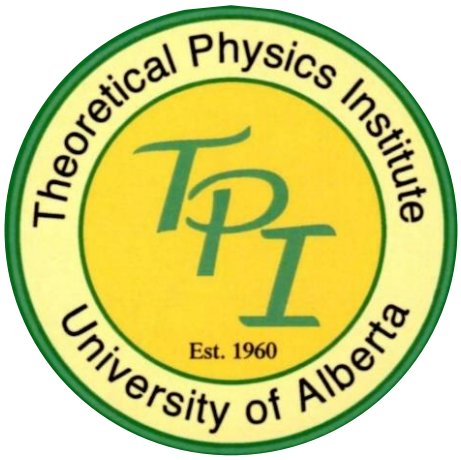

Annual Report
Theoretical Physics Institute
(Founded 1960)

This report summarizes the activities and publications of the Institute Members, Research Associates, Postdoctoral Fellows, Graduate Students and Visitors for the period

July 1, 2017 – June 30, 2018

Further information can be obtained from:

The Director
Theoretical Physics Institute
Department of Physics
University of Alberta
Edmonton, Alberta T6G 2E1
Canada

http://www.physics.ualberta.ca

July 1, 2018

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Director's Report

The Theoretical Physics Institute (TPI) enters its 58th year and continues to play an important role in fostering contacts and collaborations, particularly among Physics, Mathematics and Chemistry Departments in the Faculty of Science and the University. The TPI is a unique Canadian institution and through the excellence of its members and scientific activities it is widely recognized internationally.

This report describes accomplishments of Institute members in the 2017-2018 academic year. The Institute currently has 26 Active members, 9 Emeritus members and 2 Honorary members (Werner Israel and Juergen Kreuzer) along with 17 Postdoctoral/Research Associates and 66 Graduate Students. The two newest members of the TPI who joined last year are Prof. Rodrigo Fernandez (Theoretical Astrophysics) from the Department of Physics and Prof. Thomas Creutzig (Mathematical Physics) from the Department of Mathematical and Statistical Sciences. Both gave overviews of their research programs in TPI seminars last fall. Two other new members of the Institute include Dr. Rufus Boyack (PhD, University of Chicago) who is the recipient of the inaugural TPI Postdoctoral Fellowship and Dr. Yasaman K. Yazdi (PhD, Perimeter Institute for Theoretical Physics), recipient of the Avadh Bhatia Postdoctoral Research Fellowship. These outstanding young researchers play an important role in the major goal of the Institute which is creating new fundamental ideas and expanding the role of mathematical concepts in expressing the laws of nature.

The Research Programs and Research Highlights sections of the report give detailed accounts of subject areas and presents examples of the topics which are investigated in the Institute. The research of the members includes topics such as mathematical physics, gravitation and cosmology, subatomic physics and quantum field theory, condensed matter physics, quantum computing, theoretical chemistry, astrophysics, plasma physics, geophysics and biophysics.

International Collaborations are a key element to the success of the Institute and two of the recent major efforts include the recent TPI participation in the Canadian membership of the Asian Pacific Center for Theoretical Physics (APCTP) and the TPI – Charles University, Czech Republic, spearheaded by Prof. Valeri Frolov. The Canadian membership in the APCTP consists of the 3 institutions: TPI, Perimeter Institute for Theoretical Physics and TRIUMF at UBC. With the support of the APCTP we were able to co-organize and host the Joint Canada-Asia Pacific Conference on General Relativity and Relativistic Astrophysics here at the University of Alberta, June 25-29,2018. Highlights of the conference are presented in the Conference section of this report. As part of this conference a Stephen Hawking Memorial Session was held with excellent presentations by some of his colleagues.

As part of the Hiroomi Umezawa Lecture Series we had the pleasure of hosting Professor Patrick Diamond, Distinguished Professor from the Department of Physics and Center for Astrophysics and Space Science, University of California, San Diego. In addition there were 10 TPI Seminars presented by TPI members and International and Canadian researchers.

Finally, the TPI sponsored the annual Lake Louise Winter Institute where members were involved in the organization and presentation of invited talks. A special highlight of the TPI was the 2 day workshop on "Contemporary Topics in Mathematical Physics" held at the Banff Research Station (BIRS) last fall, organized by Thomas Creutzig, Terry Gannon and myself. It consisted of TPI members and two visiting professors, Juergen Fuchs and Marcus Berg, internationally renowned researchers in String and Conformal Field Theory as well Prof. Mark Walton, University of Lethbridge.

TPI Council and Members

Council of the Institute

Director: Richard D. Sydora, Department of Physics

Ex Officio Institute Members

Mauricio Sacchi, Chair, Department of Physics
Jonathan Schaeffer, Dean, Faculty of Science
Peter Minev, Applied Mathematics Institute
Matthias Ruth, Vice-President Research

Honorary Members

W. Israel, PhD (Dublin), FRS, FRSC
H.J. Kreuzer, PhD (Bonn, Germany), DSc, FRSC

Active Members

- Vincent Bouchard, PhD (Oxford)
- John Bowman, PhD (Princeton)
- Alexander Brown, PhD (University of Western Ontario)
- Thomas Creutzig, PhD (Hamburg, Germany)
- Andrzej Czarnecki, PhD (Alberta)
- Charles Doran, PhD (Harvard)
- Rodrigo Fernández, PhD (Toronto)
- David Favero, PhD (University of Pennsylvania)
- Valeri Frolov, PhD (PN Lebedev Physical Institute, Russia)
- Terry Gannon, PhD (McGill)
- Gabriel Hanna, PhD (Toronto)
- Natalia Ivanova, PhD (Oxford)
- Mariusz Klobukowski, PhD (Nicolas Copernicus University, Poland)
- Joseph Majiecko, PhD (Stanford)
- Frank Marsiglio, PhD (McMaster)
- Marc de Montigny, PhD (Université de Montréal)
- Sharon Morsink, PhD (Alberta)
- Don Page, PhD (California Institute of Technology), FRSC
- Alexander Penin, PhD (Moscow Institute for Nuclear Research)
- Dmitri Pogosyan, PhD (Tartu University, Estonia)
- Wojciech Rozmus, PhD (Warsaw)
- Mauricio Sacchi, PhD (UBC)
- Barry Sanders, PhD (Imperial College, London), DSc, FRSC
- Richard Sydora, PhD (University of Texas, Austin)
- Jack Tuszynski, PhD (Calgary)
- Eric Woolgar, PhD (Toronto)
- Andrei Zelnikov, PhD (Moscow Institute of Physics and Technology)

Emeritus Members

FA Baragar, PhD (Brandeis)

W Brouwer, PhD (Alberta)

AN Kamal, PhD (Liverpool)

FC Khanna, PhD (Florida State)

HP Künzle, PhD (King's College, London)

G Ludwig, PhD (Brown University)

RV Moody, PhD (Toronto), OC, FRSC

M Razavy, PhD (Louisiana)

HS Sherif, PhD (University of Washington)

Postdoctoral Fellows/Research Associates (17)

Aghil Alaee (PDF), *PIMS Postdoctoral Fellow*

Amsalu Anagaw (PDF)

Rufus Boyack (PDF), *TPI Postdoctoral Fellow*

Chun Chen (PDF)

Coleman Dean (RA)

Shashank Kanade (PDF)

Junjie Liu (PDF)

Tao Liu (RA)

Akihiro Nishiyama (PDF)

Felix Oghenekohwo (PDF)

Jordane Preto (PDF)

Pouri Ramazi (PDF)

Namrata Shukla (PDF)

Yasaman Kouchekzadeh Yazdi (PDF), *Avadh Bhatia Postdoctoral Research Fellowship*

Fenglong You (PDF)

Guangpeng Zhang (PDF)

Mohammad Akbar Hosain Zuberi (PDF)

Graduate Students (66)

Charlee Amason, MSc student

S. Arabimoghadam, PhD student

Jean Auger, PhD student

Breno Figuereido Bahia, PhD student

Clayton Bell, MSc student

Tobias Bernstein, MSc student

Travis Boblin, MSc student

Jens Boos, PhD student

Colin Bruulsema, PhD student

Fernanda Carozzi, PhD student

Nitin Chidambaram, PhD student

Minako Chinen, MSc student

Archismita Dalal, PhD student

Masoud H. Davijani, MSc student

Pedram Emami, PhD student

Steven Fahlman, MSc student

Shankar Ganesh, MSc student

Wenlei Gao, PhD student

F. Gentile, PhD student
Zayd Ghoggali, MSc student
Matharu Gian, PhD student
Victor Arturo Mora Gomez, PhD student
Chantelle Hanratty, PhD student
Roger Hatull, MSc student
Dylan Hennessey, MSc student
Miriam van Hoeve, MSc student
Joel Hutchinson, PhD student
James Iverson, MSc student
Aniket Joshi, MSc student
Aarat Kalra, MSc student
Scott Karbashewski, PhD student
Abdullah Khalid, PhD student
Majid Kheirkhah, PhD student
Dinesh Kandel, MSc student
Jordan Kostiuk, PhD student
Joshua Ludwig, PhD student
Nehad Mabrouk, PhD student
Pablo Carpio Martinez, PhD student
Moshen B. Mehrab, PhD student
Sepideh Mirabi, MSc student
Anna Morozova, MSc student
M. Moshari, PhD student
Jorge Calderon Noguez, MSc student
Meagan Oakley, PhD student
S.I. Omar, PhD student
Adrien Ooms, MSc student
Kento Osuga, PhD student
Eduardo Paez, PhD student
Pantita Palittaponggarnpim, PhD student
Iliana Papathanasaki, PhD student
Min Jun Park, MSc student
Shyam Parshotam, PhD student
Hamza Qureshi, MSc student
Mason Protter, MSc student
Ahmed Rayyan, MSc student
Wolfgang Riedler, PhD student
Bernal Manzanilla Saavedra, PhD student
María del Sagrario R. Tapia, PhD student
Gonzalo Rubio, MSc student
Mathew Rupert, PhD student
Amanda Swan, PhD student
Kenny Van, PhD student
Andres Ambros Vargas, MSc student
Zhibo Wang, PhD student
Yadong Wu, PhD student
Hennadii Yerzhakov, PhD student

Research Programs

Research Programs

The research programs of the TPI members are summarized. The areas of research in the Theoretical Physics Institute range from Mathematical subjects related to Quantum Phenomena and Gravitation as well as Particle Physics and Astrophysics, Cosmology, Condensed Matter, Quantum Computing, Chemical Physics as well as Plasma Physics, Fluid Dynamics, Geophysics, and Biophysics.

Vincent Bouchard: Mathematical Physics

John Bowman: Mathematical Physics, Turbulence theory and Computation

Alexander Brown: Theoretical Chemistry

Thomas Creutzig: Mathematical Physics

Andrzej Czarnecki: Particle Physics

Charles Doran: Mathematical Physics, String Theory

Rodrigo Fernández: Theoretical Astrophysics

David Favero: Mathematical Physics

Valeri Frolov: Gravitational Physics

Terry Gannon: Mathematical Physics

Gabriel Hanna: Theoretical Chemistry

Natalia Ivanova: Theoretical Astrophysics

Mariusz Klobukowski: Theoretical Chemistry

Joseph Majiecko: Condensed Matter

Frank Marsiglio: Condensed Matter

Marc de Montigny: Mathematical Physics

Sharon Morsink: Theoretical Astrophysics

Don Page: Gravitational Theory, Cosmology

Alexander Penin: Particle Physics, Quantum Field Theory

Dmitri Pogosyan: Cosmology, Theoretical Astrophysics

Wojciech Rozmus: Plasma Physics

Mauricio Sacchi: Geophysics

Barry Sanders: Quantum Computation

Richard Sydora: Plasma Physics

Jack Tuszynski: Biophysics

Eric Woolgar: Mathematical Physics, General Relativity

Andrei Zelnikov: General Relativity, Quantum Field Theory

Vincent Bouchard: Mathematical Physics

My research interests focus mainly on the interface between mathematics and physics. More precisely, I am interested in the interconnections between string theory, geometry, topology, number theory, quantum field theory and gauge theory. I am using string dualities to uncover new mathematical structures in geometry, such as in mirror symmetry.

Recent Publications

- Hecke operators on vector-valued modular forms.
  By Vincent Bouchard, Thomas Creutzig, Aniket Joshi.
  [arXiv:1807.07703 [math.NT]].

- Supereigenvalue Models and Topological Recursion.
  Vincent Bouchard, Kento Osuga.
  JHEP 1804 (2018) 138.

- Quantizing Weierstrass.
  Vincent Bouchard, Nitin K. Chidambaram, Tyler Dauphinee.
  Commun.Num.Theor.Phys. 12 (2018) 253-303.

- String-Math 2014 : Proceedings, Alberta, Canada, June 9-13, 2014.
  Vincent Bouchard, Stefan Méndez-Diez, Callum Quigley, Charles Doran.
  Proc.Symp.Pure Math. 93 (2016).

- Reconstructing WKB from topological recursion.
  Vincent Bouchard, Bertrand Eynard.
  Journal de l'Ecole polytechnique -- Mathematiques, 4 (2017), p. 845-908.

- Vertical D4–D2–D0 Bound States on K3 Fibrations and Modularity.
  Vincent Bouchard, Thomas Creutzig, Duiliu-Emanuel Diaconescu, Charles Doran, Callum Quigley, Artan Sheshmani.
  Commun.Math.Phys. 350 (2017) no.3, 1069-1121.

John Bowman: Mathematical Physics, Turbulence theory and computation

My past work on the analytical and numerical aspects of statistical closures in turbulence has led to the recent development of Spectral Reduction, a reduced statistical description of turbulence. The agreement with full numerical simulations appears to be remarkably good, even in flows containing long-lived coherent structures. Among the practical applications, such a tool can be used to assess the effect of various dissipation mechanisms in large-eddy simulations, as a sub-grid model, or even as a substitute for full simulation of high-Reynolds number turbulence.

My other research interests include: implicit de-aliasing of linear convolutions, 3D vector graphics, inertial-range scaling laws for two-dimensional fluid, plasma, and geophysical turbulence; nonlinear symmetric stability criteria for constrained non-canonical Hamiltonian dynamics; turbulent transport and the role of anisotropy in plasma and geophysical turbulence; realizable statistical closures; electroosmotic flow; parcel advection algorithms; exactly conservative integration algorithms; anisotropic multigrid solvers.

Recent Publications

- The Partial Fast Fourier Transform, J. C. Bowman and Z. Ghoggali, *Journal of Scientific Computing*, **76**, 1578-1593 (2018).
- Multithreaded Implicitly Dealiased Convolutions, M. Roberts and J. C. Bowman, *Journal of Computational Physics* **356**, 98-114 (2018).
- On the Global Attractor of 2D Incompressible Turbulence with Random Forcing, P. Emami and J. C. Bowman, *Journal of Differential Equations* **264**, 4036-4066, (2018).
- A Patient-Specific Anisotropic Diffusion Model for Brain Tumor Spread, A. Swan, T. Hillen, J. C. Bowman, A. D. Murtha, to appear in *Bulletin of Mathematical Biology*, 2017.
- Adaptive Matrix Transpose Algorithms for Distributed Multicore Processors, J. C. Bowman and M. Roberts, *Interdisciplinary Topics in Applied Mathematics, Modeling and Computational Science, Springer Proceedings in Mathematics & Statistics* **117**, 97-103 (2015).
- A Fully Lagrangian Advection Scheme, J. C. Bowman, M. A. Yassaei, and A. Basu, *Journal of Scientific Computing* **64:1**, 151-177 (2015).

Alexander Brown: Theoretical Chemistry

My research program encompasses a number of different areas in theoretical and computational chemistry including: (1) examining photo-excited states of molecules with a variety of applications; (2) studying novel inorganic molecules with applications to materials chemistry and phosphorescent materials; (3) development of methods for fitting of high-dimensional potential energy surfaces for quantum dynamics and quantum control application.

In the general area of the photo excited states of molecules, we have a number of different research thrusts. We have embarked on a program to investigate one-photon and two-photon absorption (OPA and TPA, respectively) in fluorescent proteins (FPs), including those incorporating non-canonical amino acids (ncAAs). Research continues on several projects related to development and use of fluorescent probes for studying RNA. These projects include: (i) understanding of various binding motifs (Watson-Crick hydrogen-bonding, non-wAtson-crick, and base-stacking) of the emissive analogues relative to natural nucelobases as well as the corresponding UV-vis absorption spectra, (ii) examination of the relative energies of tautomers and (iii) design and understanding of emissive RNA analogs utilizing TPA.

We are also working on benchmarking a variety of computation approaches for determining TPA. In addition to our work on excited electronic states, research continues in collaboration with Eric Rivard (University of Alberta) primarily examining the excited electronic states of phosphorescent molecules. In addition to these static studies, we are developing computational tools for the study of dynamics in excited electronic states.

Recent Publications

- B. Ibrahim, M. Alaraby Salem, T. W. Fasih, A. Brown, T. M. Sakr, 2018, Radioiodinated doxorubicin as a new tumor imaging model: preparation, biological evaluation, docking and molecular dynamics, Journal of Radioanalytical and Nuclear Chemistry, accepted.

- Y. Simsek, and A. Brown, 2018, Two-photon absorption properties of gold fluorescent protein: A combined molecular dynamics and quantum mechanical study, J. Phys. Chem. B 122, 5738-5748 DOI: 10.1021/acs.jpcb.8b00885

- Rodrigo A. Mendes, S. K. C. Almeida, Iuri N. Soares, C.A. Barboza, R.G. Freitas, A. Brown, G.L.C. de Souza, 2018, A computational investigation on the antioxidant potential of myricetin 3,4'-di-O-α-L- rhamnopyranoside, J.Mol. Model., 24: 133 DOI: 10.1007/s00894-018-3663-2

- R.A. Mendes, B.L.S. e Silva, R. Takeara, R.G. Freitas, A. Brown, G.L.C. de Souza, 2018, Probing the antioxidant potential of phloretin and phlorizin through a computational investigation, J.Mol. Model. 24, 101 DOI: 10.1007/s00894-018-3632-9

- B. N. Thomas, P.J. Moon, S. Yin, A. Brown, R. J. Lundgren, 2018, Z-Selective Iridium-Catalyzed Cross-Coupling of Allylic Carbonates and -Diazo Esters, Chem. Sci. 9, 238-244 DOI: 10.1039/C7SC04283C

- W. Torres Delgado, C.A. Braun, M.P. Boone, O. Shynkaruk, R. McDonald, M.J. Ferguson, P.R. Data, S. K. C. Almeida, I. de Aguiar, G.L.C. de Souza, A. Brown, G. He, and E. Rivard, 2018, Moving beyond boron-based substituents to achieve phosphorescence in tellurophenes, ACS-Applied Materials and Interfaces 10, 12124–12134 DOI: 10.1021/acsami.7b11628

- E. Pradhan and A. Brown, 2017, Neural Network Exponential Fitting of a Potential Energy Surface with Multiple Minima: Application to HONO, Phys. Chem. Chem. Phys. 19, 22272-22281. DOI: 10.1039/C7CP04010E

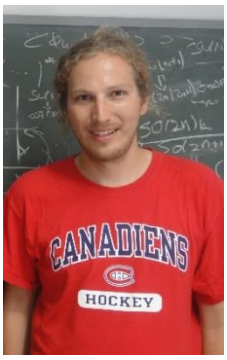
- E. Pradhan and A. Brown, 2017, Fitting potential energy surfaces to sum-of-products form with neural networks using exponential neurons, J. Theor. Comput. Chem., 16, 1730001 [Invited Review]. DOI: 10.1142/S0219633617300014

- D. Moseguí González, K.N. Raftopoulos, G. He, C.M. Papadakis, A. Brown, E. Rivard and P. Müller-Buschbaum, 2017, Bandgap-Tuning in Triple-Chalcogenophene Polymer Films by Thermal Annealing, Macromolecular Rapid Communications, 38, 1700065. DOI: 10.1002/marc.201700065

- S. Sun and A. Brown, 2017, Effects of Hydrogen Bonding with H2O on the Resonance Raman Spectra of Uracil and Thymine, Comp. Theo. Chem. 1100, 70-82. DOI: 10.1016/j.comptc.2016.12.014

- C. A. Braun, D. Zomerman, I. de Aguiar, Y. Qi, W. Torres Delgado, M. J. Ferguson, R. McDonald, G. L. C. de Souza, G. He, A. Brown, and E. Rivard,, 2017, Probing the nature of peripheral boryl groups within luminescent tellurophenes, Faraday Discussions, 196, 255-268. DOI: 10.1039/C6FD00172F

Thomas Creutzig: Mathematical Physics



My research in mainly concerned with problems connected to vertex algebras. A vertex algebra is the mathematician's notion of the symmetry algebra (or chiral algebra) of a two-dimensional conformal field theory. There are thus various natural connections to physics, but also to interesting topics of pure mathematics. The type of conformal field theories that interest me most are called logarithmic. The name reflects that logarithmic singularities can appear in correlation functions and operator products. On the vertex algebra side this amounts to non semisimple module categories. Over the last years, we have explored such theories in various examples and connected the structures to interesting problems in representation theory and number theory. There are actually more surprising isomorphisms of vertex algebras around and I plan to continue proving them. These isomorphisms will prove gauge theory conjectures as corollaries. There is a new and exciting research direction for which my research turns out to be extremely helpful. Problems in four-dimensional supersymmetric gauge theories, in the quantum geometric Langlands correspondence and in vertex algebras are very closely related. Vertex algebras relate categories of line defects of three-dimensional topological boundary conditions in the gauge theory and at the same time serve as a kernel for the quantum geometric Langlangs correspondence, i.e. they establish equivalences of twisted D-modules.

Recent Publications

- T. Creutzig, Y.-Z. Hunag and J. Yang, Braided tensor categories of admissible modules for affine Lie algebras, accepted in Commun. Math. Phys.
- T. Creutzig, J. F. R. Duncan and W. Riedler, Self-Dual Vertex Operator Superalgebras and Superconformal Field Theory, J. Phys. A 51 (2018) no.3, 034001.
- V. Bouchard, T. Creutzig, D. E. Diaconescu, C. Doran, C. Quigley and A. Sheshmani, Vertical D4-D2-D0 bound states on K3 fibrations and modularity, Comm. Math. Phys. 350 (2017), no. 3, 1069-1121.
- T. Arakawa, T. Creutzig, K. Kawasetsu and A. Linshaw, Orbifolds and Cosets of Minimal W-Algebras. Comm. Math. Phys. 355 (2017), no. 1, 339-372.
- T. Creutzig and T. Gannon, Logarithmic conformal field theory, log-modular tensor categories and modular forms, J.Phys. A50 (2017) no.40, 404004. (article is part of the "Highlights of 2017" selection of the journal)
- T. Creutzig and A. Linshaw, Orbifolds of symplectic fermion algebras, Trans. Am. Math. Soc. 369, No. 1 (2017), 467494,
- T. Creutzig, A. Milas and S. Wood, On Regularised Quantum Dimensions of the Singlet Vertex Operator Algebra and False Theta Functions, Int. Math. Res. Not. IMRN 2017, no. 5, 1390-1432.
- T. Creutzig and A. Milas, Higher rank partial and false theta functions and representation theory. Adv. Math. 314 (2017), 203-227.

Andrzej Czarnecki: Particle Physics

My research interests focus on the phenomenology of strong and electroweak interactions. Those activities range from detailed calculations of Standard Model predictions to studies of new physics effects from supersymmetry or other exotic phenomena. I am examining particle production near thresholds and properties of QCD and QED bound states. These results improve the accuracy of fundamental physical constants, such as parameters describing the mixing of various quark species, the strong interaction coupling constant αs, and the masses of elementary particles, such as muon and electron.

Recent Publications

- Czarnecki, W. J. Marciano, and A. Sirlin, The Neutron Lifetime and Axial Coupling Connection, Phys. Rev. Lett. 102 (2018) 202002-1 - 202002-5.

- Czarnecki, S. Groote, J. G. K¨orner, and J. H. Piclum, NNLO QCD corrections to the polarized top quark decay t(↑) → Xb + W+, Phys. Rev. D97 (2018) 094008-1 - 094008-8.

- Czarnecki, B. Leng and M. B. Voloshin, Stability of tetrons, Phys. Lett. B778 (2018) 233 - 238.

- Andrzej Czarnecki, Matthew Dowling, Jan Piclum, and Robert Szafron, Two-loop binding corrections to the electron gyromagnetic factor, Phys. Rev. Lett. 120 (2018) 043203-1-043203-5.

- Czarnecki and W. J. Marciano, Top-quark loops and the muon anomalous magnetic moment, Phys. Rev. D96 (2017) 113001-1 - 113001-6, Erratum Phys. Rev. D97 (2018) 019901.

- Pokraka and A. Czarnecki, Parapositronium can decay into three photons, Phys. Rev. D96 (2017) 093002-1 - 093002-6.

- Czarnecki and S. G. Karshenboim, Decay of the dimuonium into a photon and a neutral pion, Phys. Rev. D96 (2017) 011302-1 - 011302-4(R).

Charles Doran: Mathematical Physics, String Theory

Using Mathematics to answer physical questions at the interface between Geometry, Topology, and Number Theory, my work sets up a framework for new and emerging physics, taking highly structured physical systems and using the language of geometry to constrain, classify, and evolve physical theories.

Recent Publications

- Hodge Numbers from Picard-Fuchs Equations. Charles Doran, Andrew Harder, Alan Thompson. SIGMA 13 (2017), 045, 23 pages.
- Off-shell Supersymmetry and Filtered Clifford Supermodules. Charles Doran, Michael Faux, Jim Gates, Tristan Hübsch, Kevin Iga, Greg Landweber. Algebras and Representation Theory, DOI: 10.1007/s10468-017-9718-8, July 2017.
- Vertical D4-D2-D0 Bound States on K3 Fibrations and Modularity. Vincent Bouchard, Thomas Creutzig, Duiliu-Emanuel Diaconescu, Charles Doran, Callum Quigley, Artan Sheshmani. Communications in Mathematical Physics 350, 1069-1121 (2017).
- Picard-Fuchs Uniformization of Modular Subvarieties. Brent Doran, Charles Doran, Andrew Harder. 31 pages. To appear in Uniformization, Riemann-Hilbert Correspondence, Calabi-Yau Manifolds, and Picard-Fuchs Equations, Institut Mittag-Leffler.
- Mirror Symmetry, Tyurin Degenerations, and Fibrations on Calabi-Yau Manifolds. Charles Doran, Andrew Harder, Alan Thompson. 38 pages. To appear in String-Math 2015.
- Special Function Identities from Superelliptic Kummer Varieties. Adrian Clingher, Charles Doran, Andreas Malmendier. 46 pages. To appear in Asian Journal of Mathematics.
- An Application of Cubical Cohomology to Adinkras and Supersymmetry Representations. Charles Doran, Kevin Iga, Greg Landweber. To appear in Annales de l'Institut Henri Poincaré D: Combinatorics, Physics and their Interactions.
- Calabi-Yau Threefolds Fibred by Mirror Quartic K3 Surfaces. Charles Doran, Andrew Harder, Andrey Novoseltsev, Alan Thompson; 2016; Advances in Mathematics, Volume 298, 6 August 2016, 369-392.
- Toric Degenerations and Laurent Polynomials related to Givental's Landau-Ginzburg Models. Charles Doran, Andrew Harder. 24 pages; 2016; Canadian Journal of Mathematics, Volume 68 (2016), 784815.
- Calabi-Yau Threefolds Fibred by Kummer Surfaces Associated to Products of Elliptic Curves. Charles Doran, Andrew Harder, Andrey Novoseltsev, Alan Thompson; 2016; In String-Math 2014, American Mathematical Society, Proceedings of Symposia in Pure Mathematics 93, 278-303.
- Humbert Surfaces and the Moduli of Lattice Polarized K3 Surfaces. Charles Doran, Andrew Harder, Hossein Movasati, Ursula Whitcher; 2016; In String-Math 2014, American Mathematical Society, Proceedings of Symposia in Pure Mathematics 93, 124-155.
- The 14th Case VHS via K3 Fibrations. Adrian Clingher, Charles Doran, Jacob Lewis, Andrey Novoseltsev, Alan Thompson; 2016; In Recent Advances in Hodge Theory: Period Domains, Algebraic Cycles, and Arithmetic, Cambridge University Press, London Mathematical Society Lecture Note Series 427, 165-227.

Rodrigo Fernández: Theoretical Astrophysics

Rodrigo Fernandez is interested in explosive astrophysical transients: neutron star mergers, supernovae, and related phenomena. These are some of the most spectacular events in the Universe, where most of the heavy elements form, and where neutron stars and stellar-mass black holes are born. These systems are highly non-linear and complex due to the interplay of multiple processes, with Physics operating in regimes beyond what can be tested in laboratories on Earth. To learn about these events Rodrigo and his group run large-scale numerical simulations on supercomputing facilities. The ultimate goal is to gain insight into these systems by making predictions that can be tested with observations.

Recent Publications

- Sen, Koushik; Fernández, Rodrigo; Socrates, Aristotle, "Subphotospheric fluctuations in magnetized radiative envelopes: contribution from unstable magnetosonic waves", Monthly Notices of the Royal Astronomical Society, Volume 477, Issue 2, p.2286-2297 (2018).

- Coughlin, Eric R.; Quataert, Eliot; Fernández, Rodrigo; Kasen, Daniel, "A physical model of mass ejection in failed supernovae", Monthly Notices of the Royal Astronomical Society, Volume 477, Issue 1, p.1225-1238 (2018).

- Fernández, Rodrigo; Quataert, Eliot; Kashiyama, Kazumi; Coughlin, Eric R., "Mass ejection in failed supernovae: variation with stellar progenitor", Monthly Notices of the Royal Astronomical Society, Volume 476, Issue 2, p.2366-2383 (2018).

- Lippuner, Jonas; Fernández, Rodrigo; Roberts, Luke F.; Foucart, Francois; Kasen, Daniel; Metzger, Brian D.; Ott, Christian D., "Signatures of hypermassive neutron star lifetimes on r-process nucleosynthesis in the disc ejecta from neutron star mergers", Monthly Notices of the Royal Astronomical Society, Volume 472, Issue 1, p.904-918 (2017).

- Fernández, Rodrigo; Foucart, Francois; Kasen, Daniel; Lippuner, Jonas; Desai, Dhruv; Roberts, Luke F., Classical and Quantum Gravity, Volume 34, Issue 15, article id. 154001 (2017).

David Favero: Mathematical Physics, String Theory

My research utilizes a blend of ideas from string theory, algebraic geometry, and category theory to address problems in mathematical physics. Some of my recent works attack a long-standing conjecture of Bondal-Orlov and Kawamata and explore enumerative geometry uses homological methods.

Recent Publications

- Variation of Geometric Invariant Theory Quotients and Derived Categories, joint work with M. Ballard and L. Katzarkov (63 pages). Journal f ur die reine und angewandte Mathematik. doi.org/10.1515/crelle-2015-0096

- Derived Categories of Degree d Hypersurfaces, joint work with M. Ballard, D. Deliu, U. Isik, and L.Katzarkov (30 pages). Mathematische Annalen. doi.org/10.1007/s00208-017-1613-4.

- Proof of a Conjecture of Batyrev and Nill, joint work with T. Kelly. American Journal of Mathematics. 139.6, pgs 1493-1520, 2017.

- Fractional Calabi-Yau Categories from Landau-Ginzburg Models, joint work with T. Kelly (59pages). To appear in Algebraic Geometry (Foundation Compositio).

- Homological Projective Duality via Variation of Geometric Invariant Theory Quotients, joint work with M. Ballard, D. Deliu, U. Isik, and L. Katzarkov, Journal of the European Mathematical Society 19.4, pgs 1127-1158, 2017.

Valeri Frolov: Gravitational Physics

Black holes, higher dimensions, quantum gravity, strings

Recent Publications

- Separation of Maxwell equations in Kerr–NUT–(A)dS spacetimes
  Pavel Krtouš, Valeri P. Frolov, David Kubizňák, Mar 6, 2018. 32 pp. Published in Nucl.Phys. B934 (2018) 7-38.
- Separation of variables in Maxwell equations in Plebański-Demiański spacetime
  Valeri P. Frolov, Pavel Krtouš, David Kubizňák, Feb 26, 2018. 6 pp. Published in Phys.Rev. D97 (2018) no.10, 101701.
- Massive Vector Fields in Rotating Black-Hole Spacetimes: Separability and Quasinormal Modes, Valeri P. Frolov, Pavel Krtouš, David Kubizňák, Jorge E. Santos, Mar 30, 2018. 5 pp. Published in Phys.Rev.Lett. 120 (2018) 231103.
- Impact factor- 23.3: Black holes, hidden symmetries, and complete integrability, Valeri Frolov, Pavel Krtous, David Kubiznak, May 15, 2017. 195 pp. Published in Living Rev. Rel. 20 (2017) no.1, 6.
- Quantum scattering on a delta potential in ghost-free theory, Jens Boos, Valeri P. Frolov, Andrei Zelnikov, May 4, 2018. 6 pp. Published in Phys. Lett. B782 (2018) 688-693.
- Gravitational field of static p -branes in linearized ghost-free gravity, Jens Boos, Valeri P. Frolov, and Andrei Zelnikov, Feb 26, 2018. 11 pp. Published in Phys.Rev. D97 (2018) no.8, 084021.
- Principal Killing strings in higher-dimensional Kerr-NUT-(A)dS spacetimes, Jens Boos, Valeri P. Frolov, Dec 30, 2017. 15 pp. Published in Phys.Rev. D97 (2018) no.8, 084015.
- Stationary black holes with stringy hair, Jens Boos, Valeri P. Frolov. Nov 16, 2017. 11 pp. Published in Phys.Rev. D97 (2018) no.2, 024024.
- New metrics admitting the principal Killing–Yano tensor, Valeri P. Frolov, Pavel Krtous, David Kubiznak, Dec 21, 2017. 10 pp. Published in Phys.Rev. D97 (2018) no.10, 104071.
- On the Liouville 2D dilaton gravity models with sinh-Gordon matter, Valeri P. Frolov, Andrei Zelnikov, Dec 20, 2017. 12 pp. Published in JHEP 1802 (2018) 088.
- Remarks on non-singular black holes, Valeri P. Frolov, Aug 15, 2017. 10 pp. Published in EPJ Web Conf. 168 (2018) 01001, Conference: C17-07-03.12 Proceedings e-Print: arXiv:1708.04698.
- Weakly charged generalized Kerr–NUT–(A) dS spacetimes, VP Frolov, P Krtouš, D Kubizňák, Physics Letters B 771, 254-256 (2017).
- Quantum radiation from an evaporating nonsingular black hole, VP Frolov, A Zelnikov, Physical Review D 95 (12), 124028 (2017).
- Quantum radiation from a sandwich black hole, VP Frolov, A Zelnikov. Physical Review D 95 (4), 044042 (2017).

Terry Gannon: Mathematical Physics, Field Theory

My work is on the interface of algebra (especially representation theory), number theory (especially modular forms), analysis (especially subfactors), and mathematical physics (especially conformal field theory). Some topics I'm currently (or at least recently) working on are: Moonshine; the classification of conformal field theories of Wess-Zumino-Witten type; the theory of vector-valued modular forms; and reconstruction of a conformal field theory from its category of representations.

Recent Publications

- J. Fuchs, T. Gannon, G. Schaumann, C. Schweigert: ``The logarithmic Cardy case: Boundary states and annuli", Nucl. Phys. B390 (2018), 287--327.

- T. Gannon: ``A pariah finds a home", Nature 550, 191--192 (12 October 2017).

- C. Franc, T. Gannon, G. Mason: ``On the arithmetic of hypergeometric series", 28 pp, to appear in J. Number Th} (accepted May 25, 2018)

- T. Gannon: ``Reconstruction I. The classical part of a vertex operator algebra", 38 pp, to appear in Advanced Studies in Pure Mathematics (accepted August 28, 2017)

- T. Gannon, S. Morrison: ``Modular data for the extended Haagerup subfactor", Commun. Math. Phys. 356 (2017), 981--1015.

- T. Creutzig, T. Gannon: ``Logarithmic conformal field theory, log-modular tensorcategories and modular forms", 41 pages, J. Phys A: Math. Theor. 50 (2017) 404004

- D.E. Evans, T. Gannon: ``Non-unitary fusion categories and their doubles via endomorphisms", Adv. Math. 310 (2017), 1--43.

- T. Gannon: ``Much ado about Mathieu." Adv. Math. 301 (2016), 322--358.

Gabriel Hanna: Theoretical Chemistry

Our research focuses on a variety of theoretical problems related to condensed phase systems, but a common thread connects them: the decomposition of a system into a subsystem of interest and its environment, followed by the study of the influence of the environment on the dynamics of the subsystem. We take a mixed quantum-classical approach in our modeling, where the subsystem is treated quantum mechanically while the environment is treated in classical-like fashion. Our interests lie in the development and testing of efficient and accurate mixed quantum-classical methodologies, and their applications to the dynamics and spectroscopy of physical, chemical, and biological systems of fundamental and technological importance.

Recent Publications

- Liu, J.; Hanna, G. "Efficient and deterministic propagation of mixed quantum-classical Liouville dynamics" *Journal of Physical Chemistry Letters*, 2018, 9: 3928.

- Liu, J.; Mora-Gomez, V. A.; Hanna, G. "Modeling heat transfer at the nanoscale: A mixed quantum-classical approach" *AIP Conference Proceedings*, in press.

- Dell'Angelo, D.; Hanna, G. "On the performance of multi-state transition filtering in mixed quantum-classical Liouville surface-hopping simulations: Beyond two- and three-state quantum Subsystems" *Theoretical Chemistry Accounts*, 2018, 137: 15.

- Dell'Angelo, D.; Hanna, G. "Importance of eigenvector sign consistency in computations of expectation values via mixed quantum-classical surface-hopping dynamics" *Theoretical Chemistry Accounts*, 2017, 136: 75.

- Li, M.; Freedman, H.; Dell'Angelo, D.; Hanna, G. "A model platform for rapid, robust, directed, and long-range vibrational energy transport: Insights from a mixed quantum-classical study of a 1D molecular chain" *AIP Conference Proceedings*, 2017, 1906: 030007(1)-030007(4).

- Freedman, H.; Hanna, G. "Mixed quantum-classical Liouville simulation of vibrational energy transfer in a model alpha-helix at 300 K" *Chemical Physics*, 2016, 477: 74-87.

- Shakib, F.; Hanna, G. "A mixed quantum-classical Liouville approach for calculating proton-coupled electron transfer rate constants" *Journal of Chemical Theory and Computation*, 2016, 12: 3020-3029.

- Dell'Angelo, D.; Hanna, G. "Using multi-state transition filtering to improve the accuracy of expectation values via mixed quantum-classical Liouville dynamics" *AIP Conference Proceedings*, 2016, 1790: 020009(1)-020009(4).

- Martinez, F.; Hanna, G. "Mixed quantum-classical simulations of transient absorption pump-probe signals for a photo-induced electron transfer reaction coupled to an inner-sphere vibrational mode" *Journal of Physical Chemistry A*, 2016, 120: 3196-3205. (Invited article for the Ronnie Kosloff Festschrift special issue)

Natalia Ivanova: Theoretical Astrophysics

Theoretical studies of interacting binaries: mass transfer in binaries, common envelope evolution, stellar evolution codes, stellar hydrodynamics codes, population's studies, compact binaries in globular clusters.

Recent Publications

- "Planetary Nebulae Embryo after a Common Envelope Event", Galaxies, as part of the Special Issue Asymmetric Planetary Nebulae VII (2018)
- *"On the Use of Hydrogen Recombination Energy during Common Envelope Events"* Ivanova, N.., *Astrophys. J. L.* , 885, 24 (2018)
- *"New Cataclysmic Variables and other Exotic Binaries in the Globular Cluster 47 Tucanae"* Rivera-Sandoval, L. E., van den Berg, M., Heinke, C. O., Cohn, H. N., Lugger, P. M., Anderson, J., Cool, A. M., Edmonds, P. D., Wijnands, R., Ivanova, N., Grindlay, J. E., *MNRAS* , 475, 481 (2018)
- *"Episodic mass ejections from common-envelope objects"* Clayton, M., Podsaidlowski, Ph., Ivanova, N., Justham, S., *MNRAS* , 470, 1788 (2017)
- *"Formation of Black Hole X-Ray Binaries with Non-degenerate Donors in Globular Clusters"* Ivanova, N., da Rocha, C. A., Van, K. X., Avendano Nandez, J.L., *Astrophys. J. L.* , 843, 30 (2017)
- *"Stability of mass transfer from massive giants: double black hole binary formation and ultraluminous X-ray sources"* Pavlovskii, K., Ivanova, N., Belczynski, K., Van, K. X., *MNRAS* , 465, 2092 (2017)
- *"Common envelope events with low-mass giants: understanding the transition to the slow spiral-in"* Ivanova, N., Avendano Nandez, J.L., *MNRAS* , 462, 362 (2016)
- *"Mass transfer and magnetic braking in Sco X-1"* Pavlovskii, K., Ivanova, N., *MNRAS* , 456, 263 (2016)
- *"Common envelope events with low-mass giants: understanding the energy budget"* Avendano Nandez, J.L., Ivanova, N., *MNRAS* , 460, 3992 (2016)

Mariusz Klobukowski: Theoretical Chemistry

Within our research program we develop and apply new pseudopotential methods required to deal with large molecules or molecular systems containing heavy atoms; our model core potentials allow for the description of both the scalar relativistic effects as well as spin-orbit coupling. These methods are suitable for the studies of both ground and excited electronic states of molecular systems. We also study molecular structure and properties of very large molecules and molecular clusters using both non-relativistic and scalar-relativistic model core potential representation of the core electrons and correlated wavefunctions or density functionals for the description of the valence electrons. We focus on both strongly- and weakly-bonded systems in ground and excited electronic states; we are particularly interested in molecules containing rare-gas atoms and transition metal ions. Within this direction of our research program we search for novel stable compounds that contain atoms of rare-gas elements from argon to radon. In collaboration with the research group of Professor Jack Tuszynski we search for novel anti-cancer drugs. In this case, in order to be able to represent both the drug molecule as well as the target protein, we use the hybrid QM/MM approach, with the quantum mechanical treatment used for the drug molecule, and molecular mechanics used to model protein.

Recent Publications

- Miriam van Hoeve and Mariusz Klobukowski,"Computational Study of the Electronic Spectra of the Rare Gas Fluorohydrides HRgF (Rg = Ar, Kr, Xe, Rn)" J. Phys. B: At. Mol. Opt. Phys, 51 (2018) 055103 (10pp)
- Meagan S. Oakley, Jie J. Bao, Mariusz Klobukowski, Donald G. Truhlar, and Laura Gagliardi "Multireference Methods for Calculating the Dissociation Enthalpy of Tetrahedral P_4 to Two P_2)" J. Phys. Chem. A, 122 (2018) 5742-5749.
- Meagan Oakley and Mariusz Klobukowski,"Computing UV-Vis Spectra of 1-Bromo-1-Propene: A Comparison of Model Core Potential and All Electron Approaches" Canadian Journal of Chemistry, 2017, (Vol. 95, No. 5) 627-631
- Melanie W. Lui, Olena Shynkaruk, Meagan S. Oakley, Robert McDonald, Michael J. Ferguson, Mariusz Klobukowski, and Eric Rivard,"Engaging Dual Donor Sites within an N-Heterocyclic Olefin Phosphine Ligand", Dalton Transactions, 46, (2017) 5946-5954
- Dylan Hennessey and Mariusz Klobukowski, "Hydrogen bonding and autoionization in confined bifluoride system FHF^-" Journal of Physics B: Atomic, Molecular, and Optical Physics, 2017, 50 (15) Article Number: 155101
- Travis J. A. Craddock, Philip Kurian, Jordane Preto, Kamlesh Sahu, Stuart R. Hameroff, Mariusz Klobukowski, and Jack A. Tuszynski, "Anesthetic Alterations of Collective Terahertz Oscillations in Tubulin Correlates with Clinical Potency: Implications for Anesthetic Action and Post-Operative Cognitive Dysfunction", Scientific Reports, 2017, 7, 9877/1-12
- Ahmed Taha Ayoub, Michael Staelens, Alessio Prunotto, Marco A. Deriu, Andrea Danani, Mariusz Klobukowski, Jack A. Tuszynski, "Explaining the Microtubule Energy Balance: Contributions Due to Dipole Moments, Charges, van der Waals and Solvation Energy" International Journal of Molecular Sciences, Int. J. Mol. Sci. 2017, 10, 2042/1-6

Joseph Majiecko: Condensed Matter

Theoretical condensed matter physics: emergent phenomena in quantum many-body systems; topological phases of matter including topological insulators, superfluids, and superconductors; the quantum Hall effect; quantum spin liquids; quantum transport in low-dimensional systems; fractionalization and strongly correlated systems; quantum criticality; field theories of many-body systems and connections between condensed matter physics and high-energy physics.

Recent Publications

• H. Yerzhakov and J. Maciejko, “Disordered fermionic quantum critical points”, arXiv:1807.04845.

• R. Boyack, C.-H. Lin, N. Zerf, A. Rayyan, and J. Maciejko, “Transition between algebraic and Z2 spin liquids at large N”, arXiv:1804.00054, to appear in Phys. Rev. B.

• R. Lundgren, H. Yerzhakov, and J. Maciejko, “Nematic order on the surface of a three-dimensional topological insulator”, Phys. Rev. B 96, 235140 (2017).

• C. Prosko, S.-P. Lee, and J. Maciejko, “Simple Z2 lattice gauge theories at finite fermion density”, Phys. Rev. B 96, 205104 (2017).

• J. Hutchinson and J. Maciejko, “Universality of low-energy Rashba scattering”, Phys. Rev. B 96, 125304 (2017): Editors' Suggestion.

• N. Regnault, J. Maciejko, S. A. Kivelson, and S. L. Sondhi, “Evidence of a fractional quantum Hall nematic phase in a microscopic model”, Phys. Rev. B 96, 035150 (2017): Editors' Suggestion.

• S.-P. Lee, D. Nandi, F. Marsiglio, and J. Maciejko, “Fractional Josephson effect in nonuniformly strained graphene”, Phys. Rev. B 95, 174517 (2017).

• S.-P. Lee, R. M. Lutchyn, and J. Maciejko, “Odd-frequency superconductivity in a nanowire coupled to Majorana zero modes”, Phys. Rev. B 95, 184506 (2017): Editors' Suggestion.

• S.-K. Jian, C.-H. Lin, J. Maciejko, and H. Yao, “Emergence of supersymmetric quantum electrodynamics”, Phys. Rev. Lett. 118, 166802 (2017).

• M. Rashidi, M. Taucer, I. Ozfidan, E. Lloyd, H. Labidi, J. L. Pitters, J. Maciejko, and R. A. Wolkow, “Time-resolved imaging of negative differential resistance on the atomic scale”, Phys. Rev. Lett. 117, 276805 (2016): Featured in Physics (see Focus story).

Frank Marsiglio: Condensed Matter

Marsiglio's group studies how electrons interact with one another and with phonons, typically in a solid state environment. One of the outcomes of such interactions is Superconductivity, and this is his main focus. However, another outcome is magnetic correlations, and sometimes magnetic and pairing effects compete and/or effect one another.

He also explores interesting consequences of quantum mechanics, often in the context of a trap or double well. This latter area of research is typically discussed at a level accessible to beginners in the field, in particular undergraduates.

Recent Publications

- The effect of strong electron-rattling phonon coupling on some superconducting properties, S. Tajik, B. Mitrovi'c, and F. Marsiglio, To be published in Can. J. Phys. (2018). (see arXiv:1807.04658).
- Eliashberg Theory in the Weak Coupling Limit, F. Marsiglio, To be published in Phys. Rev. **98**, xxxxx (2018). (see arXiv:1807.04907)
- Enhancement of superconducting T_c due to the spin-orbit interaction, J. Hutchinson, J.E. Hirsch and F. Marsiglio, Phys. Rev. **B97**, 184513 (2018).
- Double Well Potentials with a quantum moat barrier or a quantum well barrier give rise to similar entangled wave functions, Ibrahim and F. Marsiglio, American Journal of Physics **86** (3), 180-185 (2018).
- The tight-binding formulation of the Kronig-Penney model, F. Marsiglio and R.L. Pavelich, Scientific Reports **7**, 17041 (2017).
- Microscopic Origin of the Drude-Smith model, T.L. Cocker, D. Baillie, M. Buruma, L.V. Titova, R.D. Sydora, F. Marsiglio and F.A. Hegmann, Phys. Rev. **B95**, 205439, (2017).
- The possible role of van Hove singularities in the high T_c of superconducting H_3S., T.X.R. Souza and F. Marsiglio, International Journal of Modern Physics **B31**, 1745003, (2017).
- Two and three particles interacting in a one-dimensional trap, MengXing Na and F. Marsiglio, American Journal of Physics **85** (10), 769-782 (2017).
- Fractional Josephson effect in nonuniformly strained graphene\hfil\break, S.P. Lee, D. Nandi, F. Marsiglio, and J. Maciejko, Phys. Rev. **B95**, 174517, 2017.
- The Coulomb potential in quantum mechanics revisited, A.A. Othman, M. de Montigny, and F. Marsiglio, American Journal of Physics **85** (5), 346-351 (2017).

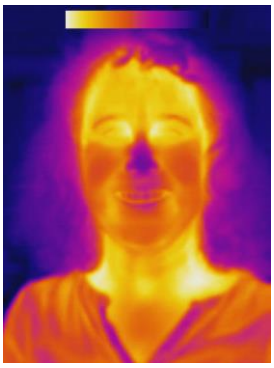
Marc de Montigny: Mathematical Physics

My research program deals with symmetry methods applied to various physical systems. My interests focus on the kinematical symmetries of nature, their applications in field theory, and the connections between these symmetries. Kinematical symmetries, such as the Poincare' algebra (which underlies the relativistic theories), Galilei algebra (intrinsic to low-energy physics), the de Sitter or Newton-Hooke algebras (both of interest in cosmology), determine the basic structures of physical theories, which often exhibit additional dynamical symmetries. These symmetries can be transformed into one another through mathematical procedures called "contractions" and "deformations" of Lie algebras. The Galilei algebra is a contraction of the PoincarŽ algebra in the limit of low-velocity and large time-like intervals. My general objective is to study physical applications of the Galilei symmetry, which contains some surprising and intricate features. I am mostly interested in using Galilean invariance in order to facilitate the treatment of non-relativistic systems. An example would be the description of new models of low-energy phenomena in condensed matter physics (spin systems, superfluidity, superconductivity) and nuclear physics with Galilean symmetry.

Recent Publications

- J. Ramos, M. de Montigny, F.C. Khanna, "Weyl gravitoelectromagnetism", General Relativity and Gravitation 50 (2018) 83(13pp)
- M. de Montigny, S. Zare, H. Hassanabadi, "Fermi field and Dirac oscillator in a Som-Raychaudhuri space-time", General Relativity and Gravitation 50 (2018) 47(24pp)
- MoEDAL Collaboration, Search for magnetic monopoles with the MoEDAL forward trapping detector in 2.11fb^{-1} of 13TeV proton–proton collisions at the LHC, Physics Letters B 782 (2018) 510–516
- H. Hassanabadi, M. Hosseinpour, M. de Montigny, "Duffin-Kemmer-Petiau equation in curved space-time with scalar linear interaction", European Physics Journal Plus 132 (2017) 541 (12pp)
- M. Hedayatipoor, J. Finlay, S. Massoudi, C. Nokes, M. de Montigny, "Quasi-elastic neutrino reactions on carbon and lead nuclei", Journal of Physics G: Nuclear and Particle Physics 45 (2018) 025201(18pp).
- A.A. Othman, M. de Montigny and F. Marsiglio, "The Coulomb potential in quantum mechanics revisited", Americal Journal of Physics **85** (2017) 346-351.
- S. Zare, M. de Montigny and H. Hassanabadi, "Investigation of the non-relativistic Fermi-Gas model by considering the position-dependent mass", Journal of the Korean Physical Society, **70** (2017) 122-128.
- B. Acharya et al (MoEDAL Collaboration, 70 authors), "Search for magnetic monopoles with the MoEDAL prototype trapping detector in 13 TeV proton-proton collisions at the LHC", Physical Review Letters, 118 (2017) 061801(6pp).

Sharon Morsink: Theoretical Astrophysics



Determining the masses and radii of neutron stars is important, not only for understanding the astronomical properties of these stars, but also for understanding the physical properties of the cold dense matter within them. The NICER mission will measure the masses and radii of several rotation-powered pulsars by fitting pulse waveform models using general relativity to observations of the soft X-ray waveforms produced by the rotation of hot spots located near their magnetic polar caps. My research involves modelling the X-ray data from the NICER mission in order to constrain the properties of neutron stars.

Recent Publications

- The highest frequency kHz QPOs in neutron star low-mass X-ray binaries, van Doesburgh, M., van der Klis, M., Morsink, S.M. (2018), *Monthly Notices of the Royal Astronomical Society*, **479**, 426.

- Neutron Star Mass-Radius Constraints Using Evolutionary Optimization, Stevens, A.L., Fiege, J.D., Leahy, D.A., et al. (2016), *Astrophysical Journal*, **833**, 244.

- Measuring Neutron Star Radii via Pulse Profile Modeling with NICER, Özel, F., Psaltis, D., Arzoumanian, Z., et al. (2016), *Astrophysical Journal* , **832**, 92.

- The Impact of Surface Temperature Inhomogeneities on Quiescent Neutron Star Radius Measurements, Elshamouty, K.G., Heinke, C.O., Morsink, S.M., et al. (2016), *Astrophysical Journal*, **826**, 162.

- Colloquium: Measuring the neutron star equation of state using x-ray timing, Watts, A.L., Andersson, N., Chakrabarty, D., et al. (2016), *Reviews of Modern Physics*, **88**, 21001.

Don Page: Gravitational Theory, Cosmology

One of my main focuses is on quantum cosmology, applying quantum theory to the universe as a whole. One of the deepest problems in theoretical cosmology today is the measure problem, how to obtain testable probabilities for observations by finite observers in a model for the universe, particularly for a quantum model and perhaps most challenging when the model predicts an infinite universe with an infinite number of observers, so that it becomes ambiguous to try to define normalized probabilities by the ratios of observers who make different possible observations. In addition to the problem of the ambiguity of the ratios of infinite quantities, even for a finite universe there is the problem that we do not know what the rules are for obtaining the probabilities of observations in quantum theory. A related issue in quantum cosmology is the quantum state of the universe. Hartle and Hawking have made the brilliant proposal of a particular quantum state given by a path integral over complex geometries with no boundary except for the 3-geometry that is the argument of the wave function, so that this proposal is known as the no-boundary wave function (NBWF). However, Susskind raised an objection to this model, which I fleshed out, that when there is something like a positive cosmological constant to explain the observed accelerated expansion of the universe, then it appears that the path integral is dominated by universes that are empty (except for whatever it is that produces the accelerated expansion).

Another main focus of my continuing research is on black hole thermodynamics and Hawking evaporation, particularly for the information puzzle of what happens to the information that falls into a black hole. To me (though many disagree), the most conservative option is what I proposed in 1980, that the information is not lost (so that the quantum evolution of our universe is unitary), which after more than 20 years of disagreement Hawking came to believe. But there is still the big puzzle of how the information comes out in the Hawking radiation. This puzzle was heightened by the argument of Almheiri, Marolf, Polchiski, and Sully, that one cannot have information retention along with local effective quantum field theory outside the black hole unless there is a firewall surrounding the black hole which would immediately destroy anything falling in. I have written several papers critiquing this argument (such as by questioning the assumption of local effective quantum field theory, which almost certainly is just an approximation in quantum gravity), and my graduate student Kento Osuga and I have built a toy model for getting the information out without firewalls with a certain type of nonlocality for the quantum gravitational field.

Recent Publications

- Osuga K, Page, D. (2018). Qubit Transfer Model for Unitary Black Hole Evaporation without Firewalls. Physical Review and arXiv:1607.04642 (both Open Access). D97(6): 066023-1---066023-7.
- Page D. (2018). Finite Upper Bound for the Hawking Decay Time of an Arbitrarily Large Black Hole in Anti-de sitter Spacetime. Physical Review and arXiv:1507.02682 (both Open Access). D92(2): 024004-1---024004-5.
- Scully M, Fulling S, Lee D, Page D, Schleich W, Svidzinsky A. (2018). Quantum Optics Approach to Radiation from Atoms Falling into a Black Hole. Proceedings of the National Academy of Sciences of the United States of America and arXiv:1709.00481 (both Open Access). In Press.

- Page, D. (2018). Normalized Observational Probabilities from Unnormalizable Quantum States or PhaseSpace Distributions. Foundations of Physics and arXiv:1203.1837 (Open Access). 2018: 1-10. In Press.
- McNutt D, Page D. (2017). Scalar Polynomial Curvature Invariant Vanishing on the Event Horizon of Any Black Hole Metric Conformal to a Static Spherical Metric. Physical Review D and arXiv:1704.02461 (Open Access). 95(No. 8): 084044-1---084044-5.
- Osuga K, Page D. (2017). A New Way to Derive the Taub-NUT Metric with Positive Cosmological Constant. Journal of Mathematical Physics and arXiv:1603.05714 (Open Access). 58(8): 082501-1---082501-7.
- Abdolrahimi S, Page D, Tzounis C. (2016). Ingoing Eddington-Finkelstein Metric of an Evaporating Black Hole. Physical Review and arXiv:1607.05280 (Open Access). Revision Requested
- Chen P, Ong Y, Page D, Sasaki D, Yeom D. (2016). Unclothed Firewalls. International Journal of Modern Physics D. 25(No. 13): 1645003-1-1645003-10.

Alexander Penin: Particle Physics, Quantum Field Theory

The core of the research program is the calculation of the high-order perturbative corrections in a wide class of the quantum field theory problems ranging from nonrelativistic threshold to ultra-relativistic Sudakov limit, which are of primary phenomenological importance for current and future experiments. The focus of the research proposal is on high-energy asymptotic behavior of gauge theories, heavy quarkonium physics, and high-precision non-accelerator physics. Main research interests: a) Effective field theory approach including NRQCD, HQET, SCET, and χPT. Effective field theory of unstable particles; b) Renormalization group and evolution equations; c) High precision physics at the LHC and electron-positron colliders, in particular Higgs boson and top quark pair production; d) High-energy asymptotic behavior of gauge theory amplitudes; e) Asymptotic expansion of Feynman integrals; f) High order perturbative analysis of the nonrelativistic bound states in QCD and QED, perturbative lattice QCD; g) Field theory aspects of Quantum Hall and Josephson effects; h) Instantons and solitons in supersymmetric gauge theories in various dimensions.

Recent Publications

- High-Energy Limit of QCD beyond Sudakov Approximation, T. Liu and A. A. Penin, Phys.Rev.Lett. **119** (2017) 262001, e-Print arXiv:1709.01092 [hep-ph]

- Coulomb Artifacts and Breakdown of Perturbative Matching in Lattice NRQCD, A.A. Penin and A. Rayyan, JHEP 1712 (2017) 007, arXiv:1710.03244 [hep-lat]

- Three-loop quark form factor at high energy: the leading mass corrections, T. Liu, A.A. Penin and N. Zerf, Phys.Lett. **B771** (2017) 492, e-Print arXiv:1705.07910 [hep-ph]

- Coulomb Artifacts and Bottomonium Hyperfine Splitting in Lattice NRQCD, T. Liu, A.A. Penin and A. Rayyan, JHEP **1702** (2017) 084, e-Print arXiv:1609.07151 [hep-lat]

- Two-loop Bhabha Scattering at High Energy beyond Leading Power Approximation, A.A. Penin and N. Zerf, Phys.Lett. **B760** (2016) 816, e-Print arXiv:1606.06344 [hep-ph]

- On the light quark mass effects in Higgs boson production in gluon fusion, K. Melnikov and A. Penin, JHEP **1605** (2016) 172, e-Print arXiv:1602.09020 [hep-ph]

Dmitri Pogosyan: Cosmology, Theoretical Astrophysics

Inflation, initial cosmological perturbations, origin and evolution of the Large-Scale Structure in the Universe, Cosmic Microwave Background, tests for Cosmological Theories.

Recent Publications

- On the connectivity of the cosmic web: theory and implications for cosmology and galaxy formation, Codis, Sandrine; Pogosyan, Dmitri; Pichon, Christophe, Monthly Notices of the Royal Astronomical Society, Volume 479, Issue 1, p.973-993 (2018).
- Inflationary study of non-Gaussianity using two-dimensional geometrical measures of CMB temperature map, Junaid, M., Pogosyan, D., Physical Review D, Volume 98, Issue 2, id.023519 (2018).
- Statistical properties of Galactic CMB foregrounds: dust and synchrotron, Kandel, D.; Lazarian, A.; Pogosyan, D., Monthly Notices of the Royal Astronomical Society, Volume 478, Issue 1, p.530-540 (2018).
- Galaxy evolution in the metric of the cosmic web, Kraljic, K., et al., Monthly Notices of the Royal Astronomical Society, Volume 474, Issue 1, p.547-571 (2018).
- A question of separation: disentangling tracer bias and gravitational non-linearity with counts-in-cells statistics, Uhlemann, C., et al., Monthly Notices of the Royal Astronomical Society, Volume 473, Issue 4, p.5098-5112 (2018).
- Can the observed E/B ratio for dust galactic foreground be explained by sub-Alfvénic turbulence?, Kandel, D.; Lazarian, A.; Pogosyan, D., Monthly Notices of the Royal Astronomical Society: Letters, Volume 472, Issue 1, p.L10-L14 (2017).
- Effects of dust absorption on spectroscopic studies of turbulence, Kandel, D.; Lazarian, A.; Pogosyan, D., Monthly Notices of the Royal Astronomical Society, Volume 470, Issue 3, p.3103-3123 (2017).
- Beyond Kaiser bias: mildly non-linear two-point statistics of densities in distant spheres, Uhlemann, C., et al., Monthly Notices of the Royal Astronomical Society, Volume 466, Issue 2, p.2067-2084 (2017).
- Study of velocity centroids based on the theory of fluctuations in position-position-velocity space, Kandel, D.; Lazarian, A.; Pogosyan, D., Monthly Notices of the Royal Astronomical Society, Volume 464, Issue 3, p.3617-3635 (2017).

Wojciech Rozmus: Plasma Physics

My research is focused on theoretical and numerical studies of laser matter interactions in different physical systems and for a wide range of parameters. The interactions between intense laser beams and plasmas have broad and far reaching applications in applied and fundamental sciences. These include: (1) inertial confinement fusion (ICF), (2) laboratory astrophysics and high energy density plasmas, and (3) novel applications of laser produced plasmas in particle accelerations, laser pulse compression and amplification as well as utilizing plasmas to manipulate the basic properties of light waves. All three areas have been subjects of my research. In addition to high intensity laser beam applications we have also used (4) laser light scattering as a noninvasive diagnostic tool for biological cell enumeration and sorting.

Our research methodology combines analytical theory with large scale numerical simulations and close collaborations with several experimental groups conducting research on large ICF facilities (e.g. National Ignition Facility (NIF) at Lawrence Livermore National Laboratory), ultrashort relativistic pulse lasers (University of Michigan, University of Alberta), pulse power devices (Imperial College), free electron x-ray lasers (SLAC), basic laser plasma facilities (LLE, University of Rochester) and different medical and biological research facilities (UBC Pediatric Hospital, NINT).

Recent Publications

- R.J. Henchen, M. Sherlock, W. Rozmus, J. Katz, D. Cao, J.P. Palastro, and D.H. Froula, *Observation of nonlocal heat flux using Thomson scattering*, Phys. Rev. Lett., in press (2018).
- A. E. Hussein, J. D. Ludwig, K. T. Behm, Y. Horovitz, P.-E. Masson-Laborde, V. V. Chvykov, A. M. Maksimchuk, T. Matsuoka, C. McGuffey, V. Yanovsky, W. Rozmus and K. Krushelnick, *Stimulated Raman Backscattering from a laser wakefield accelerator*, New J. Phys., **20**, 073039 (1-10) (2018).
- J. D. Ludwig, P.-M. Masson-Laborde, S. Hüller, W. Rozmus, and S.C. Wilks, *Enhancement and control of laser wakefields via backward Raman amplifier*, Phys. Plasmas **25**, 053108(1-14), (2018).
- W. Rozmus, A. V. Brantov, M. Sherlock, and V. Yu. Bychenkov, *Return current instability driven by a temperature gradient in ICF plasmas*, Plasma Phys. Controlled Fusion 60, 014004, (2018).
- W. Rozmus, A. V. Brantov, C. Fortmann-Grote, V. Yu. Bychenkov, and S. Glenzer, *Electrostatic fluctuations in collisional plasmas*, Phys. Rev. E 96, 043207 (1-15) (2017).
- V.Yu. Bychenkov, W. Rozmus, *A model of anomalous absorption of laser light on ion acoustic turbulence*, Phys. Plasmas **24** (1), 012701 (2017).
- H. Shahin, M. Gupta, A. Janowska-Wieczorek, W. Rozmus, and Y.Y. Tsui, *Physical characterization of hematopoietic stem cells using multidirectional label-free light scatterings*, Optics Express **24** (25), 28877-28888 (2016)
- N. Naseri, W. Rozmus, and D. Pesme, *Self-channeling of intense laser pulses in underdense plasma and stability analysis*, Phys. Plasmas 23, 113101 (2016).

Mauricio Sacchi: Geophysics

In collaboration with graduate students, I have been researching in the area of statistical and transform methods for seismic data processing, waveform imaging and inversion in applied and global seismology. Over the past ten years, we have become recognized for the development of algorithms for multi-dimensional seismic data reconstruction, de-noising and the application of sparsity promoting methods to seismic data processing. We are currently studying problems of optimal acquisition design for simultaneous source acquisition, imaging, and full waveform inversion.

Recent Publications

- Ibrahim A, P Terenghi and M D Sacchi, 2018, Simultaneous reconstruction of seismic reflections and diffractions using a global hyperbolic Radon dictionary: Geophysics, accepted.
- Mostafa Naghizadeh, Mauricio Sacchi, 2018, Ground-roll attenuation using curvelet downscaling: Geophysics, 83(3), V185-V195.
- G Matharu, MD Sacchi, 2018, Source encoding in multi-parameter full waveform inversion: Geophysical Journal International, 214 (2), 792-810.
- Tho NHT Tran, Lawrence H Le, Mauricio D Sacchi, Vu-Hieu Nguyen, 2018, Sensitivity analysis of ultrasonic guided waves propagating in trilayered bone models: a numerical study: Biomechanics and modeling in mechanobiology, 1-11.
- Anagaw A, and M D Sacchi, 2018, Model parametrization strategies for Newton-based acoustic Full Waveform Inversion, in press JAG.
- Mengyao Sun, M D Sacchi and J. Zhang, 2018, An efficient tomographic inversion method based on the stochastic approximation:
  Geophysics 83 (4), R283-R296
- A Anagaw and M D Sacchi, 2018, Edge-preserving smoothing for simultaneous-source FWI model updates in high-contrast velocity models: Geophysics, 83 (2), 1-18.
- Ramin M H Dokht, Y Gu, M D Sacchi, 2018, Migration Imaging of the Java Subduction Zones: Journal of Geophysical Research: Solid Earth
- W Gao and M D Sacchi, 2018, Multicomponent seismic data registration by no-linear optimization: Geophysics 83 (1), V1-V10.
- Linan Xu and M D Sacchi, 2018, Preconditioned acoustic least-squares two-way wave equation migration with exact adjoint operator: Geophysics 83 (1), S1-S13.
- Ismael Vera Rodriguez and M D Sacchi, 2017, Seismic Source Monitoring with Compressive Sensing, in Compressive Sensing of Earth Observations, 2017 - CRC Press.

- S Martins, J M Travassos and M D Sacchi, 2017, Interpolating GPR data using anti-alias singular spectrum analysis (SSA): Near Surface Geophysics, 15 (5), 447-455.
- Vu-Hieu Nguyen, Tho N.H.T. Tran, M D Sacchi, Salah Naili, and Lawrence H Le, 2017, Computing dispersion curves of elastic/viscoelastic transversely-isotropic bone plates coupled with soft tissue and marrow using semi- analytical finite element (SAFE) method. Venue: Computers in Biology and Medicine, 87, 371-381.
- A Stanton and M D Sacchi, 2017, Elastic least-squares wave equation migration: Geophysics, 82 (4), 1-58.
- K Chen and M D Sacchi, 2017, Elastic least-squares reverse time migration via linearized elastic full waveform inversion with pseudo-Hessian preconditioning: Geophysics 82 (5), S341-S358.
- A Gholami and M D Sacchi, 2017, Time-Invariant Radon Transform by Generalized Fourier Slice Theorem: Inverse Problems and Imaging, 11 (3), 501-519.
- H Wang, M D Sacchi and J Ma, 2017, Linearized dynamic warping with l1-norm constraint for multicomponent registration: Journal of Applied Geophysics, 139, 170-176.
- R M H Dokht, Yu J Gu and M D Sacchi, 2017, Singular spectrum analysis and its applications in mapping mantle seismic structure: Geophysical Journal International, 208 (3), 1430-1442.
- D Perez, D R Velis and M D Sacchi, 2017, Three-term inversion of prestack seismic data using weighted l2-1 mixed norm: Geophysical Prospecting, 65, 1477-1495.
- R M H Dokht, Y J Gu, and M D Sacchi, 2016, Waveform inversions of SS precursors: An implication of the northwestern Pacific subduction zones and intraplate volcanoes in China: Gondwana Research, 40, 77-90.
- Jianjun Gao, Jinkun Chen and M D Sacchi, 2017, 5D seismic reconstruction using parallel square-matrix factor- ization: IEEE Transactions on Geoscience and Remote Sensing: IEEE Transactions of Geoscience and Remote Sensing, 55(4), 2124-2135.

Barry Sanders: Quantum Computation

The focus is to advance knowledge and implementations of phenomena, processes, and protocols that exploit quantum effects and includes quantum algorithms for quantum simulation, machine learning for quantum control, multi-photon multi-channel interferometry, scalable quantum computing and long-distance quantum communication.

B. C. Sanders, How to build a quantum computer, Published by IOP Publishing, Bristol, United Kingdom, 2017 (ISBN 978-0-7503-1536-4).

Recent Publications

- S. Asgarnezhad-Zorgabad, R. Sadighi-Bonabi and B. C. Sanders, Excitation and propagation of surface polaritonic rogue waves and breathers, *Physical Review A* **98**(1): 013825 (17 pp.), 13 July 2018.

- J.-Z. Wu, H. de Guise and B. C. Sanders, Coincidence landscapes for polarized bosons, *Physical Review A* **98**(1): 013817 (11 pp.), 10 July 2018.

- Y.-D. Wu, A. Khalid and B. C. Sanders, Efficient code for relativistic quantum summoning, *New Journal of Physics* **20**(6): 063052 (18 pp.), 29 June 2018.

- M. Ahmadi, H. B. Dang, G. Gour and B. C. Sanders, Quantification and manipulation of magic states, *Physical Review A* **97**(6): 062332 (9 pp.), 20 June 2018.

- A. Khalid, D. Spivak, B. C. Sanders and H. de Guise, Permutational symmetries for coincidence rates in multimode multiphotonic interferometry, *Physical Review A*(6): 063802 (18 pp.), 5 June 2018, arXiv.org:arXiv:1709.06615.

- S. Xu, X. X. Sun, J. Z. Wu, W. W. Zhang, N. Arshed and B. C. Sanders, Quantum walk on a chimera graph, *New Journal of Physics* **20**(5): 053039 (13 pp.), 15 May 2018.

- P. Palittapongarnpim and B. C. Sanders, Enter the machine, *Nature Physics* **14**(5): 432 - 433, 1 May 2018.

- Z. Shaterzadeh-Yazdi, B. C. Sanders and G. A. DiLabio, Ab-Initio characterization of coupling strength for all types of dangling-bond pairs on the hydrogen-terminated Si(100)-2x1 surface, *Journal of Chemical Physics* **148**(15): 154701 (8 pp.), 16 April 2018. (Editor's Pick).

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- D.-X. Quan, L.-L. Zhu, C.-X. Pei and B. C. Sanders, Fault-tolerant conversion between adjacent Reed-Muller quantum codes based on gauge fixing, *Journal of Physics A: Mathematical and Theoretical* **51**(11): 115305 (16 pp.), 19 February 2018.

- N. Sang-Nourpour, B. Lavoie, R. Kheradmand, M. Rezaei and B. C. Sanders, Characterization of surface-plasmon polaritons at lossy interfaces, *Journal of Optics* **19**(12): 125004 (12 pp.), 20 November 2017.

- W. W. Zhang, B. C. Sanders, S. Apers, S. K. Goyal and D. L. Feder, Detecting topological transitions in two dimensions by Hamiltonian evolution, *Physical Review Letters* **119**(19): 197401 (6 pp.), 6 November 2017.

- X. Zhan, L. Xiao, Z. H. Bian, K. K. Wang, X.-Z. Qiu, B. C. Sanders, W. Yi and P. Xue, Detecting topological invariants in nonunitary discrete-time quantum walks, *Physical Review Letters* **119**(13): 130501 (6 pp.), 27 September 2017.

- M. Ahmadi, Y.-D. Wu and B. C. Sanders, Relativistic (2,3)-threshold quantum secret sharing, *Physical Review D* **96**(6): 065018 (10 pp.), 25 September 2017.

- P. Fraser and B. C. Sanders, Loophole-free Bell tests and the falsification of local realism, *The Journal of Student Science and Technology* **10**(1): 23 - 30, 28 August 2017.

- H.-L. Huang, Q. Zhao, X. F. Ma, C. Liu, Z.-E. Su, X.-L. Wang, L. Li, N.-L. Liu, B. C. Sanders, C.-Y. Lu and J.-W. Pan, Experimental blind quantum computing for a classical client, *Physical Review Letters* **119**(05): 050503 (5 pp.), 2 August 2017.

- L. Xiao, X. Zhan, Z. H. Bian, K. K. Wang, X. Zhang, X. P. Wang, J. Li, K. Mochizuki, D. Kim, N. Kawakami, W. Yi, H. Obuse, B. C. Sanders and P. Xue, Observation of topological edge states in parity-time-symmetric quantum walks, *Nature Physics* **13**: 1117 - 1123, 31 July 2017.

- M. Ghosh, A. Karigowda, A. Jayaraman, F. Bretenaker, B. C. Sanders and A. Narayanan, Demonstration of a high-contrast optical switching in an atomic Delta system, *Journal of Physics B: Atomic, Molecular and Optical Physics* **50**(16): 165502 (8 pp.), 31 July 2017.

- S. M. Barnett, A. Beige, A. Ekert, B. M. Garraway, C. H. Keitel, V. Kendon, M. Lein, G. J. Milburn, H. M. Moya-Cessa, M. Murao, J. K. Pachos, G. M. Palma, E. Paspalakis, S. J. D. Phoenix, B. Piraux, M. Plenio, B. C. Sanders, J. Twamley, A. Vidiella-Barranco and M. S. Kim, Journeys from quantum optics to quantum technology, *Progress in Quantum Electronics* **54**: 19 - 45, 19 July 2017.

- D. Wang, C. Liu, C.-S. Xiao, J.-X. Zhang, H. M. Alotaibi, B. C. Sanders, L.-G. Wang and S.-Y. Zhu, Strong coherent light amplification with double electromagnetically induced transparency coherences, *Scientific Reports* **7**: 5796 (8 pp.), 19 July 2017.

- W. W. Zhang, S. K. Goyal, C. Simon and B. C. Sanders, Decomposition of split-step quantum walks for simulating Majorana modes and edge states, *Physical Review A* **95**(5): 052351 (7 pp.), 30 May 2017.

- P. Palittapongarnpim, P. Wittek, E. Zahedinejad, S. Vedaie and B. C. Sanders, Learning in quantum control: High-dimensional global optimization for noisy quantum dynamics, *Neurocomputing* **268**: 116 - 126, 30 April 2017.

- H. Lu, C. Liu, D.-S. Wang, L.-K. Chen, Z.-D. Li, X.-C. Yao, L. Li, N.-L. Liu, C.-Z. Peng, B. C. Sanders, Y. -A. Chen and J.-W. Pan, Experimental quantum channel simulation, *Physical Review A* **95**(4): 042310 (8 pp.), 10 April 2017.

- T. Hill, B. C. Sanders and H. Deng, Cooperative light scattering in any dimension, *Physical Review A* **95**(3): 033832 (5 pp.), 24 March 2017.

Richard Sydora: Plasma Physics

My research primarily concerns energy conversion and transport processes in plasmas and the interrelationships between laboratory and space/astrophysical plasma environments.

• Magnetic field Reconnection, Plasmoid and Flux Rope dynamics: One of the main mechanisms of energy conversion in magnetized plasmas is through a process called magnetic reconnection, a ubiquitous phenomenon in the plasma universe. In this mechanism of explosive energy release, anti-parallel magnetic field components merge and cross-connect, leading to global magnetic topology changes, plasma energization and production of high energy charged particles. Using 3D kinetic plasma simulation models and theoretical analysis we have identified a new form of electromagnetic turbulence leading to an enhanced or anomalous resistivity localized to the magnetic reconnection region and begin to understand how magnetic flux ropes are generated there.

Other topics include:

- Particle acceleration: through nonlinear plasma waves and in intense laser fields
- Non-diffusive Transport in Magnetized Plasmas
- Self-organization and pattern formation in non-equilibrium plasmas

Recent Publications

- Spiky electric and magnetic field structures in flux rope experiments, W. Gekelman, S. Tang, T. DeHaas, S. Vincena, P. Pribyl, S. Vincena, R. Sydora, *Proc. National Academy Sciences*, in press (2018), www.pnas.org/cgi/doi/10.1073/pnas.1721343115.

- Nonlocal Ohms Law, Plasma Resistivity, and Reconnection During Collisions of Magnetic Flux Ropes, W. Gekelman, T. DeHaas, P. Pribyl, S. Vincena, B. Van Compernolle, R. Sydora, S. Tripathi, *Astrophysical Journal*, **853**, 33 (17 pages), (2018).

- Microscopic Origin of the Drude-Smith model, T.L. Cocker, D. Baillie, M. Buruma, L.V. Titova, R.D. Sydora, F. Marsiglio and F.A. Hegmann, Phys. Rev. **B95**, 205439, (2017).

- Non-local Ohms Law During Collisions of Magnetic Flux Ropes, W. Gekelman, T. DeHaas, P. Pribyl, S. Vincena, B. Van Compernolle, R. Sydora, *Physics of Plasmas*, **24**, 070701 (6 pages), (2018).

- Linear theory of the current sheet shear instability, K. Fujimoto, R. Sydora, *Journal of Geophysical Research: Space Physics*, Volume **122**, Issue 5, pp. 5418-5430 (2017).

- Current-driven Langmuir oscillations and formation of wave packets via modulational instability: Relevance to STEREO observations, *Geo. Res. Lett.*, Volume **43**, Issue 14, pp. 7348-7355 (2016).

- The Kelvin-Helmholtz instability of boundary-layer plasmas in the kinetic regime, B. Steinbusch, P. Gibbon, R.Sydora, *Phys. Plasmas*, Volume **23**, Issue 5, 052119 (2016).

Jack Tuszynski: Biophysics

Jack Tuszynski currently head a multi-disciplinary team creating "designer drugs" for cancer chemotherapy using computational biophysics methods. To make advances in this new promising field of biophysical modeling, Jack Tuszynski drew on his physics background to create computer software programs that screen proteins against chemical compounds to find the perfect match based on the lock and key principle. The goal of Tuszynski's computational biophysics work is to create optimized drugs that would target cancerous cells with minimal side-effects to the healthy cells. Dr. Tuszynski's research interests are strongly linked to the protein tubulin and the microtubules assembled from it. These have been studied using methods ranging from simple stochastic models to detailed molecular dynamics computer simulations, as well as through laboratory manipulations of living cells. Due to its prominent role played in eukaryotic cell division, tubulin is an important target for anti-cancer cytotoxic treatments. His on-going research aim is to identify variants of known compounds showing greater tubulin isotype-specific effects. These compounds could potentially lead to more efficacious chemotherapy treatments with lower side effects. The group has also examined microtubule's biochemical, electrical, structural, and mechanical properties; proteins that bind to microtubules (MAPs); and the motor proteins in cells that travel along microtubules and actin filaments. Over the past few years, one of the main research interests in the Tuszynski lab was the creation of 3D models of p53 and its mutants as well as a search for inhibitors of the wild type p53 protein and activators of its mutants. His group is also developing physiologically-based models and simulations for pharmacokinetic and pharmacodynamic applications. The computational biophysics group is supported by funding from the Alberta Cancer Foundation, the Allard Foundation, Alberta's Advanced Education and Technology as well as NSERC and strategic industrial partners: HP, IBM, Cathton Holdings Inc. and Sinoveda. Through these funding sources and partnerships the group has been able to acquire state-of-the-art hardware (more than 9,000 processing cores) and software aimed at high-throughput computational drug discovery involving three strategies: (a) finding new applications for old drugs, (b) changing old drug structures to optimize their action and (c) designing completely novel compounds. He designed a novel anti-mitotic compound, CR42-24 which is in final stages of pre-clinical development for metastatic bladder cancer.

Recent Publications

- H. Freedman, P. Winter, J.A. Tuszynski, D. L. Tyrrell and M. Houghton, A computational approach for predicting off-target toxicity of antiviral ribonucleoside analogues to mitochondrial RNA polymerase, **Journal of Biological Chemistry** (accepted May 8, 2018).
- MoEDAL Collaboration: B. Acharya, et al. Search for magnetic monopoles with the MoEDAL forward trapping detector in 2.11~fb−1 of 13 TeV proton-proton collisions at the LHC, **Physics Lettes B** (accepted May 14, 2018).
- A. Nishiyama and J.A. Tuszynski, Non-equilibrium Quantum Electrodynamics: Entropy Production During Equilibration, **International Journal of Modern Physics B** (accepted July 9, 2018).
- N. Barvitenko, A. Lawen, M. Aslam, A. Pantaleo, C. Saldanha, E. Skverchinskaya, M. Regolini and J.A. Tuszynski, Integration of intracellular signaling: biological analogues of wires, processors and memories organized by a centrosome 3D reference system, **Biosystems** (revisions, June 18, 2018)
- J.A. Tuszynski, Electric conduction effects in the neuronal cytoskeleton hold the key to our understanding of the biophysics of consciousness, **Journal of Cognitive Science**, June 2018 Special issue.
- S.I. Omar, M. G. Lepre, U. Moribucci, M. Deriu and J.A. Tuszynski, Virtual screening using covalent docking to find activators for G245S mutant p53, **PLoS One** (accepted July 3, 2018).

- J.J. Timmons, J. Preto, J.A. Tuszynski and E.T. Wong, Tubulin's response to external electric fields by molecular dynamics simulations, **PLoS One** (minor corrections), 2018.
- R. R. Poznanski, L.A. Cacha, M.A. Tengku, A.L.A. Zubaidi, S. Hussain. J.Ali and J.A. Tuszynski, Biomolecular consciousness in the electromagnetic brain: a polaritonic approach to the two-brain hypothesis, **Journal of Integrative Neuroscience** vol. 18 (accepted May 21, 2018).
- A. Mbengashe, S. Ndo, W. Chen, U. Nebutanda, L.S.L. Tshane, H.D. Bamal, L.M. Senate, A.K. Basson, A. P. Kappo, R.A. Mosa, J.S. Shandu, C. van der Westhuizen, S.S. Mashele, J.A. Tuszynski, J.M. Blackburn, J-H Yu, D.R. Nelson, K. Syed, Similarities, variations and evolution of cytochrome P450s in *Streptomyces versus Mycobacterium*, **Scientific Reports** (major revisions, April 19, 2018)
- F. Gentile, K.H. Barakat and J.A. Tuszynski, Computational Characterization of Small Molecules Binding to the Human XPF Active Site and Virtual Screening to Identify Potential New DNA Repair Inhibitors Targeting the ERCC1-XPF Endonuclease, **International Journal of Molecular Sciences** 2018 Apr 30; 19(5). pii: E1328. doi: 10.3390/ijms19051328.
- O.A. Attalah, M.A. Al-Ghobashy, A.T. Ayoub, J.A. Tuszynski and M. Nebsen, Computer-aided design of magnetic molecularly imprinted polymer nanoparticles for solid-phase extraction and determination of levetiracetam in human plasma, **RSC Advances**, 8 (2018) 14280.
- S.M. Saberi Fathi and J.A. Tuszynski, Using spectral representation to classify proteins' conformational states, **International Journal of Molecular Sciences** (accepted, June 28, 2018).
- I.V. Hosamani, G. Chan and J.A. Tuszynski, Homology modeling of suv39h1 and prediction of its small molecule inhibitors by virtual screening, **Interntional Journal of Molecular Sciences** (major revisions, March 14, 2018).
- H. D. Bamal, S. S. Mashele, D. R Nelson, A. P. Kappo, R. A. Mosa, J-H Yu, W. Chen, J. A. Tuszynski, K. Syed, Phylogenetic and *in silico* structural analysis of novel P450 fusion protein family CYP5619 from Oomycetes: Special focus on CYP5619A1, **Scientific Reports** 2018 Apr 26;8(1):6597. doi: 10.1038/s41598-018-25044-0.
- G. Grasso, M. Rebella, S. Muscat, U. Morbiducci, J. A. Tuszynski, A. Danani and M.A. Deriu, Conformational Dynamics and Stability of U-Shaped and S-Shaped Amyloid Beta Oligomers, **International Journal of Molecular Sciences**, (2018) *19*, 571; doi:10.3390/ijms19020571.
- M. A. Deriu, M. Cangiotti, G. Grasso, G. Licandro, A. Lavasanifar, J.A. Tuszynski, M. Ottaviani and A. Danani, Self-assembled ligands targeting TLR-7; a molecular level investigation, **Langmuir,** Dec 19;33(50):14460-14471. doi: 10.1021/acs.langmuir.7b03168. Epub 2017 Dec 11.
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- M. Cocchi, F. Gabrielli, L. Tonello and J.A. Tuszynski, A dialogue on the issue of the "quantum brain" between consciousness and unconsciousness, **Journal of Integrative Neuroscience,** Vol. 16, Supplement 1, S13-S18 (2017).
- M. Cocchi, G. Bernroider, M. Rasenick, L. Tonello, F. Gabrielli and J.A. Tuszynski, Document of Trapani on animal consciousness and quantum brain function: A hypothesis, **Journal of Integrative Neuroscience,** Vol. 16, Supplement 1, S99-S104 (2017).
- Ayoub, Ahmed Taha, Michael Staelens, Alessio Prunotto, Marco A. Deriu, Andrea Danani, Mariusz Klobukowski, and Jack Adam Tuszynski. "Explaining the Microtubule Energy Balance: Contributions Due to Dipole Moments, Charges, van der Waals and Solvation Energy. **International Journal of Molecular Sciences** 18, no. 10 (2017): 2042.
- V. Salari, S. Barzanjeh, M. Cifra, C. Simon, F. Scholkmann, A. Rezaei and J.A. Tuszynski, Novel Approaches for Non-invasive Cancer Diagnosis and Treatment: Microtubules and Electromagnetic Fields in Focus, **Frontiers in Biosciences**, Landmark 23, 1391-1406, March 1, 2018.
- P. Zarkeshian, S. Kumar, J.A. Tuszynski, P. Barclay and C. Simon, Are there optical communication channels in the brain? **Frontiers in Biosciences**, Landmark 23, March 1 2018, 1407-1421.
- M. G. Lepre, S. I. Omar, G. Grasso, U. Morbiducci, M. A. Deriu and J. A. Tuszynski, Insights into the effect of the G245S single point mutation on the structure of p53 and the binding of the protein to DNA, **Molecules 22**:8, 1358 (2017).

Eric Woolgar: Mathematical Physics, General Relativity

Research topics: Riemannian Geometry, Mathematical Physics, General Relativity

1. Asymptotically hyperbolic metrics and their behaviour under Ricci flow.

2. Asymptotically hyperbolic static metrics with various conformal boundaries, and various conjectures about them, including the Horowitz-Myers ``new positive energy conjecture."

3. Bakry-Emery Ricci curvature for spacetimes: singularity and rigidity theorems.

Recent Publications

- New Restrictions on the Topology of Extreme Black Holes, M Khuri, E Woolgar, and W Wylie, *Lett Math Phys*, to appear [arxiv:1804.01220].

- Nonexistence of Degenerate Horizons in Static Vacua and Black Hole Uniqueness, M Khuri and E Woolgar, *Phys Lett B* 777 (2017) 235--239 [arxiv:1710.09669].

- Nonexistence of de Sitter Black Rings, M Khuri and E Woolgar, *Class Quantum Gravit* 34 (2017) 22LT01 http://iopscience.iop.org/article/10.1088/1361-6382/aa9154 [arxiv:1708.03627].

- Curvature-dimension bounds for Lorentzian splitting theorems, E Woolgar and W Wylie, *J Geom Phys* 132 (2018)131--145 [arxiv:1707.09058].

- Ricci flow and volume renormalizability, E Bahuaud, R Mazzeo, and E Woolgar [arxiv:1607.08558].

- The rigid Horowitz-Myers conjecture, E Woolgar, *JHEP* 1703 (2017) 104 [arxiv:1602.06197].

Andrei Zelnikov: General Relativity, Quantum Field Theory

Some of my favorite topics include quantum field theory in curved spacetime, black holes, analogue gravity models, extra dimensions.

• In my recent works with Valeri Frolov we have found a new effect of an anomaly of the self-energy of scalar and electric charges near higher-dimensional black holes. Anomalies are usually considered as a purely quantum phenomenon. But it is not always the case. Quantum field theory methods provided us with the tools to study also a purely classical problem of self-energy of charged particles in higher dimensions, and we found out new features that do not appear in four-dimensional spacetimes.

• I am working on the problem of relation of the area of minimal surfaces in asymptotically AdS spacetimes and the entanglement entropy of quantum fields at the boundary of AdS. This project is related to the hot topic in contemporary theoretical physics: the AdS-CFT correspondence.

• Another topic I am interested in now is the application of methods of quantum field theory in curved spacetime to the calculation of quantum effects (similar to the Unruh effect) in condensed matter systems (like deformed monolayer graphene), where an analogous curved spacetime description emerges naturally.

Recent Publications

- Quantum scattering on a delta potential in ghost-free theory, Jens Boos, Valeri P. Frolov, Andrei Zelnikov, May 4, 2018. 6 pp. Published in Phys. Lett. B782 (2018) 688-693.

- Gravitational field of static p -branes in linearized ghost-free gravity, Jens Boos, Valeri P. Frolov, and Andrei Zelnikov, Feb 26, 2018. 11 pp. Published in Phys.Rev. D97 (2018) no.8, 084021.

- On the Liouville 2D dilaton gravity models with sinh-Gordon matter, Valeri P. Frolov, Andrei Zelnikov, Dec 20, 2017. 12 pp. Published in JHEP 1802 (2018) 088.

- Quantum radiation from an evaporating nonsingular black hole, VP Frolov, A Zelnikov, Physical Review D 95 (12), 124028 (2017).

- Quantum radiation from a sandwich black hole, VP Frolov, A Zelnikov. Physical Review D 95 (4), 044042 (2017).

Research Highlights

Valeri Frolov

a) In 1972 Teukolsky demonstrated separability of Maxwell equation in the background of four dimensional black holes. During next 45 years there were a lot of (unsuccessful) attempts to generalize this result to the case of higher dimensional black holes. In the past year we (with Pavel Krtous and David Kubiznak) solve this problem for the most general higher dimensional rotating black holes (so called Kerr-NIT-AdS spacetime). This remarkable discovery was made by using the techniques of principal tensor, developed in our work earlier. This result opens wide opportunities for study Hawking radiation of phonons and stability of higher dimensional black holes. These results were published in 2 papers.

b) Another important discovery is demonstration of separability of massive vector field equations in the four and higher dimensional rotating black holes. Light vector (Proca) particles are predicted by different beyond the standard models of elementary particles. Their existence might result in instability of astrophysical black holes and powerful emission of gravitational waves. Before our discovery of separability property modes of instability were studied by finding complex eigenvalues of a set of complicated partial differential equations. Now such quasinormal modes are obtained by numerical solution of our separated ODEs, that can be done hundred times faster.

c) During the past year we (with Pavel Krtous and David Kubiznak) completed our three-year work and published a joint paper in the journal "Living Reviews in Relativity". The impact factor of this journal is 23.333 [https://link.springer.com/journal/41114]. As far as I know, this is the journal in theoretical physics with the highest impact index. This extended (about 200 pages) paper besides review of the results obtained in our group during past 10 year contains also a number of new unpublished earlier results. The most important one is construction of action-angle variables for the motion of particles in the space of higher dimensional black holes. (A list of other new results, presented in the paper, can be found in Section 7.7 Final remarks.)

Frank Marsiglio

Superconductivity is traditionally about Cooper pairs with equal and opposite momenta and anti-parallel spins. Spin-orbit coupling, ubiquitous in systems for a variety of reasons, ruins this orderly delineation of momentum and spin. This has been recognized since the beginning, but it is only in more recent times that a proper accounting of spin-orbit coupling has been incorporated into the calculation of the superconducting critical temperature, Tc. Normally, incorporation of spin-orbit coupling with an attractive interaction between two electrons leads to a deterioration of Tc. We have found that certain characteristics of the real interaction between two electrons in a crystal leads to a significant enhancement of Tc. This may explain some recent observations in the $LaAlO_3/SrTiO_3$ interface where Rashba spin-orbit coupling is known to be important. We also predict a tunnelling asymmetry of universal sign in the density of states for such an interaction; observation of this asymmetry would point the crucial role of hole carriers in the superconductivity of the material. See Phys. Rev. B97, 184513 (2018) for more information.

Alexander Penin

In Phys.Rev.Lett. **119** (2017) 262001 we study the high-energy limit of the scattering amplitudes suppressed by the leading power of the quark mass in perturbative quantum chromodynamics. We prove the factorization and perform all-order resummation of the double-logarithmic radiative corrections which determine the asymptotic behavior of the amplitudes. In contrast to the Sudakov logarithms, the mass-suppressed double-logarithmic corrections are induced by soft quark exchange. The structure of the corrections and the asymptotic behavior of the amplitudes in this case crucially depend on the color flow in a given process and are determined by the eikonal color charge nonconservation. We present explicit results for the Higgs boson production in gluon fusion mediated by a light-quark loop and for the leading power-suppressed contributions to the quark form factors, which reveal ”magical” universality. Nontrivial relations between the asymptotic behavior of different amplitudes and the amplitudes in different gauge theories are found.

Don Page

https://www.ualberta.ca/science/science-news/2016/april/full-frontal-physics

For the last four years, physicists studying the mathematical underpinnings of black holes have been wrestling with a strange idea: that black holes contain a region known as a "firewall," which utterly annihilates matter that dares to cross its boundaries. However, a new paper titled “*Unclothed Black Hole Firewalls*” (Chen P, Ong Y, Page D, Sasaki D, Yeom D. (2016), International Journal of Modern Physics D. 25(No. 13): 1645003-1-1645003-10), co-authored by University of Alberta physics professor Don N. Page, aims to attack the fundamental tenets that give rise to this strange idea—with something much stranger.

“The putative black hole firewall is one of the hottest problems in physics today, and we hope that our paper makes a significant contribution to the field,” says Page. “As part of the University of Alberta community, I've been privileged to be able to interact with many others in this field around the world.”

Page’s contributors include Pisin Chen of the National Taiwan University and Stanford University, Yen Chin Ong of the Nordic Institute for Theoretical Physics (Nordita), Misao Sasaki of Kyoto University and Dong-han Yeom of the National Taiwan University.

The classic picture of a black hole comes directly from Einstein's theory of general relativity: a massive object warps the fabric of spacetime and, given sufficient material, this region of spacetime becomes so steep that not even light has sufficient speed to escape. Because no light can escape, these objects became known as black holes, entering our cultural consciousness as the universe's most terrifying garbage disposals. A hapless space traveller entering the black hole's event horizon, according to this model, would be completely destroyed inside the black hole.

Figure: The five authors of the paper with another colleague during the discussion at the Yukawa Institute for Theoretical Physics (from left): Dong-han Yeom, Yen Chin Ong, Pisin Chen, Don Page, Yasusada Nambu and Misao Sasaki.

Despite their apparent simplicity, however, black holes have been devilishly difficult to describe, and in the 1970s, physicist Stephen Hawking proposed that some particles *could* in fact escape from a black hole through a process involving the creation of entangled particles, in a theory now known as Hawking radiation. Since then, the field of black hole physics has been a wellspring of interesting phenomena, requiring the mathematics of both quantum theory and general relativity for a complete description.

In the intervening four decades, an outstanding problem—the black hole information paradox—has continued to stymie physicists as a direct result of introducing the mathematics of quantum theory into the mix. “At first, most scientists working on Einstein's theory of gravity thought Hawking's original suggestion was right, that information is lost when black holes form and evaporate," says Page, who wrote the first paper objecting to Hawking's suggestion. "Now most, though not all, gravitational physicists, including Hawking himself, believe that information is not lost. However, it is still mysterious how the information is preserved in detail."

In quantum mechanics, the two principles of quantum determinism and reversibility suggest that information must always be preserved. But since material falling into a black hole—along with the information describing that material—are apparently annihilated sometime after they cross the event horizon, physicists have been left scratching their heads about this seeming inconsistency.

The paradox itself arises due to Hawking radiation, which demonstrates that matter can be emitted from a black hole, but initially it appeared that no information about the matter that once fell into the black hole is carried away. In 2012, a group of physicists studying this paradox found that three basic assumptions involved in this paradox cannot all be consistent.

“If a firewall exists, not only would an infalling object be destroyed by it, but the destruction could be visible, even from the outside.” —Misao Sasaki (Kyoto University)

Namely, principles of unitarity and local quantum field theory contradicted the assumption of “no-drama”—meaning that nothing unusual should happen when an object falls through the event horizon. Instead, they proposed that the most conservative solution to this contradiction is that there would indeed be "drama" at the surface of the black hole in the form of a "firewall" that would destroy an infalling object. This seems rather surprising, because the curvature is negligibly small at the event horizon of a sufficiently large black hole, where general relativity should hold and one would expect nothing special when crossing the horizon.

"So-called firewalls, or high-energy density regions that we would otherwise think of as the surface of the black hole, would destroy anything falling in," explains collaborator Pisin Chen at the National Taiwan University.

The putative position of the firewall is something that didn't sit well with the authors of the paper, who began work on this project at a workshop at the Yukawa Institute for Theoretical Physics in Kyoto, Japan. Since the firewall was proposed to be hidden behind the event horizon, an observer travelling past the gently curved event horizon of a large black hole, hoping to glimpse its interior, would instead be instantly incinerated the moment they passed behind the veil. Attacking the fundamental tenets used to create the firewall, the authors demonstrate that this region of quantum-mechanical destruction can strangely migrate to a region outside of the black hole due to the quantum fluctuations of the Hawking radiation, allowing an observer a full-frontal view of a black hole's "naked firewall."

“If a firewall exists, not only would an infalling object be destroyed by it, but the destruction could be visible, even from the outside,” says Misao Sasaki, a contributor from Kyoto University.

Page emphasizes that such a "naked firewall" outside of the event horizon is problematic. If a firewall actually exists, the authors argue that it wouldn't simply be confined to a region within the black hole, but its destructive power could reach beyond the limits of the event horizon, into a region of space that could be observed. This makes the notion of firewalls less conservative than previously thought, and suggests putting more effort into finding a better solution to the firewall paradox.

International Collaborations

TPI—Charles University collaboration

During many past years there was intensive collaboration between the members of TPI and Physics Department of the Charles University (Prague). This collaboration was officially recognized by signing "**The Memorandum of Understanding between Charles University in Prague, Czech Republic and the University of Alberta, Canada"** on April 25, 2013. During the past 4 years this collaboration continued in the form of mutual visits, writing joint papers, giving lectures and PhD students exchange.

The curators of the collaboration are Professor Valeri Frolov (from TPI side) and professor Pavel Krtous (from Charles University). Main subjects of our joint work were study different aspects of black hole physics and quantum theory in curved spacetime. The most important contribution was made in the area of hidden symmetries and complete integrability in application to four and higher dimensional black holes. The results of this work were summarized in the recent review which was written by the invitation of the Living Review in Relativity Journal (its 2016/2017 Impact Factor is 29.3) [1] (see also [2-3]). Another direction of joint research was study of the relation between the entanglement entropy and minimal surfaces in the AdS/CFT correspondence (papers [4-5] by Krtous and Zelnikov). The results of the joint work were reported at several international conferences.

Andrei Zelnikov twice gave mini course lectures "Heat Kernel in Quantum Field Theory" for students and postdocs of the Physics Department of the Charles University. Both Valeri Frolov and Andrei Zelnikov gave lectures on their work during their visits to Prague. A PhD student from Charles University, I. Kolar, spent 7 month in 2015-2016 at our Departments working together with the members of our gravity and cosmology group.

To summarize, the collaboration between TPI and Charles University was very fruitful in the past and we hope it continues to be as successful in the future.

TPI curator of the collaboration, Killam Memorial Chair,
Professor Valeri Frolov

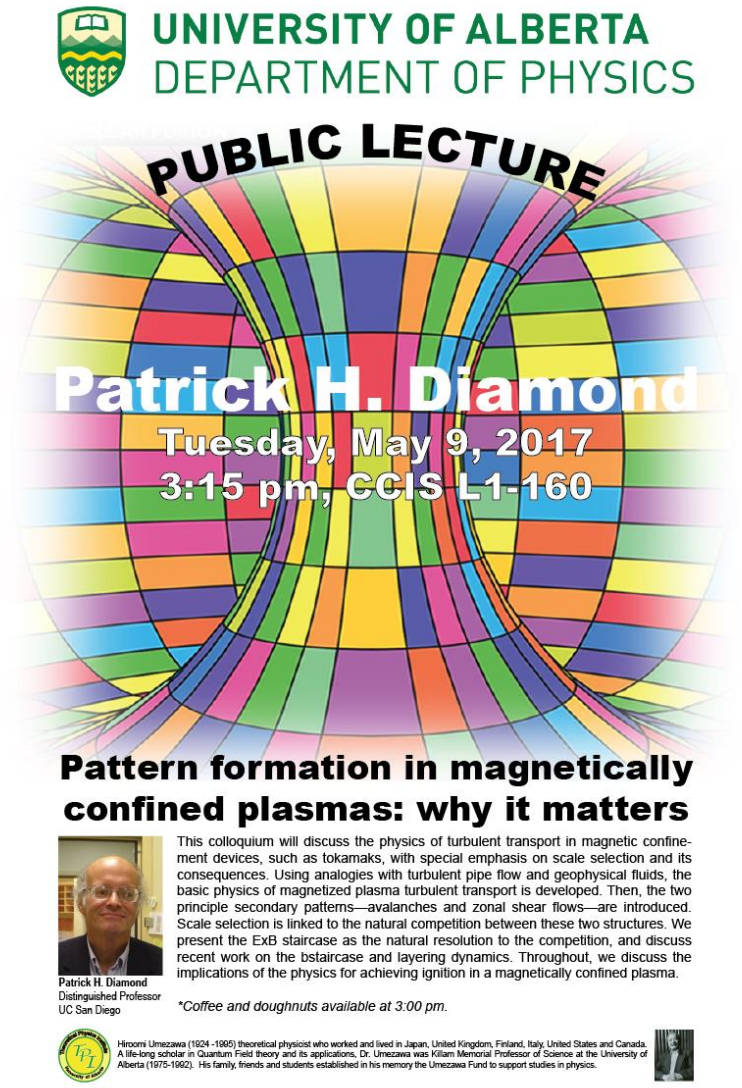
References:

1. "Black holes, hidden symmetries, and complete integrability", V. Frolov, P. Krtous, and D. Kubiznak. 195 pp. e-Print: **arXiv:1705.05482 [gr-qc]; accepted by the LRR Journal.**
2. "Weakly charged generalized Kerr–NUT–(A)dS spacetimes", V. Frolov, P. Krtous, and D. Kubiznak, **Phys.Lett. B771 (2017) 254-256;** e-Print: **arXiv:1705.00943 [gr-qc].**
3. "Deformed and twisted black holes with NUTs", P. Krtous, and D. Kubiznak, V. P. Frolov, I. Kolar , **Class.Quant.Grav. 33 (2016) no.11, 115016**; e-Print: **arXiv:1511.02536 [hep-th].**
4. "Minimal surfaces and entanglement entropy in anti-de Sitter space",
P. Krtous and A. Zelnikov ,**JHEP 1410 (2014) 077**; e-Print: **arXiv:1406.7659 [hep-th].**
5. "Entanglement entropy of spherical domains in anti-de Sitter space", P. Krtous and A. Zelnikov, **Phys.Rev. D89 (2014) no.10, 104058;** e-Print: **arXiv:1311.1685 [hep-th].**

Visitor Program

Hiromi Umezawa Lecturer

The Umezawa lecture for 2017 was give by Professor Patrick Diamond, Distinguished Professor from the Department of Physics and Center for Astrophysics and Space Science, University of California, San Diego. His lecture was on the topic of "Pattern Formation in Magnetically Confined Plasmas" and its implications in fusion energy research.



TPI Seminars 2017/2018

September 14th 2017
Rodrigo Fernandez (UofA)
Electromagnetic emission and nucleosynthesis in neutron star mergers

September 28th 2017
Thomas Creutzig (UofA)
Vertex Algebras and S-duality

October 5th 2017
Chong-Sa Lim (TWCU, Japan)
Space-time dimension and the unity of forces

October 26th 2017
Alexandra Landsman (MPI PKS, Germany)
Ultrafast light-matter interaction: shedding new light with analytic approximations

November 9th 2017
Rufus Boyack (UofA)
Collective mode contributions to the Meissner effect in Fulde-Ferrell and pair-density-wave superfluids

November 23rd 2017
William Witczak-Krempa (U. Montréal)
Conformal field theories and quantum phase transitions: an entanglement perspective

December 7th 2017
Marcus Berg (Karlstad Univ., Sweden)
Aspects of the color confinement problem

January 4th 2018
Pavan Hosur (U. Houston)
Probing quantum dynamics via out-of-time-ordered measurements

February 1st 2018
David Feder (U. Calgary)
Ultracold atoms with synthetic spin-orbit interactions, mostly in cavities

April 5th 2018
Jim Sauls (Northwestern)
The Left Hand of the Electron

Conferences

Contemporary Topics in Mathematical Physics: Banff Research Station (BIRS)

Organizers: Thomas Creutzig (University of Alberta)
Terry Gannon (University of Alberta)
Richard Sydora (University of Alberta)

The Banff International Research Station hosted the "Contemporary Topics in Mathematical Physics" Workshop in Banff from October 28, 2017 to October 29, 2017 for the Theoretical Physics Institute.

In the past ideas of physics have often given spectacular new insights into mathematics. On the other hand, the development of a rigorous mathematical foundation for the techniques used in theoretical physics is essential. This workshop brought together theoretical physicists and mathematicians working on the physics and mathematics of particle physics, condensed matter physics, quantum gravity, string theory and more. The goal was to learn about exciting ideas and insights of the participants research with the aim of close future interaction.

Saturday, Oct. 28, 2017

8:45-9am Opening Remarks, Organizers

Session Chair – Terry Gannon

9- 9:30am: Juergen Fuchs, “Conformal Field Theory Correlators”
9:30 - 10am: Don Page, “Anthropic Estimates for Many Parameters of Physics and Astronomy”
10 - 10:30am: Mark Walton, “TBD”
10:30 – 10:50 Coffee break
10:50 – 11:20am: Marcus Berg, "Loops of gauge fields, gravitons, and strings"
11:20 – 11:50am: Joseph Maciejko, “Superconducting Dirac fermions and mirror symmetry”
11:50 – 12:20pm: Thomas Creutzig, “Intro to logarithmic conformal field theory”

12:20 – 2pm: Lunch (Sally Borden)

Session Chair – Richard Sydora

2- 2:30pm: Frank Marsiglio, “More than 100 years of superconductivity: do we need a paradigm shift?”
2:30 – 3pm: Vincent Bouchard, “TBD”
3 – 3:30pm: Natalia Ivanova, “Contemporary tools for stellar interactions”
3:30 – 4pm: Coffee break
4 – 4:30pm: Rodrigo Fernandez, "Open issues in neutron star merger astrophysics"
4:30 – 5pm: Dmitri Pogosian, “Connectivity of the Cosmic Web”

Sunday, Oct. 29, 2017

Session Chair – *Thomas Creutzig*

9- 9:30am: Terry Gannon, “Moonshine – old and new”
9:30 - 10am: Richard Sydora, “Measures of Statistical Complexity and Dynamical System Applications”
10 - 10:25am: Yasaman Yazdi, “Spacetime Entanglement Entropy: From Continuum Geometries to Discrete Causal Sets”
10:25 – 10:45am: Coffee break
10:45 – 11:10am: Rufus Boyack, “Importance of amplitude collectives mode in the path integral approach to Fermi superfluids”
11:10 – 11:35am: Fenglong You, “What is mirror symmetry?”

11:35 – 12pm: Chun Chen, “A New Type of Many-Body Majorana Zero Modes in Fermionic Flux Ladder Model”

Lake Louise Winter Institute 2018

The Lake Louise Winter Institute 2018 took place from February 18th to February 24th. The event attracted 93 participants from Canada, China, Europe, Japan, Korea, and the US. They presented the results of the most important and recent analysis of over 30 top experimental collaborations. In total 91 talks were given. Twelve one-hour lectures were given by the invited speakers, which reviewed selected topics of the experimental and theoretical physics.

The program of the conference covered wide range of topics including Higgs physics, top quark physics, BSM searches, flavor physics, direct and indirect dark matter searches, neutrino mass and mixing, neutrino astronomy, etc. Comprehensive reviews of the LHC physics have been presented by the speakers from ATLAS, CMS, and LHCb collaborations.

The invited talks addressed the models of new physics, QCD applications at the LHC, neutrino physics and astroparticle physics, high precision muon physics. Status of WIMP dark matter has been reviewed by Prof. Dan Hooper, one of the leading world experts in the field. Prof. Peter Tinyakov has discussed a possible role of primordial black holes in the resolution of the dark matter problem. The first observations of the gravitational waves from a neutron star merger and comprehensive introduction to the gravitational wave astronomy was presented by Dr. Katerina Chatziioannou from CITA. An outstanding review of emergent phenomena at the interface between condensed matter and particle physics has been given by Prof. Joseph Maciejko.

In compliance with the spirit of the Lake Louise Winter Institute the theoretical reviews were intended to expose the young researchers working in experimental physics to the modern theoretical concepts and results.

The TPI sponsorship is indicated at the conference official website:

https://www.ualberta.ca/physics/research/lake-louise-winter-institute

The timetable of the conference, list of participants and the talks in pdf format are available at the conference Indico site:

Joint Canada - Asia Pacific Conference on General Relativity and Relativistic Astrophysics University of Alberta, June 25th-29th, 2018

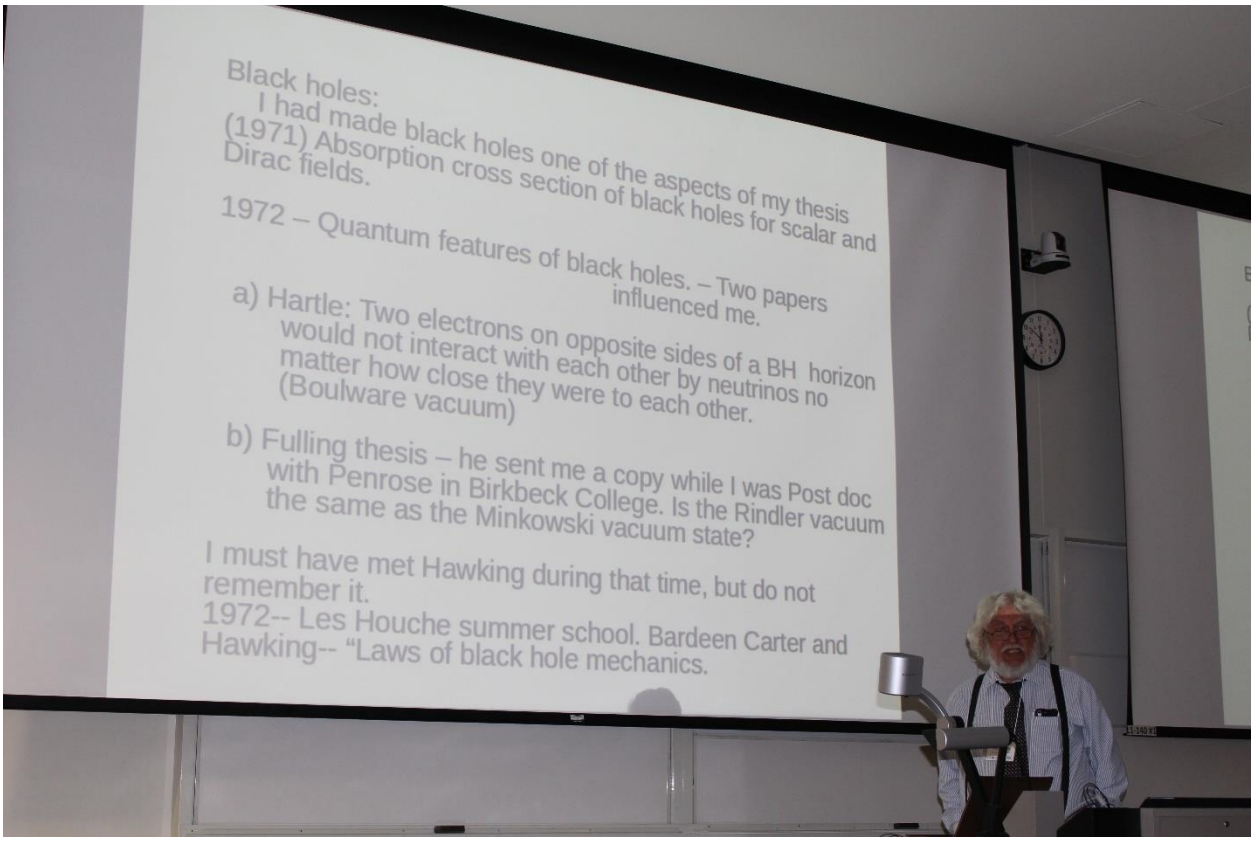
The Canadian Conference of General Relativity and Relativistic Astrophysics (CCGRRA) has been held in Canada every two years. The 17th such meeting was to be held in2018. Since June 2016, Canada has become a member of the Asia-Pacific Center for Theoretical Physics (APCTP).

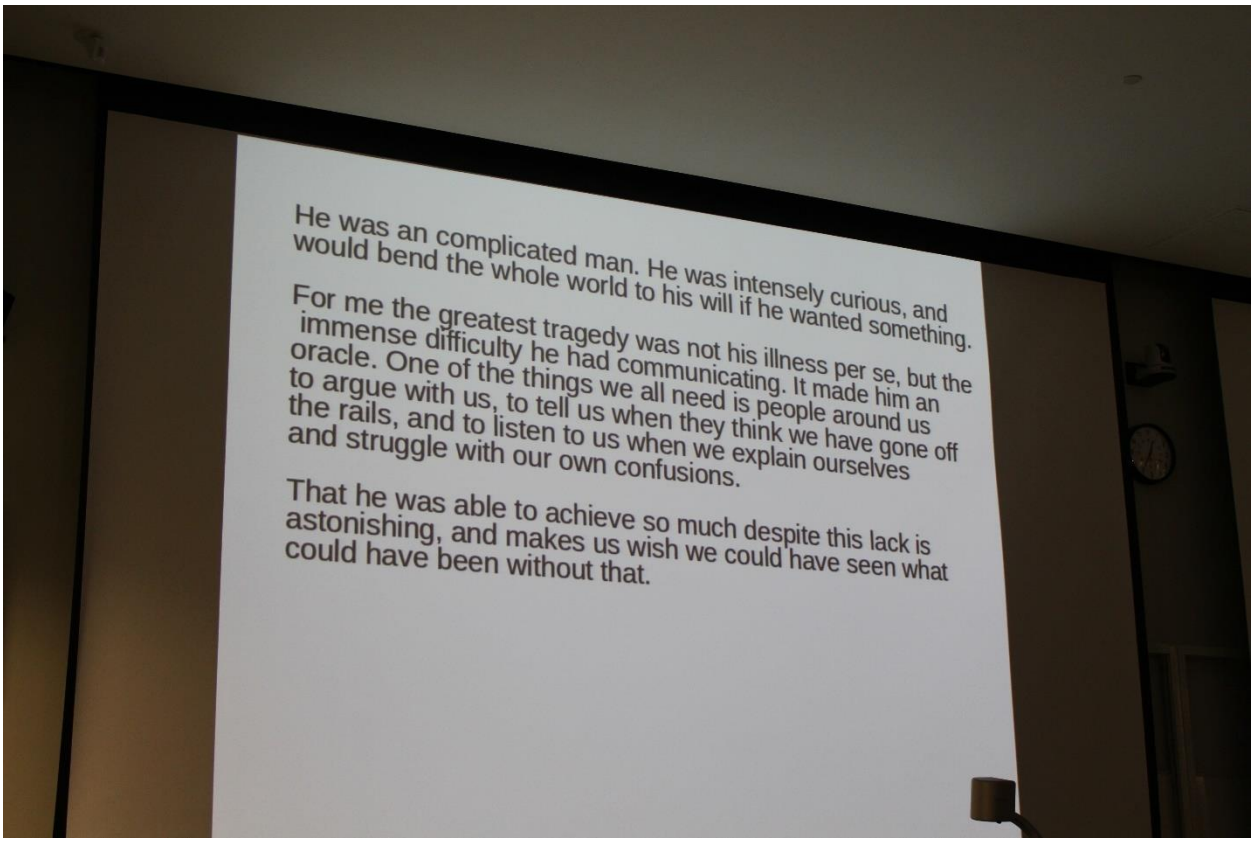
The first **Joint Canada Asia Pacific Conference on General Relativity and Relativistic Astrophysics** brings the two communities together and was held at University of Alberta, Edmonton Canada, hosted by the Theoretical Physics Institute, Faculty of Science, June 25th-29th, 2018.

The goal of the conference was to bring together both Canadian and international relativists for scientific discussion and exchange. The meeting was broadly based, covering the wide range of research including mathematical and numerical relativity, quantum gravity, string-theoretic approaches to gravity, relativistic astrophysics and cosmology.

In addition to the plenary lectures, time was allotted in the afternoons for contributed talks from members of the national and international community. Post-docs and grad students also presented talks.

One of the highlights of the conference was the special session entitled the “Remembrances of Stephen Hawking” where presentations were made by several of his close collaborators: Prof. Don Page (University of Alberta), Professor Bernard Carr (QMWC, Univ. of London), and Prof. Bill Unruh (UBC).


Black holes:
I had made black holes one of the aspects of my thesis
(1971) Absorption cross section of black holes for scalar and
Dirac fields.
1972 – Quantum features of black holes. – Two papers
influenced me.
a) Hartle: Two electrons on opposite sides of a BH horizon
would not interact with each other by neutrinos no
matter how close they were to each other.
(Boulware vacuum)
b) Fulling thesis – he sent me a copy while I was Post doc
with Penrose in Birkbeck College. Is the Rindler vacuum
the same as the Minkowski vacuum state?
I must have met Hawking during that time, but do not
remember it.
1972-- Les Houche summer school. Bardeen Carter and
Hawking-- "Laws of black hole mechanics.


He was an complicated man. He was intensely curious, and
would bend the whole world to his will if he wanted something.
For me the greatest tragedy was not his illness per se, but the
immense difficulty he had communicating. It made him an
oracle. One of the things we all need is people around us
to argue with us, to tell us when they think we have gone off
the rails, and to listen to us when we explain ourselves
and struggle with our own confusions.
That he was able to achieve so much despite this lack is
astonishing, and makes us wish we could have seen what
could have been without that.