition the section regularly offers video-conferencing services for official meetings.

New Facility

Up-gradation of 3 axes Coordinate Measuring Machine

The machine has been upgraded to measure form errors of the curved surfaces with in the accuracy of 1.5 microns over a length of 300mm. Also the same equipment may now be used to process best fit curved geometry from the measured point cloud. In other words the equipment is ready for the reverse engineering.

Major Achievements

1. DEGAS Assembly, DEGAS Detector for Electromagnetic Spectroscopy

The DESPEC Germanium Array Spectrometer (DEGAS) is a high-purity germanium Gamma detector array for high-resolution spectroscopy of electromagnetic decays from exotic nuclear species. The instrument is designed to hold 3 long Germanium crystals in a big single aluminum End Cap (Housing) along with 3 BGOs on the top of it. The 3 BGOs are housed in 3 separate aluminum

Back Catcher End Caps. The entire assembly is around 300mm high and comprised of 14 structural components (10 major and 4 minor). 6 of 10 major and 4 minor components are fabricated in CWK.

Major components are configured to suit minimum weight philosophy. Therefore shapes of all housings and flanges have been optimized and wall thicknesses are kept between 1 and 2 mm. Since many parts are joined together, position tolerances are very crucial. These requirements make machining very critical. Various indigenously developed Jigs and Fixtures have been employed to ensure achievement of desired positional and angular dimensional accuracy. All dimensional and form errors have been verified on CMM. The assembly has been so highly appreciated by GSI Germany that the Workshop has received an order to produce 15 more assemblies. The order will be processed during 2016-17.

2. Support to Thirty Meter Telescope (TMT), India

Participation in the Thirty Meter Telescope (TMT) will provide Indian astronomers an opportunity to carry out frontline research in astronomy. The primary mirror of the TMT has an aperture diameter of 30 m, consisting of 492 individual 1.44 m hexagonal segments. The main challenge is to maintain the final wavefront at the focal plane as though formed by a single monolithic 30 m diameter mirror. This involves developing a host of new technologies in mechanics, electronics, optics and control software. India chose, with the aim of acquiring key technologies, to provide a portion of the 492 segments and the complete segment support system consisting of around 1,500 actuators and around 3,000 edge sensors. Segment Support Assemblies (SSAs): Each mirror segment will be mounted on a Segment Support Assembly (SSA). Each mirror segment requires an SSA that has about 80 sub-components that are to be manufactured separately and integrated. Two companies viz. M/s Avasarala Technologies Limited, Bangalore and M/s Godrej and Boyce Manufacturing Co. Ltd, Mumbai were qualified and awarded the contract to manufacture 3 Nos each of prototype SSAs. The capability of the companies will be assessed accordingly. Central Workshop has been entrusted to witness 3rd party inspection of all SSA sub components and to do the assembly of SSA at M/s Godrej and Boyce Manufacturing Co. Ltd. During past 1 year inspection of 3 prototypes and assembly tools has been carried out. Inspection involved use of various metrology tools such as CMM, Vernier, Micrometer, Digital Profile Projector and various gauges.

3. Production Jobs

Fabrication of 45 HE Calibration Box Housings with 17 various aluminum parts each for CMS project at CERN, Geneva. These Boxes are required to calibrate Si Photo Multipliers with LED lights when LHC beam is off. The housing supports various electronic cards and optic sub-assemblies. Depending on different accuracies required for different jobs, a CNC and two conventional machines have been dedicated for the work.

Yearly production of brass housings and pins for holding service medals/mementos

Following yearly trend and rise in the demand of Ultra High Vacuum components, central workshop continues to manufacture UHV components. The components are available as a stock item with the central stores. Following types of popular UHV components are being manufactured: KF blanks, Center rings, Weldable stub ends for NW10 NW16 NW25 and NW40, reducing adapters, reducing center rings and non-rotational blank flanges of CF35, CF50, CF63 and CF100

4. Fabrication of 2 Gearbox free motorized rolling Writing Boards for first year graduate students, University Cell, Prof. Amol Dighe.

The new tubular motor design is almost standardized and popular among users. The entire project from configuration to fabrication to installation and testing was done in-house. In the new design, conventional gearbox has been replaced with high torque and low RPM curtain motors. The new design looks sleek and requires less floor space.

5. Fabrication of Electron Gun for Dr. Prabhudesai and Mr. Krishanndu Gope, DNAP

The gun is required to produce electron beam of the range 1-20eV with energy resolution of 0.5eV. The assembly consists of various titanium and ceramic parts. Concentricity requirement of the mating parts is up to 0.1mm because the final aperture for the electron beam is 1.2mm. All parts are machined within 0.05mm dimensional accuracy. The electron gun is designed for ultra-high vacuum applications.

6. Major carpentry fabrication jobs

- 35 study cum utility tables for graduate students
- in the newly created sitting place for the students. Each table (42" x 24") has 3 drawers with lock and key facility, a book shelf and a 2' x 2' notice board.

The job was completed before the desired time frame.

- 40 teakwood chairs for Lecture Theater identical to the original chairs of the lecture theater. The job

was done in the production mode using various bending and assembly fixtures and drilling fixtures.

Members

Chief Engineer:

Sangam Sinha

Machine Shop: RD Chogale, Yogesh Arora, SS Yadav, BS Basavraj, PS Choudhari, DK Satpute, CS Panchal, AA Jaitapkar, DM Patil, MK Thakor, 47 Tradesmen and 4 Work Assistants.

Auto Workshop: A F Fernandes, S B Shetey, 6 Tradesmen, 1 Work Assistant and 1 office clerk.

Glass Blowing Section: AR Dhanawade, DV Sawant and SH Shirke

Design And Drawing Office: UR Morje and V Kale

Lecture Theatre & Auditorium Facility: RK Mistry, SH Ghadiali, PS Labad

Office Staff: YS Akre, SM Nadkar and PV Pawar

Technical Services Group

Technical Services Group is responsible for maintaining following services on a round-the-clock basis:

- Operation and maintenance of Air-Conditioning, Refrigeration, Ventilation and Process Cooling systems consisting of 3 Centrifugal chillers of 1650 TR total capacity; 86 window A/C units and 126 split A/C units; 12 Packaged units; 40 Water Coolers; 234 Fan Coils units; 48 Air-Handling Units; Dedicated A/C Plants of different capacities at Speech Laboratory, MOVPE Lab., INO Lab. & Animal House.
- Operation & Maintenance of 1,50,000 ltrs. per day capacity Sewage Treatment Plant.
- Operation and maintenance of electrical power distribution and lighting installations, consisting of 11,000 volts & 415 V switchgears; 7 Nos. distribution transformers; 7 MW connected load installations & distribution network; 14 nos. lifts, 200 KVA Generator set etc.; providing additional power points as and when required as well as energizing new laboratories.
- Receipt of water at Cuffe Parade from Mumbai Municipal Corporation & Distribution to TIFR Housing Complex and the Institute through 4 Pumping stations located at Cuffe Parade, Colaba Residential Complex & the Institute.
- Maintaining water supply and Hydrant systems, Sanitary & Drainage systems including pumps, pipe lines, valves etc.
- Civil maintenance such as masonry, carpentry, painting, plumbing and mechanical maintenance of doors, windows, steel furniture and fabrication

works, etc. for 5,00,000 sq.ft. built up area of laboratories and common facilities.

- Operation and maintenance of Sewage disposal system of laboratories located in the basement and other areas of the Institute through sewage disposal pumps pumping out to BMC sewer tunnels.
- Electrical and Mechanical maintenance of all user equipments such as, process cooling systems, air-compressors, water pumps, kitchen equipments and hoists etc. totaling to more than a few hundred numbers.
- Maintenance & arranging special lighting for public performances at our Auditorium.
- Providing Engineering support for functions held at Multi Purpose Hall and Colony.
- Arranging procurement of materials, equipments needed for maintenance and upgrading and maintaining proper inventory of stores and disposal of obsolete/non-usable items.

This group also plans and implements up-gradation/replacement & new projects in the above areas on a continuous basis to ensure all systems are in good working condition at all times. It also coordinates with Government Departments and Directorate of Construction Services and Estate Management (DCS&EM) of Department of Atomic Energy for construction of new buildings and major restoration works.

This group provides engineering support to the ongoing research activities in the Institute as also during conferences, workshops etc. It also

provides technical liaison for its affiliated units at GMRT-Pune, Gravitational Laboratory at Gauribidanur, Balloon Facility at Hyderabad; Cosmic Ray Laboratory at Ooty; Homi Bhabha Centre for Science Education at Mumbai, NCRA, Pune and NCBS, Bangalore.

All the above works are looked after by a team of qualified engineers, technicians & auxiliary staff totaling to 180. Out of these, 45 members are deployed for round-the-clock shift duty to provide

essential services such as Air-Conditioning, Electrical and Water supply, whereas the balance staff is split into: 1) Air-Conditioning Section; 2) Electrical Engineering Section; 3) Civil Engineering Section; and 4) Administration & Stores Section.

Modernization of infrastructure utilities by incorpo-rating State-of-the-Art systems continues to be the thrust area for Technical Services.

Major works completed by this group during 2015-2016 are

A) Major Air-Conditioning Works:

1. Successful SITC of Precision AC & Cooling System for the super computer of 1LGTI at Balloon Facility at Hyderabad.
2. SITC of low noise, variable refrigerant, flow (VRF) type air-conditioning system for Interferometer lab.
3. SITC of 3 way motorized temperature control valves at 6 AHU sites.
4. Replacement of approx. 30 Nos. very old inefficient window & split ACs by new STAR rated energy efficient AC unit.
5. Laying new chilled water lines & making provision of cooling facility for 3 new installations of computing servers.
6. Tender preparation & release of order for replacement of 2 Nos. chilled water pumps at AC Plant Room to improve the efficiency.
7. Major maintenance work with procurement of spares of 600 TR centrifugal chilled water plant (RC#3).
8. Successful SITC of fully automated, state of the art, variable refrigerant flow (VRF) type low noise AC system for class room & sitting room at 1st floor Central Store.
9. Renovation of AC network in the East Canteen renovation work.

B) Major Electrical Works:

1. Replacement of electrical wiring in 8 Nos. flat and. Flat wiring and lightening Arrestor in Jagdish Building.
2. Fabrication, SITC of Cubicle type switchboard other accessories for A block Pent house and Central Stores 1st Floor labs.
3. SITC of Protection relays for LT1 & LT2 along with metering.
4. SITC of Protection Relay units for 6.6 KV switchgear
5. SITC of 750KVA Transformer with Electrical Panels.
6. SITC of 2 nos passenger Lifts at Ramanujan Guest house & 1 No. of A-Block freight lift.
7. Modernization of electrical network of approx. 20 labs.

C) Major Civil Works:

1. Completer renovation of East Canteen.
2. Complete external restoration of Jagdish building including removing of existing plaster, replastering & painting and terrace waterproofing.
3. Waterproofing & slope correction of Colonnade area.

Departmental Works:

We have completed various major and minor addition and alteration works related to Air-Conditioning, Civil and Electrical systems. During the year, 2000 Nos. (approx.) urgent work calls were received and also 1500 Nos. (approx.) work orders for minor additions and alterations were received and attended to.

Members

Chief Engineer: Shri Sangam Sinha

Dy. Chief Engineer: Shri V.P. Srivastava

Air-Conditioning Section: Shri/s R. Sharma, R.A. Patil, R.V. Dhuri, W.V. Leitao, A.M. Bhatkar, R.A. Rule and 35 Tradesmen & Work Assistants.

Electrical Engineering Section & Electrical Stores: Shri/s A.P. Singh, D.V. Shah, K.B. Kajrolkar, P.R. Nerkar, Jagdish Prasad and 30 Tradesmen and Work Assistants.

Civil Engineering Section & Technical Services Stores: Shri/s R.H. Jagtap, J.H. Rangari, A. Rupadja, A.L. Limbare, Y.G. Phadke, Shirish Lal and 38 Tradesmen and Work Assistants.

Shift Duty Operations: Shri/s S. Samanta, Abby Joseph, J.M. Chaudhari, R.D. Patil, D.S. Cardozo, A.T. Kadam and 25 Tradesmen and Work Assistants.

Drawing Office: Shri R.B. Kambli

Administration & Office Stores: Shri/s A.M. Patwardhan, R.M. Nadkar, N.K. Kadam and 2 Work Assistants



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Publicatons
Lectures
Training



Zero pressure balloon (300 cu.m.) along with an auxiliary balloon ready for launch for carrying an atmospheric science payload during NARL-NASA-University of Wyoming's Batal campaign (July-August 2015)



Zero pressure balloon (3026 cu.m.) after bubble inflation with a parachute prior to launch during Batal campaign (13th Aug 2015)

School of Mathematics

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19. Biswas, Indranil with Sanjay Kumar Singh, Diagonal property of the symmetric product of a smooth curve. *Comptes Rendus de l'Académie des Sciences (Paris) – Mathématique*, Vol. 353, No. 5, (2015), 445–448.
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In Books

Anukul Jana, and Herbert W. Roesky, Chapter 14: "Silicon(II) as a Synthone for the access of different Silicon(IV) and Silicon(II) Compounds" in "Efficient Methods for Preparing Silicon Compounds" *Elsevier*, 2016, ISBN: 9780128035306, 183–204.

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School of Technology and Computer Science

In Journals

1. Ada A., Chattopadhyay A., Fawzi O. and Nguyen P., *The NOF Multiparty Communication Complexity of Composed Functions*, Computational Complexity, **24**(3), pp. 645–694, 2015.
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6. Czap L., Prabhakaran V., Fragouli C. Diggavi S., *Secret Communication Over Broadcast Erasure Channels with State-feedback*, IEEE Transactions on Information Theor, **61**(9), pp. 4788–4808, 2015.
7. Czap L., Fragouli C., Prabhakaran V. and Diggavi S., *Secure Network Coding With Erasures and Feedback*, IEEE Transactions on Information Theory, **61**(4), pp. 1667–1686, 2015.
8. Foss S., Juneja S., Mandjes M.R.H. and Moka S.B., *Spatial Loss Systems: Exact Simulation and Rare Event Behavior*, SIGMETRICS Performance Evaluation Review, **43**(2), pp.3-6, 2015.
9. Fragouli C., Prabhakaran V., Czap L. and Diggavi S., *Wireless Network Security: Building on Erasures*, Proceedings of the IEEE, **103**(10), pp. 1826–1840, 2015.
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11. Huang C.-C., Kavitha T., Mehlhorn K. and Michail D., *Fair Matchings and Related Problems*, Algorithmica, **74**(3), pp. 1184-1203, 2016.
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16. Moka S.B. and Juneja S., *Regenerative Simulation for Queueing Networks with Exponential or Heavier Tail Arrival Distributions*, ACM Transactions on Modeling and Computer Simulation (TOMACS), **25**(4), pp. 1-22, 2015.
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In International Proceedings

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2. Bhangale A., Harsha P. and Varma G., *A Characterization of Hard-to-cover CSPs*, Proceedings of the 30th Computational Complexity Conference, pp. 280–303, 2015.
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7. Cummings R., Ligett K., Radhakrishnan J., Roth A. and Wu Z.S., *Coordination Complexity: Small Information Coordinating Large Populations*, Proceedings of the 2016 ACM Conference on Innovations in Theoretical Computer Science, ITCS 2016, pp. 281-290, 2016.
8. Cseh Á., Huang C.-C., and Kavitha T., *Popular Matchings with Two-Sided Preferences and One-Sided Ties*, Proceedings of the 42nd International Colloquium on Automata, Languages, and Programming (ICALP), Part I, pp. 367-379,

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9. Daca P., Gupta A. and Henzinger T., *Abstraction-driven Concolic Testing*, VMCAI 2016.
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 12. Iyer S. and Vaze R., *Achieving Non-Zero Information Velocity in Wireless Networks*, Proceedings of the IEEE SPASWIN, 2015.
 13. Kumar A., Pillai S., Vaze R. and Gopalan A., *Optimal WiFi Sensing via Dynamic Programming*, Proceedings of the IEEE RAWNET, Mumbai, 2015.
 14. Mishra M., Sharma ., Dey B. and Prabhakaran V., *Private Data Transfer over a Broadcast Channel*, Proceedings of the IEEE International Symposium on Information Theory (ISIT), Hong Kong, 2015.
 15. Mishra M., Dey B., Prabhakaran V. and Diggavi S., *On the Oblivious Transfer Capacity of the Degraded Wiretapped Binary Erasure Channel*, Proceedings of the IEEE International Symposium on Information Theory (ISIT), Hong Kong, 2015.
 16. Mukhopadhyay S. and Sanyal S., *Towards Better Separation Between Deterministic and Randomized Query Complexity*, In Prahladh Harsha and G. Ramalingam, editors, Proceedings of the 35th IARCS Annual Conference on Foundations of Software Technology and Theoretical Computer Science (FSTTCS), 45, LIPIcs. Schloss Dagstuhl, pp. 206-220, 2015.
 17. Pillai S. and Prabhakaran V., *On the Noisy Feedback Capacity of Gaussian Broadcast Channels*, Proceedings of the IEEE Information Theory Workshop (ITW), Jerusalem, 2015.
 18. Raja N., *Condorcet Paradox and Program Logics*, Proceedings of the Fifth World Congress on Universal Logic (UNILOG'15), Istanbul, Turkey, 2015.
 19. Raja N., *Judgment Aggregation and Stability of Programs*, Proceedings of the Computational Logic and Reasoning, Dresden, Germany, 2015.
 20. Raja N., *On a Correspondence Between Voting theory and Denotational Semantics*, Proceedings of the Twentieth Conference on Applications of Algebra in Logic and Computer Science, Zakopane, Poland, 2016.
 21. Rajakrishnan S., Rajan S. and Prabhakaran V., *Lower Bounds for Interactive Function Computation via Wyner Common Information*, National Conference on Communications (NCC), 2016.
 22. Sanyal S., *Near-optimal Upper Bound on Fourier Dimension of Boolean Functions in Terms of Fourier Sparsity*, In Magnús M. Halldórsson, Kazuo Iwama, Naoki Kobayashi, and Bettina Speckmann, editors, Proceedings of the 42nd International Colloquium of Automata, Languages and Programming (ICALP), Part I, 9134, LNCS, Springer, pp. 1035–1045, 2015.
 23. Satpathi S., Nagda R. and Vaze R., *Optimal Offline and Competitive Online Strategies for Transmitter-Receiver Energy Harvesting*, Proceedings of the IEEE International Conference on Communications ICC, London, 2015.
 24. Sridhar A., Karamchandani N. and Prabhakaran V., *Coded Caching in Hybrid Networks*, National Conference on Communications (NCC), 2016.
 25. Subramanian A., Kanth G.S., Moharir S. and Vaze R., *Online Incentive Mechanism Design for Smart-phone Crowdsourcing*, to appear in Proceedings of the IEEE WIOPT, Mumbai, 2015.

In Books

Abhishek Kr. Singh and N. Raja: Separation Logic to Meliorate Software Testing, Trends in Software Testing, ISBN: 978-981-10-1414-7, Springer-Verlag, 2016.

Technical Reports

1. Barman S., Bhaskar U. and Swamy C., *Computing Optimal Tolls in Routing Games Without Knowing the Latency Functions*, On Arxiv.
2. Bhaskar U., Cheng Y., Ko Y.K. and Swamy C., *Near-Optimal Hardness Results for Signaling in Bayesian Games*, On Arxiv.
3. Glynn P. and Juneja S., *Ordinal Optimization - Empirical Large Deviations Rate Estimators, and Stochastic Multi-armed Bandits*, <http://arxiv.org/abs/1507.04564>, 2015.
4. Jalal A., Vaze R. and Bhaskar U., *Online Budgeted Repeated Matching*, On Arxiv.

Scientific Information Resource Centre

Publications in Proceedings

R. Prabakaran and Shalini Lihitkar, WISER Ranking of Astronomy and Astrophysics Libraries' Websites, *Proceedings of the 11th International Conference on Webometrics, Informetrics, and Scientometrics (WIS)* 2015, Delhi, pp 375-382.



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Lectures Given Elsewhere

School of Mathematics

Mahan Mj

1. Topology Seminar (co-ordinator), IIT Mumbai
2. Reading course on Riemannian Geometry, IIT Mumbai

N. Nitsure

A course of 4 lectures on Algebraic Surfaces, in the NCM summer school at Manipal University, August 2015.

D. Prasad

Gave a course of lectures in the Advanced Foundational School at HRI, Allahabad on 'Algebraic Topology' from 20th to 25th July 2015.

C.S. Rajan

Gave a course on Algebraic Number Theory to 4th year students of CEBS.

A. Sankaranarayanan

'On the discrete mean-square of the divisor function', University of Wuerzburg, Germany, August 05, 2015

J. Sengupta

Gave a lecture on 'Determination of modular forms from twisted central L values' in the University of Lille in May 2015.

Raja Sridharan

Gave 6 lectures on Visual Calculus and Differential Geometry in the N.B.H.M Madhava Mathematical Camp in St Xaviers College Kolkatta from 27, October to 06, November, 2015.

V Srinivas

1. Lectures given abroad:
 - (a) "Stratified vector bundles on simply connected

varieties in positive characteristic", Algebraic Geometry seminar, University of Chicago, Chicago, IL, USA, 5th Feb. 2016.

(b) "What are the Bloch-Beilinson Conjectures", Mathematics Colloquium, UC Berkeley, 11th Feb. 2016.

(c) "Introduction to the Weil Conjectures" and "The Diagonal problem", 2 lectures in the Eisenbud seminar "Commutative Algebra and Algebraic Geometry", UC, Berkeley, 19th Jan. 2016

(d) "Some applications of Algebraic Geometry to Commutative Algebra", Minicourse at ICMAT, Madrid, 6th and 26th May, 2015

2. Lecture course:

"The Grothendieck-Riemann-Roch Theorem", 5 lectures at NCM-sponsored Workshop, Central University, Hyderabad, 16th-18th Dec., 2015

Vijaylaxmi Trivedi

1. Two lectures on Hilbert-Kunz multiplicity and Hilbert-Kunz function in May 2015 at ICMAT Spain.

2. Hilbert-Kunz density function and Hilbert-Kunz multiplicity at RIMS Kyoto university on 28 March 2016.

T.N. Venkataramana

Gave three lectures on Early work of Harish Chandra on admissible representations, principal series and the action of enveloping algebra.

Sandeep V. Varma

Lecture on 20th April, 2015, at the Department of Mathematics, National University of Singapore: 'On applying the Deligne-Kazhdan philosophy to split classical groups.

TIFR Centre for Applicable Mathematics

C.S. Aravinda

A series of 5 lectures on 'Tiling' at the Department of Mathematics, Central University of Kashmir, Srinagar during 26-29 October, 2015.

K.T. Joseph

1. Gave 6 lectures on "Pseudo differential operators" at ATM workshop on Partial differential equations of fractional order, TIFR CAM, Bangalore 6 -18 July, 2015.

2. Gave two lectures on "The Burgers equation" at Gulbarga university, Kakaburgi, in special lecture series on mathematical science organized by Karnataka science and Technology Academy, Bangalore, December 29-December 31, 2015.
3. Gave 4 lectures in the ATM workshop on PDE and Mechanics, at Kerala School of Mathematics, Calicut February, 01-06, 2016.
4. Gave 2 lectures "On hyperbolic systems of conservation laws" at NISER, Bhubaneswer, on 22 March, 2016.

Mythily Ramaswamy

1. A short lecture course in CIMPA 2015, organised in the Mathematics dept, IIT Bombay from June 22 to July 4, 2015. Gave 3 lectures covering the topics "Optimal Control of Heat Equation", "Applications of Optimal Control", "Stabilization of Heat Equation" on July 3 and 4, 2015.
2. A short course of 5 talks on Linear Algebra, Ordinary Differential Equations in the Instructional School for Teachers, from December 7 to 10, 2015, at TIFR CAM, for College teachers and research scholars.
3. Two talks on "Introduction to Series and Convergence" at the Indian Academy Degree College for students of B.Sc and M.Sc from a few colleges in Bangalore and Tumkur, on February 26, 2016.

Praveen C.

1. "Well-balanced DG scheme for Euler equations with gravity", Oberseminar, Dept. of Mathematics, Univ. of Wurzburg, 16 April 2015.
2. "Well-balanced discontinuous Galerkin method for Euler equations with gravity", Scientific Computing Seminar, Chair of Scientific Computing, TU Kaiserslautern, 7 May 2015.
3. Four lectures on Finite difference method for hyperbolic equations, NPDE Workshop, IIT Kanpur, 1-3 June, 2015.
4. Five lectures on discontinuous Galerkin methods in NCM ATM School on PDE and Mechanics, Kerala School of Mathematics, Kozhikode, 1-6 Feb., 2016.

A.S. Vasudeva Murthy

1. Advanced level training program in differential equations, BITS Goa, June 1-3, 2015, "Weak solutions and its existence for the heat equation", 5 lectures.
2. CIMPA pre-school on current research in Finite element methods, IIT Bombay, June 29-30, 2015, "On the heat equation". 3 lectures.
3. Workshop on Computational techniques for differential equations with MATLAB, IIT Roorkee, July 1-4, 2015, "Finite element methods", 3 lectures.
4. INSPIRE CAMP for young students, K L University, Vijayawada, September 11, 2015. "Observing and modelling via differential equations".
5. Seshadripuram College, Bangalore. September 14, 2015. "Mathematical modelling".
6. Vel. Tech University, Chennai. September 20, 2015, "On the string equation of Narasimha".
7. National Workshop on parabolic differential equations and applications to image processing (PDEAIP 2015). Shri Sathya Sai Institute of higher learning, Puttaparthi. October 26-27, 2015, "Classical theory of parabolic equations." 4 lectures.
8. National Conference on evolving trends and challenges of science education and research. Basaveshwara College, Bangalore, January 29-30, 2016, "Observing and modelling through differential equations".
9. Science academic's lecture workshop on Fourier series, Fourier transforms and applications, Indian Academy Degree College, Bangalore, February 26, 2016, "Fourier series convergence and applications".

G.D. Veerappa Gowda

1. Three lectures on "Numerical Methods for Partial Differential Equations" in BITS Pilani, Goa during 12-17, October 2015.
2. Five lectures in ATM School on PDE and Mechanics held in KSOM, Khozikode during February 1-6, 2016.

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School of Natural Sciences

Department of Astronomy and Astrophysics

H. M. Antia

"Helioseismic Inversions" at IISER, Kolkata, January 9, 2016

S. Bhattacharyya

1. Invited lecture, "Timing and Spectral Properties of Neutron Star Low-Mass X-ray Binaries", a School in

the Neutron Star Workshop 2016, NCRA, Pune, India, January 06-07, 2016.

2. Invited lecture, "Thermonuclear X-ray bursts from neutron star LMXBs", a School in the Neutron Star Workshop 2016, NCRA, Pune, India, January 06-07, 2016.

3. Invited lecture, "Relativistic spectral emission lines", a School in the Neutron Star Workshop 2016, NCRA, Pune, India, January 06-07, 2016.
4. Invited lecture, "Accretion disk around neutron stars", a School in the Neutron Star Workshop 2016, NCRA, Pune, India, January 06-07, 2016.
5. Talk, "Accreting black holes and neutron stars with LAXPC", LAXPC meeting, TIFR, Mumbai, India, August 17, 2015.
6. Talk, "Nuclear-powered pulsars", a workshop on pulsars, TIFR, Mumbai, India, August 13, 2015.

A. Gopakumar

1. A set of four lectures on Pulsars and gravitational waves, Fourth Workshop for Pulsar Observatory for Students (POS), RAC, Ooty, October 2015.
2. A set of two lectures on Pulsars, Neutron Stars, Pedagogic School, 6-13, January, 2016, NCRA-TIFR, Pune

B. Mookerjee

- B. Mookerjee "Chemistry of CCC (C3) formation in Star forming regions", invited talk at the University of Kassel, Kassel, 13 May 2015

D. Narasimha

- General Relativity and Cosmology CSB and Mumbai University (Joint course) - January - May 2015

K. P. Singh

1. Clusters of Galaxies and Intra-cluster Medium, at IISER, Mohali, November 17, 2015.
2. Observational X-ray Astronomy: An Overview, at IISER, Mohali, November 16, 2015.
3. Seeing the invisible Universe in X-rays at Mata Gujari College, Fatehgarh Sahib, Punjab March 15, 2016.

T. P. Singh

- T. P. Singh, Is quantum theory exact or approximate? Colloquium, NCRA Pune March 21, 2016

M. N. Vahia

1. "Dimensions of the Universe", Lecture given to the students of Indian Junior Science Olympiad, May, 2015.

2. "India in Space, Big and Small of the Universe, and Atoms to Astronomy", Lectures given at the Indian Astronomy Olympiad programme, HBCSE, Mumbai, 2015
3. "Physical Sciences and Indian Society", Lecture course given to Academic Staff College (thrice during the period), TIFR, Mumbai, 2015
4. "Our Solar System, Mountains in the Solar System", Lecture given at the Indian National Camp for Earth Science Olympiad, Anna University, Chennai, 2015
5. Mayank Vahia and Wayne Orchiston, "India, the Andaman Island and the Orang Asli of Southeast Asia: An astronomical perspective", Presented at the South East Asian Astronomy Association meeting, Krabi, Thailand, November 2015, to appear in Journal of Astronomical History and Heritage, 2016.
6. "Southeast Asian Astronomy at the Cross-roads: Historical Links with India", Presented at the South East Asian Astronomy Association meeting, Krabi, Thailand, November 2015, to appear in Journal of Astronomical History and Heritage, 2016.

J. S. Yadav

1. Texas 28th Symposium (international Conference) held at Geneva, Switzerland, 14-18, December, 2015.
2. International conference on Jet Triggering mechanism in black hole sources, TIFR, Mumbai, 20-23 January, 2016
3. 11th IACHEC international conference at IUCAA, Pune, 29th February- 3rd March, 2016.

Nisha Yadav

1. "Harappan Civilization and its Script", Scientific Talk, TIFR, Apr 29, 2015.
2. "Computational Studies of the Indus Script", Discussion Meeting on New Scientific Approaches to Understanding The Indus Valley Phenomenon (May 4-5, 2015), The Institute of Mathematical Sciences, Chennai, May 4, 2015.
3. "Enigma of the Script of the Indus Valley Civilization", Third of Maritime History Society Monsoon Series Lecture, Maritime History Society, Capt M N Mulla Auditorium of the Western Naval Command at Navy Nagar, Colaba, 21 August 2015.

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Department of Biological Sciences

Shubha Tole

- IBRO School "Development and functions of brain circuit: From molecules to behavior" NBRC, Manesar, India March 15th-25th, 2016

Krishanu Ray

1. Nano-size motors and meter-long journeys, Nirma University, Gandhinagar, Gujarat, July 6, 2015.

2. DST INSPIRE Camp, at Dayanand Science College, Latur, Maharashtra, September 18-22, 2015.
3. Olfactory Cilia Assembly in Drosophila through step-wise transport by Kinesin-2, Centre for Cellular and Molecular Biology, Hyderabad, February 25, 2016

Vidita Vaidya

1. The Social Brain, Mumbai Local, Junoon, Somaiya College, May 2015
2. Early life experience and the programming of vulnerability to psychopathology, TCIS, TIFR Hyderabad, May 2015
3. Pharmacogenetic activation of neural circuits and the modulation of mood, Guha Research congress, Bodh Gaya, Bihar, December 2015
4. Fear and Learning, Centre for Learning, Bangalore, December 2015
5. Early life adversity and the programming of psychiatric vulnerability, University College Cork, Ireland, April 2016
6. Fast-acting antidepressants, trophic factors and adult neural stem cells, Indo-Irish Bilateral Exchange meeting, Trinity College, Dublin, Ireland, April 2016

Mahendra Sonawane

1. "Modulations in cell size, cell number and cell adhesion contribute towards the maintenance of epidermal homeostasis and integrity" in the biennial meeting of Indian society of Developmental Biologists held at the Centre for Cellular and Molecular Biology, Hyderabad during 15-18th July,

2015.

2. "Zebrafish as an animal model for biomedical research" in the Laboratory Animal Scientists Association (LASA) conference held at ACTREC, Mumbai during 15-16th October 2015.
3. "Zebrafish in epidermis biology and biomedical research" in the CEFIPRA sponsored seminars on alternatives to animal testing held at Indian Institute of Technology, Mumbai on 17th November 2015.
4. "Genetic control of the formation and maintenance of apical projections in zebrafish epithelial cells" in the annual talks of National Centre for Biological Sciences "Coming of Age: Transitions in Biology" during 11-13th January, 2016
5. "Cell size, cell adhesion and tissue homeostasis: Insights from zebrafish epidermis" in IFOM-inStem Conference on Inflammation and Tissue Homeostasis held at InStem Bangalore, during 1-3 February 2016.

Sreelaja Nair

- "Death of a Non-Diploid: The Answers beyond Dosage compensation", Indian Society of Developmental Biologists Biennial Meeting held at CCMB Hyderabad, July 15-18th 2015.

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Department of Chemical Sciences

K V R Chary

1. "Structure and Dynamics of Intrinsically Ordered and Disordered Proteins by NMR", at State Key Laboratory of Bio-organic and Natural Product Chemistry, Shanghai Institute of Organic Chemistry, Chinese Academy of Science on Friday, May 8, 2015
2. "NMR of Biological Systems: From Molecules to Human", at the Workshop on "Application of Bioinformatics in Drug Designing", Saturday, held in Kottayam, August 1, 2015.
3. "Structure and Dynamics of Intrinsically Ordered and Disordered Proteins by NMR", at University of Wisconsin, on August 4, 2015.
4. "Conformational Propensities and Dynamics of a β -crystallin, an Intrinsically Disordered Protein", at Structural Biology Initiative CUNY Advanced Science Research Center (ASRC) Monday, August 10, 2015.
5. "Flagella "A Biological product" as a Novel Alignment Medium for the Measurement of Residual Dipolar Couplings in Proteins", National Institutes of Health, National Heart, Lung, and Blood Institute, Bethesda, Maryland, USA, on August 17, 2015.
6. "Novel Methods in NMR and β -crystallins: Intrinsic Order & Disorder", at Nano Cell, University of Linz, Austria, Monday, November 23, 2015.

Jyotishman Dasgupta

1. "Ultrafast hydrogen atom abstraction inside a cationic nanocage: Role of the aqueous shell" in the 250th ACS National Meeting at Boston, Massachusetts, USA, August 2015.
2. "Probing exciton dynamics of conjugated polymers in solution through time-resolved pump-probe and stimulated Raman spectroscopy" Ultrafast Science theme meeting (UFS 2015), SN Bose Center for Basic Sciences, Kolkata, October 2015.
3. "Exciton Dynamics in Conjugated Polymers", DCS Annual Talks, November 4-6th, 2015, TIFR, Mumbai, India

Deepa Khushalani

1. Energy Issues (Storage and Application), Maithreyi College, Delhi February, 2016
2. Moderator for Panel Discussion – Trends and Skill set requirements for Chemical Industry. ChemCareers India, RSC Event, ICT Mumbai August 2015

R. V. Hosur

1. 'Moving the Frontiers of Protein NMR' UC Berkeley, USA, June 15, 2015
2. 'Advances in Protein NMR Methodologies', Stanford University, USA, June 17, 2015
3. 'New developments in Protein NMR Methods'

Scripps Clinic, San Diego, USA, June 19, 2015

4. 'Some Advances in Protein NMR Methodologies', NIH, Bethesda, MD, USA, June 25, 2015

5. 'Advances in Protein NMR' CCNY, NY, USA, June 29, 2015

6. Structure, Dynamics, folding/unfolding of SUMO proteins; workshop on NMR spectroscopy at Mysore University, November 18, 2015

7. Computational Methods in Structural Biology', MU Refresher course on Computational Methods in Basic Sciences, November 24, 2015

8. 'Strengthening the University System in India', MU refresher Valedictory, Mumbai, November 28, 2015

A.S.R. Koti

4th November 2015: "Mechanical unfolding of Azurin: Does copper influence its stability or unfolding pathways?", DCS Annual Talks,

November 4-6, 2015, TIFR, Mumbai, India

Shyamalava Mazumdar

A Full Lecture course on Bioinorganic Chemistry (CHY 414) for IISER, Trivandrum from Aug-Nov, 2015.

Sudipta Maiti

1. "Bangalore Microscopy Course", NCBS Bangalore, Sep. 2015

2. "Where the opportunity for drug discovery lies", Dec. 2015, Manipal University, Manipal

3. "Label free detection of neurotransmitters using multiphoton microscopy", Shanghai Jiao Tong University, Shanghai, China, May 12, 2015

4. "About sticky proteins", Somaiya College, Mumbai, Oct. 20, 2015

5. "Amyloid beta: membrane and beyond", Colloquium, Leipzig University, Nov. 20, 2015

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Department of Condensed Matter Physics & Material Sciences

E.V. Sampathkumaran

1. Seminar to M.Sc/Ph.D students at the Bharatidasan University, Trichy, on 5 October 2015 and at NIT, Trichi, on 6 October 2015 on "Basic concepts in magnetism"

2. Colloquium on "Novel magnetic and dielectric anomalies due to spin-chains in geometrically frustrated magnetic system, $\text{Ca}_3\text{Co}_2\text{O}_6$ ", on 13 November, 2013, at the Physics Department, San Diego State University, San Diego, USA.

Arnab Bhattacharya

1. "Engaging the Public with Science: Random musings, especially from Chai and Why?", TCIS, Hyderabad, Mar. 11, 2016

2. "Reflections on the world of Science", Inaugural address, Café Scientifica, Dhirubhai Ambani International School, Mar. 8, 2016

3. "Seeking N-lightenment - The bright world of nitride semiconductors", Institute of Science, Mumbai, Feb. 24, 2016

4. "From Henry Cavendish to Steve Jobs, via Nikolai Lobachevsky and Claude Shannon: A random walk in science", Aditya Birla World Academy, Mumbai, Feb. 24, 2016

5. "The way of science", Keynote address, Scholar's Day, D.G. Ruparel College, Mumbai, Dec. 22, 2015

6. "The ChemHistory of light!": Keynote address, CII and RSC Chemistry Everywhere Lectures and ChemCareers India, Nowrosjee Wadia College, Pune, Aug. 27, 2015.

A.V. Gopal

Taught Advanced Condensed Matter Physics course with Prof. Sangita Bose at Center for Excellence in Basic Sciences (CBS), Mumbai during Jan-April 2016.

Pushan Ayyub

1. Application of X-rays in probing the structure of solids, *Homi Bhabha Centre for Science Education*, Mumbai, 8.8.2015

2. Condensed Matter Physics at the Nanometer Scale (A Course of 5 Lectures), *Winter School on Condensed Matter Physics* at Indian Statistical Institute Kolkata, January 18-21, 2016.

3. Fabrication of Novel Materials by controlling Particle Size, *Raman Memorial Conference 2016*, Physics Dept., U. Pune, 13.02.2016

Department of High Energy Physics

Ramkrishna Dewanjee

"Search for additional heavy scalar/pseudoscalar neutral Higgs bosons at CMS", talk at the "Deep Inelastic Scattering" conference at Hamburg,

Germany in April 2016.

B.Satyanarayana

1. INO: India's very own mega science project,

BITS, Pilani - K. K. Birla Goa Campus, March 23, 2016

2. Research and Reporting, Universal College of Engineering, Vasai, October 6, 2015

3. Medical applications of microwaves, Universal College of Engineering, Vasai, October 3, 2015

4. Signal processing and data acquisition system for science experiments, TIFR, Mumbai, August 8, 2015

5. Physics and Potential of the INO Project, American College, Madurai, July 22, 2015

6. High speed signal processing techniques, K J Somaiya Institute of Engineering and Information Technology, Mumbai, April 8, 2015

7. Course on DAQ systems for Neutrino Physics Experiments, Winter School on Beyond the Standard Model Physics - 2016, BHU, Varanasi, January 24-February 14, 2016.

8. Microelectronics: Challenges and Opportunities, S B Jain Institute of Technology, Management and Research, Nagpur, January 16, 2016

9. Trends and Technologies of VLSI devices, Shri

Ramdeobaba College of Engineering & Management, Nagpur, January 16, 2016

10. VLSI: Future directions and opportunities, Kavikulguru Institute of Technology and Science, Ramtek, January 15, 2016

11. Trends and Technologies of Signal Processing Hardware, Kavikulguru Institute of Technology and Science, Ramtek, January 15, 2016

12. VLSI: Challenges and Opportunities, Usha Mittal Institute of Technology, Juhu, August 3, 2015

13. Signal processing techniques: Legacy to the latest, Universal College of Engineering, Vasai, Thane, Mumbai, July 27, 2015

14. Trends and Technologies of VLSI devices, SVPM's College of Engineering, Malegaon, July 4, 2015

15. Analog and Digital Signal Processing, SVPM's College of Engineering, Malegaon, July 4, 2015

16. Analog and Digital Signal Processing, Vidya Pratishthan's College of Engineering, Baramati, July 3, 2015

Department of Nuclear & Atomic Physics

E. Krishnakumar

“Electron – Molecule Resonances: its Physics and its Role in other Sciences and Technologies.” Prof. S. C. K. Nair Memorial Lecture, Calicut University, 28 Sept. 2015.

Vaibhav S. Prabhudesai

Refresher course on Applications of quantum

mechanics and its application to atom, molecule and radiation”, University of Mumbai, 21st Dec 2015 to 4th Jan 2016

G. Ravindra Kumar

“Quantum and Nonlinear Optics”, UM-DAE Centre of Excellence in Basic Sciences, Mumbai University, January-April 2016

Department of Theoretical Physics

Mustansir Barma:

1. Third Father Verstraeten Memorial Lecture, St. Xavier's College, Kolkata (2015).

2. Foundation Day Lecture, NISER, Bhubaneswar (2015).

3. Seminar, University of California at Santa Cruz (2015).

4. Seminar, University of Oxford (2015).

5. Five lectures on ‘Interacting Particle Systems’ at Bangalore School on Statistical Physics (2015).

Rajeev S. Bhalerao:

1. Course of nine lectures (1.5 hours each) on Quark-Gluon Plasma, XXX SERC Main School in Theoretical High Energy Physics, BITS, Pilani, 26 November-5 December 2015.

2. Quark-Gluon Plasma and Relativistic Heavy-Ion Collisions --- An Overview and Recent Advances, Saha Theory Seminar Series (STSS), SINP, Kolkata, 28 March 2016.

3. Quark-Gluon Plasma and Relativistic Heavy-Ion Collisions --- An Overview and Recent Advances, Colloquium, IOP, Bhubaneswar, 29 March 2016.

Basudeb Dasgupta:

Cosmology lectures for Astronomy Olympiad Camp, HBCSE, 31 May - 1 June 2015.

Saumen Datta:

Quantum Chromodynamics, 3-lecture course in Workshop on Recent Developments in Quantum Field Theory, Banaras Hindu University, Varanasi.

Deepak Dhar:

1. Rocks, rivers, and sand: simple models of complex systems, Physics colloquium at I.M.Sc., Chennai, May 25, 2015.

2. Directed percolation and sandpile models, a course of 4 lectures at 6th Bangalore School on Statistical Physics, Raman Research Institute,

Bengaluru, July 6-18, 2015.

3. Rocks, rivers, and sand: simple models of complex systems, invited lecture at Physics Society of Rashtasant Tukodji Maharaj Nagpur University, Nagpur, Aug. 21, 2015.

4. Rocks, rivers and sand: simple models of complex systems, colloquium talk at NISER, Bhubaneshwar, Aug. 26, 2015.

5. Evolving social networks: the Interacting Introverts and Extroverts Model, Electrical Engineering Colloquium, I.I.T. Bombay, Sep. 23, 2015.

6. Phase transitions in hard core lattice gases, a short course of two lectures in Workshop on Statistical Physics of Soft matter, Banaras Hindu Univ., Varanasi, Nov. 26-30, 2015.

7. States of matter, invited talk at INSPIRE camp, K.I.I.T., Bhubaneshwar, Dec. 6, 2015.

8. Rocks, rivers and sand: Simple models of complex systems, seminar at Physics Dept., Utkal University, Dec. 7, 2015.

9. Phase transitions in systems of particles with only hard-core interaction, three lectures in the C. K. Majumdar Memorial Lecture series, Indian Association for Cultivation of Science, Jadavpur, Kolkata, July 26-28, 2016.

Rajiv V. Gavai:

Large Hadron Collider : The Big Bang Machine, at DST INSPIRE Camp at the Panjab University, Chandigarh August 17, 2015.

Large Hadron Collider : The Big Bang Machine, in the DST-sponsored INSPIRE Camp at the Pt. Ravishankar Shukla University, Raipur, Chhattisgarh, December 22, 2015.

Sourendu Gupta:

1. Course on Effective Field Theory, given at the Mini School on Effective Field Theories, Indian Association for the Cultivation of Science, Kolkata during 29 February to 4 March, 2016.

Shiraz Minwalla:

1. Gravity at large D, Nag Lecture Series, Institute of Mathematical Sciences, Nov 2015.

2. Black Hole Dynamics at large D, ICTP Spring School, March 2016.

Rishi Sharma:

1. 5 lectures at the Mini school on Effective Field Theories at IACS Calcutta, Feb 29 - Mar 4, 2016.

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Low Temperature Facility

K V Srinivasan

gave a technical talk titled "*Liquefaction of Gases*" to the undergraduate and post graduate

students of Mechanical Engineering Department, L D College of Engineering, Ahmedabad on 16th February 2016

TIFR Centres

Homi Bhabha Centre for Science Education, Mumbai

A. Bose

Can exposure to work-contexts create opportunities for mathematics learning? A case of out-of-school measurement knowledge, Centre for Education Innovation and Action Research, TISS, July 23, 2015

A. Gupta

Scientific breakthroughs and the quantitative tradition- Their validity versus relevance to society, *Workshop on Time and Again: Challenging Science*", Sophia College, January 8-9, 2016

A. Mazumdar

1. Asteroseismology: Understanding starquakes, Indian Institute of Technology Bombay, September 30, 2015

2. Extrasolar planets, UM-DAE Centre for Excellence in Basic Sciences, March 28, 2016

3. Physics 303: Electricity and magnetism, lecture course, UM-DAE Centre for Excellence in Basic Sciences, Mumbai, 2015

A. Muralidhar

1. Environment and sustainability issues: Sustainable tourism, BMN College of Home Science, September 30, 2015

2. Tree-mapping at Nalanda Public School, NPS Mulund, February 20, 2016

A. Muralidhar, R. Kapil and S. Chunawala

Design and technology education as an inclusive approach to teaching-learning (Lead talk), *National Seminar on Education of Socially Disadvantaged Groups in India*, Regional Institute

of Education, Bhopal, March 5, 2016

A. Sule

1. Introductory mathematics – 1 (M100) lecture course, UM-DAE CBS, August - November 2015
2. Introductory mathematics – 2 (M200) lecture course, UM-DAE CBS, January - April 2015; January - April 2016
3. Sampling techniques, Pillai College of Education and Research, August 12, 2015
4. The sun, Lecture in Astronomy Basic Course of Khagol Mandal, September 12, 2015
5. The sun, Lecture at Astronomy Club, IITB (Krittika), October 16, 2015
6. Astronomy in daily life, *AEES Teachers Workshop*, December 28, 2015

D. Dutta & S. Chandrasekharan

Developing an educational framework for ecological sensibilities: A philosophical perspective, *the 3rd International Conference on Creativity and Innovations at Grassroots*, Ahmedabad, India, 2015

G. Nagarjuna

1. History and philosophy of science (5 Guest Lectures), CEBS, Kalina, August 18-22 October, 2015
2. Make, share and seek in freedom, Tyagarajar College of Engineering, Madurai, Commemorating Software Freedom Day, Festival '15, August 29, 2015
3. Simple ideas create greater impact, *Innovating for Quality Education for All* event on occasion of 55th Foundation Day, NIE Campus, NCERT, New Delhi, September 1, 2015
4. Impact of FSF during the last 30 years, Maulana Azad University Jodhpur on the occasion of 30 years of Free Software Foundation, October 3, 2015
5. Let us create a sustainable and free digital India without tears, without fear! *Yellow Talks, Unconventional Conventions*, Mysore Association Auditorium, October 10, 2015
6. Free software for digital India, *Yellow talks*, November 19, 2015
7. Principles of designing connected learning environment for quality education at scale: A view point, CEIAR Weekly Seminar Series, January 20, 2016
8. Ethics of science, University of Mumbai, Kalina, February 10, 2016

H. C. Pradhan

1. Lectures for Course on "History and philosophy of science" (H302) for students of the Integrated M.Sc. Program, UM-DAE Centre for Excellence in Basic Sciences, August- November 2015
2. Lectures for Course on "Ethics in science and Intellectual Property Rights" (H601), for students of Integrated M.Sc. Programme, UM-DAE Centre for Excellence in Basic Sciences, January-April

2016

3. Understanding the discipline of science, UGC Refresher Course in Education, Academic Staff College, University of Mumbai, June 25, 2015
4. Science and mathematics education in India – An overview, Sahvichar, Forum of Professionals of Indian Origin in Washington DC Area, Maclean, VA, USA, August 30, 2015
5. Evolution of scientific rationality from ancient times to scientific revolution, Athiests' Forum, Savarkar Smarak, Shivaji Park, Mumbai, March 26, 2016

H. Srivastava

1. Textbook analysis and assessment, *Science Teacher's Workshop by Eklavya*, Hoshangabad, May 31- June 1, 2015
2. How are environmental problems understood and discussed in high school science? *Workshop on Political Economy*, Delhi, June 20, 2015

J. Ramadas

Research in science education and its implications for curriculum. *Workshop on Science Education*, IISER, Pune, March 6, 2016

K. Haydock, G. Singh and R. D'Souza

What difference does ideology makes in framing research problems in science education", *Conference on Emerging Trends in Science and Mathematics Education*, Department of Education, University of Delhi, February 18, 2016

K. K. Mishra

Hindi mein vigyan evam praudyogiki lekhan, *Bhasha Sangoshthi*, Lucknow, March 20, 2016

K. Subramaniam

1. "Inferring pedagogical content knowledge from teaching" and "Formulating research questions", two talks at the Doctoral research school, Southern African Association for Research in Mathematics, Science and Technology Education. Johannesburg, June 2015
2. Teaching integers, *KV-ZIET Workshop for mathematics teachers*, Zonal Institute of Education and Training, Kendriya Vidyalaya Sangathan, Mumbai, June 5, 2015.
3. Four lectures on "Scientific Rationality". Summer course in Philosophy of Education, Azim Premji University, June 15 and 16, 2015
4. "Pedagogy of mathematics" and "Understanding the discipline of mathematics", Two talks given at the Refresher Course in Education, University of Mumbai, June 30, 2015
5. Mathematics learning for higher secondary school students and teachers, Kerala Govt. Model Residential Schools, CREST, Kozhikode, September 26, 2015
6. Teacher action and teacher knowledge. *Conference on Philosophy of Education*, Azim Premji University, January 12, 2016
7. Relating knowledge gained from work contexts

to school learning, *National Seminar on Mathematics Education and Social Justice Concerns*, Tata Institute of Social Sciences, Hyderabad, February 4, 2016

8. Re-conceptualizing teachers' specialized knowledge for the teaching of mathematics, *Conference on Emerging Trends in Science and Mathematics Education*, Department of Education, University of Delhi, February 19, 2016

9. Specialized knowledge that teachers need to teach school mathematics. *Workshop on Science Education*, IISER, Pune, March 6, 2016

K. Subramaniam, R. D'Souza and H. Raval

1. Teaching integers, for AECS mathematics and physics TGT teachers, December 28, 2015

2. Enhancing TLP using Geogebra, for AECS mathematics and physics TGT teachers, December 29, 2015

K. T. Hambir

Yes, you can do it!, *Raigad District Science Teacher Association Workshop* on "How to prepare science exhibits", Khopoli, October 13, 2015

M. C. Arunan

1. Convocation address at Bhiwandi, JM Momin's Womens College, January 19, 2016

2. Organized irresponsibility, *Pathways to Sustainable Society at South Asia Sustainability Hub and Network Conference*, Jawaharlal Nehru University, Delhi, January 29, 2016

M. C. Arunan, R. Sud, S. Ghumre and D. Bhatia

CUBE as a model for undergraduate biology education, *The 33rd Annual Conference of the Indian Academy of Neurosciences*, Chandigarh, October 31, 2015

M. Kharatmal

Language simplification of science texts: Action research project and concept mapping research, *One-day Teachers' Conference on Encouraging and Supporting Students' Thinking in the Learning of Science*, Navi Mumbai Science Foundation, Vashi, February 6, 2016

N. D. Deshmukh

1. Use of ICT in biology education and OER in biology education. *Collaborative Asian Association of Biology Education Pre-Conference Workshop*, organized collaboratively by HBCSE and DCT's Dhempe College of Arts & Science, Miramar, July 30, 2015

2. ICT and school education and USE of digital resources in school education, *Asian Association of Biology Education Pre-Conference Workshop* organized collaboratively by SCERT, Directorate of Education, Government of Goa, Dnyanprassarak Mandal's College, Khorlim, Goa and HBCSE, July 31 – August 1, 2015

3. Activity based learning, biology education through ICT and how to use OER, *Asian*

Association of Biology Education Pre-Conference Workshop titled "Inculcation of Activity Based Learning Practices in Science and Mathematics Teachers at Secondary Level and Exploration of Innovative Practices in Teaching – Learning and Evaluation Methods." organized collaboratively by Shri Shivaji Education Society, Amravati and HBCSE, August 8-10, 2015

4. Salient features of science teachers handbooks, *Rashtriya Madhyamik Shiksha Abhiyan Teacher Handbook Workshop*, Dr B R Ambedkar School, Pune, August 16, 2015

5. Science teachers handbooks and its significance in classroom teaching, *Rashtriya Madhyamik Shiksha Abhiyan Teacher Handbook Workshop*, Mumbai, September 12, 2015

6. Role of science teachers handbooks in classroom teaching, *Rashtriya Madhyamik Shiksha Abhiyan Teacher Handbook Workshop*, Nashik, October 4, 2015

7. Science exhibition and design of exhibits, *Akola District Science Teacher Association Workshop* on Science Exhibition 2015-16, New English School, Akola, October 26, 2015

8. Designing science exhibits, St. Mary's High School and Jr. College, Kalina, Mumbai, December 3, 2015

9. Role of science exhibition, P-ward science exhibition, Dr Sarvepalli Radhakrishnan High School, Sundar Nagar, Malad, Mumbai, December 4, 2015

10. Innovation and Ignite mind, Innovation exhibition at Rotary Club Office, Dombivali (East), Thane, December 5, 2015

11. Science exhibition for science education, P/K-ward science exhibition at Parle Tilak English Medium High School, Vile Parle, Mumbai, December 9, 2015

12. What students learn from science exhibition? K-west-ward science exhibition at Kamaldevi Jain High School, Andheri (West), Mumbai, December 10, 2015

13. Career in science education, *27th Aryabhata Science Exhibition*, IES School Mulund (East), Thane, January 13, 2016

N. D. Deshmukh and K. T. Hambir

Constructivist approach in science teaching and role of activities, *Wardha District Science Teacher Association Workshop: Theme-Constructivist Science Learning and Role of Experiments*, February 13, 2016

P. Ranadive

1. The solar system, Lecture in Astronomy Basic Course of Khagol Mandal, September 5, 2015

2. Life cycle of stars, Basic Course in Astrophysics, Extra Mural Department, University of Mumbai, December 27, 2015

3. Variable and binary stars, Basic Course in Astrophysics, Extra Mural Department, University of Mumbai, January 17, 2016

4. How and why in astronomy, A. P. S. I. T.

College Thane, February 22, 2016

5. Lecture and telescopic observation session, AECS School 6, December 30, 2015

6. Telescopes, for National Talent Search Program, HBCSE, January 5, 2016

R. D'Souza

1. Critical ethnography, disability oppression and mathematics education, Universidade Estadual Paulista (UNESP), Rio Claro, June 9, 2015

2. Can ideologies be (dis/en)abling, *Seminar on Mathematics Education and Social Justice Concerns*, TISS Hyderabad, February 4-5, 2016

R. Thengodkar, M. C. Arunan, P. Kishor and Cubists

Ecosystems and its simulation in labs, Navi Mumbai Science Foundation's Science Utsav, Vashi, February 7, 2016

S. Bhide

Assessment: A brief introduction to assessment and how to assess Project-based Learning (PBL), *KV-ZIET Teacher Workshop*, November 20, 2015

S. Chandrasekharan

1. The possibilities of new computational media: A learning sciences perspective, *Faculty Seminar*, Indian Institute of Management, Kozhikode, July 23, 2015

2. The empirical study of mathematics, Kerala School of Mathematics (jointly organised with Department of Psychology, University of Calicut), July 24, 2015

S. Chunawala

1. Introduction to PBL, *KV-ZIET Teacher Workshop*, November 18, 2015

2. Communicating research. Certificate course on Research Methodology by K J Somaiya Comprehensive College of Education, Training and Research, HBCSE, February 5, 2016

3. HBCSE and its activities (Inaugural address), Anjuman-I-Islam's Ahmed Sailor High School, Mumbai, February 13, 2016

S. Ladage

Learning from Indian Chemistry Olympiad programme: Reflections on Laboratory Experiments, *National Convention of Chemistry Teachers*, University of Lucknow, October 8-10, 2015

S. Ladage and A. Gupta

Science education research and development at HBCSE, *Symposium on Teaching Learning in Higher Technical Education* (A joint initiative of IIT Madras, TEQIP-Tamil Nadu and TEQIP-Kerala), Centre for Teaching and Learning (IIT, Madras), January 22-23, 2016

S. Naik

1. Learning through logical fallacies! Talk for secondary school students for an event organized by Institute of Science, Mumbai, February 13, 2016

2. Professional noticing: Learning through artifacts of teaching, Pre-service teachers from St. Xavier's Institute of Education, Mumbai, February 13, 2016

V. C. Sonawane, K. T. Hambir and R. Shaikh

Science through experiments, Shri Vithal Education and Research Institute (SVERI) *Pandharpur's School Teachers Workshop*, Lotus School Pandharpur, July 29-31, 2015

V. D. Lale

Use of chemistry demonstrations in day today teaching at the school level, *Chemistry Teacher Empowerment Programme organized by DIET*, Kozhikode, Regional Science Centre and Planetarium, Kozhikode, December 30-31, 2015

V. C. Sonawane

1. Harnessing light: Possibility and challenges, Ekveera school, Charkop, Kandivali, August 4, 2015

2. Guiding teachers for the preparation of exhibits, models and organizing exhibition, Malad, October 28, 2015

3. Science lecture, Royal School & Junior college, Hadapsar, Pune, January 27, 2016

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National Centre for Biological Sciences, Bangalore

Courses given Elsewhere

Jayant Udgaonkar

1. Given many talks to high school and undergraduate college students;

2. to the public at the Marathi Vigyan Parishad;

3. hosted many summer students including from under the SN Bose program.

M.K Mathew

1. Cotton College State University, Guwahati, (Aug 2015).

2. NUS IISER Thiruvananthapuram Symposium (sept 2015).

3. St. Joseph's College (feb 2016).

4. IISER Mohali (Mar 2016).

5. Basic Neuroscience at IISER Thiruvananthapuram 2010 onwards

6. Basic Neuroscience as part of the International Brain Research Organisation (IBRO) from 2013 onwards. This is a series of courses taught in countries that do not have a regular neuroscience education programme.

R. Sowdhamini

1. Lecture, University of Kerala (Jan 2016).
2. Lecture, Alagappa University, Karaikudi (Feb 2016).

Ranabir Das

Characterization, Structure and Interaction of Proteins Workshop at IBAB (2015)

P.V Shivaprasad

1. Lecture at ICAR sponsored Summer School on "RNAi in Crop Plants" at NRCPB, Delhi (May 2015).
2. Lecture at Athanasios College For Advanced Studies (MACFAST) Tiruvalla, Kerala (Dec 2015).
3. Lecture at Savithribhai Phule University, Pune (Feb 2016).
4. Lecture at University of Agricultural Sciences, Bangalore, (Feb 2016).
5. Lecture at Madurai Kamaraj University, (May 2016).

Arati Ramesh

Biofilms Conference, SASTRA University, Tanjore (Jan 2016)

Satyajit Mayor

1. Workshop on Living Matter, KITP, UCSB, USA
2. Evolutionary Biology, KITP, UCSB, USA
3. Physiology Course at Marine Biological Laboratories, Woods Hole USA

Upinder S. Bhalla

1. Transylvania Experimental Neuroscience Summer School, Romania (June 2015)
2. The Internet of living things, Or, Squishy computation, Young Investigators Meeting, Gulmarg
3. Research in Neuroscience, Deeksha high school, Bangalore

Vatsala Thirumalai

1. IBRO School in Neuroscience, BHU, Varanasi. (2015)
2. SERB School in Neuroscience, yearly, multiple locations.
3. Mahabaleshwar Seminar on Imaging in

Zebrafish, Alibaug, MH

Shannon Olsson

1. Metabolites and Bioprospecting (Lecturer; GKVK)
2. SCCS Bangalore (Workshop Organizer; IISc)
3. Chemical Ecology (Course Instructor; MPI Jena, DE)
4. Srishti School of Design, Speaker, 2016

Mahesh Sankaran

Advanced Statistics, Ecology in a changing world, Advanced topics in Plant-herbivore interactions, Field course in African Ecology (University of Leeds, UK)

Uma Ramakrishnan

National University of Singapore: Conservation genetic

Deepa Agashe

ICTS Winter School on Quantitative Biology

Radhika Venkadesan

1. Lecture at St. Aloysius College, Mangalore. (Feb 2015)
2. Cellular Microbiology course (Lecturer; GKVK)
3. Bioprospecting course (GKVK)

Mukund Thattai

1. Given multiple lectures at the Bangalore Science Forum as well as local schools and colleges.
2. Played scientific advisor for a play commissioned through a Wellcome Trust UK public Engagement event on antimicrobial resistance, which was performed at multiple venues throughout India, and involved engagement with school children at 5 schools in Bangalore.

Sandeep Krishna

1. Diversity in bacteria-virus ecosystems is facilitated by weak defences against viruses. Complex System Approach to Self-Organization meeting, IIT Chennai (Feb 2016).
2. Taught course at Niels Bohr Institute, Copenhagen (Jun 2015) covering topics including such as Complex networks, Nonlinear dynamical systems, Algorithms, Signalling, Bacterial gene regulation, Genome biology and Evolution.
3. NNMCB meeting on Mathematical Modelling of Biological Systems, Univ. of Kashmir, Srinagar (Apr 2015).

National Centre for Radio Astrophysics, Pune

Chandra, Poonam C.

1. Supernovae: shocked after violent death of stars, VSRP lectures, NCRA- TIFR, Pune, June 6, 2015
2. From birth to death: life cycle of stars, Radio Astronomy Winter School lecture, NCRA-TIFR, Pune, December 22, 2015
3. Converting an idea into a proposal, Radio Astronomy School lecture, NCRA-TIFR, Pune, September 2015
4. Sensitivity - In Radio Astronomy, Radio Astronomy School lecture, NCRA- TIFR, Pune, September 2015

Chengalur, Jayaram N.

The Faint Irregular Galaxy GMRT Survey, Colloquium at KASI, South Korea, Nov 5, 2015

Choudhury T. Roy

General Theory of Relativity (~25 Lectures), M.Sc. Course, SP Pune University, Pune, India, January - March 2016.

Gupta, Y.

1. Pulsar Astronomy, Pedagogic School of the Neutron Star Workshop, NCRA, Pune, January 6 and 11, 2016.
2. Overview and Current Status of the SKA, Neutron Star Workshop NCRA, Pune, January 15, 2016
3. Telescope Manager Consortium, Annual SKA Engineering Meet, Penticton, Canada, November 11, 2015.

Joshi, B.C.

1. Introduction to Radio Astronomy Observing for Students (POS-2015) Radio Astronomy Centre, Ooty, India, October 22, 2015
2. Introduction to Data Analysis methodology, Pulsar Observing for Students (POS-2015), Radio Astronomy Centre, Ooty, India, October 23, 2015
3. Pulsar Timing Array and Square Kilometer Array, Pulsar Observing for Students (POS-2015), Radio Astronomy Centre, Ooty, India, October 25, 2015
4. Radio Astronomy with Single element radio telescope, Radio Astronomy School for College students (RAWSC-2015), NCRA, Pune, India,

December 15, 2015

5. Pulsars and gravitational physics, Radio Astronomy School for College students (RAWSC-2015) NCRA, Pune, India December 19, 2015

Kanekar, N.

1. Modern Cosmology, Delta Corporation, Taiwan, June 2015
2. Modern Cosmology: Lecture at the Taichung High School, Taiwan, June 2015
3. High-redshift Galaxies, NCRA-TIFR Pune, June 2015
4. Interferometry and Radio Spectral Lines, Two lectures, Radio Astronomy School, NCRA-TIFR, Pune, September 2015
5. Do the Fundamental Constants Change with Time ?, (Colloquium) Arecibo Observatory, U.S.A. April 2015
6. Do the Fundamental Constants Change with Time ?, (Seminar) Columbia University, U.S.A.; April 2015
7. Stars and Gas in High-redshift Galaxies, (Seminar) National Astronomy Observatory, Socorro, U.S.A. May 2015
8. Do the Fundamental Constants Change with Time ?, (Colloquium) National Central University, Taiwan June 2015
9. Cold gas at high redshift ?, (Conference) SKA in Seoul, Seoul, South Korea, November 2015
10. The Nature of High-z Damped Lyman-alpha systems, (Colloquium), Korea Astronomy and Space Sciences Institute, Daejeon, South Korea, November 2015

Wadadekar Y.

1. Galaxy formation, IUCAA Refresher Course, May 25, 2015
2. Variable Stars, Astronomy Olympiad Training cum Selection Camp HBCSE-TIFR, May 27, 2015
3. Digital Astronomy techniques, IUCAA workshop on Astronomy with Small Telescopes at SRTM University, Nanded, December 8, 2015.
4. Basics of telescopes, IUCAA workshop on Astronomy with Small Telescopes at SRTM University, Nanded, December 9, 2015.
5. EM Wave propagation Radio Astronomy Winter School 2015, NCRA, December 15, 2015

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International Centre for Theoretical Sciences, Bangalore

Subhro Bhattacharjee

1) Title: Topological Condensed matter

Occasion: SERC School

Venue: Satyendra Nath Bose National Centre for Basic Sciences, Kolkata, India

Dates: November 23-December 12, 2015

Rajesh Gopakumar

1) *Title:* Lecture series on Higher Spin theories

Occasion: GR and Beyond Summer School

Venue: NTU, Taiwan

Date: July, 2015

2) *Title:* Lecture series on Large N vector models

Occasion: Summer school on Statistical Physics

Venue: Brandeis University, USA

Date: July, 2015

3) *Title:* Lecture series on Higher Spins and Strings

Occasion: Asian Winter School on String Theory

Venue: OIST, Okinawa, Japan

Date: January, 2016

4) *Title:* Lecture series on Mellin Representation in CFTs

Occasion: ICTP Spring School

Venue: ICTP, Trieste, Italy

Date: March, 2016

Suvrat Raju

1) *Title:* Lecture course on Black Holes and their Puzzles

Occasion: SERC School on Theoretical High Energy Physics

Venue: Birla Institute of Technology and Science

Date: November-December, 2015

TIFR Centre for Interdisciplinary Sciences, Hyderabad

Agarwal Vipin:

- Nuclear Magnetic resonance: Introduction and perspective, Visiting Students of Birla Institute of Technology, March 2016.

Barma Mustansir: "Fluctuations and Order", Fourth S. S. Bhatnagar Anniversary Lecture, Panjab University, Chandigarh (2016).

Chary K.V.R:

- Invited talk on, "Structure and Dynamics of Intrinsically Ordered and Disordered Proteins by NMR", at State Key Laboratory of Bio-organic and Natural Product Chemistry, Shanghai Institute of Organic Chemistry, Chinese Academy of Science on Friday, May 8, 2015
- Invited talk on, "NMR of Biological Systems: From Molecules to Human", at the Workshop on "Application of Bioinformatics in Drug Designing", Saturday, held in Kottayam, August 1, 2015.
- Invited talk on, "Structure and Dynamics of Intrinsically Ordered and Disordered Proteins by NMR", at University of Wisconsin, on August 4, 2015.
- Invited talk on, "Conformational Propensities and Dynamics of a $\beta\gamma$ -crystallin, an Intrinsically Disordered Protein", at Structural Biology Initiative CUNY Advanced Science Research Center (ASRC) Monday, August 10, 2015.
- Invited talk on, "Flagella "A Biological product" as a Novel Alignment Medium for the Measurement of Residual Dipolar Couplings in Proteins", National Institutes of Health, National Heart, Lung, and Blood Institute, Bethesda, Maryland, USA, on Aug 17, 2015.
- Invited talk on, "Novel Methods in NMR and $\beta\gamma$ -crystallins: Intrinsic Order & Disorder", at Nano Cell, University of Linz, Austria, Monday, November 23,

2015.

Garai Kanchan:

- Teaching Biophysics in the 2nd semester 2016 at TCIS jointly with Dr. Pramodh Vallurupalli

Krishnamurthy M:

- Two lectures given at the 7th Asian Summer School and Symposium on Laser-Plasma Acceleration and Radiation, Shanghai 2016.
- Lectures in SERB school on Lasers and Nonlinear optics, Pondicherry, April 2016.
- Three lectures in: "Special lectures series in Physics; focus: Laser atom interaction", University of Mysore, Mysore 2016

Madhu P.K:

- Structural insights into A β oligomers, University of Leipzig, Germany, July 2, 2015.
- Heteronuclear spin decoupling in solid-state NMR, ENS, Lyon, France, October 27, 2015.

Mondal Jagannath:

- Lecture on "Introduction to Chemistry" as a part of the science course conducted at Tata Institute of Social Sciences.

Sengupta Surajit:

- Okinawa Institute of Science and Technology, April 27, 2015 Tailoring defect densities in crystals using light fields: Amorphization and plastic flow of a solid in a non-affine field
- Institute of Industrial Science, University of Tokyo, May 8th, 2015 Tailoring defect densities in crystals using light fields: Amorphization and plastic flow of a solid in a non-affine field

School of Technology and Computer Science

A.Chattopadhyay

1. "Multi-party Communication Complexity", series of four lectures at the Summer School on Lower Bounds, Prague, Czech Republic, June 28 - July 01, 2015.

2. "Computational Complexity", a series of three lectures at the Santa Fe Winter School on Complex Systems, IISER-Mohali, December 07-21, 2015.



Lectures, Colloquia, Seminars at TIFR

Lectures by Visitors

School of Mathematicians

- Marco Lopez** (*Universidad Complutense de Madrid, Spain*) Geometric variational calculus of gauge theories (01.04.2015)
- Soumya Bhattacharya** (*CIRM, Trento*) Factorization of holomorphic eta quotients (01.04.2015)
- Oliver Sargent** (*Technion-Israel Inst. of Tech., Israel*) Random walks on the space of rank 2 discrete subgroups of R^3 (15.04.2015)
- Tanmay Deshpande** (*Kavli IPMU, Kashiwa, Japan*) Algebraic groups over finite fields and their representations (05.05.2015)
- Haruzo Hida** (*UCLA, USA*) Limit Tate-Shafarevich groups (06.07.2015)
- Dohyeong Kim** (*Institute for Basic Sciences, Korea*) Construction of some elliptic $K3$ surfaces and its diophantine applications (10.07.2015)
- Ambrus Pal** (*Imperial College, UK*) Simplicial homotopy theory of algebraic varieties over real closed fields (09.07.2015)
- J. Tilouine** (*Universite Paris, France*) Big image of Galois for positive slope families (14.07.2015)
- Prakash Belkale** (*University of North Carolina, USA*) Topology of hyperplane arrangements and invariant theory (30.07.2015)
- Shaunak Deo** (*Brandeis University, USA*) Hecke algebras modulo p (03.08.2015)
- Nishant Chandgotia** (*University of British Columbia, Canada*) Four Cycle Free Graphs and Entropy Minimality (07.08.2015)
- Sourav Ghosh** (*University of Paris, France*) Thermodynamics of Marguli Space Time-II 26.8.15
- Kingshook Biswas** (*RKM Vivekananda University*) Pattern rigidity of Kleinian groups (28.08.2015)
- Morten Hein Tiljeset** (*Aarhus University, Denmark*) Intrinsic diophantine approximation on polynomial graphs (04.09.2015)
- Tal Horesh** (*Technion - Israel Institute of Technology*) A problem of counting lattice points in hyperbolic space (11.09.2015)
- Arnab Mitra** (*Ben-Gurion University of the Negev, Israel*) Ladder Representations (15.09.2015)
- Brandon Levin** (*University of Chicago, USA*) Moduli of finite flat group schemes with descent (16.09.2015)
- Aditya Karnatak** (*Boston University, Boston*) On density of self-dual Artin representations (12.06.2015)
- Dubi Kelmer** (*Boston College*) Equidistribution of translated cuspidal geodesics and applications (06.11.2015)
- Riddhi Shah** (*JNU, New Delhi*) On the embeddability of certain infinitely divisible probability measures on Lie groups (13.11.2015)
- Margarida Mendes Lopes** (*Universidade de Lisboa, Portugal*) Algebraic surfaces of General Type (18.11.2015)
- Vincent Pilloni** (*ENS Lyon, France*) The spectral halo (18.11.2015)
- Mariusz Koras** (*Warsaw University, Poland*) Rational cuspidal curves in the projective plane (20.11.2015)
- Vincent Pilloni** (*ENS Lyon, France*) The Fontaine-Mazur conjecture in weight 0 (27.11.2015)
- Roman Mikhailov** (*St. Petersburg State University*) A new look at homotopy groups of spheres (02.12.2015)
- Gergely Harcos** (*Renyi Institute*) Primes, Polignac, Polymath (02.12.2015)
- Miles Reid** (*University of Warwick, UK*) The Oort-Tate cyclic group scheme of order p and Godeaux surfaces (02.12.2015)
- Gergely Harcos** (*Renyi Institute*) On the sup-norm problem for arithmetic hyperbolic 3-manifolds (04.12.2015)
- Kishore Marathe** (*City University of New York, New York*) Mock Moonshine (15.12.2015)
- Pallavi Dani** (*Louisiana State University, USA*) Large-scale geometry of right-angled Coxeter groups (16.12.2015)
- Pankaj Vishe** (*Durham University, UK*) Uniform bounds for Period integrals and sparse equidistribution (15.01.2016)
- Vinayak Vatsal** (*University of British Columbia, Canada*) p -adic families of modular forms of half integral weight (04.02.2016)
- Pierre Colmez** (*IMJ, Paris*) The p -adic Langlands program (10.02.2016)
- Jayadev Athreya** (*University of Washington, USA*) Rectangular Billiards and Volumes of Moduli Spaces (12.02.2016)
- János Pach** (*EPFL, Lausanne and Rényi Institute Budapest*) Semi-algebraic Combinatorics (18.02.2016)
- Gregory R. Conner** (*Brigham Young University, USA*) Wild Topology, Group Theory and a conjecture in Number Theory (29.02.2016)
- Marco Schlichting** (*University of Warwick, U.K.*) Homology stability for special linear groups and Euler classes of projective modules (18.03.2016)
- Jasbir Chahal** (*Brigham Young University, USA*) Elliptic curves and some questions in geometry (23.03.2016)

TIFR Centre for Applicable Mathematics, Bangalore

- Prof. Clifford Nolan** (*University of Limerick, Ireland*): Monostatic SAR with fold-cusp singularities (April 1, 2015)
- Prof. Karthik Duraisamy** (*Department of Aerospace Engineering, University of Michigan, Ann Arbor*): Data-driven Closure Modeling using Functional Inversion and Machine Learning (May 19, 2015)
- Mr. Suprio Bhar** (*Senior Research Fellow, Indian Statistical Institute Bangalore Centre.*): Senior Research Fellow, Indian Statistical Institute Bangalore Centre (June 15, 2015)
- Dr. Vamsi Pingali** (*Johns Hopkins University, USA*): A generalised Monge-Ampere equation (July 3, 2015)
- Mr. Karthik Adimurthi** (*Louisiana State University, USA.*): Lebesgue space estimates for the Laplacian and p-Laplacian on nonsmooth domains (July 9, 2015)
- Lectures on FEM and applications by Olivier Pironneau** (*Universite Pierre et Marie Curie-Paris 6, France*): Numerical Zoom for localized Multi-Scale Problems (July 20, 2015)
- Lectures on FEM and applications by Hiroshi Suito** (*Okayama University, Japan*): Fluid structure interaction analyses for blood flow related to aortic aneurysms (July 20, 2015)
- Lectures on FEM and applications by Roland Becker** (*Universite du Pays de l'Adour, France*): Nitsche's method for Incompressible Flows (July 21, 2015)
- Lectures on FEM and applications by Hiroshi Suito** (*Okayama University, Japan*): Coupled simulation for atmospheric and water current models for lakes and ponds (July 21, 2015)
- Prof. Dr. Gnter Leugering** (*Friedrich-Alexander-Universitt Erlangen-Nrnberg, Germany*): Optimal control of hyperbolic balance laws on networks (July 27, 2015)
- Prof. Debraj Chakrabarti** (*Central Michigan University, USA*): Distributional boundary values of holomorphic functions on piecewise smooth domains (July 29, 2015)
- Mokshay Madiman** (*University of Delaware, USA*): On monotonicity of the tendency towards convexity of Minkowski sums (August 3, 2015)
- Gugan Thoppe** (*ISI Bangalore*): A stochastic Kaczmarz algorithm for network tomography (August 3, 2015)
- Prof. Todd Quinto** (*ITufts University, USA*): A paradigm to classify added artifacts in limited data tomography (August 7, 2015)
- Dr. Sayan Bagchi** (*Department of Mathematics, IISc, Bangalore*): Weighted Norm Inequalities for WEYL Multipliers and Fourier Multipliers on the Heisenberg Group (August 28, 2015)
- Prof. Christian Klingenberg** (*University of Wrzburg, Germany*): Progress in all-Mach number flows and well-balanced methods for the compressible Euler equations (October 7, 2015) (via skype)
- Mr. Vinay Kumar Gupta** (*Center for Computational Engineering Science, Department of Mathematics, RWTH Aachen University, Germany*): Mathematical modeling of rarefied gas mixtures in non-equilibrium (October 9, 2015)
- Anurag Shukla** (*Dept. of Mathematics, Indian Institute of Technology, Roorkee*): Approximate Controllability of Semilinear Control Systems (October 19, 2015)
- Dr. Rajjak Gazi** (*West Bengal University of Technology*): Simulation of Singlet correlation- statistics by different resources (November 12, 2015)
- Olivier Pironneau** (*LJLL-UPMC (Paris VI)*): Automatic differentiation for the stochastic ode of finance (Nov 16, 2015)
- Dr. Haradhan Maity** (*Physics and Applied Mathematics Unit, Indian Statistical Institute, Kolkata*): Conditional Statistics of Reynolds Shear Stress over Scour-Hole Geometry (Dec 03, 2015)
- Sriram Raghunath** (*Michigan State University, United States*): Wall-resolved LES of supersonic channel flows: Subgrid-scale closures for internal energy equation formulation (Dec 11, 2015)
- Prof. Gerald Folland** (*University of Washington, Seattle*): On the dual of the discrete Heisenberg group (Dec 31, 2015)
- Kais Ammari** (*University of Monastir*): Schrodinger operator on binary tree-shaped networks (Jan 01, 2016)
- Dr. Manas Kar** (*Department of Mathematics and Statistics, University of Jyväskylä*): Inverse problems for the p-Laplace type equation (Jan 06, 2016)
- Dr. Karthyek Murthy** (*Columbia University, USA*): How do you get delayed for long in multi-server queues? (Jan 08, 2016)
- Prof. Cyril Tintarev** (*Uppsala University, USA*): Four proofs of cocompactness in Sobolev embeddings (Jan 11, 2016)
- Cyril Tintarev** (*Uppsala University, USA*): Weak convergence in metric spaces and theory of concentrated compactness in Banach spaces (Jan 14, 2016)
- Prof. Erkki Somersalo** (*Case Western Reserve University Ohio*): Non-local Boundary Conditions and Domain Truncation in Electrical Impedance Tomography (Jan 20, 2016)
- Kumarjit Saha** (*ISI Delhi*): Drainage network models in river basin modelling (Jan 21, 2016)
- Prof. Daniela Calvetti** (*Visiting Faculty, IISER Bhopal*): Parameter estimation in the context of hierarchical Bayesian models (Jan 22, 2016)
- Divyang Bhimani** (*HRI, Allahabad*): Modulation Spaces and Schrödinger Equation (Feb 04, 2016)
- Prof. Jerome Bertrand** (*University of Toulouse, France*): On the regularity of Euclidean convex surfaces (Feb 05, 2016)
- Dr. Alexander Keimer** (*Universitt Erlangen, Germany*): Some results on non local conservation laws (Feb 09, 2016)
- Guy Vallet** (*University of Pau, France*): On a Δp stochastic problem (Mar 02, 2016)
- Souvik Roy** (*ICTS, Bangalore*): Error estimates for Sanders third order accurate TVD scheme for scalar conservation laws in 1D (Mar 10, 2016)

Prof. Xu Zhang (*Sichuan University, Chengdu*): An Invitation to Control Theory of Stochastic Distributed Parameter Systems (Mar 21, 2016)

Pritam Giri (*Department of Mechanical Engineering, Indian Institute of Science, Bangalore*): Power loss minimization for drag reduction and self propulsion using surface mass transpiration (Mar 31, 2016)

Lecture Series

Prof. Malabika Pramanik (*University of British Columbia*): Directional maximal operators and lacunary sets (August 6 and 7, 2015)

Loganayagam R (*ICTS-TIFR, Bangalore*): The fluid gravity correspondence (Feb 29, Mar 08-10, 2016)

Special colloquium lecture series on the works of 2014 Fields medal and Nevanlinna prize winners by Prof. Keith Burns (*Department of Mathematics Northwestern University, USA*): On the work of Artur Avila (April 9, 2015)

Prof. Prof. Michael Renardy (*Department of*

Mathematics, Virginia Tech, Blacksburg, USA): From the Maximum Principle to Inverting the Future (July 13, 2015)

Prof. Michael Renardy (*Department of Mathematics, Virginia Tech, Blacksburg, USA*): Are viscoelastic flows under control or out of control? (July 30, 2015)

Prof. Maria Esteban (*Universit Paris-Dauphine, France*): Optimal symmetry results for the optimizers of Caffarelli-Kohn-Nirenberg inequalities (August 17, 2015)

Prof. Alejandro Adem (*University of British Columbia and Director, MITACS*): Building a talent bridge: strengthening Canada-India research collaborations (a description of Mitacs programs) & Finite Groups from a Topology Perspective (Dec 11, 2015)

Prof. John Gibbon (*Department of Mathematics, Imperial College, London, UK*): Main results for the 3D incompressible Euler and Navier-Stokes equations (Jan 20, 2016)

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School of Natural Sciences

Department of Astronomy and Astrophysics

Dr. Nisha Katyal, (*Jawaharlal Nehru University, New Delhi*) Light Scattering and Extinction Properties of Dust Grains in Interstellar and Interplanetary Medium; March 29, 2016

Dr. Nirmal Kumar Iyer, (ISRO Satellite Centre, Bangalore) Study of X-ray binary transients with ASTROSAT; March 22, 2016

Dr. Girish Kulkarni, (*Institute of Astronomy and Kavli Institute of Cosmology Cambridge, University of Cambridge, U.K.*) Small-scale Structure of the IGM and its Measurement Using Quasar Pairs; March 15, 2016

Prof. Robi Banerjee (*Hamburger Sternwarte, University of Hamburg, Germany*) Star formation out of the Magnetised Interstellar Medium; March 11, 2016

Dr. Rahul Shetty (*Institute of Theoretical Astrophysics, University of Heidelberg, Heidelberg, Germany*) Hierarchical and Bayesian methods for data analysis; March 9, 2016

Dr. Rahul Shetty (*Institute of Theoretical Astrophysics, University of Heidelberg, Heidelberg, Germany*) Diffuse molecular gas and variations in star formation scaling relationships in local galaxies; March 8, 2016

Dr. Arabindo Roy (*CEA, Saclay, Paris*) From interstellar dust to filaments-Key results from Herschel Gould Belt Survey; February 23, 2016

Dr. Thomas Giesen, (*University of Kassel, Germany*) Spectroscopy of the Heavens; February 16, 2016

Dr. Vikram R. Rana (*Space Radiation Laboratory, California Institute of Technology, Pasadena, USA*) Hard X-ray View of Ultraluminous X-ray Sources and

Cataclysmic Variables with NuSTAR; February 3, 2016

Dr. Vikram R. Rana, (*Space Radiation Laboratory, California Institute of Technology, Pasadena, USA*) NuSTAR - The First Focusing High Energy X-ray Mission in Orbit; February 2, 2016

Prof. Gungwon Kang (*KISTI, South Korea*) Gravitational radiation captures of two black holes; February 1, 2016

Prof. Raghunathan Srianand (*IUCAA, Pune*) Probing the Universe with QSO absorption lines; January 19, 2016

Prof. Janardhan P (*Physical Research Laboratory, Ahmedabad*) Is a Maunder like "Grand" Solar Minimum around the Corner? January 18, 2016

Mr. Jeronimo Voss (*Frankfurt am Main, Germany*) Aspects of the Milky Way; January 15, 2016

Kalyan Kumar (*Max Planck Institute for Astronomy (MPIA), Heidelberg, Germany*) Recent Trends in Adaptive Optics Techniques; December 18, 2015

Prof. Andrzej Królak (*IMPAN- The Institute of Mathematics, The Polish Academy of Sciences, Poland*) All sky searches for gravitational waves from rotating neutron stars in LIGO and Virgo data; Dec. 15, 2015

Dr. Nimesh A. Patel (*Harvard-Smithsonian Center for Astrophysics, USA*) The Submillimeter Array and the Greenland Telescope; December 1, 2015

Dr Kunal Mooley (*Oxford Centre for Astrophysical Surveys UK*) The Phenomenal 2015 Outburst of the Black-Hole X-ray Binary, V404 Cyg; Nov. 30, 2015

Dr. M. Pandey-Pommier (*Observatoire de Lyon, France*) Low Frequency view of merging galaxy clusters; November 20, 2015

Dr. Shabnam Iyyani, (*KTH Royal Institute of Technology, Stockholm, Sweden*) Photospheric emission in gamma-ray burst observations by Fermi gamma ray space telescope; November 3, 2015

Dr. Blesson Mathew, (*Swinburne University, Hawthorn, Australia*) Study Of Early-Type Emission-Line Stars In Different Evolutionary Phases; October 29, 2015

Dr. Henry Throop (*Planetary Science Institute in Tucson, Arizona, USA*) NASA's New Horizons Mission to Pluto and Beyond; September 8, 2015

Prof. Deepto Chakraborty, (*Massachusetts Institute of Technology, USA*) On the Origin of Quiescent Neutron Star Emission in Low-Mass X-ray Binaries; August 11, 2015

Dr. Lokesh Kumar Dewangan (*National Institute for Astrophysics, Optics and Electronics (INAOE), Mexico*) multi-scale, multi-wavelength study of massive star-forming region W42; July 28, 2015

Dr. Nilkanth Vagshette (*IUCAA - Pune*) AGN feedback mechanism in cool-core cluster galaxies; July 21, 2015

Simon Birrer (*Institute of Astronomy, ETH Zurich, Switzerland*) Strong lens modelling and the properties of dark matter; July 13, 2015

Ms. Shabnam Iyyani (*Department of Physics, KTH Royal Institute of Technology, Stockholm, Sweden*) Photospheric emission in gamma-ray burst observations by Fermi gamma ray space telescope; July 9, 2015

Dr. Watson P. Varricatt (*United Kingdom Infrared Telescope, Hawaii, USA*) Studies of massive star

forming regions at infrared wavelengths; July 7, 2015

Dr. Arnab Kumar Ray (*Jaypee University of Engineering & Tech. Madhya Pradesh*), Evolution and Instability of Bondi Accretion; June 30, 2015

Dr. Thushara Pillai & Prof. Jens Kauffmann, (*Max-Planck-Institute for Radioastronomy, Bonn, Germany*) Understanding Disk-Jet coupling in Black hole transients; June 16, 2015

Ms. Radhika D., (*ISRO Satellite Centre (ISAC), Bangalore*) Understanding Disk-Jet coupling in Black hole transients; May 22, 2015

Dr. Indrani Banerjee, (*Indian Institute of Science (IISc), Bangalore*) Investigating formation stage of black holes: nucleosynthesis and mass-spin correlation; May 15, 2015

Mr. Mayank Singh, (*Centre for Excellence in Basic Sciences, Mumbai*) Relativistic Hydrodynamic Fluctuations in Heavy-Ion Collisions; May 12, 2015

Prof. Biman Nath (*Raman Research Institute, Bangalore*) Fermi Bubbles: the biggest shock in the sky; April 21, 2015

Mr. Chandrachur Chakraborty (*Saha Institute of Nuclear Physics, Kolkata*) Lense-Thirring precession in strong gravitational fields; April 20, 2015

Dr. Suman Ghosh (*S. N. Bose National Centre for Basic Sciences, Kolkata*) On the creation of spin 1/2 particles and adiabatic renormalization in FLRW spacetimes; April 14, 2015

Ms. Hamsa Padmanabhan, (*IUCAA, Pune*) Measuring the temperature of the high-redshift intergalactic medium; April 7, 2015

Department of Chemical Sciences

Lectures by Visitors

Prof. M. Eswaramoorthy (*Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore*) Adaptive Pores: Reversible Pore Engineering of Mesoporous Silica (April 13, 2015)

Ms. Priti Sharma (*National Chemical Laboratory, Pune*) Immobilization of metal complexes (Pd, Mn) over mesoporous materials: Synthesis Characterization and application for oxidation, Hydrogenation and C-C coupling reactions (April 16, 2015)

Dr. Rohit Jain (*Max Planck Institute for Biophysical Chemistry, Germany*) Real Time Small Angle X-ray Scattering at High Flux Synchrotrons Reveals Entropy Driven Multistate Ubiquitin Unfolding Reaction (May 4, 2015)

Prof. Narayan Pradhan (*Indian Association for Cultivation of Science, Kolkata*) Designing Nanostructures in Reaction Flask (May 18, 2015)

Dr. Saumen Chakraborty (*Los Alamos National Laboratory, USA*) Grafting High Affinity Metal Coordination to Design Artificial Metalloproteins (May 19, 2015)

Dr. Saumen Chakraborty (*Los Alamos National Laboratory, USA*) Ultra-Small Gold Nanoclusters in Efficient Biofuel Cell Design (May 20, 2015)

Prof. Vishal Rai (*Indian Institute of Science Education & Research, Bhopal*) Chemical Reactivity Hotspots on Protein Landscape (June 8, 2015)

Mr. Chandrababu Putta (*Indian Institute of Chemical Technology, Hyderabad*) The Development of Green Synthetic Methodologies to Synthesize Fine Organic Chemicals Using Semiconductor Nanocomposite Based Heterogeneous Photocatalysts at the Expense of Light Radiation (June 10, 2015)

Prof. Latha Venkatraman (*Columbia University*) Physics and Chemistry at the Single-Molecule Level (June 15, 2015)

Prof. Debabrata Goswami (*Indian Institute of Technology, Kanpur*) Elucidating Structure and Dynamics under Optically and Thermally manipulated conditions: Perspectives of a Femtosecond Spectroscopist (June 22, 2015)

Mr. Imanol Usabiaga (*University of Pais Vasco, Spain*) Glucose Clusters: Unravelling The Interactions In Gas Phase (June 25, 2015)

Dr. Krishnananda Chattopadhyay (*CSIR – Indian Institute of Chemical Biology, Kolkata*) Protein Conformation, Dynamics and Aggregation: One Molecule at a time (June 29, 2015)

Prof. Harinath Chakrapani (*Indian Institute of Science Education & Research, Pune*) Small Molecule

Tools for Studying Cellular Redox Homeostasis (July 6, 2015)

Dr. Amitava Das (*National Chemical Laboratory, Pune*) Purpose-built Molecules & Molecular Assemblies for Predictive Optical Responses (July 13, 2015)

Prof. Santosh J. Gharpure (*Indian Institute of Technology, Mumbai*) New strategies for the stereoselective synthesis of oxa and aza-cycles (July 20, 2015)

Dr. Vivek Tiwari (*University of Colorado at Boulder, USA*) Towards Understanding Natural and Artificial Light Harvesting – New Theoretical Insights and Optical Techniques (July 28, 2015)

Dr. Raghunathan Ramakrishnan (*University of Basel, Switzerland*) Rapid and accurate simulation of electron dynamics across nanostructures (July 30, 2015)

Dr. Raghunathan Ramakrishnan (*University of Basel, Switzerland*) Accelerating virtual discoveries by augmenting quantum mechanics with machine learning (July 30, 2015)

Prof. Naresh Patwari (*Indian Institute of Technology, Mumbai*) Musings with Intermolecular Interactions (August 3, 2015)"

Prof. Krishna Kaliappan (*Indian Institute of Technology, Mumbai*) Domino Strategies for Syntheses of Natural Products and New Molecular Scaffolds (August 10, 2015)

Dr. Ayanjeet Ghosh (*University of Wisconsin, Madison*) Vibrational dynamics in proteins using two-dimensional infrared spectroscopy (August 11, 2015)

Dr. Ayanjeet Ghosh (*University of Wisconsin, Madison*) Structures and Dynamics using two-dimensional infrared and sum frequency generation spectroscopies (August 12, 2015)

Prof. Kausik Chattopadhyay (*Indian Institute of Science Education & Research, Mohali*) The W(Hole) Story of β -barrel Pore-forming Toxin Vibrio cholerae Cytolysin (August 17, 2015)

Prof. Mircea Dincă (*Massachusetts Institute of Technology, USA*) Teaching Sponges New Tricks: Redox Reactivity and Charge Transport in Microporous Metal-Organic Frameworks (August 25, 2015)

Prof. A.K. Tyagi (*Bhabha Atomic Research Centre, Mumbai*) Rational Design of Functional Materials: A Chemist's Approach (August 31, 2015)

Prof. Howe-Siang TAN (*Nanyang Technological University, Singapore*) Ultrafast 2D and 3D electronic spectroscopy and its applications to the study of Photosynthetic Light Harvesting Complexes (September 7, 2015)

Dr. Kalyaneswar Mandal (*The University of Chicago*) A Mirror Image Protein Antagonist of VEGF-A: Total Chemical Synthesis and Racemic Crystallography of A Heterochiral Protein Complex (September 9, 2015)

Dr. Kalyaneswar Mandal (*The University of Chicago*) Design and Construction of Protein Molecules with Novel Properties (September 10, 2015)

Dr. Amit Kumar Samanta (*University of Southern California, USA*) Spectroscopy and Dynamics of Hydrogen Bonded Networks: Imaging Bond Breaking Pathways (September 23, 2015)

Dr. Amit Kumar Samanta (*University of Southern California, USA*) Spectroscopy and Photo-induced Dissociation of Biologically and Atmospherically Relevant Hydrogen Bonded Complexes (September 24, 2015)

Dr. B.L.V. Prasad (*National Chemical Laboratory, Pune*) Molecular Tools for the Manipulation of Size, Surface Chemistry and Assemblies of Metal Nanoparticles (October 12, 2015)

Prof. T. Govindaraju (*Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore*) Molecular Probes and Templates for DNA Structures (October 26, 2015)

Dr. Ankur Gupta (*University of Oxford, UK*) Cells' Armour to Prevent Oxidative Stress - How redox non-innocent residues influence enzyme catalysis and protect cells from oxidative damage? (October 27, 2015)

Dr. Ankur Gupta (*University of Oxford, UK*) Seeing enzymes in action - Single-molecule studies of electron-transfer between copper centers of small laccase (SLAC) from *S. coelicolor* (October 28, 2015)

Prof. Michael K. Bowman (*University of Alabama, USA*) EPR and the Binding of Molecules to Cytochrome P450 Enzymes (November 2, 2015)

Prof. R. Murugavel (*Indian Institute of Technology, Mumbai*) Playing dice with zeolite secondary building blocks (November 23, 2015)

Prof. Eric Borguet (*Temple University, USA*) Ultrafast Vibrational Sum-Frequency Spectroscopy and Dynamics at Mineral/Aqueous Interfaces (November 30, 2015)

Prof. Michael J. Zdilla (*Temple University, USA*) Synthetic Molecules and Materials as Models of the Oxygen Evolving Complex of Photosystem II (December 7, 2015)

Prof. Andrew J. Orr-Ewing (*University of Bristol, UK*) Ultrafast Infra-red Spectroscopy as a Probe of Chemical Reaction Mechanisms (January 4, 2016)

Dr. Jino George (*University of Strasbourg, France*) Chiral plasmon coupling and light-matter strong coupling (January 11, 2016)

Dr. Jino George (*University of Strasbourg, France*) Light-matter strong coupling: a molecular perspective (January 12, 2016)

Dr. Prashant Kumar (*University of Sussex, UK*) Relevances of Organometallic Complexes in Catalysis, OLEDs and 3d/4f Coordination Clusters in Catalysis (February 10, 2016)

Dr. Supriya Pratihar (*Max Planck Institute for Biophysical Chemistry, Germany*) Probing Supra- τ_c Conformational Exchange in Proteins: Insight into Molecular Recognition (February 16, 2016)

Dr. Pranav Shirhatti (*Institute for Physical Chemistry and Max Planck Institute for Biophysical Chemistry, Göttingen, Germany*) Elephant, Blind Men, Molecule - Surface Scattering and Surface Chemistry (February 25, 2016)

Lectures by Department Members

Mr. Palas Roy, Molecular Basis for Optimizing Organic Photovoltaics (April 6, 2015)

Ms. Deepshikha Verma, An Unusual EF-hand Ca²⁺-binding protein: Structure, Dynamics and Ca²⁺-binding properties (April 20, 2015)

Ms. Anindita Sarkar, Sensing Manganese, Mn(II) (April 27, 2015)

Dr. Ranja Sarkar, Sequence- and Complexation-dependent Modulation in Equilibrium Flexibility of Ubiquitin and SUMO Proteins (April 30, 2015)

Mr. Baljeet Singh, Shape and Morphology Controlled Catalysis by Al-BTC Metal Organic Framework (MOF) (May 11, 2015)

Dr. Priyanka Shinde, Studies in Visible Light Photocatalysis (May 12, 2015)

Mr. Rahul Gera, Probing Excited State Redox Reactions Inside Molecular Containers (*Ph.D. Synopsis Seminar*) (May 14, 2015)

Dr. Anoop Rawat, What makes amyloidogenic peptides sticky: The case of Alzheimer's amyloid beta (A β) and human islet amyloid polypeptide (hIAPP) (May 21, 2015)

Mr. Dwaipayan Dutta Gupta, Detecting the mononuclear intermediate and minimal entity required for the formation of CuA center in cytochrome c oxidase (May 25, 2015)

Ms. K. Vijaya Lakshmi, A tale of prolycopene isomerization reaction: "Ultrafast triplet generation and redox triggered activation (May 27, 2015)

Mr. Himanshu Singh, Probing Plant Metabolism and Bio-molecular Interaction: Studies by NMR (*Ph.D. Synopsis Seminar*) (July 27, 2015)

Mr. Ramiz Sheikh, Nano-bioconjugation of Mutant Cytochrome P450cam (CYP101) for Biocatalysis (October 5, 2015)

Dr. Nisha Bayal, Nanostructured Silica-Titania Hybrid Material using Fibrous Nano-Silica (KCC-1) as Hard Template for Photocatalysis (January 15, 2016)

Ms. Sayani Das, Optical sensors for detecting metal ions and pH changes in vivo (January 18, 2016)

Mr. Mahak Dhiman, Synthesis and Application of KCC-1 Supported Ultra-small Metal Nanocatalysis (February 8, 2016)

Ms. Viola D'Mello, Investigation of Neutral and Cationic States of the N-H...X Hydrogen Bond (February 15, 2016)

Ms. Shrabasti Bhattacharya, Temperature Dependent Protein Malleability (stiffness) Probed by Force and Fluorescence (February 22, 2016)

Dr. Manish Shandilya, Directed Evolution of Cytochrome P450 : An Approach to Engineer Thermally Stable Enzyme (February 26, 2016)

Ms. Imon Mandal, Computational Studies of Optical Charge Transfer Transitions in Non-Aromatic Amino Acids and Metal-Ligand Complex (February 29, 2016)

Ms. Ananya Rakshit, Designer ligands for Mn²⁺-selective chelation and detection (March 28, 2016)

Department of Condensed Matter Physics & Material Sciences

Kasturi Saha, MIT, USA, "Towards High Resolution Sensing Using Color Centers in Diamond".

Siddharth Talluri, Analog Devices Inc., USA, "Photonics-aided MEMS: Towards High Performance

RF oscillators".

Tom Miller, Publisher with Institute of Physics, UK, "Publishing your research demystified", 2nd November 2015.

Department of High Energy Physics

Dr. Ranjan Dharmapalan, Argonne National Laboratory, Results from NOvA, 21-12-2015

Dr. Nachiketa Chakraborty, Max Planck Institute for Nuclear Physics, Germany, Variability and polarimetry as probes of TeV blazars, 09-11-2015

Dr. Xavier Janssen, University of Antwerp, Belgium, Search for the standard model Higgs boson produced by vector boson fusion and decaying to bottom quarks at the LHC by the CMS experiment, 24-09-2015

Dr. Xavier Janssen, University of Antwerp, Belgium, Study of Higgs Boson and its properties decaying to pair of vector bosons at the LHC by the CMS experiment, 18-09-2015

Dr. Debanjan Bose, Sungkyunkwan University, South Korea, Future of IceCube Neutrino Observatory : IceCube Generation 2, 15-09-2015

Dr. Debanjan Bose, Sungkyunkwan University, South Korea, IceCube Neutrino Observatory : Search of

Astrophysical Neutrinos, 14-09-2015

Dr. Ayan Paul, University of Rome, B \square K* mu mu: Analyzing Anomalies and Uncertainties with a Coherent Statistical Analysis, 18-06-2016

Prof. Ramanath Cowsik, McDonnell Center for the Space Sciences and Physics Department, Washington University, St. Louis, USA, High Energy Interstellar Positrons & Antiprotons Relevance to Cosmic-Ray & Dark-Matter Studies, 15-06-2016

Dr. Archana Sharma, CERN, Switzerland, Particle detectors for radiation: High Energy Physics and Beyond 05-05-2016

Dr. Maria Cepeda Hermida, CERN, Switzerland, Search for the Higgs boson at LHC, 02-05-2016

Mr. Sayan Biswas, Bose Institute, Kolkata, A production scenario of the galactic strangelets and an estimation of their possible flux in the solar

neighbourhood, 30-03-2016

Prof. Sunanda Banerjee, *Fermilab, USA*, Calibration of the CMS Hadron Calorimeter, 14-01-2014

Prof. Sridhara Dasu, *University of Wisconsin, USA*, Computing Systems for Hadron Collider Physics, 13-01-2016

Prof. Sridhara Dasu, *University of Wisconsin, USA*, Trigger Systems for Hadron Collider Physics, 12-01-2016

Prof. Sridhara Dasu, *University of Wisconsin, USA*, What's Next at the LHC? On the threshold of discovery...., 11-01-2016

Prof. Heinrich J. Voelk, Dr. Homi Bhabha-IUPAP Award Lecture, Cosmic Rays from our Galaxy, Dr. Homi Bhabha Auditorium, TIFR, Mumbai, 29 January 2016

Prof. Heinrich J. Voelk, Dr. Homi Bhabha-IUPAP Award Lecture, Cosmic Rays, their sources, and their movement in the Galaxy, Anna Stadium, Ooty, 27 January 2016

Department of Nuclear & Atomic Physics

Dr. Anuvab Mandal, Homi Bhabha National Institute, "Electronic spectroscopy of polyatomic molecules probed using VUV synchrotron radiation", May 27, 2015.

Prof. A. R. P. Rau, "The Beauty of Physics: Patterns, Principles, and Perspectives", June 4, 2015.

Ms Maryna Meretska, University of Twente, The Netherlands, "Diffusion of light in white LEDs", June 5, 2015.

Dr. Arpit Rawankar, Sardar Patel Collage of Engineering, Mumbai, "Pulsed Four Mirror Laser Wire System for Effective Inverse Compton Scattering", June 11, 2015.

Mr. Balaram Dey (VECC), "The temperature dependence of Giant Dipole Resonance width at excited states of atomic nuclei". June 12, 2015.

Dr. Haridas Pai, Institut für Kernphysik Technische Universität Darmstadt, Germany, "Study of low-lying dipole strength in the mass 50 region" August 3, 2015.

Dr. Haridas Pai, Institut für Kernphysik Technische Universität Darmstadt, Germany, "Study of nuclear structure near the $Z = 82$ and $N = 82$ shell", August 4, 2015.

Dr. A.K. Rhine Kumar, Dept. of Physics, IIT-Roorkee, "Giant Resonances Built On Excited States Of Nuclei", August 11, 2015.

Dr. Vivek Singh, "UORE: Search for $0\nu\beta\beta$ decay of ^{130}Te using bolometers", August 13, 2015.

Prof. Pawel J. Napiorkowski, University of Warsaw, "Coulomb Excitation: not only at the Heavy Ion laboratory", November 26, 2015.

Dr. Sandeep Banerjee, University of Nebraska, Lincoln, "Development and applications of a laser-driven, tunable, and narrowband, inverse Compton MeV x-ray source". November 30, 2015.

Dr. C. Palshetkar, "Prospects in reaction studies with weakly and tightly bound nuclei at near and above barrier

energies" December 8, 2015.

Dr. Ravitej Uppu, University of Twente, Netherlands, "Programmable quantum interference using white paint", January 7, 2016.

Prof. Eiji Ideguchi, "Shape evolution in neutron-rich $A \sim 150$ nuclei and CAGRA project at RCNP.", January 12, 2016.

Dr. Amaresh Jaiswal, GSI, Germany, "Relativistic dissipative hydrodynamics from kinetic theory: formulations and applications", January 14, 2016.

Prof. Ilya I. Fabrikant, Department of Physics and University of Nebraska-Lincoln, "Recent Progress In The Theory Of Dissociative Electron Attachment: From Diatomics To Biomolecules", January 14, 2016.

Dr. Farheen Naqvi, MSU, USA, "First total-absorption spectroscopy measurement on the neutron-rich Cu isotopes", January 18, 2016.

Dr. Prashant K. Singh, *Gwangju Institute of Science and Technology (GIST), Korea*, "Recent results of ion-acceleration from CoReLS petawatt femtosecond laser". January 18, 2016.

Dr. Balasubrahmaniam, IIT Madras, "Investigation of Radiative and Evanescent Field Coupling in Dispersive Plasmonic Systems". March 9, 2016.

Mr. Akhil Jhingan, IUAC, New Delhi, "Challenges in tracking rare isotopes at FAIR facility". March 14, 2016.

Prof. Jan-Michael Rost, Max Planck Institute for the Physics of Complex Systems, Dresden, Germany, "Short Time Spans in Ultrafast Science". March 21, 2016.

Dr. Victor Roy, J W Goethe University, Frankfurt am Main, Germany, "Importance of Magnetic Field on Hydrodynamics Evolution in Heavy Ion Collisions", March 23, 2016.

Department of Theoretical Physics

Theoretical Physics Colloquia

Sudhir Jain (BARC) Making the sound visible (May 5, 2015).

Bulbul Chakraborty (Brandeis University) Physics of Sand: Emergent Behavior in the Macro World (June 29, 2015).

Sanjay Puri (Jawaharlal Nehru University) Kinetics of Phase Transitions (July 7, 2015).

Sankar Das Sarma (University of Maryland) Why does

Graphene Behave as a Weakly Interacting System? (July 14, 2015).

Manas Kulkarni (The City University of New York) Nonlinear driven dissipative systems: Dynamics, Entanglement and Correlations (July 28, 2015).

Raghavan Rangarajan (Physical Research Laboratory, Ahmedabad) Gravitinos, Reheating and the Matter-Antimatter Asymmetry of the Universe (September 1, 2015).

Tarun Souradeep (IUCAA) Agnostic approach to Cosmology (September 29, 2015).

Sourov Roy (Indian Association for Cultivation of Science, Kolkata) Supersymmetry with R-symmetry: Neutrinos, Higgs boson and dark matter (November 3, 2015).

Gautam Bhattacharyya (SINP, Kolkata) The hierarchy problem and physics beyond the standard model (November 17, 2015).

Gunter M. Schutz (Institute of Complex Systems, Forschungszentrum Julich GmbH, Germany) The Fibonacci family of dynamical universality classes (November 24, 2015).

Nick Kaiser (Institute for Astronomy, University of Hawaii) Does Gravitational Lensing Affect The Cosmological Distance-Redshift Relation? (December 11, 2015).

Kaustubh Agashe (University of Maryland) Particle Physics from a Warped Extra Dimension (January 5, 2016).

Sankar Das Sarma (University of Maryland) Quantum Many Body Localization (January 6, 2016).

Jurgen Stilck (Federal Fluminense University, Niteroi, Brazil) The nature of the polymer collapse transition (January 15, 2016).

Sumilan Banerjee (Weizmann Institute of Science, Israel) Chiral magnetism, skyrmions and nanoscale superparamagnetism in oxide interfaces (January 27, 2016).

Krishnendu Sengupta (Indian Association for the Cultivation of Science, Kolkata) Majorana modes in condensed matter systems (February 16, 2016).

Shailesh Chandrasekharan (Duke University) Fermion Masses without Spontaneous Symmetry Breaking (February 23, 2016).

Satya Majumdar (University of Paris) Cold atoms, free fermions and the Kardar-Parisi-Zhang equation (March 8, 2016).

Aninda Sinha (Indian Institute of Science, Bangalore) Critical exponents without Feynman diagrams (March 22, 2016).

Other Seminars

Bhabani Prasad Mandal (Banaras Hindu University, Varanasi) Generalized BRST transformations (April 13, 2015).

Arjun Trivedi (University of South Carolina) Charting the evolution of the Strong Interaction's degrees of freedom (April 16, 2015).

P. Ramadevi (IIT Bombay) Knots, homologies and A-polynomials (April 21, 2015).

Bidisha Chakrabarty (Institute of Physics, Bhubaneswar) Geroch Group Description of Black Holes (May 5, 2015).

Prasanta Tripathy (IIT, Madras) Geroch Group in Einstein Spaces (May 18, 2015).

Sachin Jain (Cornell University) Causality constraints from CFT (June 8, 2015).

Debasish Banerjee (DESY Zeuthen) Real-time dynamics without Hamiltonians (June 25, 2015).

K. Narayan (Chennai Mathematical Institute, Chennai)

de Sitter space, extremal surfaces and the wavefunction of the universe (June 30, 2015).

R. Loganayagam (Institute for Advanced Study, Princeton, USA) A topological gauge theory for the entropy current (July 9, 2015).

Abhijit Gadde (Institute for Advanced Study, Princeton) No-perturbative beta function in 2d supersymmetric QCD (July 10, 2015).

R. Loganayagam (Institute for Advanced Study, Princeton) A topological gauge theory for the entropy current (Part 2) (July 15, 2015).

R. Loganayagam (Institute for Advanced Study, Princeton) Chern-Simon terms, Noether Charge and Entanglement entropy (Chern-Simon terms, Noether Charge and Entanglement entropy (July 20, 2015).

Anshuman Maharana (HRI, Allahabad) Inflation, CMB and Moduli (July 23, 2015).

Sreeraj Nair (IIT Bombay) Wigner distributions of quark (July 23, 2015).

Raj Gandhi (Harish-Chandra Research Institute, Allahabad) The Impact of Sterile ν^2 Neutrinos on CP measurements at Long Baselines (August 6, 2015).

Apratim Kaviraj (Indian Institute of Science, Bangalore) Analytic results from conformal bootstrap at large spin (August 7, 2015).

Sreedhar B. Dutta (IISER, Thiruvananthapuram) Critical dynamics of anisotropic N-vector models (August 13, 2015).

Kushal Shah (IIT Delhi) Particle dynamics in time-periodic systems (August 13, 2015).

Bipasha Chakraborty (University of Glasgow) The anomalous magnetic moment of the muon and lattice QCD (September 1, 2015).

Ashoke Sen (Harish-Chandra Research Institute, Allahabad) Superstring Field Theories (September 21, 2015).

Vikram Rentala (IIT Bombay) Discriminating Higgs production mechanisms using jet energy profiles (September 24, 2015).

Rajesh Gopakumar (ICTS-TIFR, Bangalore) The Higher Spin Square (September 28, 2015).

Tarun Souradeep (IUCAA, Pune) Sampling "ensemble" of Universes (September 28, 2015).

Suvodip Mukherjee (IUCAA, Pune) B mode polarization of CMB: A clinching window for Hemispherical Asymmetry (September 29, 2015).

Suvrat Raju (TIFR-ICTS, Bangalore) Local Operators and State Dependence in AdS/CFT (October 5, 2015).

Oleg Evnin (Univ. of Chula, Thailand) Nonlinear perturbations of AdS spacetime (October 8, 2015).

Rajan Laha (Stanford University) Non-directional and directional detection of dark matter in universal bound states (October 8, 2015).

Justin David (Indian Institute of Science, Bangalore) Anomalous transport at weak coupling (October 12, 2015).

Sumedha (NISER Bhubaneswar) Phase transitions in random k-satisfiability problems (October 12, 2015).

Shiroman Prakash (Dayalbagh Educational Institute, Agra) A test of bosonization at the level of four-point functions in Chern-Simons vector models (October 19, 2015).

B. Ananthanarayan (Indian Institute of Science,

- Bangalore) Pion electromagnetic form factor from analyticity and unitarity (October 20, 2015).
- Sunil Mukhi** (IISER, Pune) On 2d Conformal Field Theories with Two Characters (October 26, 2015).
- Jean-Yves Ollitrault** (CEA-Saclay, France) Principal component analysis applied to LHC data (October 29, 2015).
- Djordje Radicevic** (Stanford Univ.) Entanglement in weakly coupled gauge theories (October 29, 2015).
- Djordje Radicevic** (Stanford Univ.) Disorder operators in Chern-Simons-fermion theories (October 30, 2015).
- Nabamita Banerjee** (IISER, Pune) Null Fluid : A new view to Galilean Fluid (November 5, 2015).
- Sourov Roy** (Indian Association for Cultivation of Science, Kolkata) Stability constraints in triplet extension of the MSSM (November 5, 2015).
- Anirban Basu** (HRI, Allahabad) Perturbative type II amplitudes for BPS interactions (November 16, 2015).
- Gautam Bhattacharyya** (SINP, Kolkata) Naturally light uncolored and heavy colored superparticles (November 19, 2015).
- Anjan Kundu** (SINP, Kolkata) Exact asymmetric Skyrmion through generalized analytic functions (November 19, 2015).
- Nikhil Karthik** (Florida International University) Lattice study of symmetry breaking in planar QED (November 23, 2015).
- Kalol Sen** (Indian Institute of Science, Bangalore) On Critical Exponents without Feynman diagrams (November 23, 2015).
- Pratik Majumdar** (Saha Institute of Nuclear Physics, Kolkata) Origin of cosmic rays through the eyes of TeV gamma-ray astrophysics (November 26, 2015).
- Nikhil Karthik** (Florida International University) Symmetry breaking in planar QED (November 27, 2015).
- Abhishek Chowdhury** (Harish-Chandra Research Institute, Allahabad) Hilbert Series and Black Hole Microstate Counting (November 30, 2015).
- Bhuvnesh Jain** (University of Pennsylvania) Lensing measurements of galaxies, voids and filaments (December 8, 2015).
- Deepak Patil** (IIT Bombay) Time optimal feedback control of linear systems and minimum time consensus of multiple interacting double integrators (December 8, 2015).
- Ravi Sheth** (University of Pennsylvania) Standard rods in cosmology (December 10, 2015).
- Takehiro Azuma** (Setsuann University, Japan) Monte Carlo Studies of Dynamical Compactification of Extra Dimensions in a Model of Non-perturbative String Theory (December 31, 2015).
- Alexandre Refregier** (ETH, Zurich) New results in Cosmological Weak Lensing (January 4, 2016).
- Subir Sachdev** (Harvard University, U.S.A) Strange Metals and Black Holes (January 5, 2016).
- Kaustubh Agashe** (University of Maryland) Composite Higgs and Partially Composite (rest of the) Standard Model (January 7, 2016).
- Chi Ming Chang** (U. of California, Berkeley) Bootstrapping 2D CFTs in the Semiclassical Limit (January 7, 2016).
- Guruprasad Kadam** (Physical Research Laboratory, Ahmedabad) Hadron resonance gas model and the transport properties of hadronic matter (January 7, 2016).
- Shu-Heng Shao** (Harvard University) Superconformal Indices and BPS Particles (January 8, 2016).
- Ashvin Viswanath** (University of California, Berkeley) Particle-Vortex Duality of 2+1D Dirac fermions, from electric-magnetic duality of 3+1D topological insulators (January 8, 2016).
- Xi Yin** (Harvard University, USA) 2D superconformal bootstrap (January 11, 2016).
- Yifan Wang** (MIT) Argyres-Douglas theories, M5 branes and hypersurface singularities (January 12, 2016).
- Biswajit Pandey** (Visva Bharati University, Santiniketan) An information theory based search for the scale of cosmic homogeneity (January 13, 2016).
- Aoife Bharucha** (University of Marseille) The relic density of heavy neutralinos (January 14, 2016).
- Pallab Basu** (TIFR-ICTS, Bangalore) Holographic disorder and localization (January 18, 2016).
- Sayantana Sharma** (Brookhaven National Laboratory) Charm degrees of freedom above deconfinement (January 18, 2016).
- Biswajit Pandey** (Visva Bharati University, Santiniketan) Surfing the cosmic web with tessellations (January 19, 2016).
- Hitesh Changlani** (University of Illinois at Urbana Champaign) Simplex solid and spin liquid phases in two dimensional frustrated kagome antiferromagnets (January 20, 2016).
- T.R. Govindarajan** (Institute of Mathematical Sciences, Chennai) Edge states, Horizon states and moving boundaries (January 21, 2016).
- Chethan Krishnan** (IISC, Bengaluru) Lorentz Invariance vs Principle of Equivalence (January 25, 2016).
- Sumilan Banerjee** (Weizmann Institute of Science, Israel) Variable-range hopping through marginally localized phonons (January 28, 2016).
- Atish Dabholkar** (ICTP, Trieste and CNRS, Paris) Weyl Anomalies and Cosmology (February 5, 2016).
- R Loganayagam** (TIFR-ICTS, Bangalore) Topological sigma models and fluid dynamics (February 8, 2016).
- Krishnendu Sengupta** (Indian Association for Cultivation of Science, Kolkata) Dynamics of entanglement generation in periodically driven closed integrable quantum systems (February 17, 2016).
- David Tong** (DAMTP, University of Cambridge) Quantum Hall Matrix Models (February 22, 2016).
- Gunnar Bali** (University of Regensburg) QCD matter in strong magnetic fields (February 25, 2016).
- Sachin Jain** (Cornell University) Causality constraints in Conformal Field Theory (February 25, 2016).
- Nilay Kundu** (Harish-chandra Research Institute, Allahabad) Surface transport in finite lumps of stationary relativistic fluid (March 4, 2016).
- Amin Nizami** (ICTS-TIFR, Bangalore) Anomalous dimensions in epsilon expansion for the Gross-Neveu CFT (March 7, 2016).
- Zackaria Chacko** (University of Maryland) Neutral Naturalness (March 10, 2016).
- Bindusar Sahoo** (IISER, Thiruvananthapuram) N=4 conformal supergravity (March 14, 2016).
- Seema Sharma** (IISER, Pune) Searching for Supersymmetry in 13 TeV proton proton collisions at the LHC (March 17, 2016).

Aninda Sinha (Indian Institute of Science, Bangalore) Conformal bootstrap using unitary blocks (March 21, 2016).
Shamik Banerjee (IOP, Bhubaneswar) AdS-CFT and RG-

flow (March 28, 2016).

Aswin Balasubramanian (DESY – Hamburg) Describing Codimension two defects of Theory X (March 31, 2016).

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TIFR Centres

Homi Bhabha Centre for Science Education, Mumbai

Padma Sarangapani (*Tata Institute of Social Sciences*) and **G. Nagarjuna** (*HBCSE*), Introduction to the Connected Learning Initiative (CLIX), May 20, 2015

S. Balachander (*Dhrupad musician*), The art and science of music, May 21, 2015

Rajaram Nityananda (*Azim Premji University*), From irreversibility and ignorance to information and inference, June 26, 2015

Anwar Jafri (*Samavesh*), Improving quality of government elementary schools in Madhya Pradesh, October 5, 2015

John Lockley (*University of Waikato, New Zealand*), Teachers developing local curriculum and pedagogy to address national or state curricula, October 8, 2015

John Lockley (*University of Waikato, New Zealand*), The use of CoRes to enhance the Pedagogical Content Knowledge (PCK) development of initial teachers in Technology Education, October 15, 2015

Douglas Allchin (*University of Minnesota, USA*), Naturalizing as an error-type in science: Implications for science education, December 23, 2015

Sneha Khandekar (*Consultant Coordinator for the Savitribai Phule Gender Resource Centre*), Inclusive Workplaces & Sexual Ethics, December 29, 2015

Anesh Kumar Maharaj (*University of KwaZulu-Natal*), Pre-service teacher education in South African Democratic Union using Moodle. January 19, 2016

Mona Seervai (*Principal, Bombay International School*), Concept-based science education in schools. January 21, 2016

Kelly Butler (*Professor of Chemistry, Chestnut Hill College, Philadelphia, PA*), Process Oriented Guided Inquiry Learning, International Conference on Innovations in Teaching, Learning and Evaluation in Higher Education, Modern College of Arts, Science and Commerce, Shivajinagar, Pune, January 30, 2016

Shiju Sam Varughese (*Central University of Gujarat, Gandhinagar*), Science, media and risk politics: Constructing a scientific public sphere, February 17, 2016

Shiju Sam Varughese (*Central University of Gujarat, Gandhinagar*), Mediated publics of science: clinical trials controversy at the regional cancer centre, Kerala, February 18, 2016

Rashi Vidyasagar (*Resource Centre for Interventions on Violence Against Women (RCI-VAW) at Tata Institute of Social Sciences*), Sexual harassment at the workplace, March 8, 2016

V. G. Kulkarni Memorial Lecture

Narendra Jadhav (*Professor & Durgabai Deshmukh Chair in Social Development, Equity and Human Security at the Council for Social Development (CSD), New Delhi*), Global economic scenario and the future of the Indian

economy, Fourteenth V. G. Kulkarni Memorial Lecture, September 9, 2015

Lectures at Olympiads Valedictory Functions and Infosys Functions

U. K. Anandavardhanan, *IIT Bombay* (*Mathematics OCSC Valedictory Function*), Congruent numbers, May 18, 2015

R. L. Karandikar, *Chennai Mathematical Institute* (*Mathematics OCSC Valedictory Function*), Introduction to Monte Carlo simulation, May 18, 2015

Abhay Chowdhary, *Haffkine Institute* (*Junior Science OCSC Valedictory Function*), Current trends in virology research, May 25, 2015

Somak Raychoudhury, *Presidency University* (*Astronomy OCSC Valedictory Function*), What the universe is made of: Dark matter and dark energy, June 5, 2015

Sunil Bhagwat, *Institute of Chemical Technology* (*Chemistry OCSC Valedictory Function*), Science, society, chemical industry and you, June 5, 2015

B. J. Rao, *Department of Biological Sciences, TIFR* (*Biology OCSC Valedictory Function*), The story of chromosomes, June 13, 2015

Anil Bhardwaj, *Director, Space Physics Laboratory, Vikram Sarabhai Space Centre* (*Infosys Award Function*), Indian Mars Orbiter Mission to Mars, December 22, 2015.

Sourav Pal, *Indian Institute of Technology Bombay* (*Infosys Award Function*), Science at the nano scale to atomic and molecular level - An inter-disciplinary approach, Infosys Award Function 2015, December 22, 2015

NIUS Seminars

Henry Throop (*National Aeronautics Space Agency, Washington DC, USA*), NASA's new horizons mission to Pluto and beyond, November 3, 2015

Anwesh Mazumdar, Shirish Pathare and Praveen Pathak (*HBCSE, Mumbai*), The 46th International Physics Olympiad, November 23, 2015

Review talks and workshops by visitors at epiSTEME 6, International Conference to Review Research on Science, Technology and Mathematics Education

Paul Cobb (*Vanderbilt University, USA*), A theory of action for supporting improvements in the quality of mathematics teaching on a large scale, December 15, 2015

Paul Cobb (*Vanderbilt University, USA*), Workshop on

Design Research Methodology: Orientation and Issues, December 18, 2015

Douglas Allchin (*University of Minnesota, USA*), From test tubes to Youtube: Nature of science in socio-scientific issues and history, December 15, 2015

Douglas Allchin (*University of Minnesota, USA*), Post-conference workshop on teaching the nature of science through historical case studies, December 22, 2015

Gautam Biswas (*Vanderbilt University, USA*), CTSIM: A computational thinking environment for learning science using simulation and modeling, December 15, 2015

Stephen Jull (*GeoGebra Team, UK*), GeoGebra: A disruption in STEM education, December 16, 2015

Stephen Jull (*GeoGebra Team, UK*), Workshop on Design rationale for Geogebra, December 16, 2015

David Landy (*Indiana University, USA*), When is a grounding 'Good', for whom, and how can we build them? December 16, 2015

David Hestenes (*Arizona State University, USA*), Modeling theory and modeling instruction for STEM education, December 17, 2015

National Centre for Biological Sciences, Bangalore

Dr. Bauke Buwalda, **Groningen Institute for Evolutionary Life Sciences: GELIFES, The Netherlands**, April 7, 2015, Causes and consequences of aggressive social interactions as observed in brain and behavior of rats.

Dr. Rajesh Kumar Ladher, **RIKEN CDB, Kobe, Japan**, April 13, 2015, How to make inner ear hair cells and how to make them different

Dr. Vivek Malhotra, April 15, 2015, The pathway of collagen secretion

Dr. Vivek Malhotra, April 17, 2015, The pathway of unconventional protein secretion.

Dr. Kinjal Dasbiswas, **Weizmann Institute of Science, Rehovot, Israel**, April 22, 2015, Theory links structural order and beating in a heart muscle cell

Dr. Pradeep, **National Institute of Malaria Research, Delhi**, April 28, 2015, A detailed study addressing the functional significance of /de novo /heme biosynthetic pathway in the entire life cycle of malaria parasite and its potential as drug target and vaccine candidate

Dr. Vivek Jayaraman, **Janelia Farm Research Campus, USA**, April 29, 2015, A vada that means the world to the fly

Dr. Malavika Pompaiah, **Max Planck Institute for Infection Biology, Germany**, April 30, 2015, IQGAP1 is required for TNF α -induced apoptosis

Dr. Ian Mulvany, **Head of Technology, eLife sciences, London, United Kingdom**, May 21, 2015, eLife and the early career researcher

Dr. Rajesh Arasada, **Molecular Cellular & Developmental Biology, Yale University, USA**, May 25, 2015, Functions of F-BAR proteins in clathrin-mediated endocytosis and cytokinesis

Prof. Madan Rao, **Raman Research Institute, National Centre for Biological Sciences, Bangalore**, June 08, 2015, Theory in Cell Biology : Reflections and Projections

Prof. Shobo Bhattacharya, **Presidency University, Kolkata, And Tata institute of Fundamental Research, Mumbai**, June 22, 2015, Dynamics of a minimally complex system.

Padmini Rangamani, **Dept. of Mechanical and Aerospace Engineering, University of California San Diego**, July 01, 2015, Curvature, stability, and signaling in cells

Dr. Natasha Mhatre, **Department of Biological Sciences, University of Toronto at Scarborough Canada**, July 06, 2015, The sensory ecology and evolutionary origins of actively amplified

mechanotransduction: from insects to algae.

Prof. Paul Whitford, **Department of Physics, Northeastern University, Boston, USA**, July 14, 2015, How structure guides dynamics of tRNA accommodation and translocation on the ribosome

Dr. Shruti Malviya, **Institut de Biologie de l'cole Normale Sup?ieure (IBENS), Paris, France**, July 20, 2015, Tara Oceans Expedition: an investigation into the secret world of plankton

Dr. Vijay Nagarjun, **Uppsala University, Sweden**, July 17, 2015, Speciation genomics - a perspective from vertebrate systems

Dr. Siddharth Jhunjunwala, **Mazumdar-Shaw International Oncology, Massachusetts Institute of Technology, Cambridge, Massachusetts, USA**, July 27, 2015, Immunoengineering: an intertwined tale of immunity and biomedical device engineering

Prof. John Kuriyan, **HHMI, University of California, Berkeley, USA**, July 28, 2015, Mechanism of Activation-Triggered Subunit Exchange in a Calcium-dependent Kinase

Dr. Rajesh Jayachandran, **Clotta Medical Research Fellow, Biozentrum, University of Basel**, July 31, 2015, Role for coronin 1-mediated signaling in naive T cell immune responses

Prof. Mriganka Sur, **Paul E. and Lilah Newton Professor of Neuroscience, Director of the Simons Center for the Social Brain Department of Brain and Cognitive Sciences, MIT Cambridge, USA**, July 31, 2015, The functional logic of cortical circuits.

Dr. Debajit Goswami, **Theoretical Biological Physics, Universitaet des Saarlandes, Germany**, Aug 04, 2015, Dynamics of molecular motors and diffusive proteins interacting with polar filaments

Richard G. Morris, **Department of Physics, University of Warwick, U.K.**, Aug 05, 2015, Probing deformation in membrane-embedded proteins by measuring diffusion.

Prof. Arpita Upadhyaya, **Department of Physics, IPST, University of Maryland, College Park, MD, USA**, Aug 07, 2015, Cytoskeletal dynamics and mechanosensing in immune cells.

Stefan Alexandru Rautu, **Department of Physics, University of Warwick, United Kingdom**, Aug 12, 2015, The Role of Optical Projection on Vesicle Fluctuations.

Prof. Avery August, **Professor of Immunology and Chair, Department of Microbiology & Immunology Cornell University, USA**, Aug 14, 2015, Chemical genetic approaches to understanding mast cell function.

- Dr. Darius Koester, National Centre for Biological Sciences, Tata Institute of Fundamental Research, Bangalore, Aug 31, 2015, Actin and Myosin Drive Membrane Dynamics in an Cell Inspired in vitro Active Composite.**
- Prof. B.S. Manjunath, University of California, Santa Barbara, USA, Sept 02, 2015, Bio-image informatics.**
- Dr. Masashi Tachikawa, Theoretical Biology Laboratory, RIKEN, Saitama, JAPAN, Sept 07, 2015, Coarse-grained simulation of Golgi body morphogenesis.**
- Dr. Sarit S. Agasti, New Chemistry Unit and Chemistry and Physics of Materials Unit, Jawaharlal Nehru Centre for Advanced Scientific Research (JNCASR), Jakkur, Bangalore, Sept 10, 2015, Ultra multiplexed and nanoscopic imaging with DNA.**
- Dr. Pragya Srivastava, Physics Building, Syracuse University, Syracuse, NY, USA, Sept 14, 2015, Instabilities and patterns in an active nematic film.**
- Neha Agrawal, Institute of Biology Valrose, Universite Nice Sophia-Antipolis, Nice, France, Sept 14, 2015, The Drosophila TNF Eiger mediates the nutritional regulation of body size.**
- Dr. Anabha Basu, National Institute of Biomedical Genomics, Sept 21, 2015, Extant ethnic populations of India: Genetic history of their ancestry, admixture and endogamy.**
- Prof. Michael Arnold, Dept of Genetics, University Of Georgia, USA, Sept 21, 2015, The Web of Life: An Evolutionary Stimulus in Changing Environments.**
- Dr. Anjana Badrinarayanan, Human Frontier of Science Long-term Fellow, Department of Biology, Massachusetts Institute of Technology, Cambridge, USA, Sept 28, 2015, Dynamics of double-strand break repair in bacteria.**
- Prof. Jean Pieters, Biozentrum Basel, Switzerland, Oct 06, 2015, Modulation of intracellular signaling in leukocytes and neurons by coronin 1 regulates immune responses and neurobehavior.**
- Prof. Steve Granick, Director, IBS Center for Soft & Living Matter, South Korea, Oct 08, 2015, Active Cargo Trafficking in Living Cells.**
- Tamal Das, Department of New Materials and Biosystems, Max Planck Institute for Intelligent Systems, Stuttgart, Germany, Oct 12, 2015, Mechanobiology of Collectively Migrating Epithelial Cells.**
- Dr. Ajit G. Chande, Virus-Cell Interaction Laboratory, Centre for Integrative Biology, University of Trento-Italy, Oct 12, 2015, Host factors that restrict HIV-1 infectivity and are counteracted by Nef**
- Dr. Vivek Malhotra, Center for Genome Regulation, Barcelona, Oct 13, 2015, ESCRTing unconventional secretion without MVBs.**
- Dr. Adil Khan, Biozentrum, University of Basel, Oct 23, 2015, Simultaneous imaging of activity from the same excitatory and inhibitory neuronal populations during learning and task-switching.**
- Dr. Roshan Kumar Vijendravarma, Department of Ecology and Evolution, University of Lausanne, Switzerland, Oct 26, 2015, Evolutionary consequences of chronic malnutrition: insights from Drosophila.**
- Dr. Aswin Seshasayee, National Centre for Biological Sciences, Bangalore, Oct 28, 2015 Gene acquisition, its silencing and chromosome organisation.**
- Dr. Ankur Gupta, Department of Chemistry, University of Oxford, Oxford, UK, Nov 02, 2015, Unraveling the Mechanism of Multicopper Oxidases: From Ensemble to Single-Molecule.**
- Prof. Daan van Aalten, College of Life Sciences, University of Dundee, United Kingdom, Nov 03, 2015, Molecular and biological mechanisms of O-GlcNAc signalling in development**
- Dr. Siddhesh Kamat, Department of Chemical Physiology, The Scripps Research Institute, USA, Nov, 16 2015, A lipid signaling pathway that controls immune cell extravasation in a human neurological disease.**
- Dr. Avisek Das, Department of Biochemistry and Molecular Biology, University of Chicago, USA, Nov 23, 2015, Computational studies of large-scale conformational transitions in proteins.**
- Dr. Aashiq H. Kachroo, Institute for Cellular and Molecular Biology, The University of Texas at Austin, Nov 30, 2015, Saccharomyces sapiens - Towards humanizing yeast.**
- Dr. Kartik Sunagar, The Department of Ecology, Evolution and Behavior, The Hebrew University of Jerusalem, Israel, Dec 03, 2015, The Rise and Fall of an evolutionary innovation.**
- Dr. B. Venkatesh, Institute of Molecular and Cell Biology A*STAR, Singapore, Dec 04, 2015, The slow-evolving genome of elephant shark.**
- Prof. Wilhelm Boland Max Planck Institute for Chemical Ecology, Jena Germany, Dec 07, 2015, Chemical defense of leaf beetles: Molecular basis of sequestration of plant-derived glucosides.**
- Prof. Steve Busby School of Biosciences University of Birmingham, Dec 10, 2015, Regulation at simple and complex bacterial promoters.**
- Dr. Harpreet Shah Technical University Munich, Germany & Indian Institute of Technology Bombay, India, Dec 14, 2015, Modeling Conformational Changes and Ligand Binding in Proteins.**
- Prof. Ranjith Padinhateeri Indian Institute of Technology Bombay Mumbai, Dec 15, 2015 Nucleosome kinetics and gene regulation.**
- Dr. Patrick Varga-Weisz, Babraham Institute Cambridge, UK, Dec 29, 2015, Chromatin dynamics in homeostasis and inflammatory response of the intestinal epithelium.**
- Dr. Swetha Murthy, Department of Molecular & Cellular Neuroscience, The Scripps Research Institute, Jan 4, 2016, Mechanically activated Piezo1 ion channels: characterization of the pore domain, and their link to hereditary xerocytosis.**
- Dr. Manish Jaiswal, Department of Molecular and Human Genetics Baylor College of Medicine, USA, Jan 6, 2016, Genetic dissection of neuronal maintenance and demise.**
- Dr Kalika Prasad, School of Biology, IISER, Thiruvananthapuram, Kerala, Jan 18, 2016, Plasticity of developmental programs in plants: search for new horizons.**
- Dr. Vishwesh Kulkarni, University of Warwick, UK, Jan 18, 2016, Implementing Linear and Nonlinear Dynamic Systems using Nucleic Acids.**
- Dr. Alexandre G. de Brevern, (DSIMB), UniversitParis**

Diderot, Paris FRANCE, Jan 22, 2016, A slight extension of turn classifications: does it turn right?

Dr. Amitava Roy, Bioinformatics and Computational Biosciences Branch (BCBB) NIH, USA, Jan 25, 2016, Unraveling Dynamics in Allosteric Protein from Correlated Atomic Fluctuations.

Dr. Anjana Badrinarayanan, Massachusetts Institute of Technology, Cambridge, Massachusetts, USA, Feb 1, 2016, Dynamics of DNA double-strand break repair in bacteria

Dr. Vaibhav H Wasnik, Department of Physics, Saarland University, Germany, Feb 3, 2016, Protein localization in biological systems.

Dr. LazlSzabados, Biological Research Centre, Hungary, Feb 4, 2016, Functional identification of stress regulatory genes in model and extremophile plants using the Conditional Overexpressing System (COS).

Dr. Senjuti Sinharoy, Department of Biotechnology, Calcutta University, Feb 8, 2016, Utilizing genomic tools to understand the molecular mechanism of root nodule symbiosis.

Dr. Subhashis Haldar, School of Engineering, University of California, USA, Feb 15, 2016, Mechanism of Chaperonin -Assisted Protein Folding: Investigation at Single Molecular Resolution.

Prof. Padmini Srinivasan, University of Iowa, USA, Feb 16, 2016, Health Data Analytics: Opportunities & Challenges.

Prof. Fred Maxfield, Department of Biochemistry, Weill Cornell Medical College, USA, Feb 26, 2016, How macrophages digest objects larger than themselves.

Prof. Sascha Hilgenfeldt, Department of Physics, University of Illinois at Urbana-Champaign, Urbana, IL, USA, Mar 2, 2016, The Interplay of Structure and Mechanics in Cellular Tissues.

Dr. Dinesh A. Nagegowda, Molecular Plant Biology and Biotechnology group, CSIR-Central Institute of Medicinal and Aromatic Plants Research Centre, Allalassandra, Bengaluru, Mar 10, 2016, Understanding the regulation of specialized terpene biosynthesis in medicinal plants.

Dr. Santosh Kumar, National Institute of Allergy and Infectious Diseases, National Institutes of Health, Maryland, USA, Mar 11, 2016, Immunoreceptor signaling by zinc-induced polymerization into filaments.

Dr. Hunter King, School of Engineering and Applied Sciences, Harvard University, Cambridge, Mar 14, 2016, Mechanics of animal structures.

Dr. Viduth Chaugule, The MRC Protein Phosphorylation and Ubiquitylation Unit, Univ. of Dundee, Dow Street, Mar 14, 2016, A novel E3 ligase family reveals mechanics of SUMO polymer assembly.

Dr. Shirish Mishra, Department of Biochemistry, University of Fribourg, Switzerland, Mar 15, 2016, Targeting of proteins to lipid droplets in *Saccharomyces cerevisiae*.

Prof. Darren Williams, Department of Developmental Neurobiology, King's College London, Mar 17, 2016, Fruitfly topiary using *Drosophila* to study neuron pruning.

Prof. Angela Giangrande, IGBMC, France, Mar 18, 2016, A novel anti inflammatory pathway in flies

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National Centre for Radio Astrophysics, Pune

Manoj Puravankara (TIFR, Mumbai) Infrared spectroscopy of protostars with Herschel & Spitzer: Probing the earliest stages of stellar birth, April 20, 2015

Dave Green (University of Cambridge, UK) An updated Galactic supernova remnant catalogue -- 30 years old!, April 27, 2015

Arnab Rai Choudhuri (Indian Institute of Science, Bengaluru) Starspots, Stellar Cycles and Stellar Flares: Lessons from Solar Dynamo Models, August 24, 2015

Vithal Tilvi (Arizona State University, USA) Probing the Epoch of Reionization, December 22, 2015

Prateek Sharma (Indian Institute of Science, Bengaluru) Overlapping supernovae, the ISM, and galactic outflows, December 7, 2015

Rishi Khatri (TIFR, Mumbai) New constraints on CMB spectral distortions using Planck data, February 1, 2016

Marek Jamroz (Jagiellonian University, Poland) Peculiar Radio Galaxies in Clusters of Galaxies, February 22, 2016

Poonam Chandra (NCRA-TIFR, Pune) Environments of massive stars and their explosions, February 26, 2016

Ramit Bhattacharyya (Udaipur Solar Observatory, PRL, Udaipur) A Tale of Two Scales: The Solar Corona, February 5, 2016

Aritra Basu (Max-Planck-Institute for Radio Astronomy, Germany) Magnetic fields: Near and far, January 8, 2016

Thushara Pillai (Max-Planck Institute fur Radioastronomie, Germany) Infrared Dark Clouds and High-Mass Star Formation, June 1, 2015

Kate Clark (NVIDIA) Exascale Radio Astronomy, June 15, 2015

A. N. Ramaprakash (IUCAA) The Thirty Metre Telescope project - status and Indian role, June 29, 2015

Tarun Souradeep (IUCAA) Planck's Cosmos, June 5, 2015

Prasun Dutta (Indian Institute of Science Education and Research, Bhopal) Characterising turbulence in the interstellar medium of galaxies, June 8, 2015

Peter Kamphuis (NCRA-TIFR, Pune) Modelling for Large Neutral Hydrogen Surveys, March 14, 2016

Yashwant Gupta (NCRA-TIFR, Pune) An MSP Potpourri, March 18, 2016

T. P. Singh (TIFR, Mumbai) Is quantum theory exact, or approximate?, March 21, 2016

Girish Kulkarni (Institute of Astronomy, Cambridge, UK) Small-scale Structure of the Intergalactic Medium, March 7, 2016

Jens Kauffmann (Max-Planck-Institute fur Radioastronomie, Germany) Exploring Distant Star Formation with ALMA, May 25, 2015

Sunder Sahayanathan (Bhabha Atomic Research Centre, Mumbai) Blazars: The Unsolved Riddles, November 16, 2015

- Nick Kaiser** (*Institute for Astronomy, Hawaii, USA*) Gravitational Redshifts in Clusters of Galaxies, November 23, 2015
- Chanda Jog** (*Indian Institute of Science, Bengaluru*) Dynamical effect of dark matter halo on galactic disk instabilities, October 26, 2015
- Rajaram Nityananda** (*Azim Premji University, Bengaluru*) Irreversibility, Ignorance, and Inference: The many faces of Information, October, 9, 2015
- Subinoy Das** (*Indian Institute of Astrophysics, Bengaluru*) Possible astrophysical signatures of dark matter particle physics, September 21, 2015
- Seminars**
- Nadeem Oozeer** (*SKA South Africa, Cape Town*) KAT 7 and MeerKAT, the SKA precursors - a status update, April 24, 2015
- Kunal Mooley** (*Caltech, USA*) The 2015 Outburst of the Black Hole X-ray Binary, V404 Cyg, December 18, 2015
- Anshu Gupta** (*Australian National University, Australia*) Do galaxy clusters form via an inside-out model ?, December 21, 2015
- Anupreeta More** (*Kavli IPMU, Japan*) Mass distribution and concentration-mass relation in galaxy groups, February 15, 2016
- Shweta Srivastava** (*Physical Research Laboratory, Ahmedabad*) A multi-wavelength view of nearby Wolf-Rayet galaxies, July 14, 2015
- Archana Soam** (*Aryabhata Research Institute of Observational Sciences, Nainital*) Magnetic fields in triggered and spontaneous star forming regions, July 7, 2015
- Sumana Nandi** (*KTH Royal Institute of Technology, Stockholm*) New insight on double-double radio galaxies, March 11, 2016
- Aditya Chowdhury** (*NCRA-TIFR, Pune*) Radio Frequency Interference mitigation for pulsar data and the release of the GMRT Pulsar Tool, March 22, 2016
- Manasvita Joshi** (*Boston University, USA*) Multiwavelength Spectral Studies Of Blazars With MUZORF, November 3, 2015
- Sambit Roychowdhury** (*Max Planck Institute for Astrophysics, Garching, Germany*) Relating gas and star formation in the HI dominated regime, October 30, 2015
- Tejaswi Nerella** (*Caltech, USA*) The redshifted 21-cm line as a cosmological probe of magnetic fields and gravitational waves, September 22, 2015

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International Centre for Theoretical Sciences, Bangalore

Beyond WIMP Dark Matter

Speaker: James Unwin (University of Illinois, United States) Date: Mar 30, 2016

Defects of Theory X, Symplectic Resolutions and SCFTs in various dimensions

Speaker: Aswin Balasubramanian (University of Hamburg, Germany); Date: March 23, 2016

Matrix Models, Quantum Hall States, and WZW Models

Speaker: David Tong (University of Cambridge, United Kingdom); Date: March 22-23, 2016

The 750 GeV diphoton signal: will it light up the particle world?

Speaker: Rohini Godbole (Indian Institute of Science, Bangalore); Date: March 21, 2016

Scales and Scaling in Turbulence in a Stratified Fluid

Speaker: JK Bhattacharjee (Harish-Chandra Research Institute, Allahabad); Date: 14 Mar 16

Growing length and time scales in glass-forming liquids

Speaker: Chandan Dasgupta (Indian Institute of Science, Bangalore); Date: February 22, 2016

Origin and consequences of disorder-induced inhomogeneities in cuprate superconductors

Speaker: Debmalya Chakraborty (Indian Institute of Science Education and Research, Kolkata) Date: February 19, 2016

Drainage network models in river basin modeling

Speaker: Kumarjit Saha (Indian Statistical Institute, Kolkata) Date: February 5, 2016

Quantitative genetics and the search for the missing heritability: The long (and ongoing) search for the source of quantitative trait variation

Speaker: Bruce Walsh (University of Arizona, USA) Date: February 4, 2016

Population genomics of adaptation

Speaker: Wolfgang Stephan (Ludwig-Maximilians University & Museum of Natural History Berlin, Germany) Date: February 3, 2016

Work Fluctuation Theorems for Quantum Systems - The role of measurement

Speaker: Prasanna Venkatesh (Institute for Quantum Optics and Quantum Information of Austrian Academy of Sciences, Austria); Date: February 3, 2016

1/f Noise and the Low-Frequency Cutoff Paradox

Speaker: Eli Barkai (Bar Ilan University, Israel) Date: February 1, 2016

Fluctuation relations for entropy and work in small systems

Speaker: Sourabh Lahiri (ESPCI ParisTech, France) Date: January 29, 2016

The effects of population pedigrees on gene genealogies

Speaker: John Wakeley (Harvard University, USA) Date: January 27, 2016

Spin Systems in Computer Science: Algorithms and Complexity

Speaker: Piyush Srivastava (CMI-California Institute of Technology, United States); Date: January 25, 2016

Conformal constraints on defects

Speaker: Abhijit Gadde (Institute for Advanced Study, USA) Date: January 20, 2016

Plastic events in soft glasses

Speaker: Roberto Benzi (University of Rome Tor Vergata, Italy); Date: January 20, 2016

Homogeneous and Isotropic Turbulence: a short survey on recent developments

Speaker: Roberto Benzi (University of Rome Tor Vergata, Italy); Date: January 18, 2016

Brownian Motion, Polar Oceans, and the Statistical

Physics of Climate

Speaker: Srikanth Toppaladoddi (Yale University, United States) ;Date: January 15, 2016

Phase Separation and Bright Solitons in Spin-Orbit Coupled Spinor Condensates

Speaker: Sandeep Gautam (Sao Paulo State University, Brazil) ;Date: January 13, 2016

The axial U(1) anomaly and topological structures in finite temperature QCD

Speaker: Sayantan Sharma (Brookhaven National Laboratory, New York) ;Date: January 13, 2016

Mutations, Immune Checkpoint Therapy and Personalized Medicine

Speaker: Gyan Bhanot (Rutgers University, New Jersey) Date: January 13, 2016

Unconventional fractional quantum Hall states in the lowest Landau level

Speaker: Sutirtha Mukherjee (Indian Association for the Cultivation of Science, Kolkata) Date: January 12, 2016

Metastability for Interacting Particle Systems

Speaker: Frank den Hollander (Leiden University, The Netherlands) Date: January 12, 2016

The incompressible 3D Euler equations: how much do we know?

Speaker: John D. Gibbon (Imperial College London, United Kingdom) Date: January 11, 2016

Model-Based Cross-Correlation Search for Gravitational Waves from Scorpius X-1

Speaker: John T Whelan (Rochester Institute of Technology, USA) Date: January 11, 2016

Lattice effects and the critical behavior of perovskite manganites

Speaker: Rohit Singh (Indian Institute of technology, Guwahati) Date: January 8, 2016

Quantum Symmetries of Classical Manifolds and Their Cocycle Twists

Speaker: Soumalya Joardar (Indian Statistical Institute, Kolkata) Date: January 8, 2016

Correlation function of one-dimensional nonequilibrium models with jamming transition

Speaker: Priyanka (Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore) Date: January 8, 2016

Crack patterns on uneven substrates

Speaker: Pawan (Max Planck Institute for Dynamics and Self Organization, Gottingen, Germany) Date: January 8, 2016

Statistical Investigations on DNA Unzipping

Speaker: Amar Singh (Birla Institute of Technology & Science, Pilani) Date: January 7, 2016

Quantum critical Mott transitions in a bilayer Kondo insulator-metal model system

Speaker: Sudeshna Sen (Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore) Date: January 7, 2016

New algorithms to compute eigenpairs of large matrices

Speaker: Mashetti Ravi (Indian Institute of Technology Madras) Date: January 6, 2016

Modelling aggregation in mass conserved and non-conserved systems with the Smoluchowski equation

Speaker: Arghya Dutta (Institute of Mathematical Sciences, Chennai) Date: January 6, 2016

Quantum Correlations, Chaos and Information

Speaker: Vaibhav Madhok (University of British Columbia, Canada)

Date: January 5, 2016

Hydrodynamic limits for gaseous mixtures

Speaker: Harsha Hutridurga (Centre for Mathematical Sciences, University of Cambridge, UK)

Date: December 31, 2015

Bayesian Modeling for Spatio-temporal Data applied to Computer Vision and Climate Science

Speaker: Adway Mitra (Indian Institute of Science, Bangalore) Date: December 30, 2015

A hybrid Krylov subspace method for FFT-based homogenisation of periodic media

Speaker: Nachiketa Mishra (IISc, Bangalore) Date: Decemeber 29, 2015

Normal forms and unfoldings of singular strategy functions

Speaker: Amit Vutha (Ohio State University, USA) Date: December 22, 2015

Rogers-Ramanujan and Umbral Moonshine

Speaker: Ken Ono (Emory University, USA) Date: Decemeber 17, 2015

Hilbert Series and Black Hole Microstate Counting

Speaker: Abhishek Chowdhury (Harish-Chandra Research Institute, Allahabad) Date: December 16, 2015

Geometric Phase in the Hopf Bundle and the Stability of Non-linear Waves

Speaker: Colin Grudzien (University of North Carolina, Chapel Hill, USA) Date: December 11, 2015

Multipartite quantum correlations in many-body systems

Speaker: R. Prabhu (Ben-Gurion University of the Negev, Israel) Date: November 26, 2015

Disorder driven quantum phase transition

Speaker: Soumya Bera (Max Planck Institute for the Physics of Complex Systems, Germany)

Date: November 19, 2015

Chiral magnetism, skyrmions and nanoscale superparamagnetism in oxide interfaces

Speaker: Sumilan Banerjee (Weizmann Institute of Science, Israel) Date: November 18, 2015

Status of Mode-Coupling Theory of Glassy Dynamics: Activated Events and Nonperturbative Phenomena

Speaker: Saroj Kumar Nandi (Max Planck Institute for the Physics of Complex Systems, Germany)

Date: November 13, 2015

Analytical investigations on linear and nonlinear wave propagation in structural-acoustic waveguides

Speaker: Vijay Prakash S (Indian Institute of Science, Bangalore) Date: October 20, 2015

Large deviations, rain showers and planet formation

Speaker: Michael Wilkinson (The Open University, England) Date: October 19, 2015

Two Universalities in Semiconductor Physics

Speaker: Michael Wilkinson (The Open University, England) Date: October 14, 2015

Fun with Phases

Speaker: Ipsita Mandal (Perimeter Institute for Theoretical Physics, Canada) Date: October 12, 2015

Development and Application of the Weather Research and Forecasting (WRF) Model Based Four-Dimensional Variational (4DVAR) Data Assimilation System

Speaker: Pankaj Kumar (Hokkaido University, Japan)

Date: October 12, 2015

Modelling Biological Systems: from genomes to populations

Speaker: Somdatta Sinha (Indian Institute of Science Education and Research, Mohali)

Date: October 5, 2015

A Fokker-Planck approach to control collective motion

Speaker: Souvik Roy (University of Würzburg, Germany)

Date: October 5, 2015

Chaos and Entanglement in Fiber Optics

Speaker: Sijo K Joseph (Rey Juan Carlos University, Madrid, Spain)

Date: September 30, 2015

Instabilities and patterns in an active nematic film

Speaker: Pragya Srivastava (Syracuse University, USA)

Date: September 22, 2015

Attempts at disentangling biological circuits by controlling them

Speaker: Sharad Ramanathan (Harvard University, USA)

Date: August 18, 2015

Optical Projection of Vesicle Thermal Fluctuations

Speaker: S. Alex Rautu (University of Warwick, England)

Date: August 11, 2015

Dynamics of molecular motors and diffusive proteins interacting with polar filaments

Speaker: Debajit Goswami (Theoretische Physik, Saarland University, Saarbruecken, Germany)

Date: August 5, 2015

Probing conformational changes in membrane-embedded proteins by measuring diffusion

Speaker: Richard Morris (University of Warwick, England)

Date: August 4, 2015

Optimal Concentration of Information for Log-Concave Distributions

Speaker: Mokshay Madiman (Department of Mathematical Sciences, University of Delaware, USA)

Date: July 31, 2015

Probing late time acceleration with observations

Speaker: Remya Nair (Inter-University Centre for Astronomy and Astrophysics, Pune)

Date: July 16, 2015

Mechanics across cellular scales: from DNA packing in nucleosomes to collective cell migration

Speaker: Mandar Inamdar (Indian Institute of Technology, Bombay) Date: July 14, 2015

Non-perturbative beta function in 2d supersymmetric QCD

Speaker: Abhijit Gadde (Institute for Advanced Study, USA) Date: July 14, 2015

Higher Reciprocity Laws

Speaker: Chandan Dalawat (Harish-Chandra Research Institute, Allahabad)

Date: July 7, 2015

Oscillation of droplets suspended in a convective flow field

Speaker: Deepu P (University of Florida, Gainesville, USA) Date: June 10, 2015

Jamming phase diagram: A low dimensional perspective

Speaker: S. S. Ashwin (Nagoya University, Japan)

Date: June 3, 2015

An abridged suite of statistical methods for inferring evolutionary processes, with special reference to the human

Speaker: Partha P. Majumder (National Institute of Biomedical Genomics, Kalyani and Indian Statistical Institute, Kolkata)

Date: May 26, 2015

Modeling and Prediction based on Recurrent Neighborhoods of a Dynamical System

Speaker: Sajini Anand P S (National Institute of Advanced Studies, Bangalore) Date: May 25, 2015

Protein diffusion on linear biopolymers

Speaker: Rahul Roy (Indian Institute of Science, Bangalore) Date: May 19, 2015

The spatial structure of turbulence in the atmosphere

Speaker: Abhijit Chougule (Technical University of Denmark, Denmark) Date: May 18, 2015

Site dilution in low dimensional chiral metals

Speaker: Sambuddha Sanyal (Indian Institute of Science, Bangalore) Date: May 18, 2015

ABJ Theory in the Higher Spin Limit

Speaker: Honda Masazumi (Harish-Chandra Research Institute, Allahabad) Date: May 13, 2015

Searches from gravitational waves from neutron stars

Speaker: Badri Krishnan (Max Planck Institute for Gravitational Physics (Albert Einstein Institute), Germany)

Date: May 8, 2015

Landauer current and mutual information

Speaker: Auditya Sharma (Tel Aviv University, Israel) Date: May 6, 2015

Neutrons Stars in The Multi-Messenger Era: Prospects and Challenges

Speaker: Sanjay K Reddy (Institute for Nuclear Theory, University of Washington, USA)

Date: May 5, 2015

Spontaneous Layer Polarization and Conducting Domain Walls in the Quantum Hall Regime of Bilayer Graphene

Speaker: Kusum Dhochak (Weizmann Institute of Science, Israel); Date: April 29, 2015

Origin of instability in astrophysical accretion disks

Speaker: Sujit Kumar Nath (Indian Institute of Science, Bangalore) Date: April 29, 2015

Two Dimensional Quantum Spin-1/2 Systems: Single Hole Dynamics in an Antiferromagnet and Phase Diagram of a Bose Holstein Model

Speaker: Satyaki Kar (Saha Institute of Nuclear Physics, Kolkata) ;Date: April 28, 2015

Dynamics of super-cooled liquids in the presence of randomly pinned particles

Speaker: Saurish Chakrabarty (IISc, Bangalore) Date: April 27, 2015

Mean field interactions in a wireless local area network

Speaker: Rajesh Sundaresan (ECE, IISc, Bangalore) Date: April 15, 2015

Experimental Investigation of Classical and Quantum Cryogenic Helium Turbulence

Speaker: L. Skrbek (Charles University, Czech Republic) Date: April 1, 2015

School of Technology and Computer Science

- N.R. Prabhala** (CAFRAL, RBI and Univ. of Maryland): Fast Provable Non-convex Algorithms for Matrix Networks in Corporate Finance: Some Applications and Research Opportunities (25/04/2015).
- G. Sen** (IIT Mumbai and Monash University, Australia): Models and Algorithms for Database Segment Location in Information Networks (11/05/2015).
- K. Lodaya** (The Institute of Mathematical Sciences, Chennai): Axiomatizing Equality of Expressions (18/06/2015).
- C. Pahlajani** (Indian Institute of Technology, Gandhinagar): Stochastic Averaging for Randomly Perturbed Hamiltonian Systems (23/06/2015).
- Y. Kanoria** (Columbia University, USA): Managing Congestion in Dynamic Matching Markets (20/07/2015).
- M. Gupta** (Xerox Research Centre India, Bangalore): Fully Dynamic $(1 + \varepsilon)$ -Approximate Matchings (23/07/2015).
- Y. Wu** (University of Illinois at Urbana-Champaign, USA): Community Detection in Networks: SDP Relaxations and Computational Gaps (28/07/2015).
- S. Bhattacharya** (Institute of Mathematical Sciences, Chennai): Dynamic Primal Dual Algorithms for Vertex Cover and Matching (August 12, 2015).
- P. Roy** (Indian Statistical Institute, Kolkata): Stable Point Processes, Branching Random Walks and a Prediction of Brunet and Derrida (14/08/2015).
- A. Bhrushundi** (Rutgers University, USA): Polynomial Approximations Over $\mathbb{Z}/p^k\mathbb{Z}$ (18/08/2015).
- P. Daca** (Institute of Science and Technology, Austria): Statistical Model Checking for Unbounded Temporal Properties (01/09/2015).
- A. Paz** (Technion Israel Institute of Technology, Israel): Algebraic Methods in Distributed Graph Algorithms (15/09/2015).
- P. Netrapalli** (Microsoft Research New England, USA): Structure in the Theory of Computing: Algorithms, Randomness, Cryptography, Hardness (29/10/2015).
- S. Agrawal** (Indian Institute of Technology, Delhi): Modeling and Constructing Cryptography for the Cloud (05/11/2015).
- U.V. Vazirani** (University of California, Berkeley): Algorithms, Games and Evolution (16/11/2015).
- R. Sapharishi** (Tel Aviv University, Israel): Lower Bounds for Shallow Circuits (23/11/2015).
- M.M. Halldorsson** (Reykjavik University, Iceland): How Well Can Graphs Represent Wireless Interference? (03/12/2015).
- S. Watanabe** (Tokyo University of Agriculture and Technology, Japan): Secret Key Agreement: General Capacity and Second-Order Asymptotics (04/12/2015).
- S.A. Seshia** (University of California at Berkeley, USA): A Theory of Algorithmic Imposition (11/01/2016).
- A. Louis** (Princeton University, USA): The Complexity of Expansion Problems (19/01/2016).
- P. Srivastava** (California Institute of Technology, USA): Graphical Models: Algorithms and Complexity (22/01/2016).
- A. Rastogi** (University of Maryland, USA): Language-based Security for Multi-party Applications (22/02/2016).
- S.R. Pillai** (Indian Institute of Technology, Mumbai): A Multiple Access Server with distributed Queues (01/03/2016).
- C-C. Huang** (Chalmers University of Technology, Sweden): Exact and Approximation Algorithms for Weighted Matroid Intersection (15/03/2016).
- S. Tirodkar** (Indian Institute of Technology, Mumbai): On Randomized Algorithms for Online Preemptive Matching (30/03/2016).

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Colloquia

Mathematics Colloquia

- Alan Haynes** (University of York) Quasicrystals and Diophantine approximation (21.05.2015)
- Varun Thakre** (HRI, Allahabad) HyperKahler manifolds and Seiberg-Witten equations (04.06.2015)
- Vikraman Balaji** (CMI, Chennai) A degeneration of moduli of Hitchin pairs (26.06.2015)
- J. Tilouine** (Universite Paris, France) Big image of Galois for positive slope families (09.07.2015)
- Haruzo Hida** (UCLA, USA) Non CM p -adic analytic families of modular forms (16.07.2015)
- Dinesh Thakur** (University of Rochester, USA) Power sums of polynomials (23.07.2015)
- Jayadev Athreya** (University of Illinois) The Erdos-Szusz-Turan distribution for equiv-ariant point processes (30.07.2015)
- Dhruv Mubayi** (University of Illinois, Chicago) Independent sets in hypergraphs (06.08.2015)
- Anand Sawant** (University of Munich, Germany) *Étale motivic analogues of Rost nilpotence* (13.08.2015)
- Sourav Ghosh** (University of Paris, France) Thermodynamics of Margulis Space Time (20.08.2015)
- Kartik Prasanna** (University of Michigan, USA) Arithmetic and geometric aspects of the Jacquet-Langlands correspondence (27.08.2015)
- Anilesh Mohari** (Institute of Mathematical Sciences, Chennai) Isomorphism theorem for Kolmogorov states in quantum spin chain (03.09.2015)
- B. Ravinder** (TIFR, Mumbai) On bases for local Weyl modules in type A (10.09.2015)
- Emilio Franco** (University of Campinas, Brazil) Moduli spaces of Lambda-modules on abelian varieties (01.10.2015)
- R. Sivaguru** (TIFR, Mumbai) Several Complex Variables: a Sampler (08.10.2015)

- Birgit Speh** (*Department of mathematics, Cornell University, U.S.A.*) Restrictions of infinite dimensional representations (15.10.2015)
- Dubi Kelmer** (*Boston College*) Counting lattice points in a random lattice (05.11.2015)
- Santosh Nadimpalli** (*TIFR, Mumbai*) Typical representations for certain Bernstein components of $GL_n(F)$ (12.11.2015)
- Omprokash Das** (*TIFR, Mumbai*) Adjunction and Inversion of Adjunction properties of MMP singularities and F -singularities in positive characteristic (19.11.2015)
- K. Sandeep** (*CAM-TIFR, Bangalore*) Moser-Trudinger and Adams Inequalities (26.11.2015)
- Saurabh Trivedi** (*Polish Academy of Sciences, Poland*) Flat currents on definable pseu-domanifolds (3.12.2015)
- Margarida Mendes Lopes** (*Universidade de Lisboa, Portugal*) Restrictions on the invariants of irregular surfaces (10.12.2015)
- Bertrand Remy** (*Centre de Math'ematiques Laurent Schwartz, France*) Presentations of profi and pro-p completions of some arithmetic groups : some uniform bounds (16.12.2015)
- Angelo Vistoli** (*Scuola Normale Superiore, Italy*) Essential dimension (18.12.2015)
- M. Ram Murty** (*Queen's University, Canada*) New Directions in Sieve Theory (31.12.2015)
- Sanju Velani** (*University of York, UK*) Metric Diophantine approximation: the Lebesgue and Hausdorff theories (21.01.2016)
- Ananyo Dan** (*TIFR, Mumbai*) Geometry of the Noether-Lefschetz locus (28.01.2016)
- Rohith Varma** (*TIFR, Mumbai*) On Higgs bundles on elliptic surfaces (04.02.2016)
- Amos Nevo** (*Technion - Israel Institute of Technology*) Arithmetic groups, the automorphic representation, and intrinsic Diophantine approximation (11.02.2016)
- Athanase Papadopoulos** (*Universite de Strasbourg, France*) Riemann surfaces and their moduli (18.02.2016)
- Denis Benois** (*University of Bordeaux, France*) p -adic L -functions and p -adic Hodge theory (25.02.2016)
- Sourav Pal** (*IIT, Bombay*) Rational dilation and complex geometry (03.03.2016)
- Vijaylaxmi Trivedi** (*TIFR, Mumbai*) Hilbert-Kunz density function and Hilbert-Kunz multiplicity (10.03.2016)
- Subhojoy Gupta** (*Indian Institute of Science, Bangalore*) Meromorphic quadratic differentials, measured foliations, and harmonic maps to trees (17.03.2016)
- Souvik Goswami** (*TIFR, Mumbai*) BUSINESS OF HEIGHT PAIRING (31.03.2016)

TIFR CAM Colloquia

- Prof. Youssef Ouknine** (*Department of Mathematics, Faculty of Sciences Semlalia, University Cadi Ayyad, Morocco*): Reflected BSDEs when the obstacle is not right-continuous and optimal stopping (August 4, 2015)
- Prof. Govind Menon** (*Division of Applied Mathematics, Brown University, USA*): A kinetic theory of mean-curvature networks in 2D (August 11, 2015)
- Upanshu Sharma** (*TU Eindhoven, Netherlands*): Passing to the limit in a class of Conservative; Dissipative systems - A variational approach (August 18, 2015)
- Prosenjit Roy** (*Inspire fellow, TIFR-CAM, Bangalore*): Extremal Functions for the Singular Moser-Trudinger Inequality in 2 Dimensions (August 25, 2015)
- Tulasi Ram Reddy** (*Dept. of Mathematics, IISc, Bangalore*): On critical points of random polynomials (September 1, 2015)
- Dr. Sivaram Ambikasaran** (*CTS-TIFR, Bangalore*): Fast algorithms for computational statistics and elliptic partial differential equations (September 8, 2015)
- Avijit Chatterjee** (*IIT Bombay*): A Multilevel higher-order framework for linear wave propagation (September 11, 2015)
- Prof. Rajesh Gopakumar** (*Director, International Centre for Theoretical Sciences, Bangalore*): Lower bounds for the greatest prime factor of consecutive integers and their applications (September 29, 2015)
- T. N. Shorey** (*Department of Mathematics, IIT Bombay, Mumbai*): Lower bounds for the greatest prime factor of consecutive integers and their applications (September 22, 2015)
- Prof. Dr. S. Sundar** (*Department of Mathematics, Indian Institute of Technology Madras.*): Understanding porosity dependence of heat flux through glass fiber insulation (October 6, 2015)
- Dr. S. Dharmaraja** (*Professor and Head, Department of Mathematics, Indian Institute of Technology Delhi*): Study of stochastic systems with catastrophe and its jump-diffusion approximation (October 13, 2015)
- Sarvesh Kumar** (*Dept. of Mathematics, Indian Institute of Space Science and Technology, Thiruvananthapuram*): Discontinuous finite volume element methods and its applications (October 20, 2015)
- Vishwesh Guttal** (*Center for Ecological Sciences, IISc Bangalore*): Abrupt transitions in ecological systems (Nov 03, 2015)
- Thirupathi Gudi** (*Dept of Mathematics, IISc Bangalore*): On the finite element approximation of the Convection-Diffusion Problem (Nov 10, 2015)
- Aniruddha Sinha** (*Department of Aerospace Engineering, IIT Bombay*): Strategies for active flow control of high-speed jets (Nov 17, 2015)
- D C V Mallik** (*Formerly professor, Indian Institute of Astrophysics, Bangalore*): Kariamanikkam Srinivasa Krishnan (Nov 24, 2015)
- S. G. Dani** (*Department of Mathematics, IIT Bombay, Mumbai*): The exponential map of a Lie group (Dec 01, 2015)
- Edriss S. Titi** (*Dept. of Mathematics, Texas A & M University, ALSO Dept. of Computer Science & Applied Mathematics, The Weizmann Institute of Science*): Mathematical Study of Certain Geophysical Models: Global Regularity and Finite-time Blowup Results (Jan 05, 2016)
- Dr. Harsha Hutridurga** (*DPMMS, Centre for Mathematical Sciences, University of Cambridge*): Asymptotic analysis of Reaction-Diffusion systems with

Entropy dissipation (Jan 05, 2016)

Shirsho Mukherjee (*Department of Mathematics and Statistics, University of Jyväskylä*): Regularity for Variational Problems in the Heisenberg Group (Jan 12, 2016)

Prof. Roberto Benzi (*University of Rome Tor Vergata, Italy*): Homogeneous and Isotropic Turbulence: a short survey on recent developments (Jan 19, 2016)

Prof. John Gibbon (*Department of Mathematics, Prof. Athanase Papadopoulos* (*CNRS and University of Strasbourg*): Riemann surfaces and their moduli (Feb 09, 2016)

Krishna Maddaly (*Institute of Mathematical Sciences, Chennai*): Eigen values of random operators (Mar 01, 2016)

Subhojoy Gupta (*Department of Mathematics, IISc, Bangalore*): Teichmüller space, harmonic maps and measured foliations (Mar 08, 2016)

Imperial College, London, UK): A look at 3D Navier-Stokes regularity using scaled higher moments of the vorticity field (Jan 27, 2016)

Prof. Bankteshwar Tiwari (*DST-CIMS, Banaras Hindu University, Varanasi*): Complete Finsler manifolds in presence of strictly convex functions (Feb 02, 2016)

Prof. K. Shiohama (*Fukuoka Institute of Technology, Japan*): Blaschke Finsler Manifolds (Feb 02, 2016)

Indira Chowdhury (*Centre for Public History, Srishti Institute of Art, Design and Technology, Bangalore*): The predicaments of institutional legacy: Archival oral histories of TIFR and what they tell us (Mar 15, 2016)

Prateek Sharma (*Department of Physics, Indian Institute of Science, Bangalore*): Numerical implementation of anisotropic diffusion (Mar 22, 2016)

Prof. Gautam Bharali (*Department of Mathematics, Indian Institute of Science, Bangalore*): A complex geometry approach to a problem in H control theory (Mar 29, 2016)

NCRA Colloquia

Manoj Puravankara (*TIFR, Mumbai*) Infrared Telescope project - status and Indian role, June 29, 2015
 spectroscopy of protostars with Herschel & Spitzer: Probing the earliest stages of stellar birth, April 20, 2015

Dave Green (*University of Cambridge, UK*) An updated Galactic supernova remnant catalogue -- 30 years old!, April 27, 2015

Arnab Rai Choudhuri (*Indian Institute of Science, Bengaluru*) Starspots, Stellar Cycles and Stellar Flares: Lessons from Solar Dynamo Models, August 24, 2015

Vithal Tilvi (*Arizona State University, USA*) Probing the Epoch of Reionization, December 22, 2015

Prateek Sharma (*Indian Institute of Science, Bengaluru*) Overlapping supernovae, the ISM, and galactic outflows, December 7, 2015

Rishi Khatri (*TIFR, Mumbai*) New constraints on CMB spectral distortions using Planck data, February 1, 2016

Marek Jamroz (*Jagiellonian University, Poland*) Peculiar Radio Galaxies in Clusters of Galaxies, February 22, 2016

Poonam Chandra (*NCRA-TIFR, Pune*) Environments of massive stars and their explosions, February 26, 2016

Ramit Bhattacharyya (*Udaipur Solar Observatory, PRL, Udaipur*) A Tale of Two Scales: The Solar Corona, February 5, 2016

Aritra Basu (*Max-Planck-Institute for Radio Astronomy, Germany*) Magnetic fields: Near and far, January 8, 2016

Thushara Pillai (*Max-Planck Institute für Radioastronomie, Germany*) Infrared Dark Clouds and High-Mass Star Formation, June 1, 2015

Kate Clark (*NVIDIA*) Exascale Radio Astronomy, June 15, 2015

A. N. Ramaprakash (*IUCAA*) The Thirty Metre

Planck's Cosmos, June 5, 2015

Prasun Dutta (*Indian Institute of Science Education and Research, Bhopal*) Characterising turbulence in the interstellar medium of galaxies, June 8, 2015

Peter Kamphuis (*NCRA-TIFR, Pune*) Modelling for Large Neutral Hydrogen Surveys, March 14, 2016

Yashwant Gupta (*NCRA-TIFR, Pune*) An MSP Potpourri, March 18, 2016

T. P. Singh (*TIFR, Mumbai*) Is quantum theory exact, or approximate?, March 21, 2016

Girish Kulkarni (*Institute of Astronomy, Cambridge, UK*) Small-scale Structure of the Intergalactic Medium, March 7, 2016

Jens Kauffmann (*Max-Planck-Institute für Radioastronomie, Germany*) Exploring Distant Star Formation with ALMA, May 25, 2015

Sunder Sahayanathan (*Bhabha Atomic Research Centre, Mumbai*) Blazars: The Unsolved Riddles, November 16, 2015

Nick Kaiser (*Institute for Astronomy, Hawaii, USA*) Gravitational Redshifts in Clusters of Galaxies, November 23, 2015

Chanda Jog (*Indian Institute of Science, Bengaluru*) Dynamical effect of dark matter halo on galactic disk instabilities, October 26, 2015

Rajaram Nityananda (*Azim Premji University, Bengaluru*) Irreversibility, Ignorance, and Inference: The many faces of Information, October, 9, 2015

Subinoy Das (*Indian Institute of Astrophysics, Bengaluru*) Possible astrophysical signatures of dark matter particle physics, September 21, 2015

STCS Colloquia/Faculty Seminars

V.M. Prabhakaran (STCS, TIFR): Broadcast Channels and Their Capacity Under Noisy Feedback (14/05/2015).

P. Harsha (STCS, TIFR): Two Player Games and Playing Them in Parallel (29/05/2015).

- M. Sudan** (Microsoft Research, England): Technology, New Delhi: Approximation Algorithms for Probabilistically Checkable Proofs (11/06/2015).
- S.K. Juneja** (STCS, TIFR): Ordinal Optimization - Empirical Large Deviations Rate Estimators, and Stochastic Multi-armed Bandits (10/08/2015).
- R. Gopalakrishnan** (Xerox Research Centre India, Bangalore): Routing and Saffing when Servers are Strategic (11/08/2015).
- A. Garg** (Princeton University): A Deterministic Polynomial Time Algorithm for Word Problem Over the Free Skew Field (25/08/2015).
- R. Roy** (Indian Statistical Institute, New Delhi): Drainage Networks and the Brownian Web (08/09/2015).
- S. Chakraborty** (Indian Institute of Technology, Mumbai): Hashing Based Almost-uniform Generation and Model Counting (22/09/2015)
- R. Vaze** (STCS, TIFR): Optimal Offline and Competitive Online Strategies for Transmitter-Receiver Energy Harvesting (06/10/2015).
- N. Garg** (Indian Institute of Technology, New Delhi): Primal-Dual Algorithms in Scheduling (17/11/2015).
- R. Raman** (Indraprastha Institute of Information Technology, New Delhi): Approximation Algorithms for Geometric Covering and Packing Problems (08/12/2015).
- D. Kapur** (University of New Mexico, USA): Interpolation Synthesis for Quadratic Polynomial Inequalities and Combination with Theory of Equality with Uninterpreted Function Symbols (EUF) (22/12/2015).
- R. Parikh** (City University of New York, USA): Group Knowledge, Signals and Behavior (12/01/2016).
- R. Sundaresan** (Indian Institute of Science, Bangalore): System Utility Maximisation With Fast Network and User Adaptation (19/01/2016).
- A. Karkare** (Indian Institute of Technology, Kanpur): Liveness-Based Garbage Collection (09/02/2016).
- M. Krishnapur** (Indian Institute of Science, Bangalore): Rigidity and Tolerance of Point Processes (23/02/2016).
- A. Bogdanov** (Chinese University of Hong Kong, Hong Kong): Threshold Secret Sharing Requires a Linear Size Alphabet (02/03/2016).
- A. Kumar** (Indian Institute of Technology, Delhi): D^2 Sampling and the k -means Problem (29/03/2016).

Wednesday Colloquia

- Prof. Naba K. Mondal** (Dept. of High Energy Physics, TIFR, Mumbai), "Particle Physics in the last 40 years", 30 Mar 2016
- Dr. Basudeb Dasgupta** (DTP, TIFR), "What's the matter with Dark Matter?", 23 Mar 2016
- Prof. Julio Fernandez** (Columbia University, USA), "An unfolding connection between yoga and muscle contraction", 16 Mar 2016
- Dr. Karthik Raman** (TIFR, Hyderabad), "Interface-assisted molecular spintronics", 09 Mar 2016
- Prof. Mahan Mj.** (School of Mathematics, TIFR), "Hyperbolic Geometry and Chaos in the Complex Plane", 24 Feb 2016
- Prof. Semir Zeki** (University College London), "Brain Strategies for Building an Image of the Visual World", 17 Feb 2016
- Prof. Mandar Deshmukh** (DCMP&MS, TIFR), "Nanomechanics with graphene drums in the strong coupling regime", 10 Feb 2016
- Prof. Tapas K. Kundu** (Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore), "Fine Tuning Gene Expression in Physiology and Pathophysiology: Implications in Therapeutics", 03 Feb 2016
- Dr. Ayelet Vilan** (Weizmann Institute of Science), "Interfaces: where chemistry meets electronics", 27 Jan 2016
- Prof. Chris Done** (Durham University, UK), "Black holes and Einstein's gravity revealed by X-ray astronomy", 20 Jan 2016
- Dr. Deepankar Misra** (DNAP, TIFR), "Decay dynamics of transient molecular ions", 13 Jan 2016
- Prof. X. C. Xie** (谢心澄) (International Center for Quantum Materials and School of Physics, Peking University), "Spin superconductor and electric dipole superconductor", 06 Jan 2016
- Prof. Juri Toomre** (JILA & Department of Astrophysical and Planetary Sciences, University of Colorado Boulder), "Probing convection and magnetic dynamos deep within stars", 09 Dec 2015
- Prof. Mustansir Barma** (DTP, TIFR), "Fluctuations and Order", 02 Dec 2015
- Prof. Karina Morgenstern** (Ruhr-University Bochum, Germany), "Fundamentals of molecular electronics: Switching molecules by electrons or light", 18 Nov 2015
- Prof. Michael K Bowman** (University of Alabama, USA), "A Molecular View of How Free Radicals Increase NMR Sensitivity by Dynamic Nuclear Polarization", 04 Nov 2015
- Prof. B. J. Rao, Prof. H. M. Sonawat & Prof. N. K. Mondal** (TIFR, Mumbai), "Nobel prizes for Chemistry, Physiology / Medicine and Physics (2015)", 28 Oct 2015
- Prof. Denis Vyalikh** (Institute of Solid State Physics, University of Technology Dresden, D-01062 Dresden, Germany), "ARPES insight into the properties of f-electrons in rare-earth intermetallics RERh₂Si₂ (RE = Ce, Eu, Gd and Yb)", 14 Oct 2015
- Dr. Goutam Sheet** (IISER, Mohali), "Unexpected superconductivity at mesoscopic point-contacts on a Dirac Semimetal", 30 Sep 2015
- Prof. Tapan Kanti Paine** (IACS, Kolkata), "Biomimetic Approaches to Oxidation Catalysis", 30 Sep 2015
- Prof. Yashwant Gupta** (GMRT Observatory, National Centre for Radio Astrophysics (TIFR, Pune), "Probing the Universe at Radio Wavelengths: from the GMRT to the SKA", 16 Sep 2015
- Prof. Vasa Parinda** (IIT Bombay), "Active plasmonics", 09 Sep 2015
- Prof. Sanjay Sane** (NCBS, Bangalore), "Inner transmissions in flying insects", 02 Sep 2015
- Prof. Sobhan Sen** (JNU, New Delhi), "Water around DNA: What's So Special about It?", 26 Aug 2015
- Prof. Stefaan Cottenier** (Center for Molecular Modeling, Ghent University, Belgium), "Materials discovery by high-throughput computation", 19 Aug 2015

- Prof. Bala Iyer** (Visiting Professor, ICTS, Bangalore), "The Elusive Gravitational Waves: A GR Centenary Perspective", 12 Aug 2015
- Prof. Jagadeesh Gopalan** (Dept. of Aerospace Engineering, IISc Bangalore), "Enchanting waves", 05 Aug 2015
- Dr. Mithilesh Mishra** (DBS, TIFR), "How to make two from one: the mechanism of cell division", 29 Jul 2015
- Dr. Ganapathy Krishnamurthi** (IIT Madras), "Deep learning for medical image analysis", 22 Jul 2015
- Dr. G Vaitheeswaran** (ACRHEM, University of Hyderabad), "Energetic Materials: Known to Unknown", 15 Jul 2015
- Dr. Vinod K. Singh** (Department of Chemistry, IIT Kanpur & Director, IISER, Bhopal), "Transfer of Chirality in Asymmetric Synthesis", 08 Jul 2015
- Prof. Utpal Nath** (IISc Bangalore.), "Shaping up a leaf – molecular control of organ growth and geometry", 06 May 2015
- Prof. Tarun Souradeep** (Inter-University Centre for Astronomy and Astrophysics (IUCAA)), "Cosmos-e-Planck", 29 Apr 2015
- Prof. M. R. Srinivasan** (National Professor and Member Atomic Energy Commission), "Present perspective on nuclear energy development in India", 22 Apr 2015
- Prof. G. Krishnamoorthy** (Dept. of Chemical Sciences, TIFR, Mumbai), "From Chemical Relaxation to RNA Switches", 15 Apr 2015
- Prof. Umakant Rapol** (IISER, Pune), "Quantum Networking: Towards distributed Quantum computing", 08 Apr 2015
- Dr. Anurag Agrawal** (Institute of Genomics & Integrative Biology, Delhi), "Public Health Needs Three-way Marriages", 01 Apr 2015

Special Wednesday Colloquia

- Prof. A. Gopakumar** (on behalf of IndIGO-LSC group) (DAA, TIFR.), "GW150914: A transient gravitational wave event from a binary black hole merger", 23 Feb 2016
- Prof. Peng Chen** (Cornell University), "Single-molecule dynamics: from energy conversion to transcription regulation", 15 Feb 2016
- Prof. Latha Venkataraman** (Department of Applied Physics, Columbia University, New York), "Chemistry and Physics of Single-Molecule Circuits", 25 Jan 2016
- Dr. Nigel Lockyer** (Director, Fermi National Accelerator Laboratory, USA), "Neutrinos are Everywhere: Towards a New Understanding of the Quantum Universe", 05 Jan 2016
- Prof. Sanjeev Galande** (Indian Institute of Science Education and Research (IISER), Pune), "From Genome to Epigenome: A new perspective towards understanding complex diseases", 16 Dec 2015
- Prof. B. Ananthanarayan** (Centre for High Energy Physics, Indian Institute of Science, Bangalore), "Physics of light flavoured quarks", 21 Oct 2015
- Prof. T. Padmanabhan** (IUCAA, Pune), "Kinetic theory of atoms of space - aka gravity", 05 Oct 2015
- Prof. Madhu Sudan** (Microsoft Research), "Probabilistically Checkable Proofs", 11 Jun 2015

Aset Colloquia

- Dr. Ashutosh Gupta** (STCS, TIFR), "Why systems fail? - blue screen, leaked pictures, dictators, cancer - How to stop them?", 18 Mar 2016
- Dr. Rahul Vaze** (STCS, TIFR), "Graph Matchings and Wireless Communication", 11 Mar 2016
- Prof. C. S. Unnikrishnan** (DHEP, TIFR), "The New Wave in Physics, Astronomy and Technology", 04 Mar 2016
- Dr. Suresh Chandvankar** (Hon. Secretary, Society of Indian Record Collectors), "Archiving Indian Music in Modern Perspectives", 26 Feb 2016
- Dr. Anand Sivaraman** (CEO, Remidio Innovative Solutions), "Keep it Simple! Innovate to Create Scalable Impact", 19 Feb 2016
- Prof. John Mathew** (IISER, Pune), "The Animalia and British India", 12 Feb 2016
- Dr. Lawrence Kazmerski**, "Photovoltaics Technology: Where we are, how we got here, and where we are going", 05 Feb 2016
- Mr. Suryanarayana Sarma K.** (Project Director, ASTROSAT; Deputy Director, MDA, ISAC, Bangalore), "Making of Astrosat", 22 Jan 2016
- Dr. Monideepa Roy** (Director of Research & Development, Invictus Oncology Pvt. Ltd., New Delhi), "Anticancer Drug Development in India: Challenges and Perspectives", 15 Jan 2016
- Mr. Kishore Rajendran** (Department of Radiology and Centre for Bioengineering, Otago School of Medicine, Christchurch, New Zealand), "MARS spectral CT for orthopaedic applications", 08 Jan 2016
- Dr. B. N. Jagatap** (BARC, Mumbai), "Positioning in the Pasteur's Quadrant: Developing Science and Technology Together", 01 Jan 2016
- Dr. D. P. Roy** (HBCSE, TIFR), "Role of Experiments in the Progress of Science: Lessons from our History", 18 Dec 2015
- Prof. Sat Gupta** (University of North Carolina), "Applied Side of Statistics – Some Real Case Studies", 11 Dec 2015
- Dr. Sandrine Maximilien** (Science Attaché, Consulate General of France in Mumbai), "Challenges and prospects for the Indo-French scientific and technological cooperation", 04 Dec 2015
- Prof. Anwesh Mazumdar** (HBCSE), **Mr. Shirish Pathare** (HBCSE), **Dr. Praveen Pathak** (HBCSE), "The 46th International Physics Olympiad", 27 Nov 2015
- Prof. Stephen J. Buckman** (Research School of Physics and Engineering, The Australian National University,

- Canberra), "Low energy positron interactions: Cross sections, reaction dynamics, bound states and resonances, applications", 20 Nov 2015
- Prof. Anil Kumar** (Department of Chemistry, IIT Bombay), "Printable Optoelectronic Devices: Opportunities and Challenges for Material Scientists", 13 Nov 2015
- Prof. Nandita Madhavan** (Indian Institute of Technology Madras), "Small can be Big: Mimicking Protein Function using Small Peptides", 06 Nov 2015
- Dr. R. Prabakaran** (SIRC, TIFR), "Websites of Astronomy and Astrophysics Libraries: A Webometric Study", 23 Oct 2015
- Prof. Indranil Mazumdar** (DNAP, TIFR), "A Decade of Lanthanum Bromide (LaBr₃:Ce) Detectors", 16 Oct 2015
- Dr. N. Madhavan** (IUAC, New Delhi), "Probing nuclear processes 'in the line of fire'", 09 Oct 2015
- Dr. Livia Bellina** (Founder and President of Mobile Diagnosis® Not for Profit Association), "Mobile Diagnosis® Model: Use of m-Technology in Rural Health Care and Education", 11 Sep 2015
- Mr. Brij Jashal** (DHEP, TIFR), "Grid Computing at LHC and CMS Tier2 centre at TIFR", 28 Aug 2015
- Prof. Joseph John** (IIT Bombay), "High-speed Communications using Multimode Fibres", 04 Sep 2015
- Prof. B. M. Hegde**, "Wellness Vs Illness", 21 Aug 2015
- Dr. P. K. Vijayan** (BARC, Mumbai), "Beam down Solar Power Tower Concept and the Ways to make it", 14 Aug 2015
- Mr. H. Raghavan** (CCCF, TIFR), "Options in voice communication", 07 Aug 2015
- Dr. Kolahal Bhattacharya** (DHEP, TIFR), "Reconstruction methods in high energy physics experiments", 31 Jul 2015
- Prof. Eun Jin Woo** (Research Professor, Yonsei University College of Dentistry), "Anthropological Analysis of Archaeological Human Remains in Korea: Current Research and Trends", 24 Jul 2015
- Mr. Laxmikant B. Sawant** (TIFR), **Ms. Neelam Milind Surve** (TIFR), "Quality control in a pathology laboratory", 17 Jul 2015
- Dr. Vilas S. Pawar** (Head, Dental section, TIFR), "A review of dental implant treatment facility in TIFR", 03 Jul 2015
- Prof. Arnab Bhattacharya** (DCMP&MS, TIFR), "50 Years of Moore's Law: Looking back, Looking forward", 26 Jun 2015
- Prof. Gagan Mohanty** (DHEP, TIFR); **Mr. K. Kameshwara Rao** (DHEP, TIFR), "Silicon Vertex detector for Belle II", 19 Jun 2015
- Prof. P. V. S. Rao** (Former Head of the Computer Systems and Communications Group, TIFR, Mumbai), "Conversing with Computers", 12 Jun 2015
- Mr. Sunil C.** (BARC), "Historical and philosophical perspectives of ionizing radiation protection", 08 May 2015
- Dr. Achintya Pal** (ONGC Executive (Retired) & TIFR Alumnus), "300 Years of the Longitude Problem", 01 May 2015
- Prof. Juzer Vasi** (IIT Bombay), "Photovoltaics: Recent Developments, Opportunities and Challenges", 24 Apr 2015
- Prof. V. Kumaran** (IISc), "Transition to Turbulence", 17 Apr 2015
- Prof. Anilava Kaviraj** (Department of Zoology, University of Kalyani), "Changing pattern of insecticide use and its impact on environment and biodiversity: An evaluation in Indian perspectives", 10 Apr 2015

Special Aset Colloquia

- Prof. Vijay Bhargava** (University of British Columbia, Vancouver), "Communications Technologies for 2020 and Beyond: An Energy-Efficient Perspective with Application to Automation", 22 Feb 2016
- Prof. Anura Jayasumana** (Colorado State University, USA), "IoT – A pervasive technology for innovation", 19 Jan 2016
- Prof. Stefaan Cottenier** (University of Gent, Belgium), "The flipped classroom: a fresh look at teaching science", 17 Aug 2015
- Ms. Loren Shure** (Principal Software Developer of MATLAB), "Advanced Programming Techniques in MATLAB", 23 Jul 2015
- Mr. Carlo Tintori** (CAEN, Italy), "Digital systems for Multi-Parametric analysis in Physics Applications" 21 March 2016
- Prof. J. S. Yadav** (TIFR) "Large Area X-ray Proportional Counter (LAXPC) instrument onboard ASTROSAT" 29 May 2015
- Prof. H. M. Antia** (DAA, TIFR), "GEANT4 Simulations of LAXPC Detectors", 05 Jun 2015
- Dr. Pankaj Nerikar** (COMSOL Multiphysics Pvt. Ltd.), "COMSOL Multiphysics for Academic Research and Teaching", 28 May 2015
- Prof. Bhavtosh Bansal** (IISER, Kolkata), "Generation of pulsed high magnetic fields in a small laboratory", 22 May 2015
- Prof. G. R. Reddy** (BARC, Mumbai), "Inexpensive technology for saving structures and life in earthquake prone areas", 15 May 2015
- Dr. Goutam Chattopadhyay** (Senior Research Scientist, NASA-Jet Propulsion Laboratory, California Institute of Technology, USA), "Terahertz Radar for Stand-Off Through-Clothes Imaging", 04 May 2015



Graduate Courses

Maths

Course Name	Instructor(s)
Topology (82 Lectures)	S.K.Roushon
Real Analysis (36 Lectures)	Anish Ghosh
Expander Graphs	Anish Ghosh jointly with Prahladh Harsha
Algebra (81 Lectures)	N. Nitsure
Number Theory (40 Lectures)	E. Ghate
Commutative Algebra (30 Lectures)	Ravi Rao
Representation theory of Lie groups (32 Lectures)	D. Prasad
Complex Analysis (31 Lectures)	J. Sengupta
Special topics in Combinatorics (16 Lectures)	A. Bhattacharya

TIFR Centre for Applicable Mathematics, Bangalore

Course Name	Instructor(s)
Complex Analysis (Aug-Dec 2015)	K.T. Joseph
PDE II (Aug-Dec 2015)	Venkateswaran P Krishnan
Mechanics (Jan-Apr 2015)	M.Vanninathan
Numerical Analysis (Jan-Apr 2015)	A.S. Vasudeva Murthy
Real Analysis (Aug-Dec 2015)	Ujjwal Koley
Topology (Aug-Dec 2015)	C.S. Aravinda
ODE (Aug-Dec 2015)	P.S. Datti
Linear Algebra (Aug-Dec 2015)	Sreekar V
Differential Geometry (Jan-Apr 2016)	Adimurthi
Probability (Aug-Dec 2016)	Imran Habib Biswas
Computational Methods (Jan-Apr 2016)	Praveen C
PDE III (Jan-Apr 2016)	Mythily Ramaswamy
Functional Analysis (Jan-Apr 2016)	K.Sandeep
Measure and Integration (Jan-Apr 2016)	Prashanth Kumar Srinivasan
PDE I (Jan-Apr 2016)	G.D. Veerappa Gowda
Algebra (Jan-May 2016)	Gururaja H A

Physics

Autumn 2015 (August 15-December 15)

Course Name	Instructor(s)
Mathematical Methods	Shravan Hanasoge
Electrodynamics I	Subhabrata Majumdar
Classical Mechanics	Sreerup Raychaudhury
Quantum Mechanics I	R. Vijayaraghavan
Experimental Methods I	A. Venugopal, S.S. Prabhu
Adv. Quantum Mechanics	Kedar Damle
Electrodynamics II	Sushil Mujumdar, Rishi Sharma
Nuclear Physics	Rudrajyoti Palit
Atomic and Molecular Physics	Vaibhav Prabhudesai
Particle Physics	Kajari Mazumdar
Astronomy & Astrophysics	Sudip Bhattacharyya
QFT II	Shiraz Minwalla
General Theory of Relativity	Gautam Mandal
Quantum Many Body Systems	Rajdeep Sensharma
The Standard Model of Particle Physics	Tuhin Roy

Superconductivity	Pratap Raychaudhuri
Advanced Electrodynamics	G. Ravindrakumar

Winter Courses 2016

Electronics	R. Vijayaragavan
Computational Physics I	G. Mohanty

Spring 2016 (Feb 16 - May 16)

Course Name	Instructor(s)
Statistical Mechanics	Basudeb Dasgupta
Quantum Mechanics II	Amol Dighe
Experimental Methods II	A. Venugopal
Computational Methods II	Subrata Pal
Solid State Physics	Pratap Raychaudhuri
Cosmology	Subhabrata Majumdar
Quantum Field Theory I	Saumen Datta
Astronomy & Astrophysics II	D. Narasimha
Atomic Collisions	Lokesh C. Tribedi
Physics of the Standard Model II	Tuhin Roy

Chemistry**Autumn 2015 (August 15-December 15)**

Course Name	Instructor(s)
Biophysics and Biochemistry	S. Maiti
Quantum Chemistry	Ranjan Das
Mathematical Methods	Ravindra Venkatramani

Spring 2016 (January 16 - May 16)

Fluorescence Spectroscopy and its applications	S. R. Koti
Nuclear Magnetic Resonance Spectroscopy	P. K. Madhu
Chemistry of Nanomaterials	Vivek Polsettiwar

Short Course - July 2016

Beginner's Course in Python Programming	Jaikumar Radhakrishnan
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Biology**Autumn 2015(August 15-January 16)**

Course Name	Instructor(s)
Molecular Biology	B. J. Rao, Gotam Jarori, Shobona Sharma, Shubha Tole, Krihsnu Ray, Roop Mallik, Sandhya Koushika, Maithreyi Narasimha, Ullas Kolthur, Himanshu Sinha, Shreelaja Nair, Mahendra Sonawane & Mithilesh Mishra
Cell Biology	
Biochemistry	
Techniques in Modern Biology and Research Tools	
Developmental Biology	
Genetics	

Spring 2016 (March 2016-July 2016)

Course Name	Instructor
Advanced Developmental Biology	Mahendra Sonawane
Advanced Cell Biology	Maitreyi Narasimha and Mithilesh Mishra
Advanced Molecular Physiology	Ullas Kolthur

Computer and System Sciences**Autumn 2015 (August 15-December 15)****Core Courses**

Course Name	Instructor(s)
Probability	Vinod Prabhakaran
Algorithms & Data Structures	T. Kavitha
Automata & Computability	Paritosh Pandya
Mathematical Logic	Ahuthosh Gupta

Communication Complexity	Arkadev Chattopadhyay
Algorithmic Game Theory	Umang Bhaskar
Communications	Rahul Vaze
Foundation Models for Computing	N. Raja

Spring 2015 (January 16 - May 16)

Course Name	Instructor(s)
Automated Reasoning and Program Verification	Ashutosh Gupta
Computational Complexity	Arkadev Chattopadhyay
Information Theory	Vinod Prabhakarn
Online Alorithms	Rahul Vaze
Advanced Probability	Sandeep K. Juneja
Semantics of Computation	N. Raja
Linear Programming and Approximation Algorithms	Umang Bhaskar
Expander Graphs	Prahladh Harsha & Anish Ghosh

HBCSE Graduate School

Autumn 2015 (August to November)	
Course Name	Instructor(s)
History of Education in India	N. Varadarajan, Azim Premji University
Education, Society and Education Policy in India	Shekhar Krishnan
Advanced Research Methods in Education	Sugra Chunawala
History of Science	Ankush Gupta
School teaching experience	K. Subramaniam and N. D. Deshmukh
Philosophy of Science	G. Nagarjuna and K. Subramaniam
Introduction to Science, Technology & Mathematics Edu. Research	Aniket Sule and Shubhangi Bhide
Reading Course on Representation	Sanjay Chandrasekharan
Reading Course on Environment and Behaviour	Sanjay Chandrasekharan
Spring 2016 (January to April)	
Cognition, Cognitive Development and Learning	Jayashree Ramadas and Ankush Gupta
Philosophy of Education	G. Nagarjuna and Abhijeet Bardapurkar
Methods of Science and Mathematics Education Research	Aniket Sule and Shweta Naik
Elective Courses	
Environmental Science Education	Ankush Gupta
Advanced Topics in Cognition [based in IIT, Powai]	Sanjay Chandrasekharan

NCBS Graduate Courses

Title	Basic/Advanced	Year & Month	Instructor
Calculus	Basic	Aug 2015	David Farris
Light in Biology	Basic	Aug 2015	MK Mathew, Akash Gulyani
Evolutionary Biology	Basic	Sep 2015	Krushnamegh Kunte
Basics Genetics	Basic	Sep 2015	Raghu Padinjat
Basic Biology A and B	Basic	Sep 2015	Sanjay Sane et al
Basic Structural Biology	Basic	Aug 2015	R Sowdhamini, S Ramaswamy, Arati

			Ramesh, Ranabir Das and Aswin Seshasayee
Cellular Microbiology	Advanced	Sep 2015	Varadha Sundaramurthy
Information Theory	Advanced	Sep 2015	Mukund Thattai
The Physical Biochemistry		Aug 2015	Jayant Udgaonkar and MK Mathew
Population genetics	Basic	Nov 2015	Uma Ramakrishnan
Animal Behaviour	Basic	Jan 2016	Axel Brockmann
Cell Signaling	Basic	Feb 2016	Raghu Padinjat, Sunil Laxman
RNA Biology	Basic	Jan 2016	Ravi Muddashetty, Dasaradhi Palakodeti, PV Shivaprasad and Arati Ramesh
Development and Stem cells	Advanced	Feb 2016	Tina Mukherjee, Arjun Guha and Ramkumar Sambasivan
Neurobiology	Basic	Jan 2016	Upinder Bhalla et al.
Cell Biology	Basic	Feb 2016	Jitu Mayor, Colin Jamora, Arjun Guha, Mihnaj Sirajuddin and Srikala Raghavan
Differential equations	Basic	Feb 2016	David Farris

NCRA Graduate Courses

Electrodynamics and Radiative Processes I, IUCAA-NCRA Graduate School, 2015-2016	Chandra, Poonam C.
General Theory of Relativity (M.Sc. - Part I), Savitribai Phule Pune University, 2015 - 2016	Choudhury, T. Roy
Astronomical Techniques II, IUCAA-NCRA Graduate School, 2015-16	Oberoi, D.
Introduction to Astronomy and Astrophysics I IUCAA-NCRA Graduate School, 2015-2016	Roy, S.

ICTS Graduate Courses

Numerical Methods for Physics and Astrophysics (January- April, 2015)	P Ajith
General Physics Lab (August- November, 2015)	T G Ramesh, Abhishek Dhar, Vishal Vasana, Vijay Kumar Krishnamurthy, Amit Apte, Shashi Thutupalli
Physical Biology (Aug- Nov, 2015)	Vijay Kumar Krishnamurthy, Madan Rao (NCBS)
Advanced Classical Mechanics: (August- November, 2015)	Pallab Basu
Data Assimilation and Dynamical Systems (January- April, 2016)	Amit Apte
Numerical Methods for Physics and Astrophysics (January- April, 2016)	Amit Apte
General Physics Lab (Jan-April, 2016)	T G Ramesh, Abhishek Dhar, Vishal Vasana, Vijay Kumar Krishnamurthy, Shashi Thutupalli
Reading course on the Gross Pitaevskii Equation (Jan- April, 2015)	Samridhhi Sankar Ray
Reading course on the KPZ and Burgers Equation (Jan- April, 2015)	Samridhhi Sankar Ray
Reading course on Topics in Geometry, Topology and Physics (August- November, 2015)	Rukmini Dey
Reading course on String	Suvrat Raju

Theory(August- November, 2015)	
Reading course on Advanced GR and Black Holes (Aug- Nov, 2015)	Pallab Basu
Reading course on Non equilibrium statistical physics (Jan- April, 2016)	Abhishek Dhar

TCIS Graduate Courses

Solid-State Nuclear Magnetic Resonance, Jan-May, 2016	Agarwal Vipin
Phase Transitions, Ordering and Dynamics	Barma Mustansir & S. Ramaswamy
Course on “NMR in Biological Systems” (Jan – May, 2015)	Chary K.V.R
Advanced Inorganic and Organic Chemistry, for the Chemistry PhD and IPhD students, August-December 2015	Jana Anukul
Advanced Statistical Mechanics, Aug - Nov 2015	Karmakar Smarajit
Numerical Methods, Jan - April 2016	Karmakar Smarajit & Dr. P. Perlekar
Nuclear Magnetic Resonance, January-May, 2016, TIFR, Mumbai.	Madhu P.K
Solid-State Nuclear Magnetic Resonance, January-May, 2016, TCIS, TIFR, Hyderabad.	
Basic Cell Biology (August - December, 2015)	Mazumder Aprotim
Statistical Mechanics I (August 2015 to November 2015)	Mondal Jagannath
Physics & Chemistry of Materials: Bulk to Nano (Jan. 2016- May 2016)	T. N. Narayanan
Experiments Methods and Advanced Experimental Methods (Aug.2015-Nov.2015 & Jan. 2016-May 2016)	
Classical Mechanics and Advanced Computational Physics.	Perlekar Prasad
Taught a graduate level course on Physics & Chemistry of Materials: Bulk to Nano	Raman Karthik V
Electromagnetic Theory - I	Sengupta Surajit
Topics in biophysics	Vallurupalli Pramodh & Kanchan Garai

Visiting Students' Research Program VSRP Lectures

Nitin Nitsure : Functional Analysis and Physics (3 lectures) (09.06.2015 - 11.06.2015)

Sandeep Varma: A distant glimpse into the Langlands program (3 lectures) (16.06.2015 - 18.06.2015)

Stephan Baier: Gauss Circle problem (22.06.2015)

Raja Sridharan: Some applications of Algebra to Geometry (2 lectures) (23.06.2015 & 25.06.2015)

Sagar Kolte: An introduction to Algebraic Geometry and a Theorem of Pascal (30.06.2015)

Degrees Awarded by TIFR Deemed University

Ph.D. Theses

Sr. No	Name Surname	Sub Board	Guide/ Supervisor Name	Thesis Title
01.	Monica Nagendran	Biology	Mahendra Sonawane	Regulation of Epithelial Patterning by Canonical Wnt and BMP Signalling in Zebrafish Appendages
02.	Arindam Bose	Science Education	Subramaniam K.	Work, Knowledge and Identity: Implications for School Learning of out-of-school Mathematical Knowledge
03.	Kiran Lakhchaura	Physics	K.P. Singh	Intracluster Medium of Clusters of Galaxies with Substructures
04.	Nilay Kundu	Physics	Sandip Trivedi	A Study of Symmetries and Phases in Gravity with Application to Holography and Cosmology
05.	Priti Gupta	Physics	Arnab Bhattacharya	Epitaxial Growth of III Nitride Semiconductors on Layered Materials
06.	Jasmine Sethi	Physics	Rudrajyot Palit	Structure of odd-odd nuclei in $A \sim 110$ region
07.	Naveen Yadav	Physics	Alak Ray	Massive Stars: Their Life and Death
08.	Pranab Kumar Das	Physics	A Thamizhavel	Crystal Growth and anisotropic magnetic properties of Ce and Pr based binary intermetallic compounds
09.	Aditya Gilra	Biology	Upinder Bhalla	Olfactory bulb model predicts connectivity and coding roles of interneurons
10.	Narendra Patra	Physics	Jayaram N. Chengalur	The Interstellar Medium of Dwarf Galaxies
11.	Ankush Agarwal	Computers	Sandeep Juneja	Monte Carlo based Methods for Pricing American Options
12.	Devika Sharma	Mathematics	Eknath Ghate	Local Behaviour of Galois Representations Attached to Ordinary Modular Forms
13.	Sunaina Surana	Biology	Yamuna Krishnan	A framework to apply DNA nanodevices to a multicellular model organism
14.	Sagnik Chakraborty	Mathematics	R.V. Gurjar	A Study of Pure Subrings and Factorially Closed Subrings of Commutative Rings
15.	Saurabh Sandilya	Physics	Gagan Mohanty	Study of Bottomonium States in Radiative (look for symbol in word file) ($2S$) Decays at Belle
16.	Abhishek Singh	Physics	S.S. Prabhu	Tera Hertz Spectroscopy: Generation, detection studies of materials and new antenna designs using SI-GaAs
17.	Anirban Pal	Physics	Pushan Ayyub	Optical, Structural, Magnetic and Ferroelectric Properties of One Dimensional Solids and Nanorod Aggregates
18.	Jogender Singh	Biology	Jayant Udgaonkar	Characterization of the molecular mechanisms of prion protein misfolding

Sr. No	Name Surname	Sub Board	Guide/ Supervisor Name	Thesis Title
				and oligomerization
19.	Bhanu Prakash Joshi	Physics	S. Ramakrishnan	Exploring Unconventional Superconductivity in Ordered Noncentrosymmetric Superconductors
20.	Saurabh K. Singh	Mathematics	A Sankaranarayanan	Some Problems in Number Theory
21.	Saheli Halder	Biology	Yamuna Krishnan	I-motif based DNA pH sensors:design, delivery and spatiotemporal pH mapping of endocytic pathways
22.	Anand M. Osuri	Biology	Mahesh Sankaran	The effects of rainforest fragmentation on tree communities and aboveground carbon storage in the Western Ghats
23.	Manoj Choudhuri	Mathematics	C.S. Aravinda	Geodesic Flow on the modular surface and Diophantine approximation
24.	Debanjan Bhowmik	Chemistry	Sudipta Maiti	Change of Protein Conformation and Function associated with amyloid aggregation.
25.	Tathamay Basu	Physics	E. V. Smapathkumar	Magnetodielectric coupling and multiferroicity in geometrically frustrated and spin-chain magnetic systems
26.	Garima Saraswat	Physics	Pratap Raychaudhuri	Visualising Local Density of States:Scanning Tunneling Spectroscopic Studies on Conventional Superconductors
27.	Abinash Das	Physics	Tariq Aziz	Study of rare B (Please refer Thesis Report Format)
28.	KrishnaPriya Tamma	Biology	Uma Ramakrishnan	Mammals of South Asia:Biogeographic patterns, macroevolution and speciation
29.	Nisha Mathias Ramdas	Biology	G.V. Shivashankar Apurva Sarin	Cytoskeleton Control of Nuclear Morphology and Chromatin Dynamics
30.	Shalini Bhattacharya	Mathematics	Eknath Ghate	Local Langlands correspondences for GL ₂ :Some Applications
31.	Rajesh Gunage Dattaram	Biology	VijayRaghavan K.	Novel muscle stem-cell lineages form flight muscles of Drosophila Melanogaster
32.	Rudra Nayan Das	Biology	VijayRaghavan K.	The development of serotonergic neuromodulation in the Drosophila olfactory system and its role in larval and adult behaviour
33.	Naqueeb Ahmad Warsi	Computers	Jaikumar Radhakrishnan Pranab Sen	One-shot bounds in Classical and Quantum Information Theory
34.	Subha Bhaktavatsalam	Chemistry	Ankona Datta	Design and Development of Chemical Tools and animal models for probing Mn(II)in Vivo
35.	Atul Kumar Upadhyay	Biology	R. Sowdhamini	Prediction of 3D-domain swapping from mere sequence information and its application to human and plant genomes:special case of Ocimum tenuiflorum genome
36.	Malay Dalui	Physics	M. Krishnamurthy	Ion and Neutral atom Acceleration in Intense Laser produced plasmas

Sr. No	Name Surname	Sub Board	Guide/ Supervisor Name	Thesis Title
37.	Ajay Jha	Chemistry	Jyotishman Dasgupta	Probing the Molecular basis of photo-induced charge generation in (π symbol)-conjugated organic materials for photovoltaic applications
38.	Sufia Sadaf	Biology	Gaiti Hasan	Synaptic activity and intracellular calcium signalling in <i>Drosophila</i> flight interneurons
39.	Vishal Singh Chaudhari	Biology	B. J. Rao	Probing diurnal variation of UV sensitivity in <i>Chlamydomonas reinhardtii</i> : Involvement of photosynthesis and DNA excision repair processes

Integrated M.Sc.-Ph.D.

Sr. No.	Name of Student	Sub Board	Guide/ Supervisor Name	Thesis Title
01.	Dipankar Nath	Physics	C. S. Unnikrishnan	Sub-Doppler Cooling of 39K Atoms in Three Level Gray Molasses with Raman Dark State
02.	Chitra P.	Biology	Sudhir Krishna	Partially differentiated progenitors in cervical-pre-cancers are linked to the HPV life cycle and have neoplastic traits
03.	Anupam Pal Choudhary	Mathematics	K.T. Joseph	Distribution Solutions for some Non Conservative Systems
04.	Ananta Kumar Majee	Mathematics	Imran Habib Biswas	Analytical and Numerical study of stochastic balance laws driven by Levy White noise
05.	Souvik Roy	Mathematics	A.S. Vasudevamurthy C. Praveen	On Some Inverse Problems in Fluid Flows and Imaging
06.	Kshitiz Kumar Mallick	Physics	Devendra Ojha	Young Stellar Clusters in Galactic H II Regions: A Multiwavelength Analysis
07.	Deepak Kumar	Physics	Shankar Ghosh	Friction Induced Organisation
08.	Tapan Shah	Computers	Onkar Dabeer	Signal Processing for Systems with Low Precision Quantization
09.	Rahul S. Dandekar	Physics	Deepak Dhar	Studies in Non-Equilibrium Statistical Physics: Pattern Formation and Absorbing Phase Transitions
10.	Sudarsan R.	Biology	Shobhona Sharma	Characterization of Regulation of Zoonotic Surface Localization of Ribosomal Proteins PO and P2 in <i>Plasmodium falciparum</i> and <i>Toxoplasma gondii</i>
11.	Karthyek Rajhaa Annaswamy Murthy	Computers	Sandeep Juneja	Rare Events in Heavy Tailed Stochastic Systems: Algorithms and Analysis
12.	Saranya Samik Ghosh	Physics	Gobinda Majumder	Measurement of Muon Charge Asymmetry in Inclusive W Production at CMS
13.	Bodhayan Roy	Computers	S. K. Ghosh	Studying Triangulations and Visibility Graphs of Planar Point Sets

Sr. No.	Name of Student	Sub Board	Guide/ Supervisor Name	Thesis Title
14.	Kushal Banerjee	Biology	Ullas Kolthur	Role of Drosophila Sirt1/SIR2 in maintaining organismal homeostasis: Integration of metabolic sensing with inter-organ communication
15.	Sudipta Dubey	Physics	Mandar Deshmukh	Tunable 1-D Lateral Superlattice-Effect on Band Structure and Quantum Hall in Graphene
16.	Tarun Sharma	Physics	Shiraz Minwalla	Constraints on Fluid Dynamics from Equilibrium partition Function
17.	Pankaj Kushwaha	Physics	K.P. Singh	Blazars Variability and its Implications on Physical Processes
18.	Amitava Adak	Physics	G. Ravindrakumar	Ultrafast Dynamics in High Intensity Femtosecond Laser-driven Plasma
19.	Abhishek Sarkar	Mathematics	Prashant. K. Srinivasan	Some Results for Fourth Order Semilinear Epitopic PDES
20.	Tanvi Deora	Biology	Sanjay Sane	Biomechanics of the Dipteran Thorax
21.	Debanjana Mitra	Mathematics	Mythily Ramaswamy	Controllability and Stability of compressible Navier-Stokes system
22.	Debayan Maity	Mathematics	Mythily Ramaswamy	Control and Stabilization of Fluid Models
23.	Kolahal Bhattacharya	Physics	N.K. Mondal	Event Reconstruction for ICAL Detector and Neutrino Mass Hierarchy Sensitivity Analysis at India-based Neutrino Observatory(INO)
24.	Nirupam Hatui	Physics	Arnab Bhattacharya	Epitaxial Growth and Characterization of Semipolar Group-III Nitride Semiconductors
25.	Ch. Vineeth Reddy	Mathematics	Ravi Rao	On Suslin Matrices and Their Connection to Spin Groups
26.	Girish R. Varma	Computers	Prahladh Harsha	Hardness of Approximate Coloring
27.	Surat Saravanan	Biology	Maithreyi Narasimha	Regulation of pulsed constriction and myosin dynamics during Drosophila dorsal closure
28.	Rajdeep Mohan Chatterjee	Physics	Manoranjan Guchait	Measurements with Drell-Yan Events in 8 TeV pp Collisions using the CMS detector
29.	Saumya Gupta	Biology	Himanshu Sinha	A study to identify Molecular Pathways Defining Genotype to Phenotype Relationships for Causal Variants
30.	Deepnarayan Biswas	Physics	Kalobaran Maiti	Novel electronic structures at the surfaces
31.	Anirban Baral	Biology	M. K. Mathew	Modulation of endocytic pathways in the Arabidopsis root by salinity stress
32.	Tarjani Agarwal	Biology	Gaiti Hasan	Identification and characterisation of GPCRs functioning through intracellular calcium signalling in context of flight

M.Sc. Theses

Sr. No.	Name of Student	Sub Board	Guide/ Supervisor Name	Thesis Title
01.	Mudassar Ali Khan	Biology	Shobhona Sharma	Evaluation of ribosomal protein trafficking at sub-cellular locations in <i>Toxoplasma gondii</i>
02.	Sneha Dutta	Biology	G.K. Jarori	Exploring the Structural Determinants for the moonlighting functions and protective properties of plasmodium Spp. Enolase
03.	Yogesh Vasant Gadgil	Biology	Krishanu Ray	Spatiotemporal Dynamics of Olfactory Cilia Assembly in <i>Drosophila melanogaster</i>
04.	Aparajita Madhavan	Biology	Himanshu Sinha	MKT1: Mediating Stress resistance through post-transcriptional regulation of mitochondrial function
05.	Disha Sengupta	Biology	Shobhona Sharma	Exploring the Non-Ribosomal properties of ribosomal protein P2 in <i>Plasmodium Falciparum</i>
06.	Divya Chaubey	Biology	Sreelaja Nair	Understanding the functions of Eomesodermins in early Zebrafish Development
07.	Shampa Singh	Biology	Roop Mallik	Study of Organisation of Dyenin on Phagosomes
08.	Abhrojyoti Sen	Mathematics	Based on Course work	Based on course work
09.	Amit Kumar	Mathematics		
10.	Amrita Ghosh	Mathematics		
11.	Jayesh Vinay Badwaik	Mathematics		
12.	Prashant Kumar	Mathematics		
13.	Sourav Mitra	Mathematics		
14..	Sudip Ghosh	Physics	Sandip Trivedi	
M.Sc. (Wildlife Conservation and Biology)				
01.	Kadambari Devarajan	Biology	Abi Tamim Vanak/ Vishwesh Guttal	The Company Canids Confront: Resource Partitioning in Sympatric Carnivores in an Arid Ecosystem



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Science Popularization and Public Outreach

The Science Popularization and Public Outreach Committee (SPPOC) of TIFR conducts various programmes to convey the importance of exciting new developments in science and technology to the general public with a special emphasis on showcasing the research being done in TIFR. A major focus of this effort is to reach out to school/college students and teachers, especially in under-served communities, and to inspire students to pursue a career in basic sciences.

We continued with our annual “Frontiers of Science” programme that provides a unique opportunity for 10th standard students and teachers from selected schools in the Mumbai metropolitan area to visit the institute for an exciting full day program of informative lectures, exciting science demonstrations, and laboratory visits. Outstation schools from rural areas of Satara, Raigad, Thane, and Palghar districts, as well as from Nashik, Pune, and Rajkot also participated in the programme. As usual, TIFR graduate students, along with B.Sc. and M.Sc. students from local colleges volunteered to escorts the groups around the institute and interact with them. Held on 22nd November 2015, Frontiers of Science 2015 saw close to 1500 visitors on campus, including students and teachers from more than 80 schools. 39 laboratory stations and facilities of TIFR were especially open for the day. A wide cross section of schools, including those from a rural or underprivileged background participated in the programme, including orphanages in Mumbai and two Adivasi ashram schools from Thane and Palghar district.

TIFR’s flagship science café series “Chai and Why?” is now in its 8th year, running without a break since 2009. Apart from our regular sessions at Prithvi theatre on the 1st Sunday and Ruparel college on the 3rd Sunday of every month, we introduced a third monthly session, on months with a 5th Sunday, at Alexandra School, Fort. Chai and Why? has proved to be an extremely popular platform for informal discussions on interesting scientific topics. In 2015-16, our 29 sessions covered a wide range of topics relating to science and technology. From the world of dark matter and globular clusters to making colourful patterns with polarized light, and from traffic jams in the brain to finding links between non-Euclidean geometry and

knitting patterns the Chai and Why? sessions reflected the eclectic mix of research at TIFR. In 2015 a number of sessions on light and optics were especially organized to celebrate the UN International Year of Light 2015. Our popular vacation specials with a focus on children had sessions on e.g., the Rubik’s cube, planets of the solar system, hands-on experiments exploring the science of ice-cream, and even on why humour was funny. Our online presence on social media has expanded significantly, with Chai and Why’s Facebook page having a reach of almost 5000 people per week.

As in the earlier years, the outreach team along with students and staff from HBCSE set up a science *mela* with many hands-on demonstrations during the TIFR Founder’s Day programme. Apart from our participation in the activities at the GMRT Science Mela on National Science Day, Feb. 28th we also had a large event at TIFR Colaba campus as well. We welcomed more than 1000 visitors at the institute for a day of science demonstrations in the almond grove, special “Chai and Why?” sessions on gravitational waves, and visits to various laboratories and facilities of TIFR. We also organized a visit for the nearly 500 students and observers participating in the International Physics Olympiad 2015 that was held in Mumbai.

Simple experiments, requiring only materials easy to find at home, that permit hands-on exploration of scientific concepts, have been a key feature of outreach lec-dem programmes conducted at schools and colleges across the city and beyond. In the Mumbai region, science demos were carried out at Vaze College, SVT College, SNDT, Vissanji Academy, Witty school, EXPISCOR-2015 and INSEF Mumbai regional science fairs, etc. We also partnered with the Hindustan Times’ “No-TV Day” initiative, Nehru Planetarium’s Saturday lecture-demonstrations programme and organized a week long “Fun-damental Research” workshop for children as part of Prithvi Theatre’s summertime activities. We continued our partnership with Junoon’s “Mumbai Local” series, featuring conversations with TIFR scientists, in an effort to bring community engagement with scientists to neighbourhood venues across Mumbai.

To provide for a more inclusive outreach programme the SPPOC organised two rural science camps – in Khaniwade (Jan. 8-9, 2016, ~900 participants) and at Lavhali, (Feb. 5-7, 2016, ~1450 participants). This included night-sky watching sessions and lectures by TIFR student volunteers, as well as lecture demonstrations during the day. During the science camp at Khaniwade, TIFR students also conducted a two day workshop on Astrophysics and Astronomy for about 50 B.Sc. students from St. Xavier's College.

Our outreach efforts in outstation institutions/schools in rural areas continued with visits to various schools from different parts of the

country. Part of these outstation activities were supported by an outreach award from the Royal Society of Chemistry. The team visited schools in Kolthare, Karajgaon, Dabhol, and Panchnadi in Ratnagiri district (~1370 students and teachers). In Sangli district, apart from schools in Sangli city, the team also performed lecture demonstrations in Pusegaon, Khatav, Vihe, etc. (~1430 students and teachers). The year also saw an extensive outreach in schools and colleges in Madurai and nearby areas, covering more than 1000 students. Apart from this, the outreach team was invited for demonstrations at various locations across the country such as Amreli, Chandigarh, Kurukshetra and Udumalpet.

A list of "Chai and Why?" sessions organized in 2015-16 is as follows:

#	Date	Venue	Speaker	Topic
1	Apr. 5, 2015	Prithvi Theatre	Basudeb Dasgupta	Darkness on the Edge of Town
2	Apr. 19, 2015	Ruparel College	Debjyoti Bardhan	Party with the Planets
3	May 3, 2015	Prithvi Theatre	Arnab Bhattacharya	I Scream, You Scream, What's the Science of Ice Cream?
4	May 17, 2015	Ruparel College	Kushal Banerjee	LOL, ROFL, PJ & the Brain : the science of humour
5	Jun. 7, 2015	Prithvi Theatre	Shubhayan Kabir, Nikhil Mande	40 Riddicubous Years!: The Story of Erno Rubik's Magic Cube
6	Jun. 21, 2015	Ruparel College	Joe Ninan	The eight wanderers of the Solar System
7	Jul. 5, 2015	Prithvi Theatre	Suvrat Raju	Scientists and their social role in India
8	Jun. 19, 2015	Ruparel College	Tajinder Singh	Rainbows, Halos and Glories!
9	Aug. 2, 2015	Prithvi Theatre	Vijay Singh	The Joys of Creative Laziness
10	Aug. 16, 2015	Ruparel College	Mayank Vahia	The Enigma of Pluto
11	Sep. 6, 2015	Prithvi Theatre	Saumen Datta	Supercomputers in Physics
12	Sep. 20, 2015	Ruparel College	Amitava Bhattacharya	The Art of Counting
13	Oct. 4, 2015	Prithvi Theatre	PC Agrawal	Probing the Invisible Universe with ASTROSAT – Indian Multiwavelength Observatory
14	Oct. 18, 2015	Ruparel College	Amol Dighe / Arnab Bhattacharya	How fast is the fastest
15	Nov. 1, 2015	Prithvi Theatre	Ronak Soni	Back to the Future
16	Nov. 15, 2015	Ruparel College	Randhir Kumar	The amazing world of polarized light
17	Nov. 29, 2015	Alexandra School	Naba Mondal	Neutrinos: Chameleons of the particle world
18	Dec. 6, 2015	Prithvi Theatre	Sandhya Koushika	Running through traffic jams in the brain
19	Dec. 20, 2015	Ruparel College	Anish Ghosh	Geometries Galore
20	Jan. 3, 2016	Prithvi Theatre	Arnab Bhattacharya	50 Years of Moore's Law: Looking back, Looking forward
21	Jan. 17, 2016	Ruparel College	Nairit Sur	The Science of Photography
22	Jan. 31, 2016	Alexandra School	Arnab Bhattacharya	Science in the kitchen
23	Jan. 31, 2016	Alexandra School	Charlotte Sleigh & Nicholas Thurston	Mysteries of the mind
24	Feb. 7, 2016	Prithvi Theatre	Aniket Sule	Sankranti and other calendar quirks
25	Feb. 14, 2016	Ruparel College	Parul Sood	Let's play with water!
26	Feb. 28, 2016	TIFR, Colaba	A. Gopakumar	Listening to Black Hole collisions with LIGO
27	Feb. 28, 2016	TIFR, Colaba	C.S. Unnikrishnan	A new wave that shook the world
28	Mar. 6, 2016	Prithvi Theatre	Alak Ray	Globular Clusters: Cradles of Life and Advanced Civilizations?
29	Mar. 20, 2016	Ruparel College	Anusheela Chatterjee	An insight into colour blindness

Popular Science Articles / Lectures

B. Satyanarayana

Science and Mathematics for Inclusive Development, Mumbai KP-West Ward Science Exhibition, Department of Education,

Maharashtra, Kamla Devi Jain High School and Junior College, Andheri (West), December 8, 2015

Vaibhav S. Prabhudesai

"The world of low energy electrons: from Astrochemistry to Cancer Therapy" on 3rd December, 2015 at Ramnarain Ruia College, Mumbai

G. Ravindra Kumar and Amit D. Lad
“Creating Extreme States in the Lab”, Popular Science Lecture and Demonstration at TIFR for International Physics Olympiad 2015 students (July 08, 2015).

G. Ravindra Kumar
“Reaching for the stars”
http://www.harmonyindia.org/hportal/VirtualPageView.jsp?page_id=25324

Basudeb Dasgupta

1. Science of Harry Potter, Science Show, Kitabkhana, Mumbai, 29 May 2015
2. Darkness at the Edge of Town, “Chai and Why?” Talk, Prithvi Theatre, Mumbai, 5 April 2015

Deepak Dhar

Bohr’s Correspondence Principle for Hydrogen-like Atoms: Kepler orbits from Quantum-mechanical Wave Functions, *Resonance* 21 (6) 565-573 (2016).

Amol Dighe

1. Large and small, NSS Hill Spring International School, Mumbai, Apr 2015.
2. How fast is the fastest?, Chai-and-Why talk, Ruparel College, Oct 2015.
3. Changing Flavours of Neutrinos: the journey to Nobel 2015 and beyond, Science Academies’ Refresher Course, Mumbai University, Nov 2015; Vijyoshi National Science Camp, IISER Kolkata, Dec 2015; MathTriX, Ruia College, Jan 2016; NTS Program, HBCSE, Mumbai, Jan 2016; INSPIRE Internship Program, Amity University, Gwalior, Jan 2016; Sir P. T. Sarvajanic College of Science, Surat, Feb 2016.
4. Monthly series of articles in the Marathi newspaper Maharashtra Times: ekaatmatechaa vedh (The search for unity), Jan 2016; kRshnavesh (Looking for the Dark one), Feb 2016; hiraNyagarbhaachaa vedh (Exploring the Sun), Mar 2016.

Subhabrata Majumdar

Ubiquitous Dark Matter, Joint IIT-TIFR talk, IIT Bombay, August 24, 2015.

A. Sule

1. Careers in physics (Marathi), Marathi Vijnan Parishad, April 5, 2015
2. Careers in science (English), Vishnudas Bhave Auditorium, Vashi, December 8, 2015
3. Careers in science (Marathi), Topiwala High School and Desai High School, December 11-12, 2015
4. Night sky watching programme, Topiwala highschool, Malvan, December 11-12, 2015
5. India in space (English), Cipla, Vikhroli. February 11, 2016

H. C. Pradban

1. Constructivism in teaching mathematics in primary schools, A. B. Goregaonkar Vidyalay, Goregaon, Mumbai, June 11, 2015
2. On scientific temper, *Seminar on Science and Society*, Y. B. Chavan Foundation, Y. B. Chavan Centre, Colaba, Mumbai, December 5, 2015
3. Relevance of nayee taleem today, Chief Guest’s Address, Maa-Baba Puraskar for Educational Work for the Underprivileged, Nayee Taleem Samiti, Sevagram, Wardha, December 12, 2015
4. Learning science, Nayee Taleem School, Sevagram, Wardha, December 13, 2015
5. Face to face with scientists, Children’s Question and Answer Session, National Children’s Science Congress, Chandigarh University, Mohali, December 28 and 29, 2015
6. Teaching science can be exciting, Teachers’ Session, National Children’s Science Congress, Chandigarh University, Mohali, December 28, 2015
7. Milestones in educational reforms, *Seminar for School Counsellors*, Mumbai Psychological Society, Nehru Centre, Worli, Mumbai, January 7, 2016
8. Planning for a meaningful career, Convocation Address, Dnyansadhana College, Thane, January 16, 2016

P. Ranadive

1. Sun and solar system, Bal Vidyalay, Kota, January 30, 2016
2. Sky observation program, Cipla, Vikhroli, February 11, 2016

3. Sky observation program, Navy Nagar School, Colaba, February 12, 2016
4. Overnight sky observation programs with Khagol Mandal, Mumbai, for general public, Neral, April 18, 2015; May 16, 2015; January 9, 2016; March 9, 2016
5. Overnight sky observation programs with Khagol Mandal, Mumbai, for Teach for India, Umbroli, Badlapur, January 2, 2016; February 13, 2016

P. K. Joshi

1. Misconceptions in science, Inspire Science Award, Nanded, September 1, 2015
2. Science olympiads, Nagarjuna High school, Nanded, September 2, 2015
3. Misconception in science, Prof. Rajendra Singh Science Centre, Nagpur, October 2, 2015
4. Science olympiads a movement, AEC School No. 3, Mumbai, December 28, 2015
5. Science olympiads a movement, Gujarat Science City, Ahmedabad, January 29, 2016
6. Role of observation in science and handling of data, Kutch University, Bhuj, February 15, 2016

A. Muralidhar

1. Think, create and test. *Teacher Plus*, 46-47, August 2015
2. The big story of everything! *Teacher Plus*, 40-41, September 2015

H. Srivastava

Nazar-nazar ka pher. *Sandarbh*, 43(100), 1-13, September-October 2015

J. Vijapurkar

This big round earth. *Teacher Plus*, 13(7), 25-29, August 2015

K. K. Mishra

1. Vigyan- Itihaas ke aaiyne mein, *Awishkar*, 31-37, April 2015
2. Ganga pradushan- Varanasi ke sandarbh mein, *Vigyan Ganga* 5(8), 29-34, 2015
3. Vigyan - Itihaas ke aaiyne mein, *Awishkar*, 30-35, May 2015
4. Vigyan - Itihaas ke aaiyne mein, *Awishkar*, 28-32, June 2015
5. Vigyan - Itihaas ke aaiyne mein, *Awishkar*, 27-33, July 2015

6. Vigyan - Itihaas ke aaiyne mein, *Avishkar*, 20-29, August 2015
 7. Vitamin-C : Ek adbhut rasayan, *Dream 2047*, 11, August 2015
 8. Vitamin-C: An Amazing Chemical, *Dream 2047*, 17(11), 26, August 2015
 9. Vigyan - Itihaas ke aaiyne mein, *Avishkar*, 21-28, September 2015
 10. Vigyan - Itihaas ke aaiyne mein, *Avishkar*, 19-25, October 2015
 11. Vigyan - Itihaas ke aaiyne mein, *Avishkar*, 28-34, November 2015
 12. Baal kendrit shiksha aur uske sarokaar, *Vigyan*, 11-13, November 2015
 13. Vigyan- Itihaas ke aaiyne mein, *Avishkar*, 25-32, December 2015
 14. Neurotransmitters: The chemical messengers of neurons (Cover Story), *Science India* 19(1), 6-12, January 2016
 15. Naino mein simatti duniya, *Technical Today*, 1(1), 42-45, Jan-March 2016
 16. Antioxidants- Swastha aur dirghjeevan ki kunji, *Avishkar*, 13-17, March 2016
 17. Hindi mein vaigyaanik evum takaniki lekhan, *Hindi Garima*, 17-18, March 2016
- P. Ranadive*
Vidnyan yugat apan (Marathi), *Samna paper*, February 27, 2016
- P. Navale*
Gharacha Abhyas Karuya Anandane (Marathi). *Jivan Shikshan*, 23-24, October, 2015
- S. Bhide*
Modelling learning from life. *Teacher Plus*, 42-43, September 2015
G N Dey, Mar 30, 2016, Aphasia and the Future of Human Communication.
- Semir Zeki, Professor of Neuroaesthetics at UCL*, Feb 11, 2016, The Neurobiology of Aesthetic Experiences and the Significance of Beauty
- Charlotte Sleigh*, University of Kent, Jan 28, 2016, Marvels and microscopes: How science in Europe got started.
- Jon Agar*, Professor of Science and Technology Studies at University College, London, Jan 5, 2016, Major Themes in the history of science in the twentieth century.
- Jon Turney*, Nov 2, 2015, Futurama do past futures cloud our thinking about futures to come?
- Anil Ananthaswamy*, Sept 10, 2015, Perceptions of Self.
- Sanjeev Shankar*, Apr 17, 2015, Resilience: Living Root Bridges and the Khasi Tribes.
- Aswin Sai Narain Seshasayee*
1. Biology, Like Modern Art, Has Need for the Abstract in its Study of Life. *The Wire* (2016)
 2. Let Us Celebrate the Success of Pulse Polio. *The Wire* (2016)
 3. Why Biology Will Be Very Different, Even Medieval, Without Open Access to Publication. *The Wire* (2016)
 4. Antibiotic Resistance is Inevitable But Not Insurmountable. *The Wire* (2016)
 5. A New DBT Strategy Could Be a Big Win for Bioinformatics if Done Right. *The Wire* (2016)
 6. The basic question INK (2016)
 7. A Human History of Infectious Agents and the Reality of Antimicrobial Resistance. *The Wire* (2016)
 8. Whether by Stealth or Aggression, Viruses Get to Make a Meal of it. *The Wire* (2015)
 9. How Viruses Engineer their Way to Bringing Disease, and Also Life *The Wire* (2015)
 10. Why Genetic Engineering is Stranger Than You Think it is. *The Wire* (2015)
 11. Bacteria, Genetics and a Pitch for Basic Science. *The Wire* (2015)
 12. The age of big biology INK (2015)
- Gaiti Hasan*
1. Unexpected connections: Calcium refill mechanisms in nerve cells affects gene expression, October 8, 2015, Phys.org
 2. Unexpected connections: Calcium refill mechanisms in nerve cells affects gene expression: Researchers identify new roles for calcium refill mechanisms in regulating dopamine in the brain, October 8, 2015, Science Daily
3. Unexpected connections: Calcium refill mechanisms in nerve cells affects gene expression: Researchers at the National Centre for Biological Sciences, identify new roles for calcium refill mechanisms in regulating dopamine in the brain, October 8, 2015, Eureka Alert
 4. Calcium? the key, October 19, 2015, The Telegraph
 5. Not just bones, brain to need calcium, October 19, 2015, Times of India
- Shannon Olsson*
1. TEDx MAIS, December 8, 2015
 2. INK Salon, December 18, 2015
 3. Syntalk Episode #TRAI, October, 2015
 4. Newspaper coverage:
 - i. "Communicating in nature? language The Hindu. August 8, 2015
 - ii. "Rs. 25-crore grant to study if flowers talk to each other The Hindu April 26, 2015
 - iii. "Home away from Home Economic Times, October 10, 2015
 - iv. "IIIM organizes interaction session between Scientists, Gandhian scholars Daily Excelsior, Jammu and Kashmir, December 3, 2015
 - v. "NCBS, ATREE travel with Science Express The Hindu. December 6, 2015
 - vi. "NCBS working on natural cure for stem borer disease Deccan Herald, December 25, 2015.
- Wadadekar, Y.*
1. 25 years of the Hubble Space Telescope, Jyotirvidya Parisanstha, Pune, April 26, 2015
 2. Exploring our solar system, GHSS Nadukallur School, Tirunelveli, Tamilnadu, November 17, 2015
 3. Observing Galaxies with radio light (in English and Marathi), IUCAA Second Saturday school program, January 9, 2016
- Choudhury T. Roy*
Public Talk : Square Kilometre Array: Exploring the Universe with the worlds largest radio telescope, Outreach Programme on Different Aspects of Astroparticle Physics and

Cosmology, Saha Institute of Nuclear Physics, Kolkata, India, October 2015.

Parameswaran Ajith

1. Title: The discovery of gravitational waves

Venue: Public lecture in Malayalam organized by the Galileo Science Center, Perintalmanna, India

Date: March 26, 2016

2. Title: Undreamt by Einstein: The discovery of gravitational waves

Venue: Inaugural lecture of the Physics festival BHOUTICS 2016, IIT Madras

Date: March 4, 2016

3. Title: Undreamt by Einstein: The discovery of gravitational waves

Venue: Science Day Lecture, Indian Institute of Astrophysics, India

Date: February 28, 2016

4. Title: Gravitational-wave astronomy : A new window to the Universe

Venue: Public lecture as part of the Einstein Lectures series, Regional Science Center and Planetarium, Calicut, India

Date: February 19, 2016

5. Title: Undreamt by Einstein: The discovery of gravitational waves

Venue: Public lecture as part of the Einstein Lectures series, Providence College, Calicut, India

Date: February 20, 2016

6. Title: LIGO Observation of Gravitational Waves from a Binary Black Hole Merger

Venue: Public lecture as part of the ICTS LIGO discovery event The Universe in a New Light, ICTS-TIFR, Bangalore, Date: February 13, 2016

7. Title: LIGO Observation of Gravitational Waves from a Binary Black Hole Merger

Venue: Presentation as part of the LIGO discovery event organized by the Indian team in LIGO, IUCAA, Pune Date: February 11, 2016

Rajesh Gopakumar

1. Title: The Remarriage of Mathematics and Physics

Venue: Silver Jubilee Lecture, Chennai Mathematical Institute, Chennai

Date: September, 2015

2. Title: GM Thomas endowment Lecture

Venue: CMS College, Kottayam

Date: October 2015.

3. Title: From the Very Large to the Very Small

Venue: Talk at Silver Jubilee Reunion, IIT Kanpur, Kanpur, India, Date: December 2015

4. Title: String Theory and the Quest for Quantum Spacetime

Venue: ICTS Einstein Lecture, Jain College, Bangalore; Date: January 2016

Spenta Wadia

Title: 100 years of General Relativity, Albert Einstein's Revolution in Physics

Venue: Ruia College, University of Bombay

Date: 30 November 2015

S.K. Juneja

"Modeling Uncertainty- A Tale of Tails", Mumbai Local, Junoon, Kitabkhana, Mumbai, January 15, 2016.

J. Radhakrishnan

1. "A Matchless Match", Bhau Daji Lad Museum. August 09, 2015. (A version of this talk was given on the occasion of the TIFR Founder's Day, 30 Oct 2015.)

2. "Primes to Privacy", Indian Institute of Science Education and Research, Pune. National Science Day, February 28, 2016.

Radio & TV Programmes

G. Ravindra Kumar

1. CNN18 news item; <https://www.youtube.com/watch?v=LlhOI6K9ors>

2. NDTV news item; <http://m.ndtv.com/video/news/news/create-small-star-in-the-lab-392177>

3. Panel discussion on CNN News 18; <http://www.news18.com/videos/india/science-is-all-about-unravelling-nature-says-narayana-murthy-1204285.html>

A. Sule

1. Use of space technology in daily life (interview), DD Sahyadri, September 7, 2015

2. Water on Mars (interview), Jai Maharashtra, September 28, 2015

3. Water on Mars (interview), IBN Lokmat, September 29, 2015

4. Young Tarang: Careers in astronomy (interview), DD Sahyadri, January 2016

M. Vahia and P. Ranadive

Water in the universe (interview), All India Radio, January 2016

P. K. Joshi

Gold for India in International Junior Science Olympiad 2015, Good News India, DD News, January 3, 2016



Obituaries

Mr. Bandu D. Kharat

*Tradesman (F), Central Workshop
(12.08.1970 - 30.01.2016)
Date of Joining TIFR : 10.03.1997*

Mr. Dattaram A. Amte

*Senior Bearer
Gen. Admn. (Guest House)
(29.12.1963-14.02.2015)
Date of Joining TIFR : 01.12.1988*

Mr. Manohar R. Pandkar

*Tradesman (C)
Technical Services
(08.09.1967-08.08.2015)
Date of Joining TIFR : 24.08.1992*

Mr. H.Ramanjanaiah

*Work Assistant (E), TIFR-CAM
(01-06-1956-17-05-2015)
Date of Joining TIFR : 01-01-1978*