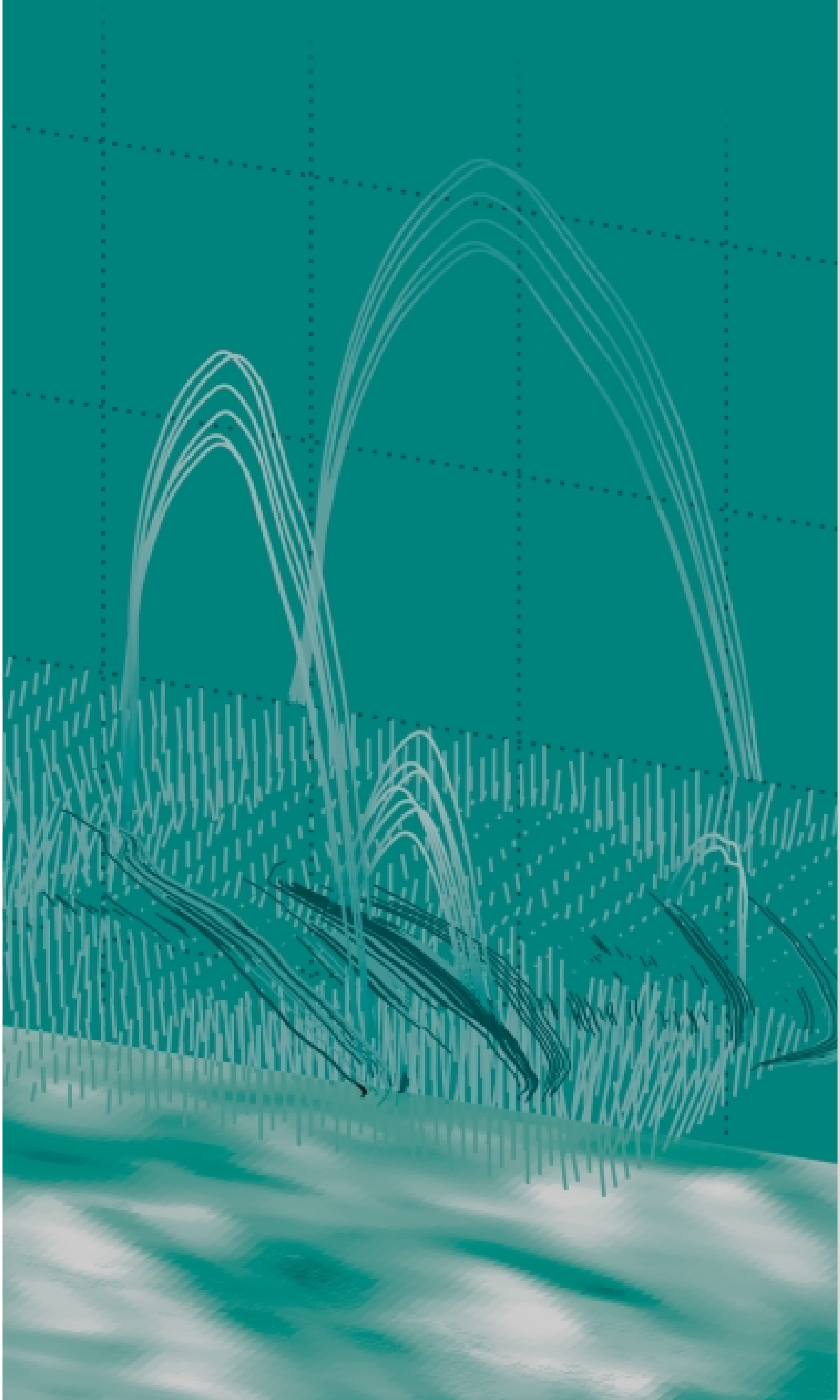

MAX-PLANCK-GESELLSCHAFT

Report
2002 - 2003

Max-Planck-Institut für
Sonnensystemforschung
Katlenburg-Lindau

Max-Planck-Institut für Sonnensystemforschung

ist seit dem 1. Juli 2004 der neue Name für das
is, since the 1st of July 2004 the new name of the

Max-Planck-Institut für Aeronomie

Zum Bild auf dem Umschlag/The cover picture

Magnetfeldbögen einer jungen, aktiven Region auf der Sonne: Eine am MPAe neu entwickelte Mess- und Analysemethode erlaubt erstmalig die Rekonstruktion der Magnetfeldstruktur am unteren Rand der Korona mit Hilfe von Messungen des Infrarot-Spektropolarimeters am deutschen Vakuum-Turm-Teleskop (VTT) auf Teneriffa. Bisher konnten solche Strukturen nur durch indirekte Methoden und Modelle bestimmt werden.

(Siehe Abb. 45 auf Seite 48)

Magnetic loops of a young, active region on the Sun: a new measurement and analysis technique developed by MPAe scientists allows for the first time the direct reconstruction of the magnetic field structure near the lower coronal boundary using data from the infrared spectropolarimeter at the German Vacuum Tower Telescope (VTT) on Tenerife. Up to now only indirect measurements and models could be used to determine these structures.

(see Fig. 45 on page 48)

MAX–PLANCK–INSTITUT FÜR AERONOMIE

KATLENBURG–LINDAU

Report
für die Jahre 2002 und 2003

Herausgegeben von der Institutsleitung:	*Prof. Dr. Ulrich R. Christensen* *Dr. Helmut Rosenbauer* *Prof. Dr. Sami K. Solanki* *Prof. Dr. Vytenis M. Vasyliūnas*
Redaktion:	*Dr. Reinhard Borchers* *Dr. Patrick W. Daly* *Gerlinde Bierwirth* *Sabine Deutsch*
Koordinatoren des wissenschaftlichen Teils:	*Dr. Patrick W. Daly* *Dr. Norbert Krupp* *Prof. Dr. Rainer Schwenn*

Einen guten, allgemeinverständlichen Überblick über Geschichte und Arbeitsgebiete des Instituts bietet eine Institutsbroschüre, die im August 2004 neu erscheinen wird. Außerdem kann ein Videofilm vom Institut bezogen werden.

Erschienen im August 2004.

Anschrift:

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I. **Allgemeines zum Institut**/Institute Overview

Gegenstand und Methoden der Forschung/Subject and Methods of Research

Die Erforschung des Sonnensystems steht heute im Mittelpunkt. Erforscht werden insbesondere die Sonne und ihre Atmosphäre und das interplanetare Medium, das Innere und die Oberflächen, Atmosphären, Ionosphären und Magnetosphären der Planeten, deren Ringe und Monde, Kometen und Asteroiden, Strahlung und energiereiche Teilchen von der Sonne und die kosmische Strahlung. Arbeiten auf dem Gebiet der Aeronomie der Erde sind zurückgefahren worden zu Gunsten der zwei zukünftigen Hauptforschungsrichtungen des Instituts: Sonne und Heliosphäre einerseits und Planeten einschließlich ihrer näheren Umgebung, ihrer Monde und anderer Körper (z.B. Kometen und Asteroiden) andererseits. In den Magnetosphären, im Sonnenwind und in der Umgebung von Kometen werden Teilchen und Wellen von Instrumenten auf Satelliten und Raumsonden in situ gemessen. Die Untersuchung der chemischen Zusammensetzung und räumlichen Verteilung der Teilchen und ihrer Verteilungsfunktionen im Geschwindigkeitsraum und das Studium von Transportvorgängen, Beschleunigungsprozessen, Turbulenz und Plasmainstabilitäten stehen dabei im Vordergrund. Die Korona der Sonne wird mit optischen Instrumenten im gesamten Spektralbereich vom Sichtbaren bis zum weichen Röntgenlicht vom Weltraum aus beobachtet, und ihre Plasmaeigenschaften werden mit spektroskopischen Methoden diagnostiziert. Die untere Atmosphäre der Sonne (die Photosphäre und Chromosphäre) wird anhand von spektropolarimetrischen Messungen sowohl vom Boden wie auch vom Weltraum aus untersucht. Dabei geht es vor allem um die Untersuchung des solaren Magnetfeldes, welches eine grundlegende Rolle für eine Vielzahl solarer Phänomene spielt. Bilder werden mit Instrumenten auf Raumsonden und auf der Erde (CCD-Kameras, Teleskopen) gewonnen und zur Erforschung der Sonne, der Kometen, der Planeten (insbesonders Mars) und deren Monde analysiert. Bei der überwiegend experimentell ausgerichteten Arbeitsweise des Instituts stehen Entwicklung und Bau von Instrumenten und Gewinnung und Auswertung von Messdaten im Vordergrund. Diese Aktivitäten werden jedoch intensiv von theoretischen Arbeiten und der Bildung von physikalischen Modellen begleitet. Hier liegt das Hauptgewicht zunehmend bei numerischen Simulationen mit Schwerpunkten im Bereich planetarer Dynamos, MHD-Prozessen in der Konvektionszone und Atmosphäre der Sonne sowie Konvektionsströmungen im Gesteinsmantel terrestrischer Planeten und den tiefen Gashüllen der Riesenplaneten.

Research on all regions of the solar system that are filled with plasma, gas, and dust stands today at the centre of interest. Subjects of investigation in particular are the Sun and its atmosphere and the interplanetary medium, the interior and the surfaces, atmospheres, ionospheres, and magnetospheres of the planets, their rings and moons, comets and asteroids, radiation and energetic particles from the Sun, and cosmic rays. Efforts in the area of aeronomy of the Earth have been reduced in favour of the Institute's two main research directions for the future, the Sun and the heliosphere on the one hand, and planets (including their environment, moons, and other bodies such as comets and asteroids) on the other. In magnetospheres, the solar wind and in the vicinity of comets, particles and waves are measured in situ with instruments aboard satellites and space probes. The emphasis here is on determination of the chemical composition and spatial distribution of the particles and their distribution functions in velocity space and on studies of transport mechanisms, acceleration processes, turbulence, and plasma instabilities. The solar corona is observed with optical instruments in space over the entire spectral range from the visible to soft X-rays, and its plasma properties are determined by spectroscopic methods. The lower solar atmosphere (the photosphere and chromosphere) are investigated with spectropolarimetric techniques, both from the ground and from space. The main aim is to study the Sun's magnetic field, which plays a fundamental role in driving a large number of solar phenomena. Imaging techniques with both space-borne and Earth-based instruments are used to investigate the Sun, comets, planets (especially Mars) and their moons. The Institute is oriented predominantly toward experimental research, with emphasis on development and construction of instruments and the accumulation and analysis of observational data. These activities are, however, accom-

panied by intensive theoretical work and modelling. Here the emphasis is increasingly being placed on numerical simulations.

Struktur und Leitung des Instituts/Structure and Management of the Institute

Das Institut wurde von den Direktoren Prof. Dr. U. R. Christensen, Dr.-Ing. H. Rosenbauer, Prof. Dr. S. K. Solanki und Prof. Dr. V. M. Vasyliūnas gemeinschaftlich geleitet (Gesamtkollegium).

Seit dem Jahr 2001 ist Prof. Dr. S.K. Solanki Geschäftsführender Direktor.

Seit dem 6. Juni 1991 ist das Institut auf Beschluss des Senats der MPG in zwei Abteilungen aufgegliedert: Abteilung experimentelle Planetenphysik, von Dr.-Ing. H. Rosenbauer geleitet, und Allgemeine Abteilung, kollegial von den übrigen Direktoren geleitet.

Das Kollegium der Allgemeinen Abteilung wird in seiner Arbeit durch einen technischen Geschäftsführer (Dr. I. Pardowitz, Dr. P. Czechowsky bis Juni 2003) und einen Direktionsbeirat unterstützt. Letzterer besteht aus drei Mitarbeitern aus dem wissenschaftlich-technischen Bereich, die von allen Mitarbeitern des Instituts für jeweils einjährige Amtsperioden gewählt werden.

Für die einzelnen Forschungsvorhaben werden jeweils Projektgruppen gebildet, die nach Abschluss des Projektes wieder aufgelöst werden. Die Initiative zur Aufnahme eines Projektes und zur Gründung einer entsprechenden Arbeitsgruppe kann jeder Wissenschaftler im Institut ergreifen.

Im technischen Bereich bestehen zentrale Einrichtungen, die allen Arbeitsgruppen zur Verfügung stehen: eine Konstruktionsabteilung, Werkstätten für Mechanik, ein Entwicklungslabor für Elektronik, ein Rechenzentrum und eine spezielle Bibliothek.

The institute was managed jointly by the directors Prof. Dr. U. R. Christensen, Dr.-Ing. H. Rosenbauer, Prof. Dr. S. K. Solanki, and Prof. Dr. V. M. Vasyliūnas (general board of directors)

Since 2001 Prof. S. K. Solanki is the managing director.

From 6th June 1991 the institute was divided into two departments, by decree of the Senate of the Max Planck Society: The Department Experimental Planetary Physics, led by Dr.-Ing. H. Rosenbauer, and the general department, led jointly by the remaining directors.

The board of directors of the general department is assisted by a technical manager (Dr. I. Pardowitz, Dr. P. Czechowsky until June 2003) and a director's advisory committee. This consists of three members of the scientific-technical staff who are voted in for a one-year period by all the institute staff.

For each proposed research project a group is established which is dissolved at the end of the project. The initiative to start a new project and to form a corresponding working group can be taken by any member of the institute.

In the technical area there are central facilities which are available to all groups: A mechanical design department, mechanical workshops, an electronic development laboratory, a computing centre and a library.

Personelle Entwicklung/Personnel Development

In den Jahren 2002 und 2003 hat sich die Zahl der Mitarbeiterinnen und Mitarbeiter des Instituts entsprechend dem Sozialplan verändert.

Die Zahl der Planstellen verringerte sich bis Ende Dezember 2003 auf 126. Davon waren 32 mit Wissenschaftlern besetzt. Die Zahl der am Institut wissenschaftlich Tätigen war jedoch mit Einbeziehung der aus Mitteln des BMBF finanzierten Wissenschaftler und der Doktoranden beträchtlich größer und betrug am 31. Dezember 2003 etwa 80.

Mitarbeiter, die nach dem Sozialplan ausgeschieden sind:

2002: Lothar Bemmann, Marlis Borghold, Klaus-Dieter Eulig, Ingeborg Güttler, Lucia Ristau, Bernhard Wand

2003: Wolfgang Engelhardt, Peter Hemmerich, Gustav Schlemm, Dr. Manfred Witte, Irmtraud Wolf

In den Ruhestand traten:

2002: Dr. Jürgen Röttger, Prof. Dr. Kristian Schlegel, Ingrid Schrader, Dr. Klaus Wilhelm

2003: Bernhard Goll, Prof. Dr. J.F. McKenzie, Margarete Schmidt

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During the years 2002 and 2003 the number of institute staff was reduced according to the social plan.

The number of permanent positions decreased to 126 by the end of December 2003. Of these 32 were filled *by scientists. The number of people working scientifically, through BMBF-financed scientists and through Ph.D. students, was nevertheless substantially greater, consisting of 80 on 31st December 2003.*

Staff members who have left according to the social plan are:

2002: Lothar Bemmann, Marlis Borghold, Klaus-Dieter Eulig, Ingeborg Güttler, Lucia Ristau, Bernhard Wand

2003: Wolfgang Engelhardt, Peter Hemmerich, Gustav Schlemm, Dr. Manfred Witte, Irmtraud Wolf

The following have retired:

2002: Dr. Jürgen Röttger, Prof. Dr. Kristian Schlegel, Ingrid Schrader, Dr. Klaus Wilhelm

2003: Bernhard Goll, Prof. Dr. J.F. McKenzie, Margarete Schmidt

Das Kuratorium des Instituts/Board of Trustees of the Institute

Dem Kuratorium des Instituts gehörten in den Jahren 2002 und 2003 die folgenden Mitglieder an:

Dr. Herbert Diehl, Ministerialdirigent im BMBF (Bundesministerium für Bildung und Forschung), Bonn;

Herr Axel Endlein, Präsident des deutschen Landkreistags, Mitglied des Niedersächsischen Landtags, Landrat a.D. des Landkreises Northeim;

Prof. Dr. Klaus J. Fricke, Universitäts-Sternwarte, Göttingen;

Dr. Gernot Hartmann, Leiter der Abtlg. Weltraumwissenschaften, Abt. RD-GW, DLR, Bonn;

Dr. Hubert Hofmann, Mitglied der Geschäftsleitung, Astrium GmbH, Earth Observation and Science, Friedrichshafen;

Prof. Dr. Martin C.E. Huber, Küsnacht, Schweiz;

Prof. Dr. Oskar von der Lühe, Kiepenheuer-Institut für Sonnenphysik, Freiburg;

Frau Erika Mann, Mitglied des Europäischen Parlaments, Hannover;

Dr. Fritz Merkle, OHB-System GmbH, Bremen;

Dr. Uwe Reinhardt, Staatssekretär im Niedersächsischen Ministerium für Wissenschaft und Kultur, Hannover;

Das Kuratorium tagte am 13. November 2002 in Lindau.

The following were members of the board of trustees of the institute in the years 2002 and 2003:

Dr. Herbert Diehl, Ministerialdirigent, BMBF (German Federal Ministry for Education and Research), Bonn;

Mr. Axel Endlein, president of the German counties legislative assembly, member of the Lower Saxony state legislative assembly, district administrator a.D. of Northeim county;

Prof. Dr. Klaus J. Fricke, University Observatory, Göttingen;

Dr. Gernot Hartmann, leader of the Department of space sciences, Dept. RD-GW, DLR (German space agency), Bonn;

Dr. Hubert Hofmann, member of the management, Astrium GmbH, Earth Observation and Science, Friedrichshafen;

Prof. Dr. Martin C.E. Huber, Küsnacht, Schweiz;

Prof. Dr. Oskar von der Lühe, Kiepenheuer Institute for Solar Physics, Freiburg;

Frau Erika Mann, member of the European Parliament, Hannover;

Dr. Fritz Merkle, OHB-System GmbH, Bremen;

Dr. Uwe Reinhardt, permanent secretary in the Lower Saxony Ministry for Science and Culture, Hannover.

The board of trustees met on 13 November 2002 in Lindau.

Der Fachbeirat des Instituts/Scientific Advisory Board of the Institute

Im Jahr 2001 wurde vom Präsidenten der Max-Planck-Gesellschaft ein neuer Fachbeirat für das Institut berufen. In den Jahren 2001 – 2006 gehören dem Fachbeirat die folgenden Mitglieder an:

Prof. Dr. D. Crisp, Pasadena, CA, USA;
Prof. Dr. G. Hensler, Wien, Österreich;
Dr. L.J. Lanzerotti, Murray Hill, NJ, USA;
Prof. Dr. Ph. Lognonné, Saint Maur, Frankreich;
Prof. Dr. E.R. Priest, St. Andrews, Großbritannien;
Prof. Dr. R. Rosner, Chicago, IL, USA;
Prof. Dr. D.J. Southwood, Paris, Frankreich;
Prof. Dr. D.J. Stevenson, Pasadena, CA, USA.

Im Berichtszeitraum fand die Zusammenkunft des Fachbeirats vom 11. – 12. November 2002 im MPAe in Lindau statt.

In 2001 a new advisory board for the institute was appointed by the President of the Max Planck Society. During the years 2001 – 2006 the following were members of the scientific advisory board:

Prof. Dr. D. Crisp, Pasadena, CA, USA;
Prof. Dr. G. Hensler, Vienna, Austria;
Dr. L.J. Lanzerotti, Murray Hill, NJ, USA;
Prof. Dr. Ph. Lognonné, Saint Maur, France;
Prof. Dr. E.R. Priest, St. Andrews, UK;
Prof. Dr. R. Rosner, Chicago, IL, USA;
Prof. Dr. D.J. Southwood, Paris, France;
Prof. Dr. D.J. Stevenson, Pasadena, CA, USA.

During the period of this report the advisory board met in Lindau from 11 – 12 November 2002.

Für das Institut aufgewendete Mittel/Institute Resources

Die vom Bund und den Ländern getragene und durch die Generalverwaltung der Max-Planck-Gesellschaft zugeteilte Grundausstattung des Instituts an Personal- und Sachmitteln betrug im Jahre 2002 8,9 Millionen EURO für Personal und 2,7 Millionen EURO für Sachen. An Investitionsmitteln (Geräte mit Preisen über 5.000 EURO) wurden 0,7 Millionen EURO bewilligt. Für das Jahr 2003 lauten diese Zahlen: 9,1 Millionen EURO für Personal, 2,8 Millionen EURO für Sachausgaben und 1,4 Millionen EURO für Investitionen.

Besondere Forschungsvorhaben sind durch das BMBF (Bundesministerium für Bildung und Forschung) und die ESA (European Space Agency) gefördert worden. Vom BMBF (DLR) erhielt das Institut 2002 insgesamt 5 Millionen EURO und 2003 3,6 Millionen EURO. Die entsprechenden Beträge der ESA waren 0,2 Millionen EURO und 2,8 Millionen EURO.

Für diese Förderungen, ohne die viele experimentelle Forschungsvorhaben nicht durchführbar gewesen wären, möchten wir auch an dieser Stelle ausdrücklich danken.

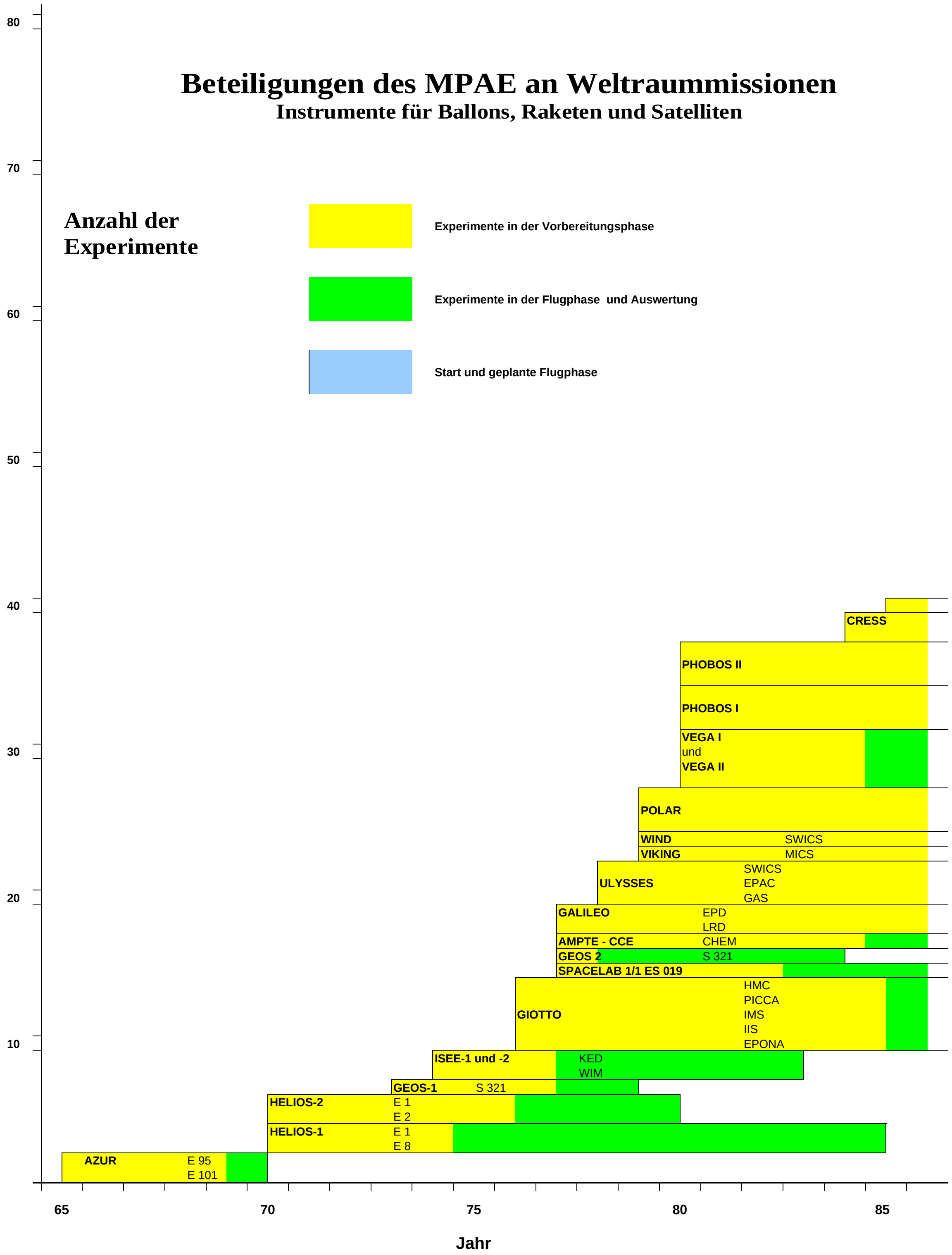
The basic funding of the institute, from the federal and state governments and allocated through the administrative headquarters of the Max Planck Society, amounted to 8.9 million EURO for personnel and 2.7 million EURO for materials in 2002. Capital investment funds (equipment over 5000 EURO) of 0.7 million EURO were approved. For 2003 the figures are: 9.1 million EURO for personnel, 2.8 million EURO for materials, and 1.4 million EURO for capital investment.

Special research needs were funded by BMBF (German Federal Ministry for Education and Research) and ESA (European Space Agency). From BMBF (DLR) the institute received 5 million EURO in 2002 and 3.6 million EURO in 2003. The corresponding sums from ESA were 0.2 million EURO and 2.8 million EURO.

For this financial assistance, without which many experimental research programmes would not be possible, we wish to express our gratitude.

Folgende Seiten:
Beteiligung des MPAe an Projekten mittels Satelliten und Raumsonden als Instrumententräger. Dargestellt ist, welche Messgeräte (Experimente) in welcher Zeitspanne bei den einzelnen Projekten im Einsatz waren, es noch sind oder entwickelt werden. Kurze Beschreibungen findet man in den einzelnen Jahres- bzw. Tätigkeitsberichten des MPAe.

Following pages:
MPAe participation in research projects with the aid of satellites and space probes. The diagram illustrates the projects to which the instruments belong and the times when they were in development and/or operation. Short descriptions of these instruments can be found in the annual reports of the MPAe.


Beteiligungen des MPAE an Weltraummissionen
Instrumente für Ballons, Raketen und Satelliten
Anzahl der Experimente
Experimente in der Vorbereitungsphase
Experimente in der Flugphase und Auswertung
Start und geplante Flugphase
80
70
60
50
40
30
20
10
CRESS
PHOBOS II
PHOBOS I
VEGA I
und
VEGA II
POLAR
WIND
SWICS
VIKING
MICS
ULYSSES
SWICS
EPAC
GAS
GALILEO
EPD
LRD
AMPTE - CCE
CHEM
GEOS 2
S 321
SPACELAB 1/1 ES 019
GIOTTO
HMC
PICCA
IMS
IIS
EPONA
ISEE-1 und -2
KED
WIM
GEOS-1
S 321
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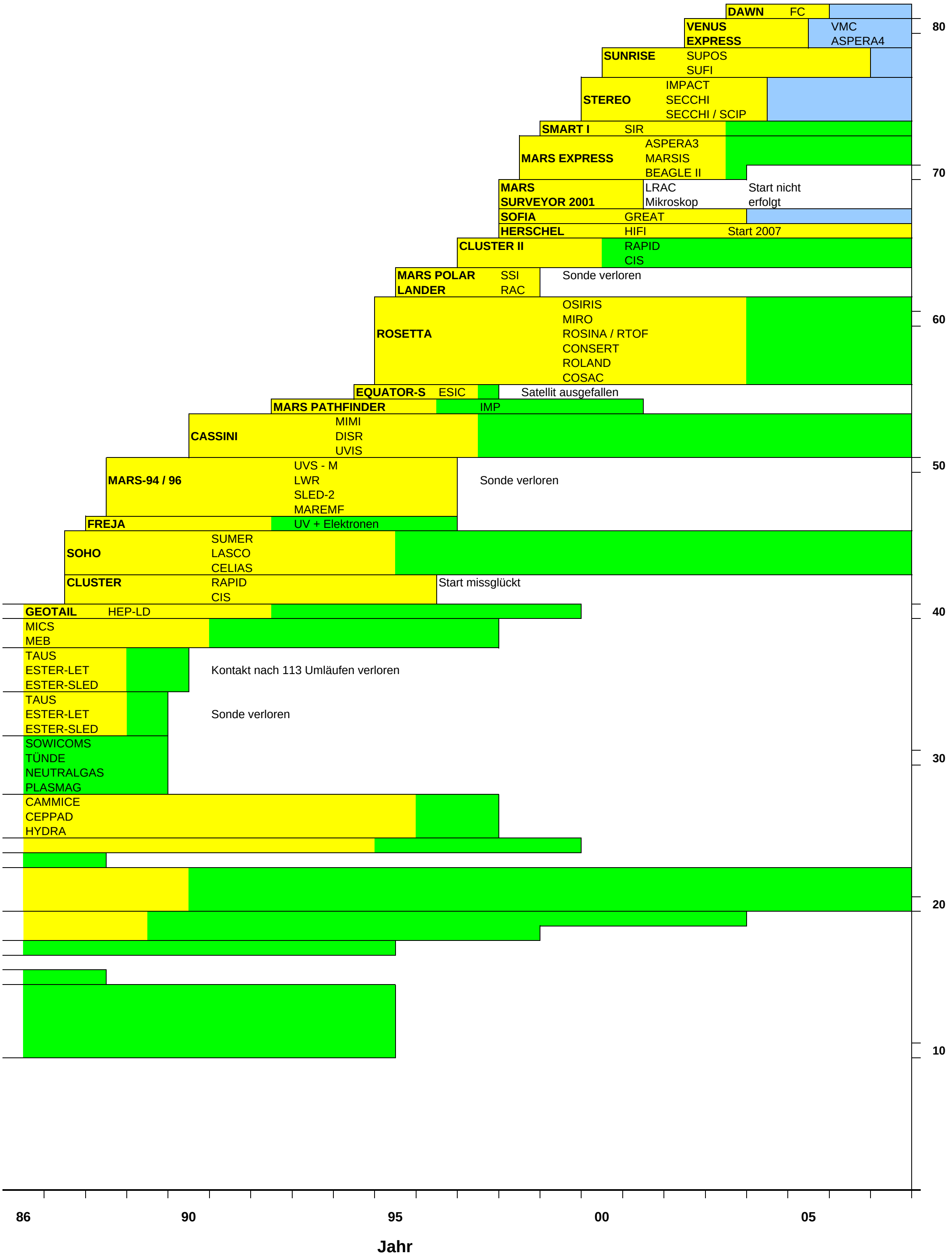
DAWN FC
VENUS EXPRESS VMC ASPERA4
SUNRISE SUPOS SUFI
STEREO IMPACT SECCHI SECCHI / SCIP
SMART I SIR
MARS EXPRESS ASPERA3 MARSIS BEAGLE II
MARS SURVEYOR 2001 LRAC Mikroskop
Start nicht erfolgt
SOFIA GREAT
HERSCHEL HIFI
Start 2007
CLUSTER II RAPID CIS
MARS POLAR LANDER SSI RAC
Sonde verloren
ROSETTA OSIRIS MIRO ROSINA / RTOF CONSERT ROLAND COSAC
EQUATOR-S ESIC
Satellit ausgefallen
MARS PATHFINDER IMP
CASSINI MIMI DISR UVIS
MARS-94 / 96 UVS - M LWR SLED-2 MAREMF
Sonde verloren
FREJA UV + Elektronen
SOHO SUMER LASCO CELIAS
CLUSTER RAPID CIS
Start missglückt
GEOTAIL HEP-LD
MICS MEB
TAUS ESTER-LET ESTER-SLED
Kontakt nach 113 Umläufen verloren
TAUS ESTER-LET ESTER-SLED
Sonde verloren
SOWICOMS TÜNDE NEUTRALGAS PLASMAG
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II. Wissenschaftliche Arbeiten/Scientific Projects

1. *Sonne und Heliosphäre/Sun and Heliosphere*

Schwerpunktthema:

Koronaseismologie: Beobachtungen oszillierender magnetischer Flussröhren

(English version see page 12)

Koronaseismologie ist ein neuer und rasant wachsender (*vibrant*) Zweig der Sonnenphysik. Sie erlaubt die Bestimmung der wichtigsten Parameter der Korona durch die Untersuchung von Erzeugung, Ausbreitung und Dämpfung von Wellen. Die Lösung von zur Zeit noch unverstandenen Prozessen wie die Heizung der Korona und die Feldlinienrekonnektion kann durch Beobachtung der Ausbreitungsgeschwindigkeit und Dämpfung von Wellen weiter eingegrenzt werden. In diesem kurzen Review werden wir den jüngsten Fortschritt in den Beobachtungen von Wellen auf koronalen Magnetfeldbögen beschreiben und einen Abriss der Interpretation dieser Beobachtungen geben.

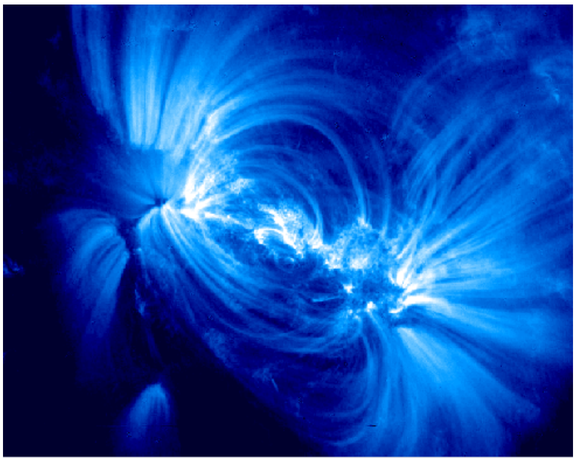

Abb. 1: Magnetfeldbögen auf der Sonnenoberfläche, beobachtet mit TRACE durch ein EUV Filter (17,1 nm), das für die Emission von 1 MK heißen Eisenatomen transparent ist. Der Durchmesser der dünnen Bögen beträgt etwa 2000 km.

Hell leuchtende Magnetfeldbögen sind die auffälligsten Strukturen in Bildern, die im EUV- und Röntgenwellenlängenbereich von der Sonne gemacht werden. Die Abb. 1 zeigt als Beispiel ein System von Magnetfeldbögen, die im EUV mit dem *Transition Region and Coronal Explorer* (TRACE) gemessen wurden. Diese Bögen bilden sich, wenn magnetischer Fluss von der Photosphäre aufsteigt. Die Fußpunkte der Bögen bleiben in der Sonne in Regionen mit hoher Feldstärke verankert. In der Korona zeigen die Bögen den Verlauf der Feldlinien, wie sie Gebiete verschiedener magnetischer Polarität verbinden. Die Form der Bögen wird durch Änderungen des Feldes an der Sonnenoberfläche, aber auch durch die Veränderung benachbarter Bögen beeinflusst. Höchst dynamische Änderungen treten während Flares und koronaler Massenauswürfe auf, bei denen Plasma in den interplanetaren Raum hinausgeschleudert wird und magnetische Verknüpfungen und Strukturen neu geformt werden. Schwächere Prozesse erschüttern die vorhandenen Bogenstrukturen und regen diese zum Schwingen an. In neuen Messungen haben wir diese Schwingungen nachweisen können. Messungen und Analyseverfahren dieser Oszillationen werden unter dem Begriff *Koronaseismologie* zusammengefasst, ein Name, der ähnlichen Untersuchungen seismischer Erdbebenwellen entlehnt ist.

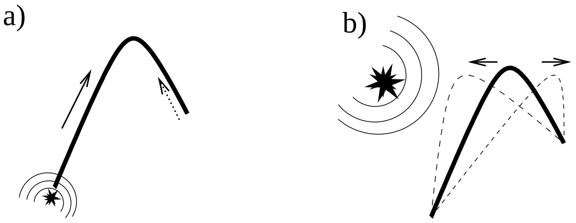

Abb. 2: Skizze von Schwingungsmoden, die auf Magnetfeldbögen in der Korona beobachtet werden. (a) Schallwelle, die von einem kleinen Flare an einem der Fußpunkte angeregt wurde. (b) Kink-Mode oder transversal polarisierte Schwingung, die von einem Flare in einiger Entfernung angeregt wird.

In der Korona können Wellen entlang der Magnetfeldbögen geführt werden, so dass die Bögen bei passender Wellenfrequenz in Resonanz zu schwingen beginnen. Die Theorie sagt verschiedene magnetohydrodynamische Schwingungsmoden voraus. Zum einen erwartet man Schallwellen, die ähnlich wie in Orgelpfeifen auf den Magnetfeldbögen vor und zurück laufen (Abb. 2a). Dabei setzen sie das Plasma entlang dem Magnetfeld in Bewegung. Die zweite Schwingungsmode, die Kink-Mode (Abb. 2b), verhält sich wie eine gezupfte Gitarrensaite und lässt das Plasma senkrecht zum Magnetfeld schwingen. Als weitere Schwingungsanregung gibt es die Sausage-Mode. Sie äußert sich in einem periodischen Aufblähen und Kontrahieren des Durchmessers der magnetischen Flussröhre. Letztlich spielen Alfvénwellen in Form von Torsionsschwingungen der Magnetfeldbögen eine wichtige Rolle im Energietransport der unteren Korona. Diese Schwingungsmoden scheinen unter verschiedenen Bedingungen angeregt zu werden. Beobachtet werden können sie nur mit Sonnenteleskopen höchster Auflösung. Bisher haben wir sowohl die Kink-Mode als auch resonante Schallwellen nach Flare-Eruptionen identifizieren können.

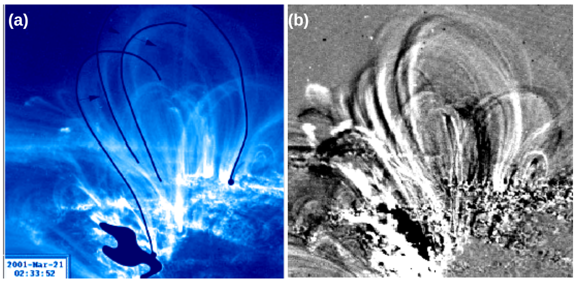

Abb. 3: TRACE-Beobachtungen von transversalen Schwingungen eines Magnetfeldbogens. a) Das EUV-(17,1 nm)-Bild oszillierender Bögen kurz nach einem Flare am 21. März 2001. b) Das gleiche System von Magnetfeldbögen als Differenzenbild von zwei Beobachtungen, die 2 Minuten auseinander liegen. Schwarz zeigt die frühere Position der Bögen, weiß die Position, zu der sie sich hinbewegt haben.

Die Kink-Mode ist am besten beobachtbar. Eindrucksvolle Beispiele sind mit TRACE gemessen worden. Sie bestehen aus Bildsequenzen (z.B. Abb. 3), in denen Magnetfeldbögen deutlich hin und her schwingen.

Dieser und ähnliche Events werden kurz nach starken Flares beobachtet. Wir vermuten, dass die vom Flare ausgehende Schockwelle die Schwingungen anregt, wie in Abb. 2b skizziert. Die Schwingungsfrequenz der Bögen ist charakteristisch für die magnetische Feldstärke und Massendichte entlang der Bögen. Aus den Beobachtungen konnten Feldstärken von einigen zehn Gauß abgeschätzt werden. Zur Zeit ist dies die einzige Methode, um die Feldstärke in dem 1 Million Grad heißen Plasma zu ermitteln. Leider werden die Schwingungen nur selten beobachtet. Das TRACE-Teleskop, das die Sonne 24 Stunden am Tag beobachtet, hat in den letzten 4 Jahren lediglich 40 Beispiele aufgespürt.

Die vielleicht überraschendste Entdeckung, die mit dem am MPAe gebauten Spektrometer SUMER gemacht wurde, sind die resonanten Schallschwingungen auf Magnetfeldbögen. Die Form des Bogens bleibt unverändert, aber das Plasma oszilliert entlang der Feldlinie erst in die eine, dann in die andere Richtung (Abb. 2a). Die Schwingungen setzten mit einem plötzlichen Impuls ein, der von einem schwachen Flare an einem der Fußpunkte verursacht sein könnte. Die Störung breitet sich mit der Schallgeschwindigkeit, etwa 300 – 400 km s^{-1}, aus. Die Strömungsgeschwindigkeit des Plasmas, die von SUMER vermittels des Dopplereffektes gemessen wird, hängt von der Schwingungsamplitude ab und beträgt typisch 40 km s^{-1}.

Seitdem wir auf die Doppleroszillationen aufmerksam wurden, haben wir in unseren Daten viele weitere Beispiele entdeckt. Oft ist die Anregung so schwach, dass der auslösende Flare fast unsichtbar bleibt und lediglich eine schwache, kurze Aufhellung einer der Fußpunkte zu sehen ist. Eine Vorraussetzung für die Beobachtung der Doppleroszillationen ist eine Plasmatemperatur auf dem Magnetfeldbogen von mehr als 6 Millionen Grad. Wir haben Bögen mit 0,1, 0,5, 1, 6 und 10 Millionen Grad untersucht, aber Schallwellen nur auf den heißesten Bögen beobachten können. Kühlere Bögen zeigen keine Anzeichen von kompressiven Oszillationen. Dies ist ein nicht erwartetes Verhalten. Entweder gibt es an den Fußpunkten der kühlen Bögen keine Flares, die die Schwingungen anregen könnten, oder die Wellen sind dort zu schwach um beobachtet zu werden.

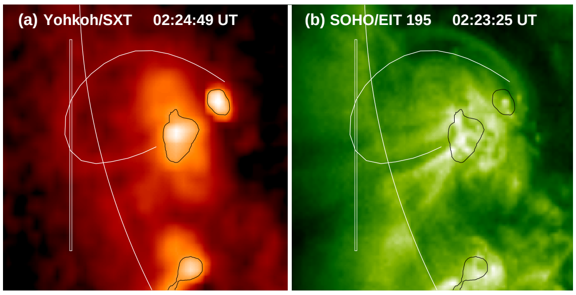

Abb. 4: Bilder eines heißen Magnetfeldbogens dessen von SUMER beobachtete oszillierende Dopplerverschiebung in Abb. 5 zu sehen sind. a) Röntgenbild von Yohkoh und b) EUV-(19,5 nm)-Beobachtung von SOHO/EIT. Die weiße Line und die schwarzen Konturen zeigen den Verlauf der Feldlinie und die Lage des Röntgenflares an ihren Fußpunkten. Die senkrechte Line deutet das Blickfeld des SUMER-Messspaltes an.

Eines der schönsten Beispiele ist das Ereignis, das in den Abb. 4 und Abb. 5 dargestellt ist. Die Lage des schwingenden Magnetfeldbogens zeigt die weiße Kurve in Abb. 4. Der Bogen ist in dem Röntgenbild sichtbar, aber nicht in dem EUV-Bild. Die Schwingungen wurden als Dopplerverschiebung einer Spektrallinie des Fe^{18+}-Ions registriert, die bei etwa

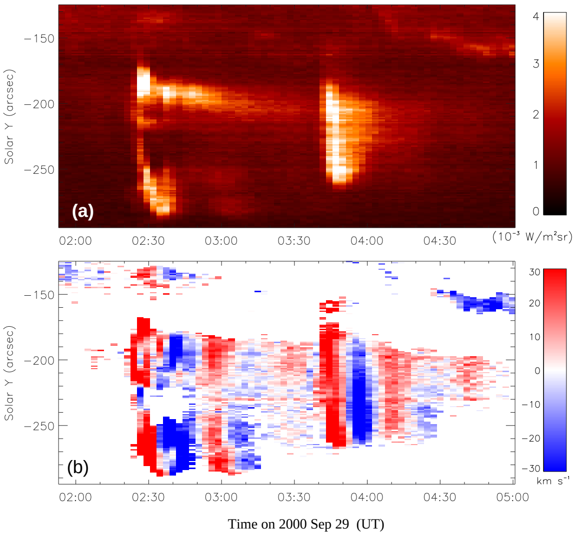

Abb. 5: Oszillationen eines heißen Magnetfeldbogens, beobachtet vom SUMER-Spektrograph in der Fe XIX (111,8 nm)-Spektrallinie entlang der in Abb. 4 markierten Spaltposition. (a) Linienintensität und (b) Dopplerverschiebung als Funktion der Zeit.

6 Millionen Grad emittiert wird. SUMER beobachtete die Spektren in dem Sichtfeld des Messspaltes, der in Abb. 4 als weiße Linie dargestellt ist. In 2,5-Minuten-Abständen wurden die Spektren entlang dem 300 Pixel langen Spaltbild aufgenommen. So konnten die in Abb. 5 wiedergegebenen Zeitserien der Fe XIX (111,8 nm)-Intensität und Dopplerverschiebung aufgebaut werden. Da der Magnetfeldbogen das Blickfeld des Spaltes zweimal schneidet, gibt es zwei helle Bereiche entlang dem Spalt, die jeweils zweimal während der Beobachtungen hell aufleuchten. Die entsprechenden Dopplerverschiebungen sind in dem unteren Diagram dargestellt. Die Oszillationen (rot-blau) sind jeweils für etwas mehr als zwei Schwingungsperioden sichtbar. Jeder der beiden Schwingungseinsätze startet mit einer roten Phase und schwingt phasengleich an beiden Schnittpunkten des Bogens mit dem Spaltbild.

Da die Schwingungsperiode etwa dreimal langsamer ist als für die Kink-Mode, die von TRACE beobachtet wurde, vermuten wir, dass es sich hier um eine Schallschwingung handelt. Eine eindeutige Identifizierung konnte in einem anderen Ereignis erreicht werden, bei dem Intensität und Dopplerverschiebung gleichzeitig gemessen wurden. Das Ergebnis ist in Abb. 6 gezeigt. Die Schwingungen für die beiden Größen haben die gleiche Periode, sind aber um 90 Grad phasenverschoben, so wie es die Theorie für Schalloszillationen vorhersagt. Die Kink-Mode sollte dagegen keine Schwankungen der Intensität zeigen.

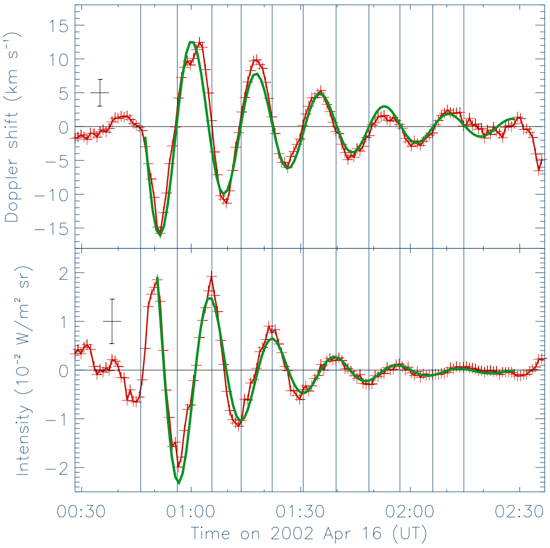

Abb. 6: Zeitliche Entwicklung der (a) Dopplerverschiebung und der (b) Linienintensität in der Fe XIX (111,8 nm)-Linie in einem Gebiet, das kohärente Schwingungen zeigt. Die rote Kurve zeigt die Messungen, von denen die Mittelwerte jeweils abgezogen sind, die grüne Kurve einen Fit mit einer gedämpften harmonischen Funktion.

Sich ausbreitende Schallwellen sind ebenfalls beobachtet worden, jedoch bislang nicht in der Dopplerverschiebung, sondern nur anhand der Helligkeitsschwankungen. Die Wellen werden stark gedämpft und sind nur dicht an der Sonnenoberfläche beobachtet worden. Es scheint, dass sie durch Störungen aus dem Sonneninneren ausgelöst wurden, die Dämpfung dagegen hängt von den Eigenschaften des koronalen Plasmas ab. Wir hoffen, dass wir durch die Untersuchung einer großen Zahl solcher Ereignisse die Struktur an den Fußpunkten der Magnetfeldbögen ermitteln können. Die Untersuchung der Wellendämpfung könnte uns weitere Einsichten in die Aufheizung des koronalen Plasmas geben, die für die Emission der Magnetfeldbögen verantwortlich ist.

Alfvénwellen in Sausage- oder Torsionsmode sind sehr viel schwerer nachzuweisen. Die Sausagemode könnte die schnellen Helligkeitsschwankungen erklären, die während der ersten Minuten eines Flares beobachtet werden. Eine Möglichkeit wäre, dass der plötzliche Energiezuwachs in der magnetischen Flussröhre die Schwingungen anregt. Die Schwingungen des Flussröhrendurchmessers sind wahrscheinlich zu klein, als dass sie mit heutiger Technik beobachtbar wären. Auch Torsionswellen sind sehr schwierig zu beobachten, da sie inkompressibel sind und damit keine Intensitätsschwankungen hervorrufen. Nur in einer entgegengesetzt gerichteten Dopplerverschiebung quer zur Flussröhrenachse, die der Plasmaströmung um die Achse herum entspricht, lassen sie sich nachweisen. Zu jeder halben Periode wechselt das Vorzeichen der Dopplerverschiebung auf beiden Seiten der Flussröhrenachse. Derzeit kann der Querschnitt einer Flussröhre allerdings kaum in den Beobachtungen aufgelöst werden. Die dafür nötigen Anforderungen, spektral aufgelöste Bilder mit ausreichender räumlicher Auflösung im 1-Minuten-Takt, gehen weit über das hinaus, was derzeitige und für die nahe Zukunft geplante Missionen bieten.

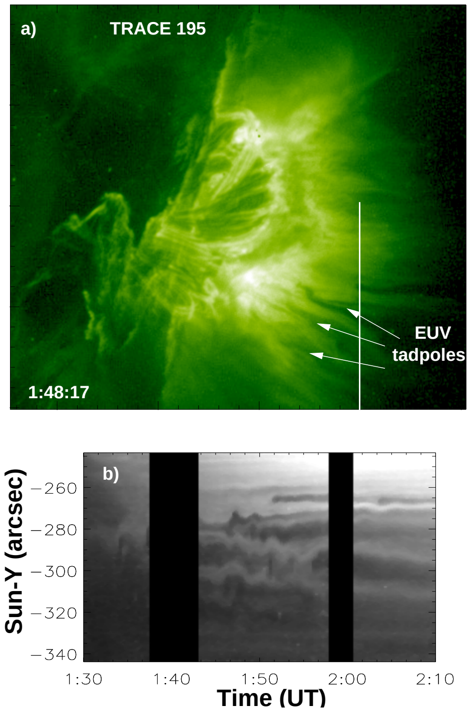

Abb. 7: TRACE-Beobachtungen von EUV-Kaulquappen. (a) TRACE-Aufnahme eines Post-Flare-Gebietes bei 19,5 nm, (b) Intensitätsschwankungen entlang der markierten vertikalen Linie in (a).

Eine weitere in der Nähe von Flares beobachtete, etwas seltsame Oszillation sollte nicht unerwähnt bleiben – die sogenannten EUV-Kaulquappen. Dies sind kleine dunkle Regionen in EUV-Bildern mit flatternden Schwänzen, die mit etwa 400 km s^{-1} auf die Sonne herunterfallen. Sie werden beobachtet, nachdem in massiven Flares große Mengen an Plasma hochgeschleudert wurden. Zur Zeit gibt es nur zwei gut analysierte Beispiele, aber es gibt Hinweise, dass sie eine regelmässige Begleiterscheinung eruptiver Flares sind. Eine TRACE-Aufnahme einer EUV-Kaulqappe ist in Abb. 7 wiedergegeben. Darunter sind die Intensitätsschwankungen entlang der weißen Linie wiedergegeben, die während des Absinkens der Kaulquappen beobachtet wurden. Diese seltsam geformten dunklen Bereiche werden entweder durch Absorption der Hintergrundstrahlung in einer dichten Gaswolke hervorgerufen oder durch die Abwesenheit von heißem, emittierenden Plasma, dass von starken Magnetfeldern zur Seite gedrängt wurde. Sollte die zweite Interpretation die richtige sein, und das ist nach heutigem Wissenstand wahrscheinlich, dann wird die Untersuchung dieser EUV-Kaulquappen wertvolle Hinweise auf Struktur und Dynamik der Korona nach einem Flare liefern. Ähnliche, auf die Sonne zu gerichtete Strömungen sind mit dem Weißlichtkoronagraphen SOHO/LASCO im Abstand von mehr als 3 Sonnenradien über der Sonnenoberfläche gesehen worden (die EUV-Emissionen in Abb. 7 reichen nur bis in eine Höhe von 0,1 Sonnenradien). Es bestünde also die Möglichkeit, das Magnetfeld noch in einem Abstand von 3 Sonnenradien zu bestimmen. Zukünftige Missionen, Solar B und das Solar Dynamic Observatory (SDO), werden mit höher auflösenden Instrumenten ausgestattet sein und uns die Beobachtung von schwächeren und kleinräumigeren Oszillationen ermöglichen. Schall- und Kink-Modes werden dann auch nach schwächeren Flares beobachtbar sein, und auch die anderen Moden werden möglicherweise nachgewiesen werden können.

Highlight:

Coronal seismology: Observations of oscillating magnetic loops

Coronal seismology is a new and vibrant branch of solar physics. It opens the possibility of determining key parameters of the solar corona by studying how waves are excited, propagate and dissipate. Contraints on dissipation coefficients and the strength of the coronal magnetic field may resolve some of the existing difficulties with heating and reconnection theories. In this short review, we highlight the recent progress in detecting waves in magnetic loops together with some background on their interpretation.

Bright systems of loops are the most prominent structures in extreme ultraviolet (EUV) and soft X-ray images of the Sun. Fig. 1 shows an example of a loop system observed in the EUV with the Transition Region and Coronal Explorer (TRACE). Loops form when magnetic flux emerges from the photosphere. Their two footpoints remain rooted below the solar surface in regions of intense and opposite polarity magnetic fields. In the corona, the loops outline the coronal magnetic field arching from one pole to the other. The loops react to changes below, above and in neighbouring loop systems. The more spectacular events, flares and coronal mass ejections, are

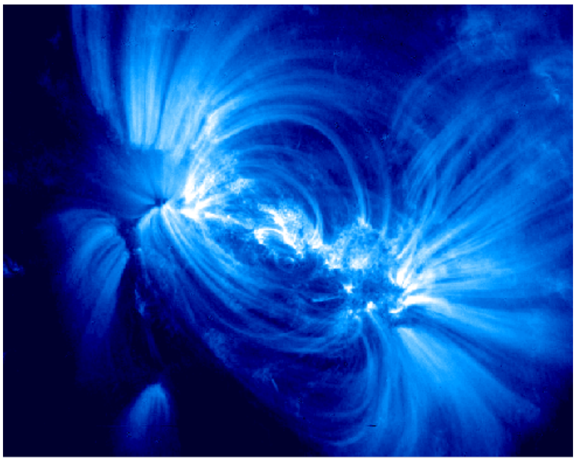

Fig. 1: Coronal loops on the Sun taken by TRACE, through an EUV filter (17.1 nm) transparent to emission from plasma at temperatures around 1 MK. The thin strands are about 2000 km wide.

associated with fast plasma ejection into interplanetary space and the partial disruption and formation of new systems of magnetic loops. But even the weaker ones send out waves that shake magnetic loops in their path. Recently we have been able to detect signatures of these waves. This science has been dubbed *coronal seismology*, a name that conveys its kinship to earthquakes and the use of seismic waves to infer the structure of the Earth's interior.

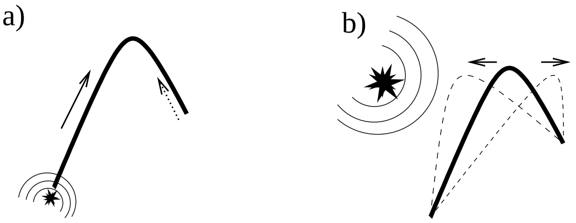

Fig. 2: Sketches of oscillation modes seen in coronal loops. (a) Slow mode sound wave triggered by a small flare at the footpoint. (b) Kink mode or transverse oscillation triggered by a large flare blast wave.

Waves are refracted and guided by magnetic loops causing the loops to resonate. Theory predicts various kinds of magnetohydrodynamic (MHD) waves supported by magnetic loops. There are sound waves, similar to those in organ pipes (Fig. 2a). These travel along the loops driving flows back and forth. The second type, the kink wave (Fig. 2b), is like a plucked guitar string and causes the magnetic loop to sway to and fro. Then there is the sausage mode, which causes the loops to expand and contract like a pulsating pipe. Finally, the torsional Alfvén wave is predicted to play an important role in the transfer of energy to the loops. There is no density perturbation or loop motion associated with this wave. Wave resonance causes the loop plasma to spin around the loop's axis first in one direction and then the other. These different wave modes seem to be excited under very specific conditions. Detecting the waves can only be done with the highest resolution solar telescopes. So far we have confidently identified both kink and sound waves resonating in loops after flare-like events.

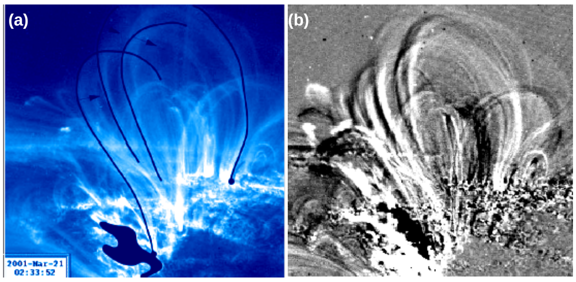

Fig. 3: TRACE observation of transverse loop oscillations. a) The EUV (17.1 nm) image of the oscillating loops just after a flare on 21 March 2001. b) The same loop system shown as the intensity difference 2 min later. Black indicates where the loops were and white where they have moved to.

The kink mode, like the plucked guitar string, is the most readily visible. Impressive examples have been observed by TRACE. One sees the loops rocking back and forth in image sequences. Fig. 3 represents their swaying (transverse) motion in a couple of images. This event, like all similar ones, was seen just after an energetic flare. A blast shock from the flare is believed to trigger the oscillation, as sketched in Fig. 2b. The loops resonate at a frequency characterised by the field strength along the loop. It has therefore been possible to deduce that the field strength in coronal loops is several tens of Gauss. There is no other known technique that could measure fields in one million degree (1 MK) solar plasma. These events are relatively rare. TRACE, which is observing the Sun almost 24 hr a day, has picked up about 40 examples in the last 4 years.

Probably the most surprising result has been the discovery, using the spectrometer SUMER built at the MPAe, of sound waves resonating along the loops. The loop itself does not move, but the plasma filling the loop is forced by the wave to swing first in one direction and then back in the opposite direction along the loop (sketched in Fig. 2a). It starts with a sudden pulse, as though kicked by a small flare at the footpoint of the loop. The wave travels at the sound speed, 300 – 400 km s^{-1}, but the plasma speed which is measured as a Doppler shift by SUMER, depends on the strength or amplitude of the wave and is usually ten times less or about 40 km s^{-1}.

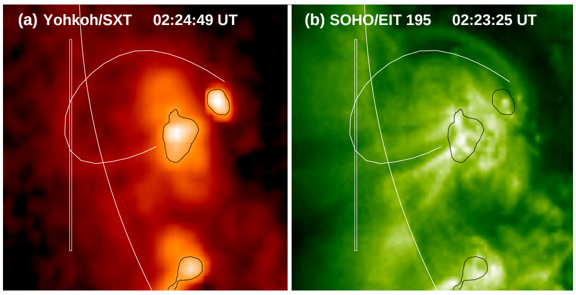

Fig. 4: Images of the hot loop from which SUMER observed the Doppler shift oscillations shown in Fig. 5. (a) *Yohkoh* X-ray image and (b) SOHO/EIT 19.5 nm image. The white curve and black contours outline the SXT loop and footpoint brightenings. The vertical lines indicate the SUMER slit position.

Since we have started looking for Doppler shift oscillations, we have found many examples. Usually the trigger is so weak that it is not even recorded as a flare and is only seen as a small brightening at the loop footpoint. The one specific requirement for the detection of these waves is that the loop be hotter than 6 MK. We have studied loops at 10 MK, 6 MK, 1 MK, 0.5 MK and 0.1 MK. Sound waves have only been seen in loops of 6 – 10 MK. The lower temperature loops do not show any wave signature. This is unexpected. Either the hot loops are the only ones that have an appropriate trigger or the wave in the cold loops is too weak to be detected.

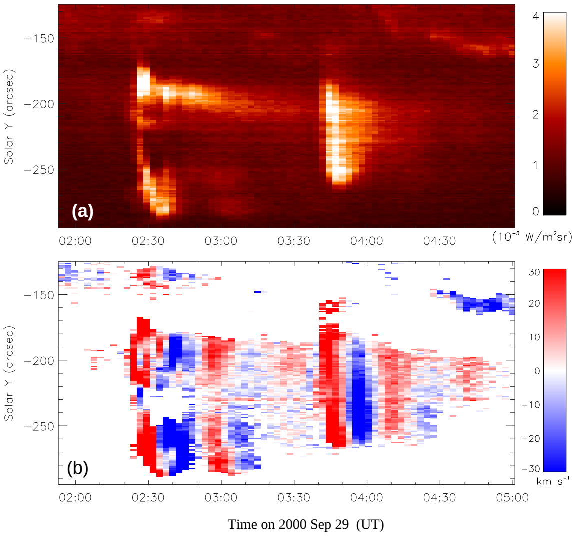

Fig. 5: Hot loop oscillations observed by SUMER in Fe XIX (111.8 nm) at the position marked in Fig. 4. (a) Spectral intensity time series. (b) Doppler shift time series.

One of the best examples is the event shown in Figs. 4 and 5. Here the oscillating loop, outlined with a white curve, can be seen in the X-ray image, but not in the EUV image. The oscillation was recorded as an oscillation in Doppler shift in a spectral line of the Fe^{18+} ion, which is characteristic of 6 MK plasma. SUMER obtained spectra from the region marked with a long narrow white strip, the spectrometer slit position, in Fig. 4. One spectrum every 2.5 min was obtained in each of 300 pixels along the slit. Thus a time-series of Fe XIX (111.8 nm) intensity and Doppler shift was built up at each position. The results are shown in Fig. 5. Here time is running left to right and position along the slit up and down. As expected, because the slit crossed the loop at two positions, there are two bright regions along the slit. These two positions brighten twice during the course of these observations. The Doppler shifts are shown below. The red-blue oscillation is seen for just over two periods in each event. Even in the first event when the two legs of the loop are well-separated along the slit, the oscillation is in phase at both positions. In each event it starts with a strong red shift.

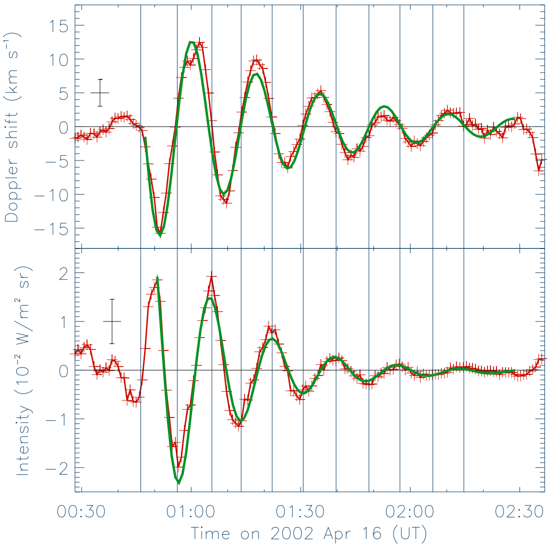

Fig. 6: (a) Evolution of Doppler shift and (b) of line intensity in the Fe XIX (111.8 nm) line at a distinct region of coherent oscillations along the slit. The green curves are the best fits with a damped sine function. The background shift and the background intensity have been removed, respectively.

A reason for identifying the Doppler shift oscillations with sounds waves, rather than kink waves, is that the periods are almost 3 times longer than the kink mode oscillations seen by TRACE. Decisive identification was made in an event in which we were able to measure simultaneous intensity and Doppler shift oscillation. The results are shown in Fig. 6. This shows that the two oscillations have the same period but are out of phase by exactly a 1/4 period, as theory predicts for the standing mode sound waves. The transverse kink mode is not anticipated to show intensity oscillations.

Travelling or propagating sound waves have also been detected in coronal loops, but not as Doppler shifts, only as intensity variations. The waves are quickly damped and have only been seen close to the surface. The trigger seems to be pulsations from the solar interior but the damping mechanism is related to the loop and corona structure. This gives hope that by studying many such systems, we will uncover features that can be related to the structure at the base of the loops and further insight into the heating mechanism that is maintaining the emitting coronal loops.

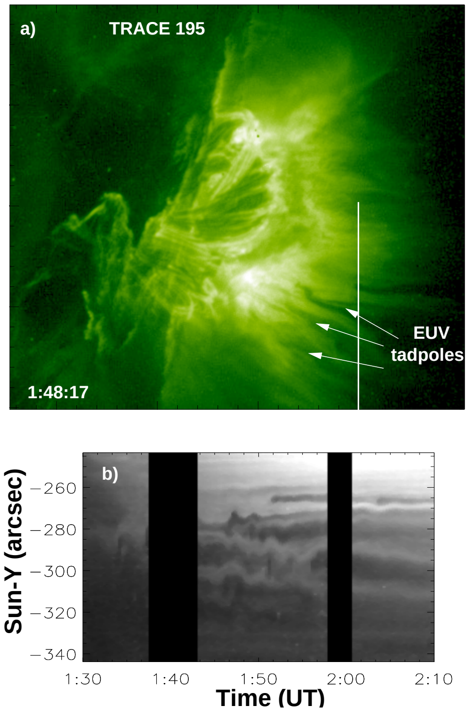

Fig. 7: TRACE observations of EUV tadpoles. (a) TRACE 19.5 nm image of arcade on 21 April 2002. (b) Intensity variations at the position marked with white line in (a).

The sausage and torsional Alfvén waves are less well established. The sausage mode may explain the rapid periodic intensity fluctuations in radio and hard X-rays seen during the first few minutes of a flare. The idea is that a sudden release of energy in the tube triggers the oscillation. The changes in the loop radius are expected to be too small to be seen in present-day images. The torsional Alfvén wave is going to be very difficult to detect since it is incompressible and so does not induce intensity variations. The only signature will be a change in line shift across the radius of the loop indicating plasma rotation around the loop axis. Every half period, the Doppler shifts will change sign as the plasma reverses its spin direction. At present the loops are barely resolvable in filter images. Obtaining spectral images in the EUV of loop systems with a rate of 1 image per minute is far in the future – even beyond currently planned missions.

We would also like to mention another curious oscillation observed at the time of flares – the so-called ‘EUV tadpoles’. These are small dark features with long wiggly tails seen falling with a speed of about 400 km s^{-1} towards the Sun. They have been seen after massive flares have ejected large amounts of material. There are currently only two well-observed examples but there are some hints that they are a regular feature of the eruptive type of flare. The TRACE image of a ‘tadpole’ is shown in Fig. 7. Underneath are the intensity oscillations one sees as the ‘tadpole’ falls past the position of the white line. The darkness is either due to absorption of background EUV light by a very dense object or because low density, high magnetic field plasma pushes the coronal field aside creating a cavity. If the second interpretation is correct, and this is at present thought to be the most likely, then analysis of these structures is expected to give valuable insight into post flare dynamics and the coronal field. There is some evidence that similar sunward flows have been seen in white light coronagraph images obtained by SOHO/LASCO over 3 solar radii above the solar limb. (The EUV emission in Fig. 7 reaches a height of one tenth of a solar radius.) This opens the exciting possibility of using coronagraph observations to measure the magnetic field right out at 3 solar radii.

Future solar missions, Solar-B and the Solar Dynamics Observatory (SDO), with higher resolution imaging capabilities are well designed to pick-up weaker and faster oscillations. It is very likely that sound and kink modes will be seen in weaker events and other modes will be discovered.

(Davina Innes, Tongjiang Wang, Werner Curdt, Sami Solanki)

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Photosphere and Chromosphere

Stokes diagnostics of solar magneto-convection simulations

The Stokes diagnostics of the solar magneto-convection simulations provides a tool to study the correspondence of physical processes in the solar (sub)photosphere, which are described by the simulations, to spectro-polarimetric observations. We use the spectral line synthesis code STOPRO to calculate Stokes profiles in the visible and the infrared spectral ranges from simulation data produced by the 3D MHD MURaM code. Examples of synthetic slit spectra are shown in the Fig. 8 below. After appropriate smearing to account for the spectral and spatial resolution of the instruments, such spectra can be compared with observational data.

The Stokes analysis of the simulation results includes the study of individual features (e.g. strong magnetic flux concentrations and protopores) and statistical analysis of the calculated Stokes parameters by way of correlation diagrams of profile parameters (e.g. line depth, Doppler shifts, Stokes V area, amplitude and asymmetry) as a function of field strength, brightness or other quantities of the numerical model. Such analysis can also be used to test methods to determine physical quantities from spectro-polarimetric data.

(S. Shelyag, S.K. Solanki, M. Schüssler, A. Vögler)

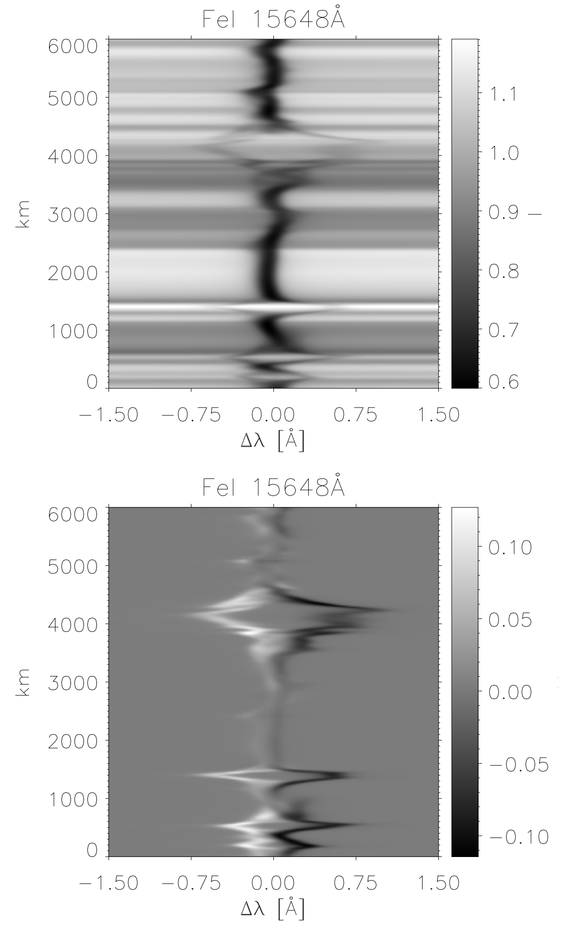

Fig. 8: Synthetic slit spectra of Stokes I (upper panel) and Stokes V (lower panel) for the infrared Fe I line at 1564.8 nm (with Landé factor $g = 3$) from a simulation of a solar plage region with an average field of 200 G. The slit crosses a number of magnetic flux concentrations of kG field strength, which leads to strong Zeeman splitting and circular polarization.

Evolution of the large-scale magnetic field at the solar surface

Magnetic flux emerging on the Sun's surface in the form of bipolar magnetic regions is redistributed by supergranulation, meridional poleward flow, and differential rotation (Fig. 9). We have developed a numerical flux-transport model and used it to carry out a systematic parameter study of the influence of model parameters and source term properties on the evolution of the large-scale field on time scales of the solar cycle and beyond. This study also gives an indication of the behaviour of solar-type stars with different levels of activity, other rotation laws, etc. The total unsigned surface flux and the flux in the polar caps are mainly affected by the assumptions about the average tilt angle of the emerging bipolar regions, the coefficient of turbulent diffusion, the total amount of emerging flux and, for the polar field, the meridional flow velocity and the cycle length. Of particular interest is the influence of the overlap between succesive cycles. With increasing overlap, an increasing background field (minimum flux at cycle minimum) is built up. This result is relevant for the secular evolution of the total surface flux and also for the open flux as a source for the heliospheric magnetic field.

(I. Baumann, D. Schmitt, M. Schüssler, S.K. Solanki)

Quiet-Sun internetwork magnetic fields

Internetwork fields are weak magnetic features of unknown origin present everywhere in the quiet Sun and best seen in the interiors of supergranule cells. Relatively little is known about them, because it requires polarimetric observations with exceptionally

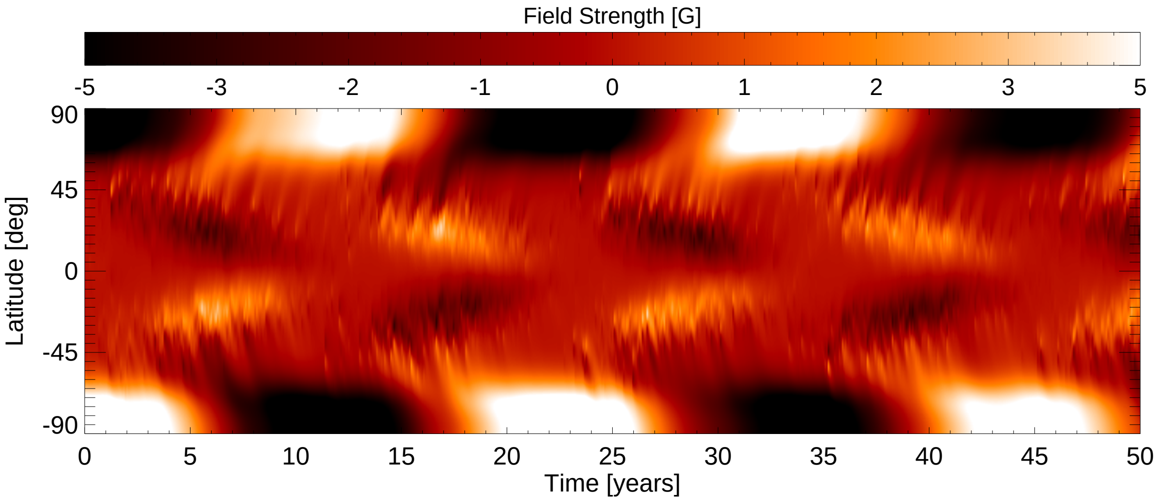

Fig. 9: Time-latitude plot of the surface magnetic field for standard solar parameters. The magnetic field is averaged over longitude and over a time period of 27 days. The equatorward propagation of the activity belts and the poleward transport of following-polarity flux leading to reversal of the polar field around cycle maximum are well visible. The saturation level of the grey scale is set to 5 G.

low noise to detect them. We have investigated internetwork fields using high-resolution infrared spectropolarimetric observations obtained with the Tenerife Infrared Polarimeter (TIP) at the German VTT of the Observatorio del Teide under exceptionally good seeing conditions. We found that the Stokes V profile of Fe I (1564.8 nm) in almost 50% of the pixels and Stokes Q and/or U in 20% of the pixels have a signal above 10^{-3} (in units of continuum intensity I_c), which is significantly above the noise level of $2 - 3 \times 10^{-4}$. This implies that we detected fluxes as low as 2×10^{15} Mx/px, which is almost an order of magnitude lower than previous studies. The data show evidence that we have detected most of the net flux that is in principle detectable at $1''$ resolution with the Zeeman effect. The observed linear polarization resulting from the transverse Zeeman effect indicates that the magnetic fields have a broad range of inclinations, although most of the pixels show polarization signatures which imply an inclination of about 20°. Nearly 30% of the selected V-profiles have irregular shapes with 3 or more lobes, suggesting mixed polarities with different LOS velocity within the resolution element. Most of the observed fields are weak with *relatively* few kG features. The field strength distribution is shown in Fig. 10. It peaks at 350 G and has a *FWHM* of 300 G.

(S. K. Solanki and A. Lagg in collaboration with E.V. Khomenko, Main Astronomical Observatory, Kyiv, Ucraine, M. Collados and J. Trujillo Bueno, Instituto de Astrofisica de Canarias, Tenerife, Spain)

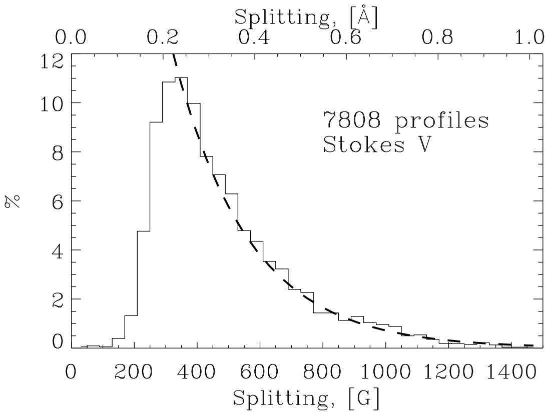

Fig. 10: Histogram of Zeeman splitting obtained from profiles of the Fe I (1564.8 nm) lines observed in a very quiet region on the Sun. Dotted line: Fit by an exponential function $A\exp(-B/B_0)$ to the right part of the histogram beyond the maximum. The upper horizonal axes indicate the splitting in Å, the lower axes in G (i.e. converted into field strength).

Simulations of solar radiative magneto-convection with different amount of magnetic flux

Numerical radiative MHD simulations are important for understanding the physical processes which govern the interaction between convective flows (granulation) and magnetic fields in the solar photosphere and convection zone. They also represent an extremely valuable tool for the interpretation of observations of photospheric structures in terms of physical quantities. Realistic MHD simulations which aim at approximat-

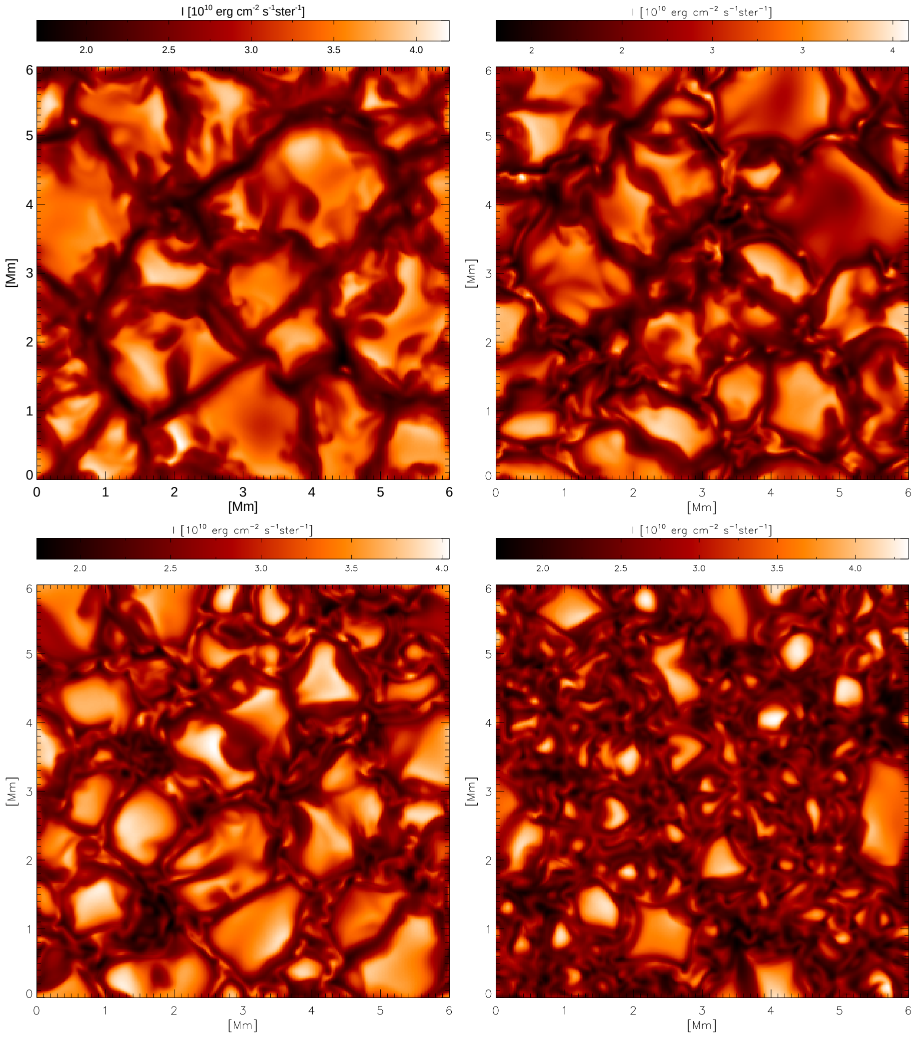

Fig. 11: Maps of (frequency-integrated) brightness for snapshots taken from four simulation runs with different average field strength B_0. Upper left: $B_0 = 10$ G, upper right: $B_0 = 200$ G, lower left: $B_0 = 400$ G, lower right: $B_0 = 800$ G. Most of the magnetic flux is assembled in magnetic flux concentrations of kG field strength in the downflow network, which appear as bright features in the dark intergranular lanes. As the average field strength increases, the granulation pattern becomes more and more disturbed and its spatial scale decreases. This reflects the growing suppression of the convective energy transport by the magnetic field.

ing the real photosphere require an elaborate treatment of the physical processes relevant in the photosphere, like the interaction between plasma and radiation and the effects of partial ionization. In collaboration with F. Cattaneo, T. Emonet and T. Linde from the University of Chicago, we have developed the MURaM code, a 3D MHD code specifically designed for photospheric applications. The code features full compressibility, a non-local and non-grey radiative transfer module, a realistic equation of state, and an open lower boundary.

Using the MURaM code, we carried out a series of simulations to study the dependence of photospheric magneto-convection on the average field strength (Fig. 11). The simulations, which cover an area of 6×6 Mm^2 in the photosphere (corresponding to 10–15 granules in the quiet Sun) with a vertical extent of 1.4 Mm, were set up by introducing a vertical homogeneous magnetic field of strength B_0 into fully developed non-magnetic convection. We have carried out runs with $B_0 = 10$, 50, 200, 400, and 800 Gauss, thus covering average field strengths ranging from quiet Sun conditions to strong plage regions and beyond. In all cases, we observe flux expulsion and convective field amplification, leading to a dichotomy of strong (kG), mainly vertical fields embedded in the granular downflow network and weak, randomly oriented fields in the hot granular upflows. In the simulation corresponding to quiet Sun conditions ($B_0 = 10$ G) the strong fields occur in form of isolated flux concentrations with diameters up to 300 km and field strength up to 1700 G. With growing average field strength, an increasing part of the downflow network is filled with kG field. The plage runs with $B_0 = 200$ G and 400 G exhibit a more or less continuous magnetic network with thin, bright sheet-like structures extending along downflow lanes and larger, dark structures with diameters of up to 1000 km (corresponding to micropores in the photosphere) and maximum field strength around 2200 G. While the overall shape of the magnetic network changes slowly on a timescale much larger than the convective turnover time, the magnetic flux is constantly redistributed within the network. With increasing average field strength, morphology and dynamics of the convective motions become more and more affected by the presence of the magnetic field. There is a clear trend towards decreasing horizontal length scales of granulation and reduced horizontal flow velocities with growing B_0. The disturbance of the granular pattern becomes rather severe in the case $B_0 = 800$ G. Here the dynamic backreaction of the magnetic field on the convective flows leads to the formation of numerous small upflows with typical diameters of 200 – 500 km. A smaller number of larger, more vigorous upflows penetrates the magnetic network and appear as isolated bright dots against a dark background of almost stagnant, strongly magnetized plasma – a situation reminiscent of a sunspot umbra interspersed with umbral dots.

(A. Vögler, M. Schüssler)

Stability of magnetic flux tubes in vortex flows

Magnetic flux concentrations in the solar (sub)photosphere are surrounded by strong downflows, which come into swirling motion owing to the conservation of angular momentum. While such a whirl flow can stabilize a magnetic flux tube against the MHD interchange (fluting) instability, it potentially becomes subject to Kelvin-Helmholtz and shear instability near the edge of the flux tube. This may lead to twisting of the magnetic field and even to the disruption of the magnetic structure.

As a first step towards studying the relevance of such instabilities, we have investigated the stability of an incompressible flow with longitudinal and azimuthal (whirl) components surrounding a cylinder with a uniform longitudinal magnetic field. We find that a sharp jump of the azimuthal flow component at the cylinder boundary always leads to Kelvin-Helmholtz-type instability for sufficiently small azimuthal wavelength of the perturbation. If the azimuthal flow component has a finite transition layer between the stagnant tube interior and the rotating external medium, which is neutrally stable according to the Rayleigh criterion, the stability of the flow depends on the ratio of the width of the transition layer to the radius of the flux tube. For perturbations that do not vary along the tube, a transition layer with a width of the order of the tube radius or larger stabilizes the azimuthal flow against perturbations with arbitrary azimuthal wavenumber, even for a discontinuous profile of the longitudinal flow. For perturbations varying along the tube as well, the Kelvin-Helmholtz instability of the longitudinal flow component leads to a reduction of the stability domain, but flux tubes with sufficiently large internal density deficit and a broad transition layer remain stable with respect to all perturbations.

An extended transition layer may naturally evolve as a result of the shear instability of a sharp transition between flux tube and external whirl flow. Consequently, strongly evacuated flux tubes in the solar photosphere surrounded by helical flows may attain stable configurations.

This work is being continued by 2D/3D MHD simulations of the non-linear development of the shear instability, also including compressibility and stratification by gravity.

(F. Kolesnikov, D. Schmitt, M. Schüssler)

Three dimensional structure of a regular sunspot and a map of its Wilson depression

Inversion techniques allow the magnetic, thermal and velocity structure of sunspots to be determined. Such studies had basically been restricted to lines in the visible. Spectropolarimetric data obtained with the Tenerife Infrared Polarimeter (TIP) in two infrared Fe I lines at 1564.85 nm and 1565.28 nm were inverted employing a technique based on response functions to retrieve the atmospheric stratification at every point in the sunspot. Profiles of Zeeman split OH lines blending the Fe I (1565.28 nm) were also consistently fit. This was the first time that Zeeman split molecular lines were inverted. In this way maps of temperature, line-of-sight velocity, magnetic field strength, inclination, and azimuth were obtained, as a function of both location within the sunspot and height in the atmosphere (Fig. 12). Numerous results were obtained from these 3-D maps. Thus it was confirmed that at a few locations in the outer penumbra the magnetic field returns into the solar interior. These locations coincide with the strongest flows in the velocity map.

The relations between thermal and magnetic quantities of the studied sunspot were then employed with the equation for lateral force balance to create the first maps of the Wilson depression of a sunspot as well as of the plasma β.

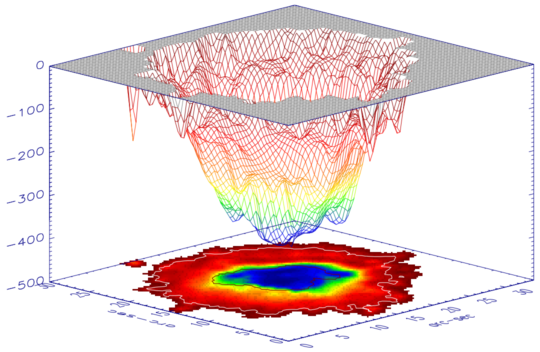

Fig. 12: Wilson depression of a symmetric sunspot. The upper part of the figure represents the structure of the Wilson depression as a contour plot, the lower part represents the depth through colour coding. The inner and outer white contours represent the umbral and penumbral boundaries deduced from the continuum image.

(S.K. Mathew, J.M. Borrero, N. Krupp, A. Lagg, S.K. Solanki and J. Woch in collaboration with M. Collados, Instituto de Astrofisica de Canarias, Tenerife, Spain, S. Berdyugina and C. Frutiger, ETH Zürich)

Moving magnetic features around sunspots

Moving magnetic features are small-scale magnetic features that often occur in pairs and are seen to move away from sunspots in the sunspot moat. Several models have been proposed to describe them. We analyze data recorded by the Michelson Doppler Imager (MDI) instrument on the Solar and Heliospheric Observatory (SOHO) to distinguish between rival models. We have identified 144 pairs of opposite magnetic polarity moving magnetic features (MMFs) in two active regions. The following results are obtained from a study of these MMF pairs: (1) The majority of MMF pairs first appears at a distance of 1000 to 5000 km from the outer boundary of the sunspot, although MMF pairs appearing closer to the sunspot may be missed. (2) MMF bipoles are not randomly oriented. The member of an MMF pair further from the sunspot has the polarity of the parent sunspot in 85% of the cases. Furthermore, the orientations of MMF pairs are associated with the twist of the sunspot superpenumbra deduced from Hα images. (3) The mean lifetime of the studied MMFs is around 4 hours. (4) The separation between the two polarities of the MMFs falls in the range of 1100 -- 1700 km. This separation remains almost unchanged, even decreases slightly as the MMF pairs move outwards. (5) MMF pairs move approximately radially outward from sunspots at an average speed of around 0.5 km s^{-1}. Their motion is deflected towards large concentrations of magnetic flux of opposite polarity to that of the parent sunspot.

These observations, in particular the polarity orientation rule and the direction of motion, are not naturally reproduced by any of the published models. Therefore, a new qualitative model based on these and other observations is proposed according to which MMF pairs are part of a U-loop emanating from the sunspot's magnetic canopy. Possible mechanisms leading to the formation of such a loop are discussed.

(J. Zhang, S.K. Solanki, in collaboration with J. Wang, National Astronomical Observatories, Beijing)

Spatial and temporal fluctuations and the heat transport in sunspot penumbrae

The penumbra radiates an energy flux that is 75% of the quiet-Sun value. One mechanism proposed to bring this flux to the surface is interchange convection, according to which hot flux tubes rise to the surface, lie horizontally there while they cool and finally sink down again. In a first step we searched for possible signatures of such a process using time series of magnetograms and continuum images recorded by the Michelson Doppler Imager (MDI) in its high resolution mode (0.6$''$ pixels). The data revealed that at the spatial scales accessible to MDI, magnetic structures are on average smaller in the azimuthal direction than brightness features. The small-scale magnetic pattern resolvable by MDI lives for well over two hours, i.e. longer than the brightness pattern. This result suggests that interchange convection is unable to account for the observed penumbral radiative flux, since the time scale required to maintain the thermal and magnetic pattern is much shorter than the observed time scale.

Another way of depositing heat in the penumbral photosphere is by steady upflows along magnetic flux tubes, which feed the Evershed outflow. This mechanism is consistent with the MDI time series observations. Heating the penumbra by steady upflows along magnetic flux tubes turns out to be sufficient to explain the penumbral brightness, under the condition that significant magnetic return flux is present within the penumbra. Associated with the magnetic return flux, downflows within the penumbra should be present, in accordance with recent observational findings. Exploring other possible heating mechanisms, we find that dissipation of magnetic energy is negligible, while dissipation of the kinetic energy of the Evershed flow could contribute significantly to the brightness of the penumbra.

(S.K. Solanki in collaboration with I. Rüedi, Physikalisch-Meteorologisches Observatorium Davos / World Radiation Center, Davos, Switzerland, and R. Schlichenmaier, Kiepenheuer-Institut für Sonnenphysik, Freiburg)

Can magnetic network and plage lead to apparent solar radius variations?

Solar radius measurements, a by-product of the magnetograms recorded several times daily at Mt. Wilson Observatory over a period of a few decades, have revealed apparent variations of about $0.4''$ that are correlated with the solar cycle. We show, analytically as well as by means of actual non-LTE radiative transfer modelling, that plage emission near the solar limb associated with the magnetic activity variation during a solar cycle produce diameter changes of the correct sign. For the purpose of this analysis we consider that the radius variations deduced from the Mt. Wilson data are a direct consequence of the solar radius definition that automatically converts intensity variations near the limb into apparent radius variations. A change in the average temperature structure of the quiet Sun can be ruled out as the source of these variations, since such a change would need to be very significant and would lead to other easily measurable consequences that are not observed. The use of plane-parallel or spherically-symmetric models to describe the faculae gives apparent radius variations that are a factor of $4-10$ too small in magnitude. If the Mt. Wilson results are correct, then this implies that the small-scale structure of faculae produces limb extensions that are considerably larger than those returned by a plane-parallel or spherically-symmetric model.

(S.K. Solanki in collaboration with J.H.M.J. Bruls, Kiepenheuer-Institut für Sonnenphysik, Freiburg)

The molecular Zeeman effect

The computation of the Zeeman splitting of molecular lines had for a long time been lying dormant before advances resulting from our earlier work paved the way for the use of molecular lines as diagnostics of solar and stellar magnetic fields. A systematic study of their diagnostic capabilities had not been carried out so far, however. In the period covered by this report we investigated how molecular lines can be used to deduce the magnetic and thermal structure of sunspots, starspots and cool stars. To this end the Stokes radiative transfer of Zeeman-split molecular lines was coded and incorporated into a response-function based inversion code. Then, we computed Stokes spectra of TiO, OH, CH, N and FeH lines and investigated their diagnostic capabilities. We also compared the synthetic profiles with observations. Spectra of TiO, OH and FeH were found to be interesting diagnostics of sunspot magnetic fields. This is also true for cool stars (see Fig. 13), where, however, the OH Stokes V profiles may require very high S/N data to be reliably employed. Finally we investigated the potential of various molecular bands for high-contrast imaging of the solar surface. The violet CN and CH bands turned out to be most promising for imaging the photosphere, the TiO bands are excellent for imaging sunspot umbrae, while the UV OH band can be used for imaging both the photosphere and sunspots.

In a next step we have started to investigate the molecular Paschen-Back effect, both theoretically and observationally using M_gH observations obtained with the Themis telescope.

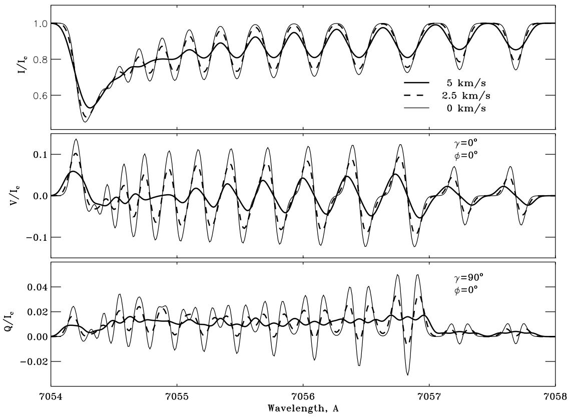

Fig. 13: The TiO $\gamma(0,0)R_3$ band head in a starspot with a field strength of 3 kG. The thin solid line represents synthetic Stokes profiles convolved with only an instrumental profile of 0.07 Å (corresponding to a revolving power of R=100 000), while thick dashed and solid lines show the spectra broadened in addition by stellar rotation with a $v \sin i$ of 2.5 and 5 km s^{-1}, respectively. The spectra are calculated for different angles of the magnetic field vector: For an angle between the vector and the line of sight $\gamma = 0^\circ$, 90° and for the azimuthal angle $\phi = 0^\circ$.

(S.K. Solanki in collaboration with S.V. Berdyugina, D. Fluri and C. Frutiger, ETH Zürich and J. Arnaud, Observatoire Midi-Pyrenées, Toulouse, France)

Origin of the brightness of magnetic flux concentrations in molecular lines

Small-scale magnetic flux concentrations with field strengths of about 1500 G in the solar surface layers comprise a significant fraction of the magnetic flux (and almost all of the magnetic energy) in the solar atmosphere outside sunspots. Images taken in Fraunhofer's 'G band', a spectral region around 430 nm wavelength, which is dominated by molecular lines

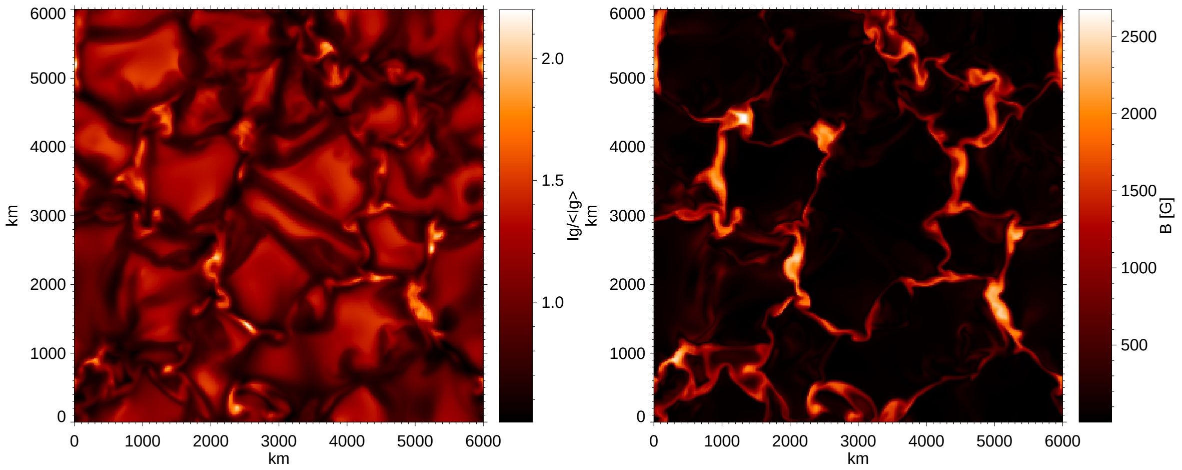

Fig. 14: Comparison between G-band brightness and magnetic field strength in a realistic simulation of solar magneto-convection. *Left:* Synthetic filter image of the simulation area in the G-band spectral region around 430 nm wavelength. The extended bright regions are convective upwellings (granules) surrounded by a network of dark downflow lanes. The small brilliant patches in the dark areas coincide with magnetic flux concentrations. *Right:* Colour-coded magnetic field strength at continuum optical depth unity for the same snapshot. About two thirds of the vertical magnetic flux penetrating the simulation box has been assembled into flux concentrations with a field strength above 1000 G.

near the CH bandhead, show conspicuous bright structures in the convective downflow regions where most of the concentrated magnetic flux is expected to reside. Much of our current knowledge about the structure, distribution, and dynamics of small-scale magnetic features is based on G-band observations under the assumption that G-band bright points represent magnetic flux concentrations.

We have provided a physical basis for such ‘proxy magnetometry’ by unraveling the relationship between G-band brightness and magnetic flux using realistic ab-initio 3D simulations of radiative magneto-convection in the solar surface layers. The bright features in synthetic G-band images calculated from the models outline the magnetic flux concentrations up to fine details in their spatial pattern (Fig. 14). The physical origin of the brightening is the high temperature and low density of the gas within the magnetic flux concentrations, which strongly reduces the concentration of CH. The resulting weakening of the spectral lines of this molecule, together with the higher level of continuum intensity, leads to a strongly increased brightness in the G band. The physical association of large field strength with higher temperature and lower density can easily be understood in terms of lateral heating by radiation of the transparent tenuous interior of a flux concentration in lateral balance of the total (gas plus magnetic) pressure.

(S. Shelyag, M. Schüssler, S.K. Solanki, A. Vögler, in collaboration with S. Berdyugina, ETH Zürich)

Millimeter observations and chromospheric dynamics

The nature of the solar chromosphere is the subject of considerable debate. Observations in the UV and visible, which depend highly non-linearly on temperature, cannot distinguish between rival models. The intensities of submillimeter and millimeter continua, which are formed in LTE and depend linearly on temperature, may provide a more sensitive test. We have taken a collection of submillimeter and millimeter wave observed brightness temperatures T_b of the quiet Sun from the literature and compared it with brightness temperatures computed from the standard static models of Fontenla, Avrett and Loeser (FAL models) and the dynamic simulations of Carlsson and Stein (CS model). The analysis of the dynamic simulations of Carlsson and Stein reveals that radio emission at millimeter wavelengths is extremely sensitive to dynamic processes in the chromosphere, if these are spatially and temporally resolved. This is illustrated in Fig. 15.

The most striking result is that the dynamic picture of the solar internetwork chromosphere is consistent with currently available millimeter an submillimeter brightness observations. The spectrum obtained by averaging over the spectra from all time-steps of CS dynamic simulations provides a good fit to observed temporally and spatially averaged millimeter data in spite of the absence of a classical temperature rise at low chromospheric heights in the simulations. This does not by itself rule out the presence of a chromospheric temperature rise as present in the FAL models,

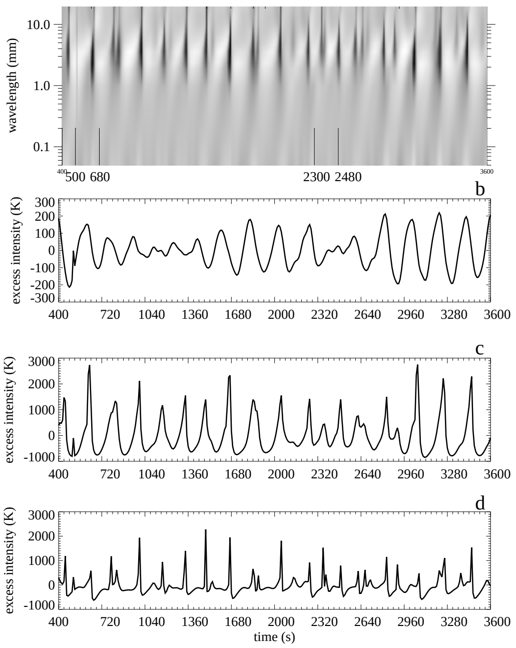

Fig. 15: The excess intensity resulting from the CS models for different wavelengths (vertical scale) and vs. time (horizontal scale). Darker is brighter. Below it the evolution of excess intensity is plotted for 3 wavelengths (0.05 mm, 1 mm and 10 mm, from top to bottom).

since a combination of such models also reproduces the (low resolution) data relatively well. Millimeter observations indicate that using radio techniques it is possible to extend observations of the solar oscillatory component to the heights above those previously observed in the photospheric and low chromospheric spectral lines and submillimeter continuum. For more precise diagnostics of chromospheric dynamics, high temporal and spatial resolution interferometric observations in the millimeter-wavelength region would be particularly useful. A first step in this direction has been taken by obtaining data with a spatial resolution of 10″ with the BIMA interferometer.

(M. Loukitcheva and S.K. Solanki in collaboration with M. Carlsson, Institute of Theoretical Astrophysics, Oslo, R.F. Stein, Michigan State University, East Lansing, USA, and S. White, University of Maryland, College Park)

Rise and separation of magnetic flux tubes in the solar convection zone

Numerical MHD simulations have yielded a wealth of information regarding the generation, storage, and transport of magnetic flux to the solar surface. Simulations exploiting the Thin Flux Tube Approximation (TFTA) have been able to explain several properties of large bipolar regions, including their emergence latitude and tilt angle. The conditions for the validity of the TFTA are no longer fulfilled in the upper layers of the solar convection zone, so that MHD simulations of 'thick' flux tubes are required to study the dynamics of flux tubes in the near-surface layers.

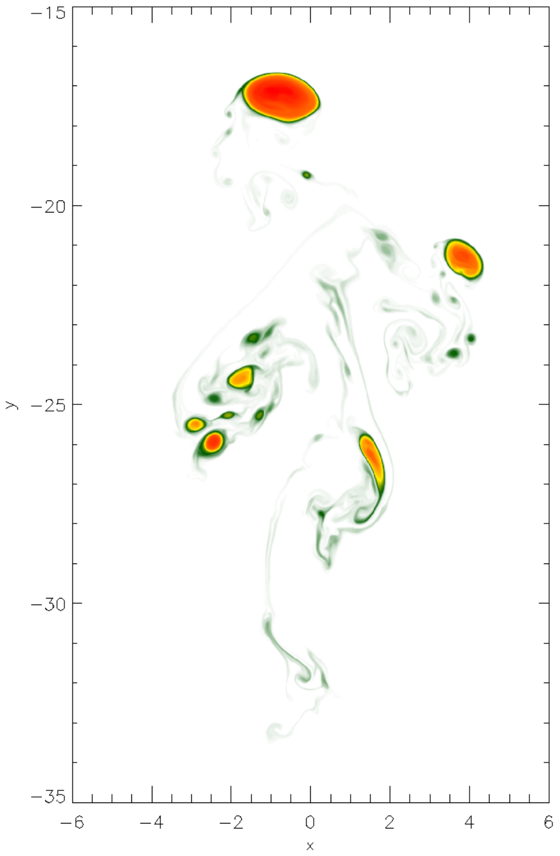

Fig. 16: Snapshot of the longitudinal component of the magnetic field. The original flux tube has been split into several smaller tubes, but a main tube near the top of the domain can still be identified. In this snapshot, the main tube retains approximately one third of the initial magnetic flux. Despite such a complex history, the mean temperature, density and plasma β in the main tube are well described by the Thin Flux Tube approximation.

Using the FLASH code (developed by the ASCI/Alliance Center for Astrophysical Thermonuclear Flashes at the University of Chicago), we have carried out a number of high-resolution 2D MHD simulations of thick, twisted flux tubes rising in an initially static, adiabatically stratified atmosphere spanning over six pressure scale heights. Using adaptive grid refinement mechanism of the FLASH code, we achieve a very good spatial resolution of the flux tube (Fig. 16). We observe that flux shedding cause the original flux tube to split into a family of smaller flux tubes, some of which undergo further separation. Despite this, we are still able to identify a 'main tube', which retains about a third of the longitudinal flux of the original tube.

The complex history of the flux tube at first suggests that the scenario in the simulation is outside the domain of the TFTA. Nevertheless, we find that the height dependence of the mean density, temperature and plasma β of the main flux tube is well consistent with the TFTA. At present, this conclusion is restricted to the plane-parallel case for flux tubes rising in an initially static atmosphere. We are now studying flux tubes rising in a convecting environment and extend the simulations to 3D.

(M. Cheung, M. Schüssler, in cooperation with F. Moreno-Insertis, IAC, Tenerife, Spain)

Realistic simulation of solar pores

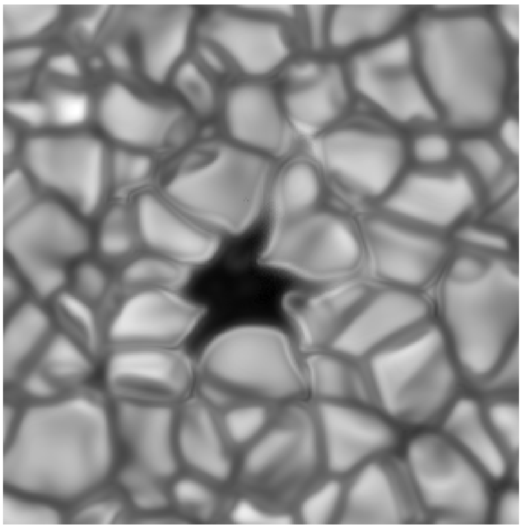

Fig. 17: Brightness image of a simulated solar pore. The horizontal extension of the computational box is $12\,000 \times 12\,000$ km^2 while its depth is 1 400 km. The box is resolved by $288 \times 288 \times 100$ grid cells.

We have used the MURaM (MPAe/Univ. of Chicago Radiative MHD) code to perform simulations of the appearance and decay of pores, magnetic structures of intermediate size between small-scale magnetic elements and full-fledged sunspots with penumbrae. We start the calculations by imposing a localized magnetic plug with a diameter of approximately 1500 km and an initial magnetic field strength of 2800 G. In order to study larger pores we began from the solution of this small pore and slowly increased the flux. The detailed treatment of the physics by MURaM enables the simulations to be compared, qualitatively and quantitatively, with observations.

Here we sketch two of the many results embedded in our simulations. Firstly, there is a conspicuous bright rim of about 100 km width at the edge of the pore. This feature is associated with the precipitous drop in height of the surface at which the plasma becomes opaque (the 'hot wall' effect). The second result concerns the evolution of pores. We have compared simulations with a vertical magnetic field at the upper boundary of the computational box with the solutions to cases where the field was matched to a potential field (Fig. 17). The former case is probably suitable for the early part of a pore's life, when the corona has not had time to dissipate all the currents created by the pore's emergence, while the latter is a better representation of the late phases. We found that the pore was much more stable with the vertical field boundary condition, consistent with this idea.

(R. Cameron, A. Vögler, M. Schüssler, S.K. Solanki)

Structure and evolution of the solar magnetic field below an EUV bright point

EUV and X-ray observations of the solar atmosphere have revealed the existence of so called "bright points" (BP). Most BPs were found to be located above bipolar, some above monopolar photospheric magnetic fields closely related with borders between supergranulation cells. Looking for magnetic field properties hinting at the reason for their close relation to BPs, we analysed the structural evolution of the underlying magnetic fields. In particular we investigated the relative evolution of smaller and larger scale magnetic field concentrations. Since spatial Fourier transformations do not directly address the natural size of structures, we utilized the Singular Value Decomposition (SVD) method. The SVD method reveals the most powerful (orthogonal) spatial modes and the temporal evolution of their weights. The SVD analysis method provides a powerful tool for the investigation of a priori unknown functions, it captures the information about localized, non-periodic structures efficiently and by a smaller number of modes than other decomposition methods Based on orthogonal functions like the Fourier analysis. Thus, SVD, allows to remove noise from the data and provides a physically meaningful decomposition of the photospheric magnetic fields below BPs into differently sized structures. For a time sequence of magnetograms it also allows to follow the evolution of the bipolar or higher order multipole magnetic structures until the structure disappears.

For definiteness we studied the structural evolution of the photospheric magnetic fields below an EUV

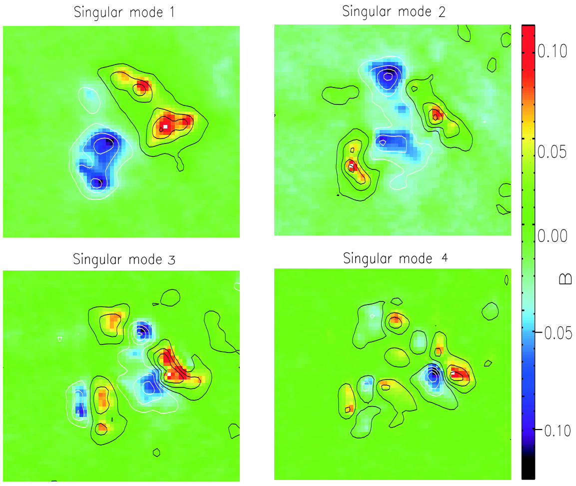

Fig. 18: Spatial structure of the four most powerful singular magnetic field (MDI) modes within an observation site 28 Mm x 28 Mm, between 15:21 UT on October 17 and 8:00 UT on October 18, 1996 located close to the Solar equator.

bright point, identified by Madjarska et al., 2003 using SOHO EIT observations in the 19.5 nm line on October 17th – 18th, 1996 in a region located close to the Solar equator. Our analysis is based on a series of 1000 high resolution SOHO-MDI magnetic field data obtained with a one minute time step starting 15:21 UT on October 17, 1996 and lasting until 08:00 UT on October 18. Fig. 18 depicts the spatial structure of the four most powerful singular modes found within a region of 28 Mm x 28 Mm (65 x 65 MDI Pixels).

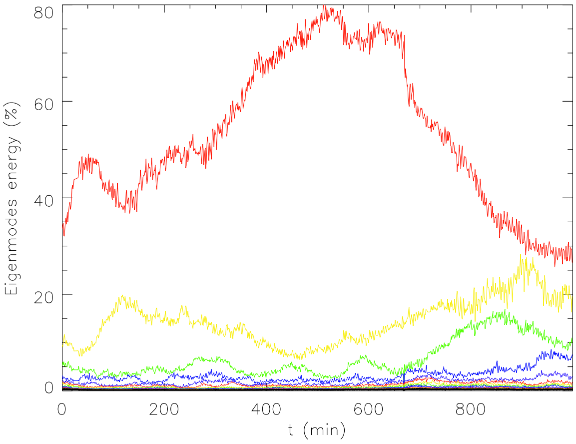

Fig. 19: Temporal evolution of the power portion of the the detected singular modes during the 1000 minute long period starting 15:21 UT on October 17 and lasting until 8:00 UT on October 18, 1996. The four most powerful of them (red, yellow, green, blue for modes 1 – 4, respectively) are shown in Fig. 18

Fig. 19 depicts the temporal evolution of the relative power contribution of each detected singular mode of the magnetic field evolution in the BP region during the 1000 minute time period from 15:21 UT on October 17 till 8:00 UT on October 18, 1996. As one can see the singular mode 1 (blue line), whose spatial structure is shown in the left upper panel of Fig. 18, contains most of the spectral energy. This is the expected result that a bipolar magnetic structure dominates the BP region. However, there are three more singular modes represented by the yellow, green and blue lines in Fig. 19, which at different times significantly contribute to the evolution of the magnetic structure. They correspond to the singular modes 2 – 3, whose spatial structure is depicted in the lower and the upper right panels of Fig. 18. These modes are characterized (cf. the lower and right upper panels of Fig. 18) by small substructures and side-maxima of the photospheric magnetic field below the BP, in particular a quadrupolar structure. When the relative power of the basic dipolar structure is still increasing, i.e. this structure is building up, the smaller structures can already fade away, i.e. by powering the BP. This would explain the permanent energy supply to the BP even in phases, where the dipolar magnetic configuration does not seem to release its energy. Based on this observation we have started numerical simulations of the plasma evolution (cf. seperate report) in order to understand the possibly important role of substructures of the photospheric magnetic field underlying a BP as compared to the dipolar structure, in the past favoured as a cause for BP.

(J. Büchner in collaboration with E. Podladchikova, Brussels)

The physical mechanism of facular brightening

Solar faculae appear as bright, small features close to the solar limb, closely related to magnetic fields. The large number of faculae around sunspot maximum more than make up for the deficit due to sunspots, which explains the slightly higher solar irradiance at solar maximum. Understanding the origin of faculae has therefore a much broader impact than just explaining one of the most prominent solar surface features.

Images from the new 1-m Swedish Solar Telescope on La Palma have revealed the structure of faculae in unprecendented detail. Facular brightenings appear as relatively extended features on the centerward side of granules. Often there is a dark, narrow lane in front of the facular brightening. We have compared the observed facular features with realistic 3D radiative MHD simulations of unipolar plage areas (Fig. 20). We find that the simulations reproduce the observed small-scale features remarkably well. In particular, the simulations show: 1) The three-dimensional impres-

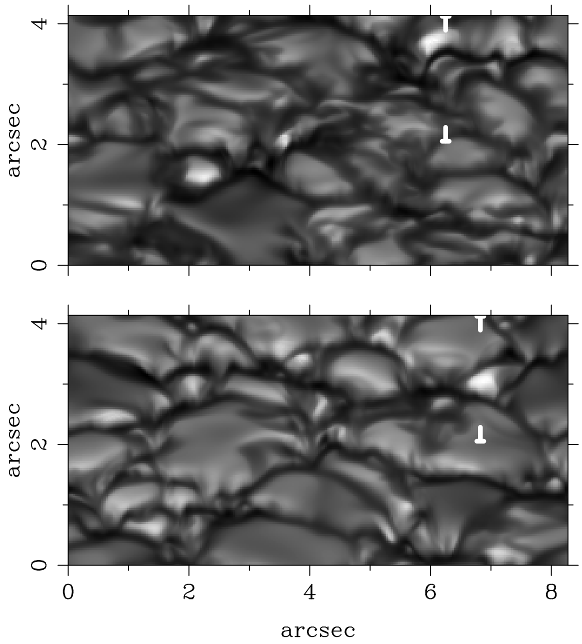

Fig. 20: Simulated images at 488 nm based on simulations with an average vertical magnetic field of 400 G (upper panel) and 200 G (lower panel), respectively, at a heliocentric angle of 60 deg. The upward direction is towards the limb. The white marks indicate facular brightenings and dark lanes.

sion one obtains when looking at the images; 2) faculae appear predominantly in plages; 3) facular brightenings occur on the disk-center side of granules; 4) the brightening can extend over about 0.5 arcsec; 5) often there are narrow, dark lanes just centerward of the facular brightening.

A detailed analysis of the the simulations reveals that faculae originate from a thin layer within granules just below largely transparent magnetic flux concentrations. The dark, narrow lanes associated with faculae occur at the front side of the magnetic flux concentration and are due to an extended layer with lower-than-average temperature. The simulations demonstrate that the expansion of the flux concentrations with height and the three-dimensional geometry of the granules lead to an limbward extension of the facular brightenings significantly in excess of the Wilson depression, which one would naively identify with the height of the 'bright wall'. At the same time, these simple geometric effects lead to the formation of the narrow, dark lanes centerward of the facular brightenings.

(C.U. Keller, M. Schüssler, A. Vögler, V. Zhakarov)

Solar transition region and corona

Ultraviolet observations of the Sun

As an invited contribution to *Space Science Reviews* a comprehensive review article was written on solar ultraviolet observations. The content of the paper as outlined in the abstract is reproduced here.

Studies of the high-temperature solar atmosphere are to a large extent based on spectroscopic observations of emission lines and continuum radiation in the vacuum-ultraviolet (VUV) wavelength range of the electromagnetic spectrum. In addition, important contributions stem from soft X-ray measurements. Most of the VUV radiation is produced by transitions of atoms and ions. The resulting atomic and ionic spectral lines have formation temperatures between 10 000 K and several million kelvin, representative of the chromosphere, the transition region and the corona (see for example Fig. 21). Some molecular lines and the continua originate in cooler regions of the Sun, around and below the temperature minimum between the photosphere and the chromosphere.

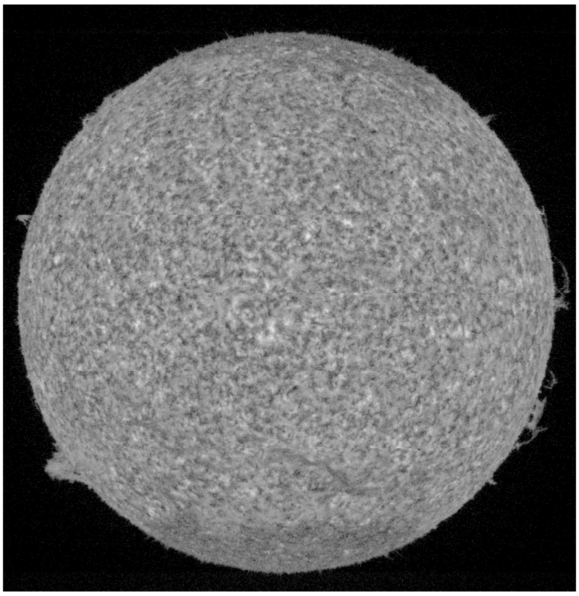

Fig. 21: A solar image in the radiation of the He I (58.4 nm) line obtained by SUMER on 2 – 4 March 1996. The chromospheric network, polar coronal holes, macrospicules, and prominences can be seen.

Radiation at VUV wavelengths is strongly absorbed by the Earth's atmosphere. Consequently, it can only be detected with instruments on sounding rockets and spacecraft operating above the atmosphere. The progress in this field of research, in particular over the last 25 years, will be presented in the first part of this review by describing the concepts and instrumentation of modern spectrographs and imaging telescopes.

This presentation is accompanied by some examples of high-resolution solar images and a discussion of radiometric-calibration aspects and wavelength measurements.

(K. Wilhelm, B.N. Dwivedi, E. Marsch, U. Feldman)

Stochastic simulation of quiet Sun EUV radiance time series

Radiance values of the ultraviolet (UV) emission of the quiet Sun follow a lognormal distribution, with shape and scaling parameters varying significantly over the temperature range from chromosphere to corona. We follow the suggestion that the quiet Sun emission is produced entirely by a stochastic micro- or nanoflaring process and employ a simple model to reproduce the measured probability densities of quiet Sun time series.

Our model consists of a time series of random kicks, each followed by an exponentially decrease. These kicks represent micro- or nanoflares. The resulting radiance values are given by the sum of the overlapping transient events. The model can analytically be described by a stochastic differential equation (with multiplicative noise) and the resulting probability density is described by a Fokker-Planck equation, i.e., a diffusion equation.

We find that a power law distributed excitation (i.e. power law distribution of micro-flare energies) generally results in a lognormal distribution for the radiances and that the shape of the lognormal is influenced by the form of the flare distribution providing the driving input, as well as by the flare frequency and the duration or damping time of the individual flares. By varying the model parameters we can establish simple relations between flaring frequency and damping times and the parameters of the resulting lognormal distribution. For example, the stronger the damping of the input process (i.e., smaller damping time) and the more frequent the excitation process, the more symmetric the resulting radiance distribution becomes. This result is plausible as the input process then approaches Gaussian White Noise.

The resulting model time series show a good statistical match with SUMER and CDS time series of equivalent sampling. It also provides a framework in which to understand the lognormal distribution of radiances in the quiet Sun. This result provides further support for the micro- and nanoflare scenario for coronal heating.

(S.K. Solanki, in collaboration with A. Pauluhn, International Space Science Institute, Bern, Switzerland)

Cyclotron wave heating of coronal ions

A scenario for coronal heating was suggested by Axford and McKenzie (1997), in which reconnection in the chromospheric network (see Fig. 22) is assumed to create high-frequency plasma waves, which are considered as the main energy source for the heating of the open corona and the generation of the fast solar wind. Many SUMER observations (described in the previous annual report) were made in the polar coronal holes and indicate that the solar wind emanates directly from the chromospheric magnetic network, whereby the whole coronal base is involved, with relatively high upward initial speeds.

Below the base, the coronal magnetic field (of about 10 G) is mainly anchored in the supergranular network, which occupies merely 10% of the base area in holes. The dynamic network field (of about 10 – 100 G) is again rooted in the photosphere in small, kG-field flux tubes (about 100 km in size) and expands rapidly with height in the transition region, thus filling the entire corona.

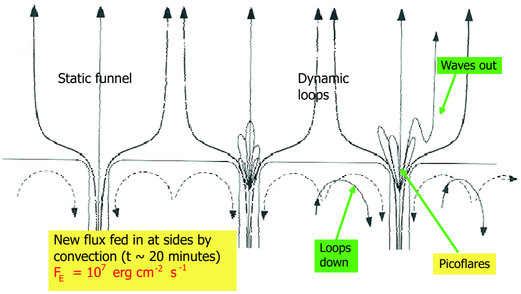

Fig. 22: Schematic of the supergranular magnetic network consisting of coronal funnels and embedded small-scale loops, which may reconnect intermittently while being driven by magnetoconvection. Thereby, high-frequency waves are generated and released on open filed lines to the overlying corona.

Multi-fluid and kinetic models on the basis of quasilinear theory (QLT), which include the damping of the cyclotron waves, were in the past years developed by us to describe coronal funnels. It was shown that a self-consistent kinetic treatment of wave damping and absorption is necessary. QLT predicts that ions in resonance with ion-cyclotron waves merely suffer pitch-angle diffusion. Evidence for this process was found in Helios *in situ* solar wind data. In the numerical results obtained from a semi-kinetic model for a coronal hole, the ion velocity distributions showed a “plateau”, which is defined by a vanishing pitch-angle gradient at the resonance and implies marginal plasma stability.

The integration of the ion velocity distribution functions (VDFs) over the velocity components perpendicular to the background magnetic field yields “reduced VDFs”. Based on them, a semi-kinetic model was developed in Lindau. Its essential ingredients are the following: The model consists of a closed set of reduced quasilinear diffusion equations and thus includes wave-particle interactions, described within the framework of QLT, and also considers ion Coulomb collisions, as calculated by using the Landau collision integral. These coupled Vlasov/Boltzmann equations for the reduced VDFs are solved numerically for a coronal funnel and hole geometry.

The wave-heating idea was corroborated in a two-fluid wave-driven solar wind model. Furthermore, parametric studies of the wind properties in dependence on the average wave amplitude at the coronal base were carried out. A key feature of this model is that the damping of Alfvén/cyclotron waves at the ion cyclotron frequency in a rapidly declining magnetic field (frequency sweeping), can provide the required strong heating close to the Sun if sufficient wave energy can initially be injected at the base or continuously be provided by a turbulent cascade.

(E. Marsch, C. Vocks, C.Y. Tu)

Waves in the solar corona

As the outcome of an invited talk given at the Assembly of the International Astronomical Union in Sidney (Australia) in 2003, a short review article was written on coronal waves. The content of the paper as given in the abstract is summarized below.

Waves at all scales, ranging in wavelength from the size of a loop (fraction of a solar radius) down to the gyroradii of coronal ions (about hundred meters), are believed to play a key role in the transport of mechanical energy from the chromosphere to the Sun’s corona and wind, and through the dissipation of wave energy in the heating and sustaining of the solar corona. A concise review of new observations and theories of waves in the magnetically confined (loops) as well as open (holes) corona is given. Evidence obtained from spectroscopy of lines emitted by coronal ions points to cyclotron resonance absorption as a possible cause of the observed emission-line broadenings. Novel remote-sensing solar observations reveal low-frequency loop oscillations as expected from MHD theory, which appear to be excited by magnetic activity in connection with flares and to be strongly damped. Kinetic models of the corona indicate the importance of wave-particle interactions that hold the key to understand ion acceleration and heating by high-frequency waves.

(E. Marsch)

Plasma outflow and mass flux in an equatorial coronal hole

With SOHO novel solar observations of an equatorial coronal hole were made. They concern the source of the fast solar wind that was identified by directly comparing Doppler-velocity maps of the ultraviolet emission line of Ne^{7+} with charts of the photospheric magnetic field in the hole, which was observed together by SUMER and NSO/Kitt Peak on November 5, 1999 (see also Fig. 20 of the previous annual report). The relationship between the velocity field, line intensity and magnetic network was analysed.

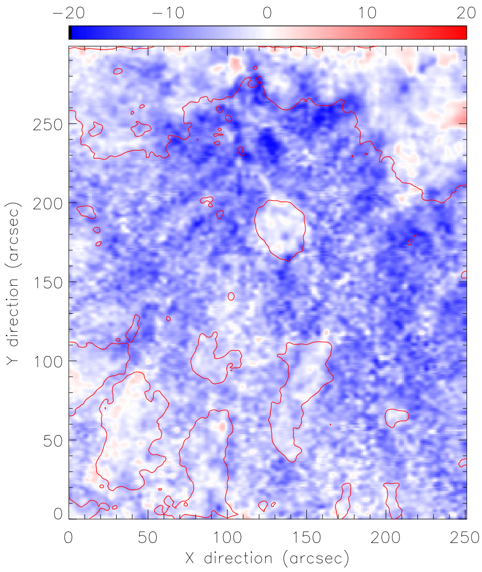

Fig. 23: Doppler shifts in km s^{-1} of the Ne VIII (77.0 nm) line, with the cool line C I (154.2 nm) as a wavelength reference. Note the predominance of blue shifts. The overlaid red contours relate to the line intensity. The uppermost part of the image is located outside the equatorial coronal hole.

The data shown in Fig. 23 indicate that there are both dark and bright regions in this coronal hole as seen in the Ne VIII (77.0 nm) (in 2nd order) line. Larger blue shifts are associated mainly with darker regions, where the strong magnetic flux with a single polarity is concentrated. Conversely, smaller blue shifts are measured mainly in brighter regions, with an underlying mixed-polarity magnetic field structure. These observational results are in agreement with the model prediction that the fast solar wind originates in coronal funnels, which are regions with globally open magnetic fields (see Fig. 22) rooted in the network lanes.

The relative contributions of the dark regions and bright points to the total outward mass flux can be estimated under the assumption that the deduced Doppler shift of the Ne VIII line really represents the outflow velocity of the Ne^{7+} ions, which can then be used as markers of the proton flow. Therefore one has,

$$f_{tot} = f_{bp} + f_{dr} = N_{e,bp} v_{bp} A_{dp} + N_{e,dr} v_{dr} A_{dr} \ , \tag{1}$$

where f, v and A are the mass flux, measured (Doppler) outflow velocity and flux tube area, which could be inferred from the simultaneously measured magnetic flux. $N_{e,bp}$ and $N_{e,dr}$ denote the electron density in bright points and dark regions. Their ratio can be estimated from the line intensity ratio, by simply assuming the emission volume for a given line has the same bottom area. Empirically one finds that

$$\frac{N_{e,bp}}{N_{e,dr}} \approx \sqrt{\frac{I_{bp}}{I_{dr}}} \approx 1.8 \ . \tag{2}$$

The mass flux contributed by bright points to the total outflow within the measured hole area, f_{bp}/f_{tot}, is thus estimated to be about 12%. This estimate is consistent with previous values in the literature, and suggests that the portion of the mass flux contributed by bright points to the fast solar wind is at most comparable to the relative area they cover and therefore negligable. Funnels make the major contributions to the mass flux of the nascent solar wind.

(L.D. Xia, E. Marsch, W. Curdt)

Network structures and Doppler shifts in solar equatorial coronal holes

By combining observations of the Sun made by SUMER and the Michelson Doppler Imager (MDI) aboard SOHO, the network structures in equatorial coronal holes have been studied, in particular the relationship between the ultraviolet emission-line parameters (line radiance, Doppler shift and line width) and the magnetic field. The bases of coronal holes as seen in chromospheric spectral lines with relatively low formation temperatures generally have similar properties as normal quiet-Sun regions, i.e., small bright patches with a size of about 2 arcsec to 10 arcsec are the dominant features in the network as well as cell interiors. With increasing formation temperature, these features become more diffuse and larger. Loop-like structures are the most prominent features in the transition region. In coronal holes, they seem to have one footpoint rooted in the intra-network and to extend into the cell interiors. Some of them appear as star-shape clusters.

In Dopplergrams of typical transition region lines, such as O VI (103.2 nm), there are also many fine structures with apparent blue shifts, although, on average they appear red shifted. Structures with blue shifts usually have also broader line widths. They seem to represent plasma above large concentrations of unipolar magnetic field, without obvious bipolar photospheric magnetic features nearby. The difference between the average Doppler shift in quiet Sun regions and coronal holes around the equator are for various emission lines shown in Fig. 24.

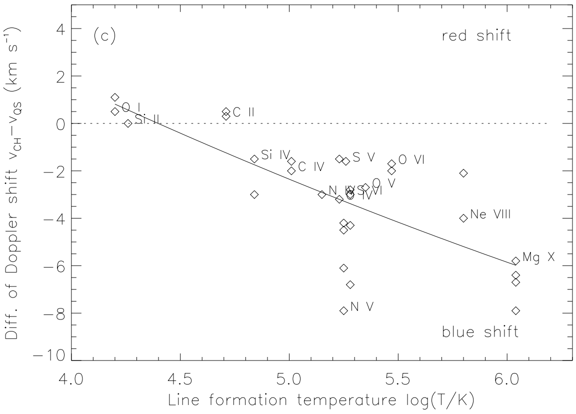

Fig. 24: Difference between the average Doppler shift in quiet Sun regions and equatorial coronal holes for various emission lines versus the line formation (electron) temperature.

(L.D. Xia, E. Marsch, K. Wilhelm)

Spatial mapping of scattering polarisation at the solar limb

To investigate the topology of scattering polarisation at the solar limb we recorded polarised filtergrams in the core of the Ca II K line with the Zurich Imaging Polarimeter ZIMPOL II at the New Swedish Solar Telescope on La Palma. The Ca II K line is chosen for the following reasons: (i) It exhibits a strong scattering polarization signal. (ii) The relatively large line width better matches the relatively broad filter pass band (0.1 nm) than is the case for most other scattering lines in the solar spectrum. (iii) This line has a rich and intriguing spectral structure with considerable diagnostic potential. (iv) Its properties have been well explored in the spectral domain.

A first inspection of the data (see Fig. 25) shows clear signatures of scattering polarisation not only in a narrow limb zone but also above the visible solar limb in spicules, as well as in regions corresponding to network boundaries. While circular polarisation due to the Zeeman effect is not detected due to spectral smearing, signatures of Hanle rotation are prominent in the limb zone as well as in the observed spicules. Observations of this type harbour potential for diagnostics of chromospheric magnetic fields. The preliminary data are promising and justify further investigation.

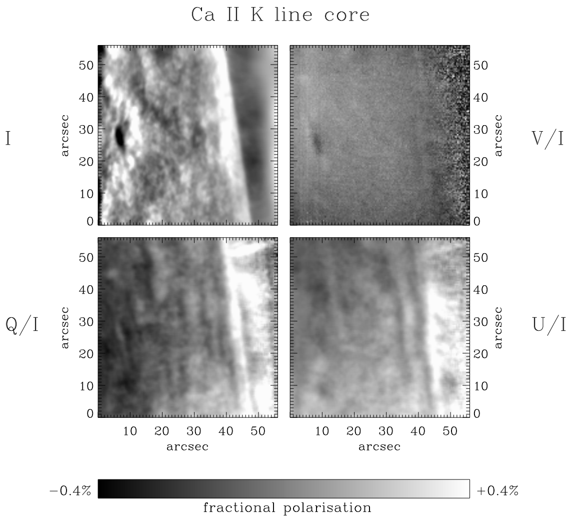

Fig. 25: Stokes images of a solar limb region in the core of the Ca II K line. While scattering induces linear polarisation (Stokes Q and U) circular polarisation due to Zeeman effect is not detected due to cancellation effects within the broad bandpass of the employed filter.

(A. Gandorfer in collaboration with A. Feller and J. Stenflo, both ETH Zurich)

Systematic exploration of the *second solar spectrum*

The linearly polarised spectrum, which can be observed at the solar limb has been referred to as the *second solar spectrum*, since it shows a remarkable spectral structuring, since different physical processes contribute to its formation. In the absence of magnetic fields, scattering is the primary source of polarisation, which can be altered by magnetic fields via the Hanle effect. Before the Hanle effect can be efficiently used for solar magnetic field diagnostics we have to explore and understand the wealth of spectral structures in the *second solar spectrum*. The observation of the *second solar spectrum* requires highly sensitive spectropolarimetry in combination with very high spectral resolution. Therefore the Zurich Imaging Polarimeter ZIMPOL II has been used at the largest solar telescope, the 1.5 m McMath-Pierce facility on Kitt Peak (Arizona). A complete survey of the scattering polarisation could be completed in the wavelength interval from 700 nm down to 316 nm near the atmospheric cut-off. The data-set is being published as a series of books (Vols. 1 and 2 are published, Vol. 3 is in preparation) to serve as a reference for future observations and to guide theoretical studies in the rapidly evolving field of solar science. A sample page is shown below (Fig. 26).

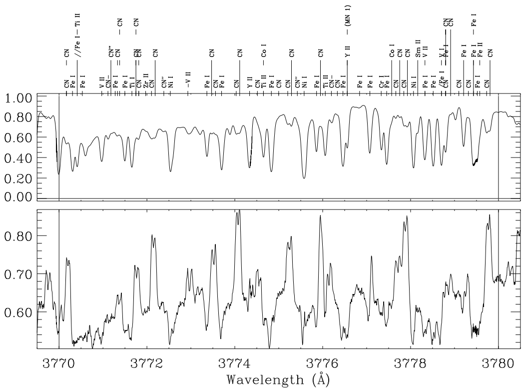

Fig. 26: Fraunhofer (upper panel) and second solar spectrum (lower panel) around 3770 Åshowing strong polarisation due to resonance scattering at the CN molecule.

(A. Gandorfer)

Transition region small-scale dynamics as seen by SUMER on SOHO

High spectral, spatial and temporal resolution UV observations of the quiet Sun transition region show a highly structured and dynamical environment where transient supersonic flows are commonly observed. Strongly non-Gaussian line profiles are the spectral signatures of these flows and are known in the literature as explosive events. We present a high spatial resolution ($\approx 1''$) spectroheliogram of a $273'' \times 291''$ wide area of the quiet Sun acquired with SUMER/SOHO in the O VI spectral line at 103.2 nm. The extremely high quality of these observations allows us to identify tens of explosive events from which we estimate an average size of 1 800 km and a birthrate of 2 500 s^{-1} over the entire Sun. Estimates of the kinetic and enthalpy fluxes associated with these events show that explosive events are not important as far as solar coronal heating is concerned. The relationship with the underlying photospheric magnetic field is also studied, revealing that explosive events generally occur in regions with weak (and, very likely, mixed polarity) magnetic flux. By studying the structure of upward and downward flows exceeding those associated to average quiet-Sun profiles, we found a clear correlation between the *excess* flows and the magnetic network. However, although explosive events are always associated with flow patterns often covering areas larger than the explosive event itself, the contrary is not true. In particular, almost all flows associated with the stronger concentrations of photospheric magnetic flux do not show non-Gaussian line profiles. In some cases, non-Gaussian line profiles are associated with supersonic flows in small magnetic loops. The case of a small loop showing a supersonic siphon-like flow is studied in detail (see Fig. 27). This is, to our knowledge, the first detection of a supersonic siphon-like flow in a quiet-Sun loop. In other cases, the flow patterns associated with explosive events suggest a relation with UV spiculae.

(L. Teriaca, in collaboration with D. Banerjee, Centre for Plasma Astrophysics, Katholieke Universiteit Leuven, Belgium, A. Falchi, Osservatorio Astrofisico di Arcetri, Firenze, Italy, J.G. Doyle, Armagh Observatory, Armagh, UK, M.S. Madjarska, Mullard Space Science Laboratory, Holmbury St Mary, UK)

On the widths of the Mg X lines near 60 nm in the corona

Harrison et al. (2002, A&A, 392, 319) reported the narrowing of the Mg X 62.50 nm line with height in the quiet near-equatorial solar corona, thereby concluding that this narrowing is most likely evidence of dissipation of Alfvén waves in closed field-line regions. Similarly, a significant change in slope of the line width as a function of height was seen in polar coronal holes by O'Shea et al. (2003, A&A, 400, 1065) at an altitude of ≈ 65 Mm. These results obtained with the Coronal Diagnostic Spectrometer (CDS), if confirmed, could be of the utmost importance in understanding the mechanisms that heat the corona. Due to the broad instrumental profile, the CDS instrument can only study line-width variations and cannot provide measurements of the line width itself, and, hence, of the effective ion temperature. The latter quantity is critical in constraining theoretical models of coronal heating and solar-wind acceleration, for instance, through the dissipation of high-frequency waves generated by chromospheric reconnection. The problem was further studied by analysing data recorded with the SUMER spectrograph in the Mg X doublet in both the quiet equatorial corona and in a polar coronal hole. Due to the high spectral resolution of SUMER, it was possible to measure the line widths of both components of the Mg X doublet at 60.98 nm and 62.50 nm. In the low corona of the quiet Sun the Doppler width (i.e. half 1/e width) broadens from $\Delta\lambda_D \approx 8.2$ pm to ≈ 9.5 pm (with an estimated relative standard uncertainty of 4%) between the limb and 220 Mm above the limb in the equatorial corona. In a polar coronal hole, the Doppler width increases from 10.8 pm near 30 Mm to 11.4 pm around 80 Mm above the limb. The analysis does not provide any evidence for a narrowing of the emission-line profiles as a function of the distance from the solar limb. In the coronal hole, the possibility of a constant width above 80 Mm cannot be excluded.

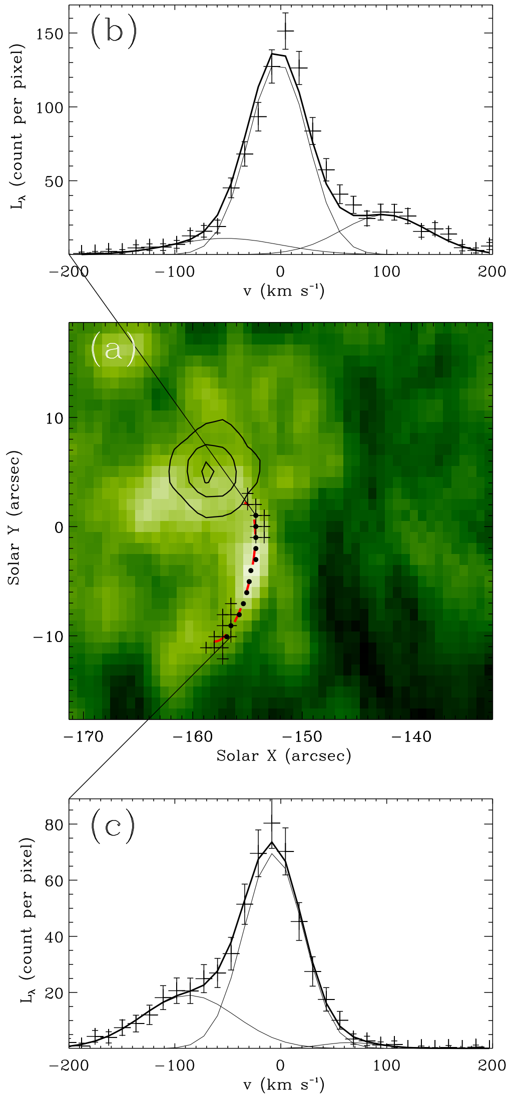

Fig. 27: **(a)** Logarithmically-scaled radiance image of the quiet Sun obtained by integrating over the O VI (103.2 nm) line after subtracting the continuum. Isocontours of the negative polarity of the longitudinal magnetic flux at (−10, −25 and −40) G are shown with black solid lines (no flux above 10 G is present in the displayed area). The locations where non-Gaussian line profiles were found are marked with a black **+**. The dashed red line indicates the projection (on the plane perpendicular to the line of sight, LOS) of a semi-circular model loop with a diameter of 13″. The loop is inclined by 18° with respect to the LOS and the footpoint line rotated by 12.5° clockwise. The black dots indicate the measured position of the observed loop. **(b)** Line profile at a location on the northern leg of the loop. The bars indicate the data points. The thin solid lines show the three components used to fit the data while the resulting fitting profile is represented by the thick solid line. **(c)** The same as for panel **b** but for the southern leg of the loop.

The observations obtained by SUMER with much higher spectral resolution seem to exclude a narrowing with altitude under quiet solar conditions. However, it was not possible to explain the discrepancy between the SUMER results and those obtained with CDS. To settle this question, new observations of the quiet corona were obtained simultaneously with SUMER and CDS in December 2003 and are currently been analysed.

(K. Wilhelm, L. Teriaca, in collaboration with B.N. Dwivedi, Department of Applied Physics, Varanasi, India)

Observations of small-scale ejecta using SUMER, UVCS and LASCO

Every six months the SOHO spacecraft, the Sun and the Ulysses spacecraft form a 90° angle. In these conditions, plasma outflowing from the Sun towards Ulysses can be detected by the instruments aboard SOHO when close to the Sun and later observed *in situ* by Ulysses. Since the fall of 2002, SUMER observations have been planned and performed in coordination with other instruments aboard SOHO and other spacecrafts.

During the fall 2002 SOHO-Sun-Ulysses quadrature, coordinated SUMER/UVCS observations were carried out off the west limb. Data were acquired over six consecutive days in several lines formed at temperatures between 2×10^4 K and 10^6 K. The SUMER slit was placed above an active region crossing the solar limb, just south of a low latitude coronal hole. In these conditions, the already partially open magnetic configuration may facilitate the escape of plasma into the heliosphere. SUMER observed repeated transient events characterized by a strong increase of the intensity of transition region and Hydrogen Lyman α and β lines with large line broadenings and line of sight velocities, while little if any variation is seen in lines formed around 10^6 K. The duration of these events varies between $10-15$ minutes up to 1 hour. The SUMER events are associated to streamer-like outflows seen in LASCO images and, in the case of a larger event, with a small jet travelling at $\sim$400 km s^{-1} across the LASCO C2 field of view.

Our results seem to confirm that high levels of activity may result from the interaction of an active region and a close-by coronal hole. This activity may include the injection of cold plasmoids into the upper corona where they may be incorporated in the solar wind.

(L. Teriaca, W. Curdt, in collaboration with G. Poletto, Osservatorio Astrofisico di Arcetri, Firenze, Italy.)

Characteristics of solar explosive events

Explosive events are one of the best studied dynamic phenomena of the transition region. They are characterized by broad line profiles with high velocity components of typically $\sim$100 km s^{-1}, a spatial size $\sim$2 arcsec (1500 km), and an average lifetime $\sim$1 min. Until now, studies of explosive events have only been made at one position, so that the overall event profiles and their structure could not be seen. In this work, we investigate the line profile behaviour across whole events in several explosive event bursts.

The spatial structure and temporal evolution of explosive events are explored using SUMER spectral observations of the Si IV (139.3 nm) line. Bursts are clustered near regions of evolving network magnetic fields. Within a burst, the explosive events are in some cases separated by $3-5$ min, suggesting that oscillations, which are known to have such periods, may play a role in triggering the individual events. Often consecutive events have very different line profile characteristics and sizes, implying that the structure of the accelerated plasma is changing at the explosive event site. One possibility is that reconnection, signalled by the event, has changed the underlying loop structure. Events tend to expand and shrink, and sometimes even move across the surface, with a speed $\sim$ 25 km s^{-1}. In the majority of events, the blue and red wing brightenings are clearly offset and $10-20$ s before the line intensity increase. As noted in an earlier study, in several events the red and blue wing emissions are offset with respect to one another implying jet-like flow.

(Zongjun Ning, D.E. Innes, S.K. Solanki)

Postflare supra-arcade dynamics

Large eruptive flares are usually followed by a period of several hours in which a highly dynamic postflare loop system develops. By obtaining SUMER spectra of the region above the loops, we hoped to discover something about the loop formation process since this is believed to be the region of reconnection that gives rise to the loops.

We observed a spectacular X1.5 flare on the west limb of the Sun on 21 April 2002 with both SUMER and TRACE. In the TRACE images, one can follow the formation of the loop arcade and above it a bright supra-arcade structure of spoke-like rays. Falling onto the arcade with a velocity of $100-400$ km s^{-1} are long dark structures, looking like tadpoles with a head and wiggly tail. Similar sunward flows have been seen in soft X-ray images but never in such sharp detail.

Several of the inflows crossed the SUMER field-of-

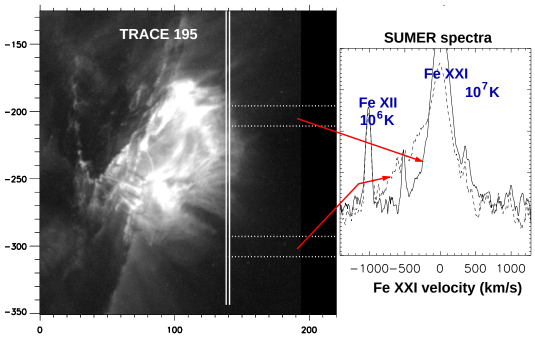

Fig. 28: TRACE 19.5 nm image and SUMER spectra showing 800 km s^{-1} Fe XXI blue shifts above the flare arcade.

view and we obtained an entirely unique series of spectra of the gas in and around the flows. The lines observed, C II, Fe XII and Fe XXI, covered the temperature range $2 \times 10^4 - 10^7$ K. There are three main results: (i) The flows are dark in all lines; (ii) Doppler shifts of 800 km s^{-1} were detected in Fe XXI in the wake of the dark inflows (see Fig. 28); (iii) oscillating red and blue Fe XXI Doppler shifts of about 10 km s^{-1} were observed along the tail of the inflows. The detection of high Fe XXI shifts tends to support the idea of a reconnection site above the arcade but because spectra were obtained at only one position we cannot rule out a disk origin. The other two results suggest that the tail is formed when background plasma is pushed aside, creating a low density, possibly high magnetic field cavity.

(Davina Innes, Tongjiang Wang)

Relationship between variability of intensity and Doppler shift in EUV-spectra

SUMER and CDS time series of spectra and images of quiet-Sun regions at the solar disc centre have been studied. The data contain ultraviolet emission lines sampling chromospheric, transition region and coronal temperature. We find a high correlation between average net Doppler shifts and relative brightness variabilities of the studied lines (correlation coefficient of 0.92), suggesting a connection between the two quantities. The anti-correlation between differential emission measures and relative brightness variabilities is weaker (correlation coefficient of -0.78). The observed relationships can be explained on the basis of differential emission measures and linear wave calculations.

(S.K. Solanki in collaboration with A. Brković and H. Peter, Kiepenheuer-Institut für Sonnenphysik, Freiburg)

Polarimetry of the solar corona

Spectropolarimetry of coronal ultraviolet lines which are sensitive to the effect of the Doppler redistribution due to ion motion and/or to the effect of the coronal magnetic field (Hanle effect) could yield more accurate information about the physical conditions of the coronal plasma. In fact, spectropolarimetry provides access to the magnetic field vector as well as the velocity field vector. In contrast, without polarimetric information the spectroscopy of lines only provides partial information on the vectorial quantities, basically through Doppler shifts.

We developed the theoretical tools necessary to study the effect of an anisotropic velocity field distribution of scattering ions on the polarization parameters of a spectral line emitted by resonance scattering in the solar corona. The anisotropy of the velocity field distribution can be interpreted in terms of the ion-cyclotron effect that is believed to influence some heavy ions in the solar corona (see papers related to UVCS/SOHO). It is found from test calculations that such a distribution measurably changes the polarization properties of the O VI (103.2 nm) coronal line. Consequently, measurements of the linear polarization of this line may serve as a new diagnostic of a possible bi-Maxwellian velocity distribution. As a preliminary application, the obtained theoretical results are used to interpret the polarization parameters of the O VI (103.2 nm) coronal line measured using SUMER/SOHO observations. The obtained results are compatible with SUMER's observations for more reasonable solar wind parameters than for an isotropic velocity field distribution of the scattering ions. These results are obtained assuming that the re-emitted photons come from a small area in the center of the coronal polar hole, with zero magnetic field. Since SUMER/SOHO observations integrate over the line of sight, the results of the current analysis must be considered preliminary pending computations including an integration along the line of sight.

(N.-E. Raouafi & S. K. Solanki)

Are large velocity distribution anisotropy really present in the solar corona?

A 3-D model of the solar corona is being developed for the calculation of spectral lines as well as of the Stokes parameters of lines emitted in the solar corona. The integration along the line of sight is taken into account and a model for the large scale of the magnetic field and a consistent treatment of the solar wind are considered. The present code can be used for any spectral line emitted at any location of the solar corona.

As a first application, we investigated the profiles of O VI (103.2 and 103.8 nm) spectral lines emitted in the corona. The influence of the electron density stratification on coronagraphic spectral observations aimed at determining the coronal macro- and microscopic velocity structure and distribution was examined. The initial computation are limited to the polar coronal holes. We found that at distances greater than 1 $R_\odot$ from the solar surface the widths of the emitted lines are significantly affected by the details of the adopted electron density profiles. In particular, the densities deduced by Doyle et al. (1999a,b) from SOHO data result in O VI profiles whose widths and intensity ratio are relatively close to the values observed by UVCS/SOHO although only isotropic velocity distributions are employed. Hence we expect the magnitude of the anisotropy of the velocity distribution deduced from UVCS observations to depend strongly on the assumed electron stratification. These results suggest the need for a careful reanalysis of the ones obtained through UVCS/SOHO observations.

(N.-E. Raouafi & S. K. Solanki)

Coronal shock waves associated with Coronal Mass Ejections (CMEs)

CMEs are the most spectacular dynamical events observed in the solar corona. Fast CMEs can create shock waves that propagate through the corona. The emission of the shocked hot gas provides a tool to determine the local plasma parameters (densities, temperature, ...). We studied on a Coronal Mass Ejection (CME) observed by the UltraViolet Coronagraph Spectrometer (UVCS) telescope operating on board the SOHO spacecraft. The analysis of data from different instruments (UVCS, LASCO, EIT/SOHO and also radio data) allowed us to determine the origin of the shock wave created during this event. Emission of hot material propagating in front of an opening system of loops generated by the CME was recorded by UVCS. The evolution of the UVCS/SOHO structure is highly correlated to the evolution of the opening loop. The data reveal excess broadening of the O VI doublet lines and an enhancement in the intensity of the Si XII (52.0 and 49.9 nm) lines (high temepratures lines) due to the motion of the expanding hot gas. The hot gas emission seems to be due to a shock wave propagating in front of a very fast gas bubble traveling along the opening loop system.

(N.-E. Raouafi, S. K. Solanki, B. Inhester, M. Mierla in collaboration with S. Mancuso & C. Benna (Observatory of Torino, Italy), G. Stenborg (NRL – Washington DC, USA) and J. P. Delaboudinière (IAS – Orsay, France))

Spectroscopic observations of heating and cooling in coronal loops

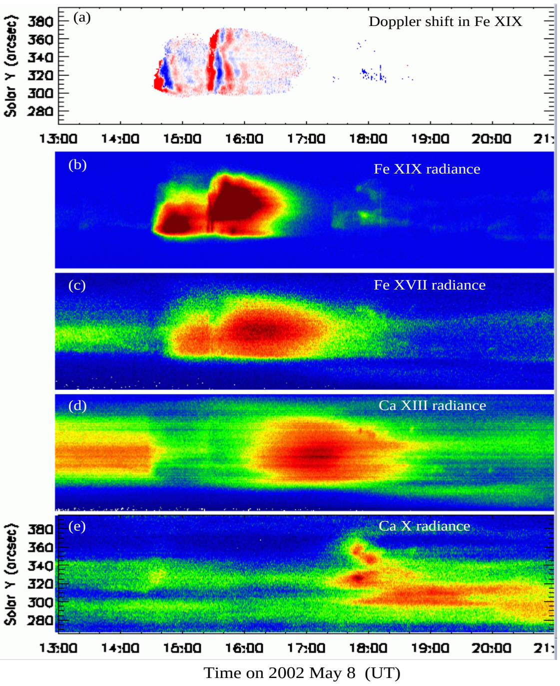

Fig. 29: A recurring micro-event observed in Fe XIX (111.8 nm) (6.3 MK, both flow and spectral radiance), Fe XVII (115.4 nm) (2.8 MK), Ca XIII (113.3 nm) (2.0 MK), and in Ca X (111.6 nm)/2 (0.7 MK).

Coronal micro-events observed by SUMER, which are known to trigger loop oscillations also carry the signatures of heating and cooling of coronal loops. We analyse the temporal behaviour of the light curves for various highly-ionized ions which were simultaneously observed during and after the trigger. From their appearance we conclude that the events have an eruptive start. This is when the impulsive energy input occurs which drives the plasma to very high temperatures of up to 10 MK within minutes. During the later phase the loops are seen in gradually decreasing temperature regimes and their undisturbed although strongly damped oscillation comes to a rest. During this undisturbed cooling phase we find the plasma in gradually decreasing ionization stages which implies that the entire loop system involved in such events is basically in the isothermal state. Therefore we assume that we see discrete (“atomic”) heating events, the majority of which occurs on subflare level.

The events seem to have a tendency to repeat. Recurring events have their initial kick always in the same direction. Therefore we conclude that the trigger must come from one of the footpoints, where the loop is anchored in the photosphere, and in a sequence of events it seems to be always the same footpoint where the activity starts. Our observations support impulsive heating models.

(W. Curdt, T.J. Wang, and D.E. Innes)

Slow-mode standing waves in hot coronal loops observed by SUMER

The SUMER spectrometer has recently discovered standing slow magnetoacoustic waves in hot coronal loops ($T \approx 6-10$ MK), through Doppler shift measurements (see *Sun and Heliosphere* highlight). We have completed an extensive study of loops with Doppler oscillations.

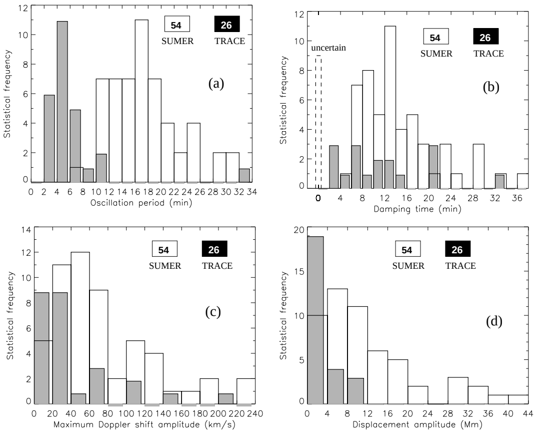

Fig. 30: Comparison of the physical parameters for the 54 SUMER loop oscillations and the 26 TRACE transverse loop oscillations. (a) Oscillation periods. (b) Decay time. (c) Velocity amplitude. (d) Displacement amplitude.

SUMER sampled loops 50 – 100 arcsec off the limb of the Sun in ultraviolet lines, mainly Fe XIX and Fe XXI. We measure physical parameters of 54 Doppler shift oscillations in 27 flare-like events (see Fig. 30). The oscillations have periods in the range 7 – 31 min, with decay times 5.5 – 37.3 min, and show an initial large Doppler shift pulse with peak velocities up to 200 km s^{-1}. They are mostly not triggered by large flares, and may recur 2 – 3 times within a couple of hours. We have found various lines of evidence to support an interpretation of these oscillations in terms of slow-mode standing waves in hot loops: (1) The intensity fluctuation lags the Doppler shifts by 1/4 period; (2) the phase speeds derived from observed periods and loop lengths roughly agree with the sound speed; (3) the dissipation time scales with period in accordance with the expectations of slow waves.

(T. J. Wang, W. Curdt, D. E. Innes, and S. K. Solanki)

Coronal holes

Coronal holes have the same properties as quiet Sun regions in chromospheric emission lines, but for coronal lines the average intensity is lower in coronal holes. A key quantity for the understanding of these phenomena is the magnetic field. We use data from SOHO/MDI and reconstruct the magnetic field in coronal holes and the quiet Sun with help of a potential magnetic field model.

Table 1: Average height H and length L of closed magnetic structures in coronal holes and the quiet Sun.

	H/Mm	L/Mm
Coronal holes	0.87 ± 0.4	7.8 ± 3.9
Quiet sun	2.78 ± 1.0	13.2 ± 4.6

Our results give evidence that closed magnetic structures in coronal holes are in average shorter and lower than in the quiet Sun (Table 1). The reason is that the majority of the magnetic flux is not balanced in coronal holes. This signed magnetic flux leads to open magnetic structures, where the plasma is dilute and of low emissivity. The small portion of balanced flux closes at low heights. High and long closed loops are consequently extremely rare in coronal holes. The source of hot coronal line emission are magnetic closed coronal loops and the lack of these loops in coronal holes explains the reduced emissivity (Fig. 31).

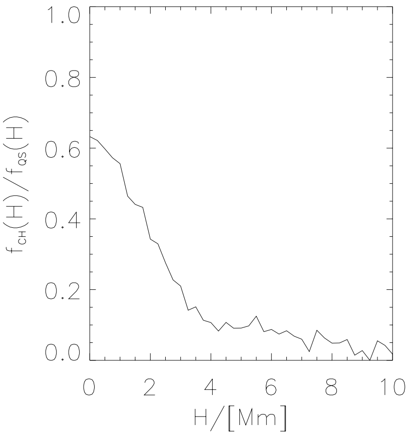

Fig. 31: Height distribution of closed magnetic loops in coronal holes compared with the quiet Sun. The lack of high reaching closed magnetic structures in coronal holes (less than 10% compared with the quiet Sun) explain the reduced hot coronal line emission.

(T. Wiegelmann, S.K. Solanki, B. Inhester)

Magnetic field modelling, stereoscopy and tomography for SECCHI on STEREO

The Sun Earth Connection Coronal and Heliospheric Investigation (SECCHI) experiment on the NASA STEREO mission is a set of telescopes which aim to observe the genesis, the eruption and interplanetary propagation of coronal mass ejections (CME). Both the initial condition on the Sun's surface and the later evolution are strongly determined by magnetic fields and their three-dimensional shape. The two STEREO spacecrafts will enable for the first time continuous and simultaneous observations of CMEs from two different vantage points in space and will thus allow to reconstruct its three-dimensional structure and evolution. One part of the institute's contribution to this project consists of the preparation of software tools for the three-dimensional analysis of the SECCHI data. These tools make use of stereoscopic and tomographic algorithms. The three-dimensional reconstruction is a deeply ill-posed problem and experiments with artificial data have shown that the information about the magnetic field can greatly improve the outcome of these reconstructions. The software contributions we are working on are therefore threefold:

- Modelling of the coronal magnetic field from photospheric surface observations
- Stereoscopic reconstruction of active region loops from EUV observations
- Tomographic inversion of white-light coronagraph observations to obtain a 3D density distribution of the corona.

All these tools collaborate to some extent and the magnetic field information has turned out to be the key information to be exchanged. For this reason most effort has gone during the last two years into the magnetic field modelling part. We have coded various magnetic field extrapolation models: Potential field, constant-α force-free field, non-linear force-free field and more general magnetostatic equilibria. They differ by the complexity of the self-consistent electric current allowed to flow in these models. The potential field has no current at all, the constant-α force-free field model includes a current density proportional to the local magnetic field. The non-linear force-free field model is more general with the proportionality constant varying among the field lines.

Concerning stereoscopy, we hope to manage the matching problem with the help of a first order magnetic field model. The image pair which is the basic input data usually displays a large number of loop structures. For the stereo reconstruction they have to be identified individually in both images. Some preliminary experiments show that the magnetic field could be a decisive help for this identification (Fig. 32).

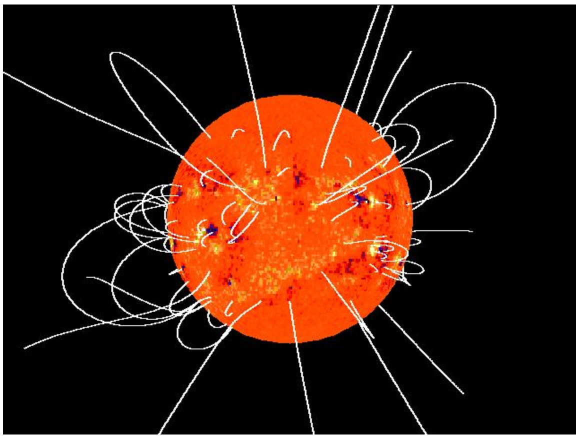

Fig. 32: Example of a potential magnetic field matched to the observed line-of-sight component of the photospheric field vector. The field is represented here by a few individual field lines.

The tomography tool is close to completion. We have been experimenting with different image patterns which allow an optimum of resolution for a given amount of data. A regularisation part which smoothes the model differently along and perpendicular to magnetic field direction has been completed but still needs to be integrated.

(R. Schwenn, B. Inhester, E. Marsch, B. Podlipnik, F. Portier-Fozzani, S. Solanki, T. Wiegelmann as part of a collaboration led by R. Howard, NRL, Washington)

Vector tomography for the coronal magnetic field

We apply a tomographic technique in order to reconstruct the configuration of the vector magnetic field in the whole solar corona. Our simulations are based on data which can be obtained from Faraday rotation and resonance scattering (emission lines of Fe^{12+} and Fe^{13+} ions) measurements. Faraday-effect provide the integrated line-of-sight component of the magnetic field. But, it is known that the divergence of a vector field cannot be reconstructed from such data. On the other side, resonance scattering measurements (Hanle-effect) provides for magnetic field only the directional information in the plane of the sky. To make the problem more determined we introduced an additional regularization constraint $\nabla \cdot \mathbf{B} = 0$ for the inversion. This term together with solar surface magnetogram data allows us to more precisely reconstruct both strength and direction of the magnetic field in the corona.

It has been found that using tomography technique based on the data obtained from Faraday- and Hanle-effect measurements, it is possible to reconstruct magnetic field configuration in the solar corona.

(M. Kramar, B. Inhester)

Solar wind and heliosphere

Solar corona and solar wind

Dynamic sun and solar wind

As a contribution to the book *Dynamic Sun* published by Cambridge University Press, a review was written about the solar wind, discussing theory and observations. The article content as summarized in the abstract is presented in the subsequent paragraph.

There are three major types of solar wind: The steady fast wind originating in coronal holes, the unsteady slow wind (coming partly from opening streamers) and the very fast transient wind in the form of coronal mass ejections. The fast streams are, at least during solar minimum, the normal modes of the solar wind. Their basic properties can be reproduced by multi-fluid models involving waves. We briefly review the history of the subject and describe some of the modern theories of the fast wind. We then discuss the boundary conditions and *in situ* constraints which are imposed on the models, in particular by Ulysses at high latitudes. The recent SOHO observations have brought a wealth of new informations on the state of the wind in the inner corona as well as the plasma source conditions prevailing in the transition region and solar chromosphere. Some of these results are presented here. Finally, problem areas are identified, and future research perspectives are outlined.

(E. Marsch, W.I. Axford, J.F. McKenzie)

The microstate of the solar wind

In an invited review talk given at the *Solar Wind Ten* conference held in Pisa (Italy) in 2002, the microscopic state of the solar wind was reviewed, in particular the measurements and models for the proton and electron velocity distributions and kinetic features of heavy ions in the fast solar wind and coronal holes. It is now generally accepted that the electron distributions are largely determined by Coulomb collisions.

Concerning the ions, there is mounting evidence that pitch-angle diffusion in resonance with ion-cyclotron waves is the main process forming the shape of ion velocity distributions. Moreover, the absorption of high-frequency waves seems to play a major role in the heating of the corona and solar wind. Understanding dispersive plasma waves and the associated wave-particle interactions holds the key to this problem. Plasma stability analyses and model calculations, as well as observations adressing these subjects were briefly reviewed, while focussing on the critical kinetic physics issues.

(E. Marsch)

Ion velocity distributions and cyclotron wave absorption or opacity

The wave absorption coefficient or opacity is a key parameter in the phyiscs of wave heating of the solar corona. In simulation results, obtained by solving our model equations numerically, it is found that heavy ions are preferentially heated, and that considerable temperature anisotropies thereby develop. The velocity distribution functions (VDFs) of the heavy ions deviate strongly from Maxwellians, an effect which increases with height in the corona due to the declining efficiency of Coulomb collisions.

The corresponding wave spectra, as calculated numerically in the diffusion model, show rather deep absorption edges that occur at and below the ion gyrofrequencies of the species involved. At a certain height, all waves with frequencies above the lowest ion gyrofrequency will have suffered severe damping. This is the essence of the *frequency sweeping* mechanism introduced and worked out in detail by the Lindau group. Because of this strong absorption, it was argued that the waves solely originating from the coronal base would not suffice to heat coronal ions, but that local wave production was required too.

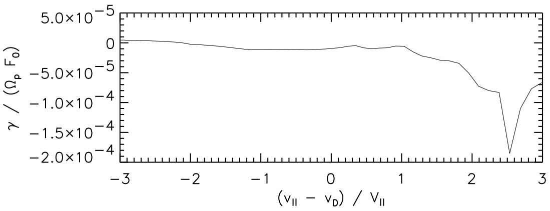

Fig. 33: Normalized damping rate (per resonant particle) as a function of the resonant speed of O^{5+} ions calculated at 2.46 R_s. The plot displays a distinct flatness of the curve over a wide range of speeds, corresponding to a quasilinear plateau in the VDF.

However, the wave damping rate γ is a sensitive function of the VDF. For cyclotron waves propagating parallel to the background magnetic field in a multicomponent plasma, this normalized damping rate is plotted in Fig. 33 for resonant oxygen ions. Over a wide range of negative speeds γ is close to zero, meaning that the VDF calculated from the diffusion model has reached marginal stability. Apparently, a major fraction of the oxygen ions then has a wave absorption coefficient close to zero, i.e. their opacity vanishes, whereupon wave heating of ions with higher resonance frequencies (such as alpha particles and protons) is facilitated in the extended corona.

(C. Vocks, E. Marsch)

Anisotropy regulation by pitch-angle diffusion of protons in resonance with cyclotron waves

For solar wind protons evidence was found that the shape and temperature anisotropy of the core part of their VDFs can be explained by wave-induced plateau formation according to quasilinear theory (QLT). The plateau is formed by protons in resonance with cyclotron waves, which are assumed to propagate both outwardly and inwardly, at phase speeds following from the plasma dispersion relation. An example is shown in Fig. 34. For VDFs measured near 0.3 AU in fast low-beta solar wind, the theoretical predictions of QLT, using the cold plasma dispersion relation, agree well with the *in situ* observations.

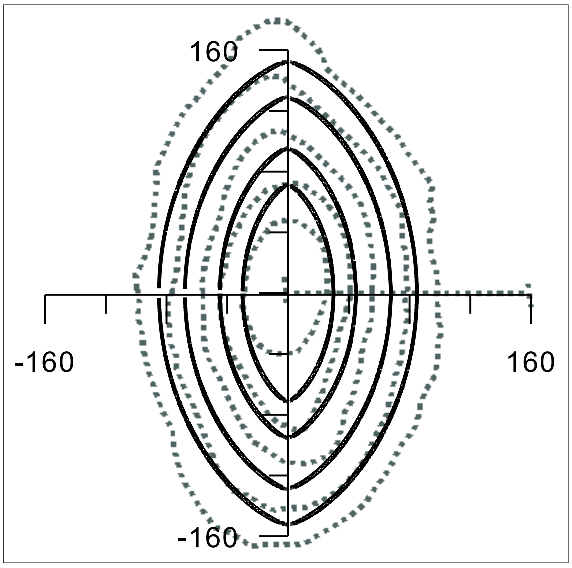

Fig. 34: Comparison of measured with theoretical contours in velocity space for a solar wind proton VDF (from Helios). Velocity components are in units of km/s, parallel and perpendicular to the field. The solid lines represent the contours (for zero pitch-angle gradient) of the diffusion plateau as formed by cyclotron resonance of protons with outward (respectively inward) propagating waves. The dotted contours are measured and given in fractions of 0.8, 0.6, 0.4, 0.2, 0.1 of the maximum.

For the proton VDFs measured near 1 AU in fast high-beta wind, the prediction of QLT, when using again the cold-plasma dispersion relation, only gives an upper limit for the anisotropy. Yet, when considering thermal effects in the dispersion relation, a better agreement between the theory based on resonant ion diffusion and the observations is obtained. For non-dispersive waves, a simple relation between the ion thermal speed parallel to the magnetic field and the ion temperature anisotropy could be derived, which was shown to be consistent with the anisotropy predicted by a numerical hybrid simulation of the ion-temperature regulation by waves.

(C.Y. Tu, E. Marsch)

Formation of the proton beam distribution in high-speed solar wind

A new mechanism was suggested to explain the formation of proton beam velocity distributions in high-speed streams of the solar wind. Observationally, proton beams move faster than the core part of the proton distribution by more than the local Alfvén speed. Until today none of the major properties of the observed beams were adequately explained. The basic difficulty faced by previous investigations was that in a proton-electron plasma hardly any cyclotron waves were found to be in resonance with the beam protons.

However, when considering a proton-alpha-electron plasma, one finds a second dispersion branch of outward propagating waves, as shown in Fig. 35. This new branch owes its existence mainly to the alpha particles drifting at the Alfvén speed. The associated waves can resonate with the beam protons.

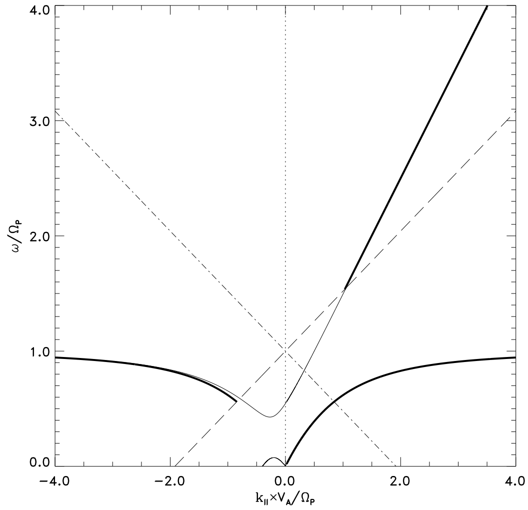

Fig. 35: The dispersion relation for left-hand polarized waves in a cold plasma with an alpha-particle abundance of $\eta_\alpha = 0.05$, and drift speed of $U_\alpha = V_A$. Similarly for the proton beam, $\eta_b = 0.1$, and $U_b = V_A$. The dashed-dotted and dashed lines show the cyclotron-resonance condition, for the speed $v_\parallel / V_A = -0.52$ and $v_\parallel / V_A = 0.52$, respectively. The thick parts of the curves indicate the new dispersion branch.

The corresponding time-dependent diffusion equation, as determined from the quasi-linear theory of ion-cyclotron-wave resonance, was solved numerically.

The results showed that, caused by diffusion in the wave field, a proton beam formed out of an initially bi-Maxwellian VDF. The drift speed of the model beam was about the Alfvén speed.

(E. Marsch in collaboration with C.Y. Tu and L.H. Wang, Department of Geophysics, Peking University, Beijing, China)

Interplanetary and solar surface properties of coronal holes

Coronal holes are magnetically open regions of the Sun. Their intrinsic properties and their evolution with time are not only of importance for the understanding of the nature of the solar magnetic field, as well as solar wind acceleration and heating, but are also of interest for the geomagnetic environment, since they constitute a major source of the interplanetary magnetic field and the near-ecliptic solar wind. The geometric simplest configuration prevails around solar minimum, with large coronal holes at both solar poles. As the Sun approaches activity maximum these polar coronal holes (PCHs) diminish in size and finally vanish. Instead, relatively short-lived, smaller-sized holes appear at all latitudes. We used data from the Solar Wind Ion Composition Spectrometer (SWICS) on the Ulysses spacecraft and synoptic maps from Kitt Peak to analyse the evolution of coronal holes in the solar activity cycles 22 and 23 (from 1990 to mid-2003). We found significant differences between the south and north polar coronal holes during cycle 22. The coronal temperature inferred from ionic charge composition data is about 15% larger in the south polar coronal hole. The ground-based magnetograms show that the north PCH covers a larger part of the solar surface than the southern one. However, the total magnetic flux and, specifically, the flux density of the north PCH is considerably lower, persistently throughout the minimum phase. Furthermore, in the beginning of the declining phase of solar cycles 22 and 23, the north PCHs appear about one year earlier than the ones in the south polar region. These independent observations strongly suggest that during solar cycle 22 and 23 the global structure of the Sun's corona exhibited significant north-south asymmetries. The ultimate cause for these hemispherical asymmetries remains yet to be resolved.

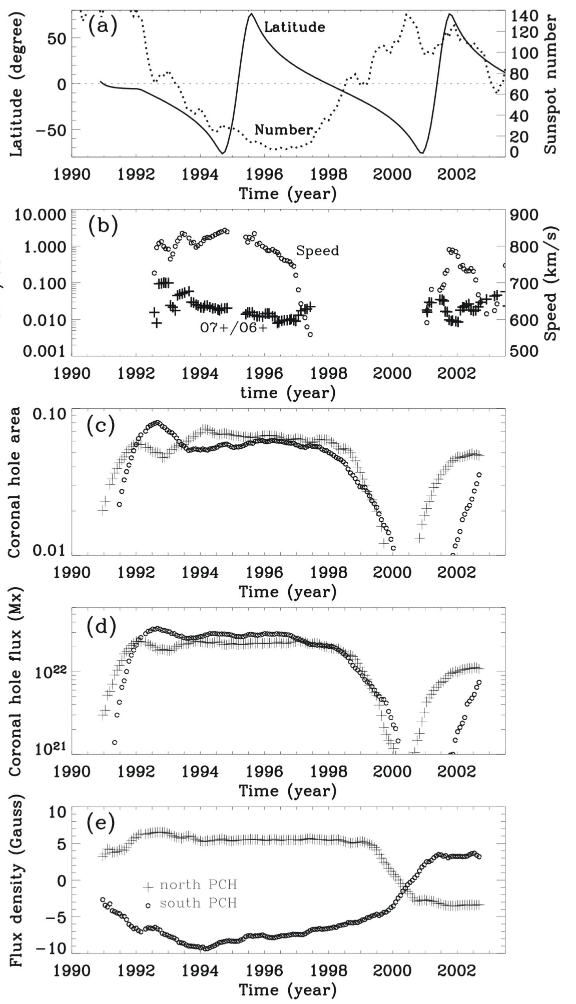

Fig. 36: Selected solar wind and polar coronal hole parameters from 1990 to the mid-2003. (a) Heliographic latitude of Ulysses and sunspot number; (b) O^{7+}/O^{6+} ratio as proxy for coronal temperatures and solar wind speed as measured by SWICS/Ulysses; (c) area of the south PCH (o) and north PCH (+) estimated from Kitt Peak He I (108.3 nm) synoptic maps as fraction of the solar surface; (d) net magnetic flux of the south (north) PCH derived from Kitt Peak synoptic magnetograms; (e) same as in (d) but for net magnetic flux density.

Ulysses observations were furthermore used to study spatial variations within PCHs. The speed of the solar wind emanating from newly forming PCHs as well as the temperature within these holes show a characteristic dependence on distance to the coronal hole center. The temperature is lowest in the center and increases towards the edges of the coronal holes, the speed is highest in the center and decreases towards the edges. Whereas the characteristic speed variation persists throughout the lifetime of a PCH, the temperature gradient disappears some time after the formation of a PCH and the temperature becomes essentially uniform in PCHs at and after solar minimum. These findings bear important implications for the formation and decay process of the PCHs.

Solar wind streams emanating from small-scale coronal holes which emerge during solar maximum at all solar latitudes generally show lower velocities of 400 to 600 km/s compared to the polar hole stream velocities of 700 to 800 km/s. However, the coronal temperatures, do not reveal a consistent difference. Though a number of solar maximum holes have a significantly higher temperature compared to the PCHs, the majority of the investigated holes, specifically those which newly emerged, have a coronal temperature within the range of polar hole temperatures. Likewise, the magnetic flux density in the solar maximum holes and in the PCHs, as derived from synoptic maps, is not strikingly different. Therefore, any intrinsic difference between solar maximum and polar coronal holes is small. The striking discrepancy in their kinetic properties, namely the lower velocity of the solar wind streams from solar maximum holes, may partly be attributed to the influence of active regions in close proximity to the holes.

(J. Zhang, J. Woch, S. K. Solanki, in collaboration with R. von Steiger, ISSI Bern)

Dynamics of the solar corona

Revealing the dynamic nature of the solar corona has made major progress in recent years using modern instrumentation both on the ground and in space. In particular, with advent of the LASCO coronagraphs on SOHO, a new quality of coronal observations could be obtained. The field of view now extends from 1.1 $R_\odot$ (C1) to 30 $R_\odot$ (C3), with sufficient sensitivity to make visible even the almost continuous solar wind outflow in the streamer belt. We report on two different approaches to study plasma motions, both in the plane of the sky and along the line of sight.

1. By means of a multi-resolution image processing technique based on wavelet packets the boundaries and the internal details of originally faint and diffuse structures are enhanced (see the figure). These contrast-enhanced coronagraph images are then subdivided in angular sectors ('Pizza slices'), with radial and angular extents chosen according to needs. A time series of such images covering a selected event forms a data cube that can be analysed in various ways: For example, height-time diagrams for given angular positions can be derived. Finally, the accurate kinematic quantities, angular extents of certain events can be determined. This technique allows to analyse quantitatively even extremely faint and diffuse processes.

2. The LASCO/C1 telescope was designed to perform spectral analysis on coronal structures. The tunable Fabry-Perot interferometer allows to obtain images at different wavelengths (Fe XIV at 530.3 nm, Fe X at 637.4 nm). From the line profiles physical quantities like temperatures (from line widths), and flow velocities (from Doppler shifts) along the line of sight are deduced.

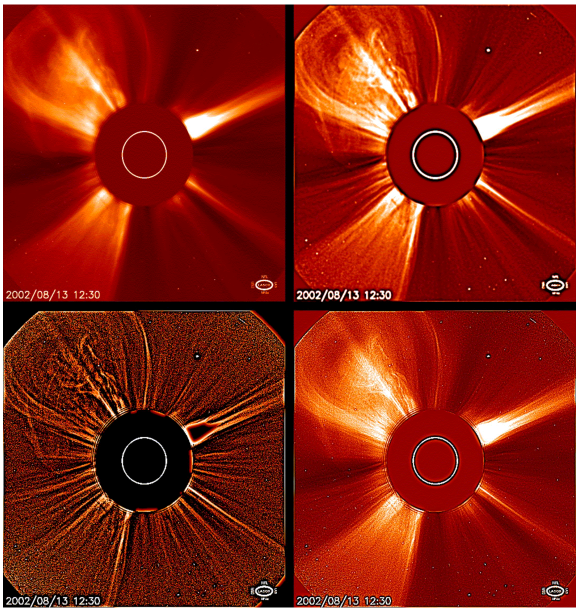

Fig. 37: A CME observed by the LASCO-C2 coronagraph on August 13, 2002 plus three different reconstruction schemes based on wavelet technique

(M. Mierla, R. Schwenn, G. Stenborg, B. Podlipnik)

EUV post-eruptive arcades: Physical properties and association with coronal mass ejections

The EIT (Extreme ultraviolet Imaging Telescope) and MDI (Michelson Doppler Imager) instruments on board SOHO (Solar and Heliospheric Observatory) provide an unique opportunity to study the low coronal and photospheric source regions of CMEs (Coronal Mass Ejections). EIT 19.5 nm data from 1997 to 2002 were investigated to study the basic physical characteristics of post-eruptive arcades (PEAs) and their relationship with CMEs. An example of a PEA observed by EIT at 19.5 nm and its associated white-light CME detected by LASCO (Large Angle Spectrometric Coronagraph) C2 is shown in Fig. 38.

In total 236 PEA events have been identified. For every PEA, the EUV emission life-time at 19.5 nm, the heliographic position and the corresponding photospheric source region in the MDI synoptic chart were determined. Further, the variation of these parameters was studied over the course of the present solar cycle. The results of this study yield, after taking into account the observational gaps of the individual instruments, that 210 (92%) PEAs were associated with a white-light CME detected by LASCO/C2. Taking into account other CME proxies, such as filament disappearances in H-alpha, the number of associations increases to 98%. The few cases in which a corresponding CME was not detected were all observed near disk

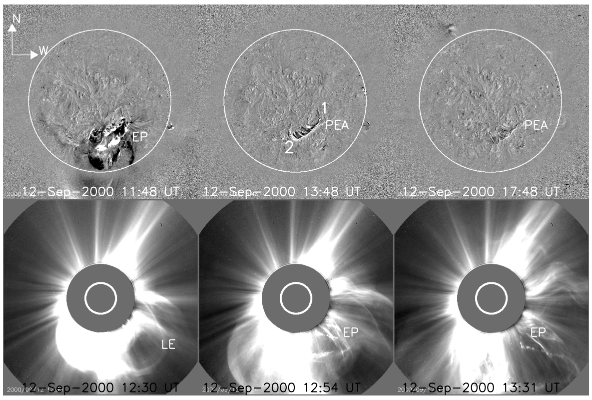

Fig. 38: Top panel: Running difference image taken by EIT 19.5 nm on 12-Sep-2000. The first two images show the disk centered erupting prominence (EP) event and consequent post eruptive arcade (PEA) formation in the southern hemisphere. Points 1 and 2 represent the start and end points of the PEA. The last image reveals the dimming of the arcade. Bottom panel: LASCO/C2 images showing the evolution of the associated CME. LE denotes the leading edge of the CME and EP the erupting prominence. In all figures, north is up and west is towards the right.

center. Taking into account that halo CMEs from these source locations on the disk require the greatest sensitivity to be observed by a coronagraph, it can be concluded that PEAs are reliable EUV disk proxies of CMEs. The heliographic lengths of the PEAs systematically increased with increasing solar latitude and its locations followed that of the activity belts in both solar hemispheres during 1997 – 2002. The implications of these results with respect to the near-Sun evolution of CMEs as well as detailed studies of the changes of the underlying photospheric field structure and overlying low corona are under investigation.

(D. Tripathi, V. Bothmer, H. Cremades)

3D magnetic field configuration in coronal mass ejections

Coronal Mass Ejections (CMEs) are enormous solar eruptions, which deliver large amounts of mass and magnetic energy into the Heliosphere. Although numerous studies have been carried out since their discovery in the early ’70s, their origins, 3D structure, and internal magnetic field configuration still remain unclear. Thanks to the high resolution telescopes of the SOHO Mission, magnetic fine structures can be resolved within CMEs close to the Sun.
A subset of the CME events recorded during the years 1996 – 2002 by the SOHO/LASCO C2 coronagraph was selected for a detailed study, comprising CMEs which exhibited clear white light structures, likely indicative of their magnetic field configuration and possible 3D structure. Their corresponding source regions in the low corona and photosphere have been identified with the aid of data from the EIT (Extreme-Ultraviolet Imaging Telescope) and MDI (Michelson Doppler Imager) instruments aboard SOHO, and from ground-based Hα measurements. In order to reveal the actual 3D profile of a CME, an approach based on the characteristics of their respective source regions is addressed. A generic scheme has been deduced, in which the projected white-light topology of a CME can be explained by taking into account the orientation of the source region’s neutral line and its location on the solar disk (see Fig. 39), among other factors such as size and shape. In addition, the study indicates that structured CMEs arise in a self-similar manner from pre-existing, low coronal, small scale loop systems located above regions of opposite magnetic polarities.

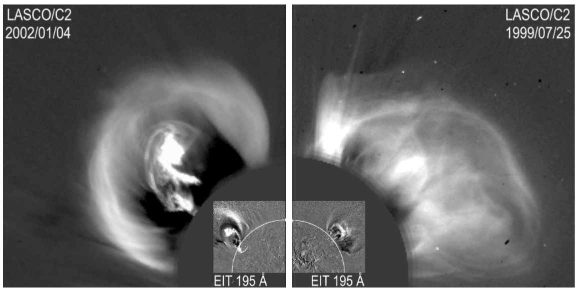

Fig. 39: Examples of LASCO/C2 CMEs, showing two extreme cases of projection, combined with their corresponding source region erupting features in EIT 19.5 nm. The left frame displays a CME with its axis oriented along the line of sight, while the axis of the CME on the right frame lies in the plane perpendicular to the line of sight.

(H. Cremades, V. Bothmer, D. Tripathi)

Properties of interplanetary coronal mass ejections

In a Coronal Mass Ejection (CME) a significant amount of relatively cool, dense, ionized gas escapes from the normally closed, confining, magnetic fields of the Sun’s atmosphere into the interplanetary medium. During its 13-year long mission the Ulysses spacecraft has observed the interplanetary remnants of numerous coronal mass ejections (ICMEs).

We combined Ulysses observations of medium energy particles, solar wind plasma parameters, magnetic field and charge state distributions of heavy ions in order to identify and characterize CME ejecta in the heliosphere. We focused on ICMEs with a magnetic cloud structure (MC).

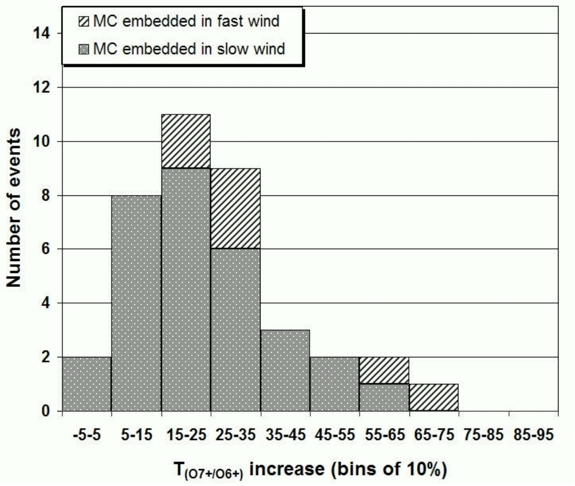

Fig. 40: Histogram showing the difference in Oxygen freezing-in temperature between magnetic clouds (MC) and the surrounding solar wind.

The large number of MCs detected by Ulysses allowed to perform a statistical analysis of the energetic particle population and the freezing-in temperature within MCs, which is a proxy for coronal temperatures in the MC source region. Based on a large statistical set, comprising events observed during all phases of the solar cycle and at all heliolatitudes we can confirm previous findings of a significant temperature increase within MCs, pointing to higher temperatures in the coronal source region of the CMEs. Furthermore, we found that the increase is independent of latitude or phase of the solar cycle. Abundance ratios of medium-energy particles, their energy spectra and the observed FIP effect are consistent with values found for gradual solar energetic particle events (SEPs). The fluxes of medium-energy particle are generally either depleted or unchanged inside the MCs. This behaviour again is found at all latitudes and solar cycle phases. A detailed comparison with CME models will provide further insights on the magnetic configuration of the MCs.

(L. Rodriguez, J. Woch, N. Krupp, M. Fränz, in collaboration with K.-H. Glassmeier, TU Braunschweig, and R. von Steiger, ISSI Bern)

Geoeffectice interplanetary structures: Their origins on the Sun and in the solar wind

The main focus of the INTAS-EU-ESA project was to carry out a detailed analysis of the causes of space storms during the years 1997 to 2000, i.e. in the rising to maximum phase of the eleven year solar activity cycle, based on hitherto unprecedented simultaneous availability of remote sensing observations of the Sun and of the solar wind by suitable equipped spacecraft. The European partners in the project consisted of:

1. Imperial College of Science Technology, and Medicine, The Blackett Laboratory, United Kingdom,
2. Institute of Terrestrial Magnetism, Ionosphere, and Radio Wave, Department of Magnetism of the Earth and Planets, Sector of Space Magnetoplasma Dynamics, IZMIRAN, Russia
3. Institute of Nuclear Moscow State University, Institute of Nuclear Physics, 119899 Moscow, Russia.

At Earth, sensitive magnetometers register worldwide continuously the high frequency changes of the Earth's magnetic field. These changes are documented as geomagnetic indices. When they exceed certain intensity levels, these periods are called geomagnetic storms. The sources of these magnetic storms, which affect power and telecommunication systems and satellite navigation amongst other hazards, are commonly assumed to be of solar origin. However the chain of physical processes through which they are caused in the Sun-Earth system are not understood to date. The condition in interplanetary space to which the Earth's outer magnetic field, its magnetosphere, is continuously imposed is currently being measured with sophisticated instruments on board the NASA Wind and ACE (Advanced Composition Explorer) satellites. Scientific data unraveling the source regions of the solar wind, the stream of charged particles permanently impinging Earth, and those of violent particle streams caused by eruptions called coronal mass ejections (CMEs), were provided by the ESA/NASA SOHO (SOlar Heliospheric Observatory) satellite through the LASCO (Large Angle Spectrographic Coronagraph) and EIT (Extreme Ultraviolet Imager) instruments. Additionally, data from the US/Japanese Yohkoh satellite, as well as ground-based observations of the Sun were considered. Based on the correlated study of the individual data sets, the main results found from the analysis of several hundred space storms in the present solar cycle can be summarized as follows:

1. The space storms leading to geomagnetic storms at Earth were caused by the following solar and interplanetary causes, as compiled at http://dec1.npi. msu.su /apev:
    (a) A low ($< 5\%$) number of turbulent, dense, slow solar wind streams of difficult to determine solar origin, responsible for low level storms ($Ap < 30$).
    (b) Fast, low density, streams ($\sim 20\%$) from coronal holes (CHs) at the Sun with inherent Alfvénic fluctuations, inclusively their

    corotating interaction regions (CIRs) in interplanetary space, responsible for moderate level storms ($Ap < 60$).

    (c) A large number of isolated transient interplanetary flows as counterparts of CMEs, often fast and associated with transient fast forward shock waves, responsible for mild to extreme storms ($20 < Ap < 200$).

    (d) Frequent isolated transient flows from CMEs that interact with ambient corotating fast flows from coronal holes responsible for mild to major storm levels ($20 < Ap < 150$, CME/CIR).

    (e) Frequent multiple transient interplanetary flows due to multiple CMEs (MCMEs) at the Sun, responsible for mild to extreme storms ($20 < Ap < 200$).

2. All major ($Ap > 150$) storms were caused through interplanetary flows due to CMEs at the Sun.

3. The number of magnetic storms in the present solar cycle reached its maximum in the years 1999 to 2000.

4. In 1999 fast streams from coronal holes produced somewhat surprisingly most of the storms, likely to be common for the rising phases in the eleven year solar cycle.

5. For almost all solar wind disturbances that caused magnetic/space storms, the source regions could be identified in the low corona based on SOHO/EIT observations taken at EUV wavelengths.

Fig. 41 shows the frequency distribution of the different sources of geomagnetic storms during the years 1997 to 2001. The project is funded for another three years by the European Union to continue the analysis of space storms until the end of the current solar cycle.

(V. Bothmer, Project Coordinator)

Long term solar variations

Reconstruction of past solar activity from terrestrial records of ^{10}Be

The cosmogenic isotope ^{10}Be is produced in the terrestrial atmosphere by cosmic-ray induced spallation of oxygen and nitrogen nuclei. It is washed out by precipitation and deposited in the polar ice shields. Since the cosmic ray flux is modulated by solar activity, the ^{10}Be concentration measured in layered ice cores drilled in Greenland and Antarctica serves as a proxy for past solar activity. On the basis of physical models for the production of ^{10}Be, the modulation of the cosmic ray flux by the varying heliospheric magnetic field, and the relationship between the open magnetic flux of the Sun and the flux emergence at the solar surface in terms of the sunspot number, we have provided the first *quantitative* reconstruction of past solar activity (sunspot numbers) from ^{10}Be data, covering the period from AD 850 until the present time. To this end, we have inverted the physical models: From the ^{10}Be data we first determine the cosmic ray flux, which is used to infer the open coronal source flux of the Sun; the latter then leads to the the sunspot number.

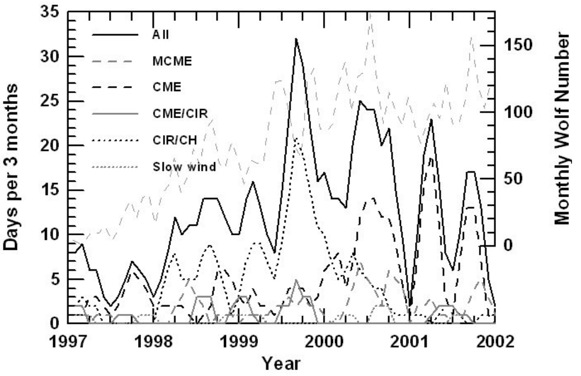

Fig. 41: Frequency distribution of the different sources of geomagnetic storms with $Ap > 20$ during 1997 – 2001, in comparison with the sunspot number.

Fig. 42 shows the time series of the sunspot number reconstructed using the 8-year averaged ^{10}Be data from Antarctica and, for comparison, the yearly ^{10}Be data from an ice core drilled in Greenland. The (11-year smoothed) historical record of the group sunspot number since 1610 is also given. The Antarctica and Greenland curves differ in detail, probably reflecting local climatic effects, but agree well in their long-term trends. The result indicates that throughout the whole interval covered, solar activity never was as intense as in the last century.

Recently, we have started to study to the ^{14}C data set, which allows us to reconstruct the solar activity throughout the whole Holocene back to the end of the last glaciation period about 11,000 years before present.

(S.K. Solanki, M. Schüssler, in collaboration with I. Usoskin, K. Mursula, University of Oulu, Finland)

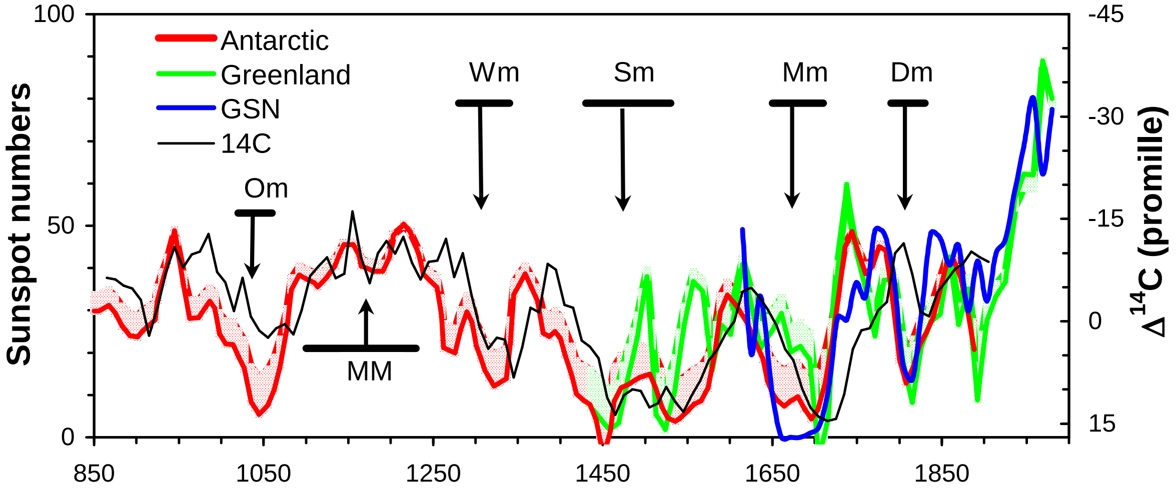

Fig. 42: Time series of the sunspot number as reconstructed from ^{10}Be concentrations in ice cores from Antarctica (red) and Greenland (green). The shaded areas indicate the uncertainty of the reconstruction. The thick black curve shows the observed group sunspot number since 1610 and the thin blue curve gives the (scaled) ^{14}C concentration in tree rings, corrected for the variation of the geomagnetic field. The horizontal bars with attached arrows indicate the times of Great Minima and Maxima: Dalton minimum (Dm), Maunder minimum (Mm), Spörer minimum (Sm), Wolf minimum (Wm), Oort minimum (Om), and Medieval Maximum (MM). The highest activity levels are reached in the 20th century (from Usoskin et al., Phys. Rev. Lett. 91.211101).

Reconstruction of solar irradiance variations

Regular space-borne measurements of solar irradiance since 1978 show that it varies on all accessible time scales. The physical cause of these variations, however, remains a subject of debate. We have developed a model of solar irradiance variations based on the assumption that solar surface magnetism is responsible for all total irradiance changes on time scales of days to years. A time series of daily MDI and Kitt Peak magnetograms and empirical models of the thermal structure of magnetic features (sunspots, faculae) are combined to reconstruct total (and spectral) irradiance from 1992 to 2002. Comparisons with observational data reveal an excellent correspondence, although the model only contains a single free parameter. This provides strong support for the hypothesis that solar irradiance variations are caused by changes in the amount and distribution of magnetic flux at the solar surface. In addition, this shows that cycles 22 and 23 behave similarly regarding irradiance, in contrast to statements in the literature.

(N. A. Krivova, M. Schüssler, S. K. Solanki, in collaboration with Th. Wenzler, M. Fligge, ETH Zürich and Y. C. Unruh, Imperial College of Science, Technology & Medicine, London)

Solar variability and global warming

The magnitude of the Sun's influence on climate has been a subject of intense debate. Estimates of this magnitude are generally based on assumptions regarding the forcing due to solar irradiance variations entering climate modelling. This approach suffers from uncertainties that are difficult to estimate. Such uncertainties are introduced because the employed models may not include important but complex processes or mechanisms, or may treat these in too simplified a manner.

We take a more empirical approach. We assume that the Sun has been responsible for climate change prior to 1970. Then, using reconstructions and measured records of relevant solar quantities as well as of the cosmic-ray flux, we estimate which fraction of the dramatic temperature rise after that date could be due to the influence of the Sun. We show that at least in the most recent past (since 1970) the solar influence on climate cannot have been dominant.

(N. A. Krivova and S. K. Solanki)

Surface magnetic fields cause UV radiance of the quiet Sun to vary over the solar cycle

The quiet-Sun UV radiance depends on the solar cycle, as shown by data collected by the SUMER spectrograph on the Solar and Heliospheric Observatory

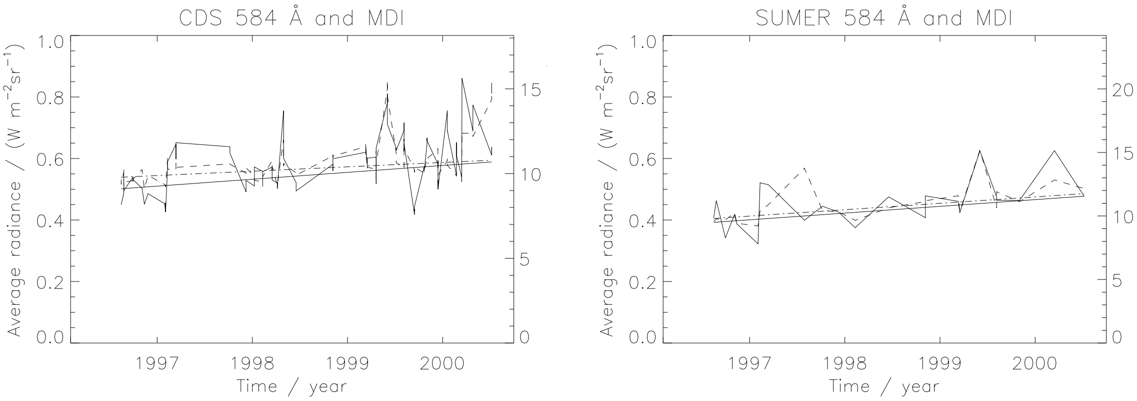

Fig. 43: Time series of the average values of the CDS and SUMER radiances and corresponding MDI magnetic fluxes. The solid lines represent the radiance data and their linear fits, the dashed and dot-dashed lines refer to the MDI data and their corresponding fits. The plotted fits indicate an increase between 15% (MDI in CDS sampling) and 22% (SUMER) within the four years from June 1996 to June 2000. Obviously the magnetic flux increases in parallel with the radiances.

(SOHO). This was a surprising result, since the quiet Sun had been perceived to be unique and time independent. The cause of this dependence was previously unclear. The hypothesis that these variations are due to changes in the magnetic network is tested for the He I (58.4 nm) line. The quiet-Sun variability is investigated with the two EUV instruments CDS (Coronal Diagnostic Spectrometer) and SUMER and with the MDI (Michelson Doppler Imager) magnetograph on SOHO. Using a monthly sampled data set of co-spatial and co-temporal observations of quiet Sun areas near disk centre we follow the evolution of the quiet Sun over four years from solar cycle minimum to maximum conditions and find that the magnetic flux of the quiet network increases during this period. Furthermore, its variation is well correlated with the radiance change in the He I (58.4 nm) line, as can be seen from Fig. 43. Also, we find that the largest fractional change is in the flux of the strong network elements (largest average field strengths), while the weaker elements do not exhibit a significant change.

(S.K. Solanki in collaboration with A. Pauluhn, International Space Science Institute, Bern)

Total magnetic flux of the Sun

A critical question related to a possible secular trend in the Sun's total magnetic flux and consequently in solar irradiance is the total amount of magnetic flux present on the Sun and how it is distributed between active regions and the quiet Sun. NSO/Kitt Peak synoptic charts have in the past been used to estimate the total flux and the fraction of the flux in active regions and in the quiet Sun. Since a single pixel of these synoptic charts is much bigger than individual small-scale magnetic elements and opposite polarities may be present within the same pixel, some magnetic flux escaped notice.

We use MDI full-disc and high-resolution magnetograms to estimate the fraction of the magnetic flux escaping detection in Kitt Peak synoptic charts. By artificially reducing the spatial resolution of MDI magnetograms we study the influence of the resolution on the measured total magnetic flux. Noise in the data poses the main difficulty to this approach and is carefully studied. Our results suggest that at least half of the magnetic flux in the quiet Sun remains undetected in Kitt Peak synoptic charts and that the total flux present on the solar surface at recent maxima of activity is around twice the flux present at activity minima.

(N. A. Krivova and S. K. Solanki)

A relationship between solar cycle strength and length

The cyclic magnetic activity of the Sun exhibits a change in amplitude from one cycle to the next as well as a variation in cycle length. These two quantities are not quite independent, however, exhibiting an inverse correlation. We investigate the relationship between cycle amplitude and length, but in contrast to earlier investigations consider the phase shift between the two time series in addition to the direct correlation. The cross-correlation between time series of solar cycle length and strength suggests that the length precedes the strength. The relationship between the two is found to be more complex than a simple lag or phase shift, however. A simple empirical model is constructed which allows the amplitude of a given cycle to be predicted with relatively high accuracy from the lengths of earlier cycles.

(N. A. Krivova, M. Schüssler, S. K. Solanki, in collaboration with M. Fligge, ETH Zürich)

Was one sunspot cycle in the 18th century really lost?

The unusually long 4th solar cycle has been proposed (Usoskin et al. 2001, A&A, **370**, L31) to be composed of two cycles. They argue that a weak and short cycle might have been lost in sparse sunspot data at the end of the 18th century. We check this hypothesis in different ways. First, we consider the sunspot number record in greater detail and compare in a statistical sense the sunspot observations of the period in question with those at other times. In a statistical sense the sunspot numbers recorded at the time of the proposed new cycle minimum are extremely untypical for other minima in the solar cycle record, but quite usual for the declining phase of the solar cycle. We also analyse other available proxies of solar activity, such as variations of the cosmogenic nuclides ^{10}Be and ^{14}C as well as auroral activity. These historical records are sufficiently long and provide an independent testimony of the cyclic behaviour of solar activity at the end of the 18th century. We found no evidence for a lost cycle in any of these data sets. Finally, we compare the proposed new cycle with the other cycles in the sunspot record. This reveals that the proposed 'missing' cycle has very unusual properties, much more so than the original, standard cycle 4. Taken together, the evidence from these various tests strongly suggests that no cycle was missed and that the official sunspot cycle numbering and parameters are correct.

(N. A. Krivova and S. K. Solanki, in collaboration with J. Beer, EAWAG, Duebendorf)

Ongoing future missions

Solar Ultraviolet Measurements of Emitted Radiation – SUMER

The vacuum-ultraviolet spectrometer SUMER on the Solar and Heliospheric Observatory (SOHO) has recorded high-resolution spectra of the solar atmosphere since 1996. This is a continuation of several reports given during the past years. For a detailed description of the instrument we refer to earlier reports.

During the last two years, SUMER was mainly pointed to off-disk targets. It is therefore logical that the recent scientific topics also have changed and moved towards the outer layers of the solar atmosphere. During the post-maximum phase of the recent sunspot cycle, SUMER made some remarkable observations of solar flares and coronal transient events, described elsewhere in this volume. A clear trend to multi-wavelength observations with other instruments aboard SOHO or other space probes and with ground-based observatories can be stated.

The data reduction and scientific analysis continues on a very high level and has produced several highlights. Several groups which have focussed on solar EUV-spectroscopy have transferred the entire SUMER data archive for efficient data access (e.g. Freiburg, Oslo, Armagh, Cambridge, Peking). Many other groups use the SUMER web-page and the internet access to the data base. In 2003 the SUMER web documentation describing the reduction of SUMER data has been extensively updated and reformatted into a SOHO standard layout. More than 800 publications have appeared until now, many of them in cooperation with external groups.

ESA and NASA have decided to extend the SOHO mission and to operate SOHO under the new title "Solar Cycle Mission" at least until July 2007. At that time, SOHO will have seen a full solar cycle. After this decision, the SUMER on-board memory was tested extensively and the ground support equipment at Greenbelt (USA) and Orsay (France) was checked out and partly replaced in order to be ready for the coming years. Although the total accumulated counts have reached very high numbers for both detectors, we anticipate that SUMER can still be operated for several years.

(W. Curdt, I.E. Dammasch, D. Germerott, D.E. Innes, E. Marsch, U. Schühle, S.K. Solanki, L. Teriaca, T.J. Wang, K. Wilhelm, L. Xia)

LASCO (Large Angle and Spectrometric COronagraph on SOHO)

For another 2 years, the LASCO telescopes C2 and C3 worked almost without any non-scheduled interruption, as did the SOHO spacecraft as a whole. No signs of degradation are visible. In fact, it is now being considered to maintain at least the LASCO operations into the year 2009, in order to allow significant overlap with the STEREO mission to be launched in May 2006) and the new SDO mission (Solar Dynamics Observatory) to be launched in 2008.

The solar activity maximum of the present solar cycle has finally been traversed. In late 2003 the Sun unexpectedly ignited several major flares with associated fast big coronal mass ejections (CMEs) and succeeding severe geomagnetic storms: On October 28, an X 17.2 flare, the second largest flare observed by SOHO, was setting off a strong high energy proton event and a fast-moving CME, hitting Earth only 19 hours later on Wednesday, October 29. On that same afternoon, an X 10.0 flare set off another round of particles and another fast-moving CME that also travelled to Earth in 19 hours. Note that there is only one single case known where a CME was faster: The famous event on September 1, 1859. It had been observed by chance by Carrington who correctly associated it with a severe geomagnetic storm only 17 hours later. In either case, bright aurorae were observed at very unusual places, e.g. all over Europe, the United States, and in Australia. Based on our real-time CME observations and using our new CME prediction tool (see last report) we could issue warnings early on. Our predictions were only 4 hours off!

(R. Schwenn, B. Inhester, B. Podlipnik)

MICA (Mirror Coronagraph for Argentina)

The MICA telescope is a ground-based coronagraph located at 2400 m altitude on the Precordillera de los Andes near San Juan, Argentina. MICA and the H-alpha telescope HASTA installed by MPE Garching are taking images of the Sun and the corona almost everyday, in a semi-automated mode. The team of the Observatorio Astronómico Félix Aguilar (OAFA) in San Juan is operating the instruments and takes care of their maintenance. After the end of the support of the bilateral project between Argentina and Germany through the "Internationales Büro der DLR" in early 2003 there is not much funding of German activities left. The responsibility for the instruments, the operations and data management is now being shifted gradually to the Argentinean side. Several research papers with Argentinean scientists as lead authors have already emerged.

(R. Schwenn, G. Stenborg, B. Podlipnik, E. Marsch, B. Inhester, in collaboration with IAFE Buenos Aires Argentina, OAFA San Juan University, San Juan, Argentina, and MPE Garching)

Sunrise: A balloon-borne telescope for high-resolution observations of the Sun

Sunrise is a light-weight solar telescope with 1 m aperture and instrumentation for spectro-polarimetric observations of the solar atmosphere on the intrinsic spatial scale of its magnetic structure (Fig. 44). The telescope will be operated in long-duration balloon flights in order to obtain diffraction-limited image quality and to study the UV spectral region down to $\simeq$ 220 nm, which is not accessible from the ground. The Sunrise project is a precursor for a comprehensive space-borne solar observatory.

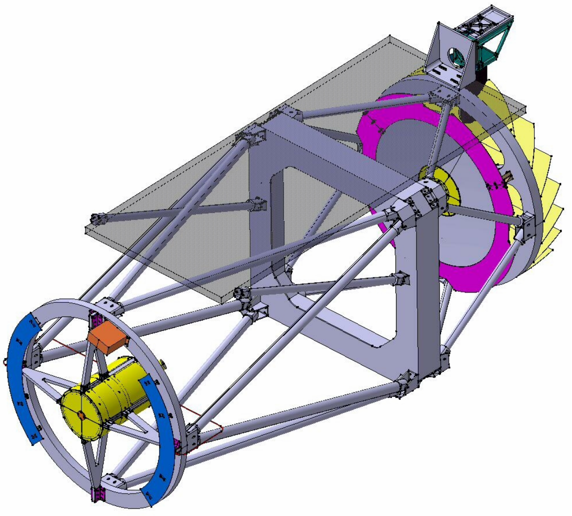

Fig. 44: Sunrise telescope with the main mirror (M1) to the right and the front ring with the secondary mirror (M2) unit to the left. The Serrurier trusswork keeps M1 and M2 parallel under gravitational deformation of the structure. After reflecting off M2, the light passes through a central hole in M1 onto two flat folding mirrors feeding the instruments mounted on the platform on top of the central frame (Fig.: Kayser-Threde).

The central aim of Sunrise is to understand the structure and dynamics of the magnetic field in the solar atmosphere. The magnetic field is the source of solar activity, controls the space environment of the Earth and causes the variability of solar irradiance, which may be a significant driver of long-term changes of the terrestrial climate. Interacting with the convective flow field, the magnetic field in the solar photosphere develops intense field concentrations on scales below 100 km, which are crucial for the dynamics and energetics of the whole solar atmosphere. These spatial scales cannot be studied systematically from the ground because of image distortion by turbulence in the lower atmosphere of the Earth. The balloon-borne Sunrise telescope will, for the first time, provide measurements of the magnetic structure of the solar atmosphere on its intrinsic spatial and temporal scales. These measurements will directly attack basic problems:

- What are the origin and the properties of the intermittent magnetic structure?
- How is the magnetic field brought to and removed from the solar surface?
- How does the field provide momentum and en-

ergy for the outer solar atmosphere?

- How does the magnetic field variation modify the solar brightness?

These questions are of fundamental importance, not only for understanding the influence of solar activity on the human environment but also for astrophysics in general. The universe abounds with objects that are dominated by magnetohydrodynamical and plasma processes, but of all astronomical objects only the Sun offers the possibility to directly and quantitatively investigate these processes with sufficient resolution.

The telescope is kept aligned and focussed by an innovative control system based upon a wavefront sensor. Image stabilisation is achieved with a correlation tracker controlling a high-speed steering mirror. The focal-plane instruments consist of a spectrograph-polarimeter (SUPOS: Sunrise Polarimetric Spectrograph) for high-precision measurements of the four Stokes parameters, a filter imager (SUFI: Sunrise Filter Imager) for high-resolution images in the visible and the UV, which will provide diffraction-limited spatial resolution down to 0.05 arcsec at 220 nm, corresponding to ≃ 35 km on the Sun, and a magnetograph (IMaX: Imaging Magnetograph Experiment) providing two-dimensional maps of the full magnetic field vector and the line-of-sight velocity.

Sunrise is a project led by MPAe with participation of the Kiepenheuer-Institut für Sonnenphysik (KIS), Freiburg, the High Altitude Observatory (HAO), Boulder, the Lockheed-Martin Solar and Astrophysics Lab. (LMSAL), Palo Alto, and a Spanish consortium led by the Instituto de Astrofísica de Canarias (IAC), Teneriffa. MPAe is responsible for the main telescope (built by industry, phase C/D started in early 2004), the instruments SUPOS and SUFI, as well as for the central computer and data storage unit. The first long-duration balloon flight of about 2 weeks from Antarctica is planned for the (northern) winter 2007/2008.

(S. K. Solanki, W. Curdt, A. Gandorfer, M. Schüssler & the MPAe engineering team in cooperation with teams led by W. Schmidt, KIS, B. W. Lites, HAO, A. M. Title, LMSAL, and V. Martínez Pillet, IAC)

Tenerife Infrared Polarimeter (TIP)

Developing active regions are the sites of copious magnetic activity such as flares, X-ray jets, etc. These high energy phenomena are thought to be produced by the emergence of Ω-shaped loops of magnetic flux from the solar interior, where the solar dynamo resides, into the atmosphere and their interaction with the ambient magnetic field. The emerging magnetic field vector has been mapped at the solar surface (i.e. in the solar photosphere), but is poorly known in the layers in which the interaction takes place (the chromosphere and the corona).

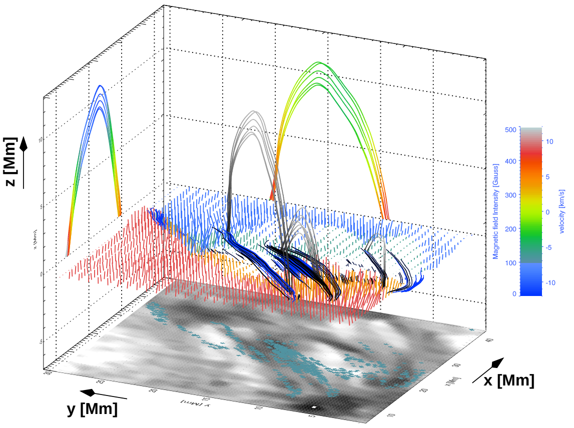

Fig. 45: A newly developed method allows the reconstruction of the magnetic field topology in the lower corona using data from the Tenerife Infrared Polarimeter (TIP) at the German Vacuum Tower Telescope. Open (red and blue arrows for north and south polarity) and closed (orange and green) magnetic field lines are overplotted on an equivalent width map for the He I line. The current sheet is localized where open field lines of opposite magnetic polarity are not separated by closed loops.

In 2001 we were able to perform the first direct measurements of the full magnetic vector near the base of the solar corona using the He I (1083.0 nm) multiplet (Solanki: 2003-082). These measurements allowed the magnetic structure of loops over a flux emergence site to be determined (Fig. 45). The central part of these loops was rising with velocities of 1 to 2 km/s. This motion transported photospheric material up to 10000 km into the lower corona from where it fell back to the photosphere resulting in downflows of up to 40 km/s at the foot points of the loops.

The observed region disclosed another interesting feature of the chromosphere. It has long been thought that current sheets in this region act a major source of coronal heating. These structures are characterized by tangential discontinuities in the magnetic field. For the first time we were able to identify such a discontinuity and to calculate a lower limit of the current flowing in such a sheet.

(A. Lagg, S. K. Solanki, J. Woch, N. Krupp, J. M. Borrero)

The NASA STEREO Mission

Two suitably equipped spacecraft are currently being developed for NASA's STEREO (Solar TErrestrial RElations Observatory) mission as part of the Sun-Earth-Connection line (Fig. 46). The twin spacecraft will provide a totally new perspective on the 3-dimensional structure of the Sun's corona and inner heliosphere, including the nature and evolution of coronal mass ejections (CMEs). CMEs are the key triggers of major space weather effects at Earth.

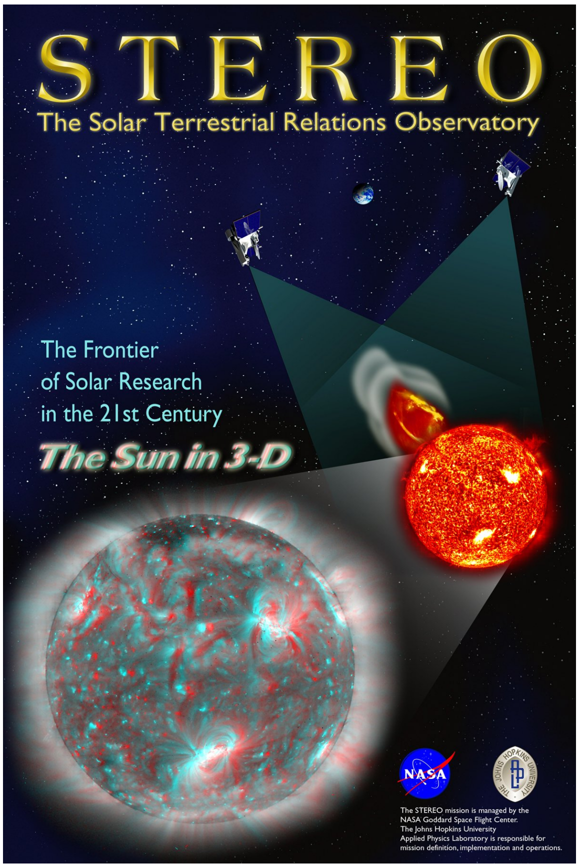

Fig. 46: Artists presentation of the STEREO mission.

The launch date for STEREO A, leading the Earth in its orbit by 22° per year, and STEREO B, lagging the Earth in its orbit by the same amount, is February 2006. The orbit is sketched in Fig. 47. The time over which the mission is designed to operate is about 5 years from launch, i.e. STEREO is meant to provide scientific data until 2011.
STEREO A and STEREO B will:

- Image the solar atmosphere and heliosphere from two perspectives simultaneously
- Track disturbances in 3-D from their onset at the Sun to beyond Earth's orbit
- Measure energetic particles generated by solar eruptions
- Sample fields and particles in the disturbances as they pass Earth's orbit

The Max-Planck-Institut für Aeronomie participates in the SECCHI and IMPACT instrument suites, two of the key payloads suites. SECCHI (Sun-Earth Connection Coronal and Heliospheric Investigation) encompasses four optical telescopes to image the inner corona at EUV wavelengths and the outer corona and heliosphere in white-light. IMPACT (*In situ* Measurements of Particles And CME Transients) is comprised of several particle detectors that will sample the 3-D distribution of solar wind plasma electrons, solar energetic particle ions and electrons, and an instrument measuring the local vector magnetic field. The science payload of STEREO is completed by SWAVES, a radio burst tracker, and the PLAsma and SupraThermal Ion and Composition (PLASTIC) instrument.

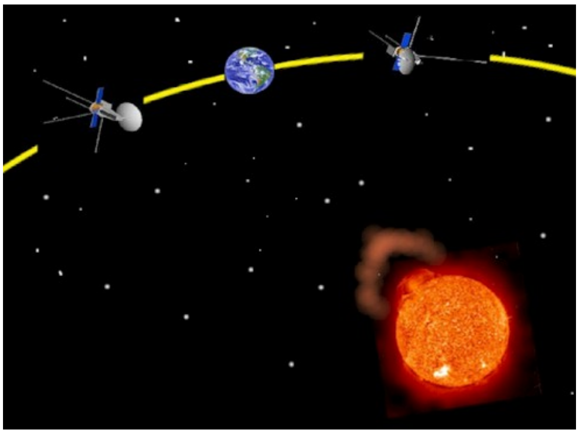

Fig. 47: Orbit of the STEREO spacecraft.

(V. Bothmer, R. Schwenn, A. Korth)

Sun Earth Connection Coronal and Heliospheric Investigation (SECCHI) for STEREO – SCIP

The Institute participates in the development of the SECCHI (Sun Earth Connection Coronal and Heliospheric Investigation) instrumentation, the key science payload package of STEREO. The optical instrument suite named after the Italian astronomer Pietro Angelo Secchi (1818 – 1878) who pioneered stellar spectroscopy and solar eclipse observations, is a combined set of optical telescopes, combining visible and EUV wavelengths, to advance our understanding of the three-dimensional nature of the solar corona and inner heliosphere and of coronal mass ejections (CMEs). The SECCHI telescopes will explore the origin and evolution of CMEs through direct observations from their birth at the Sun until their interaction with the Earth's magnetosphere, i.e. the mission is also a milestone in terms of space weather predictions.
To accomplish the science objectives, both STEREO spacecraft will carry the following identical Sun Centered Imaging Packages (SCIP, see Fig. 48):

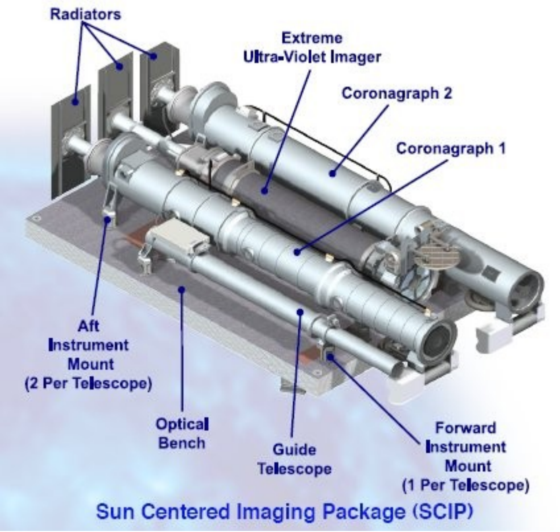

Fig. 48: The SECCHI Sun Centered Imaging Package (SCIP) for the NASA STEREO mission.

- Internally occulted Lyot coronagraph (COR1)
- Externally occulted Lyot coronagraph (COR2)
- EUV narrow-bandpass Cassegrain telescope (EUVI)

The Institute is leading the development and fabrication of the SECCHI Experiment Sun Aperture Mechanisms (SESAMe, Fig. 49) for the SCIP telescopes.

In 2002 and 2003 the SESAMe design had to undergo substantial developed to account for new thermal, mechanical, optical and cleanliness requirements caused by a change in the satellite design. The engineering and qualification units (Fig. 50) for the EUV imager (EUVI) and white-light coronagraphs (COR 1,2) have been delivered to the Naval Resyearch Laboratory, Washington, DC, USA in January 2004 after the qualification units had passed successfully the required functional and performance, and TV and lifecycle tests. The requirement changes led to tests with various surface coatings, also numerous mechanical changes had to be introduced, causing in turn a refabrication of numerous hardware parts. However, the changes could be adopted successfully and the assembly of the SESAMe flight units is in progress. The first items will be delivered in the first half of 2004.

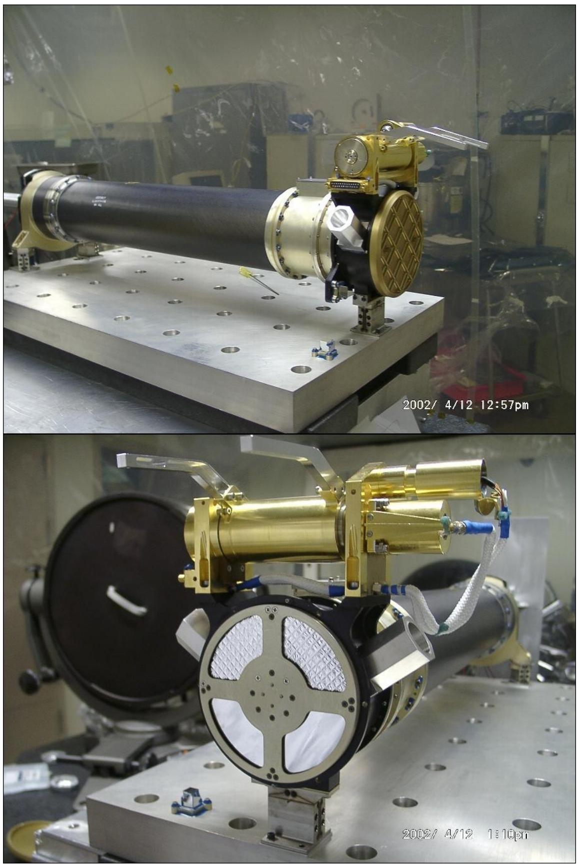

Fig. 49: Inspection of the optical filters of the EUVI Engineering Test Unit (ETU) after vibration testings. Top: EUVI ETU with SESAMe in closed position, protecting the filters. Bottom: Opened SESAMe, showing that the thin aluminium filters were successfully protected by SESAMe.

The project also involves development of stereoscopic analysis techniques in order to explore the origin, 3D magnetic field structure and heliospheric evolution of structured CMEs (Fig. 51) through collaborations within the international SECCHI consortium. A 3D visualisation, viewable with special graphic cards and LCD glasses, has been developed from SOHO/EIT 19.5 nm images for a full solar rotation. The visualisation has been presented on various occasions (e.g. Planetarium Hamburg). A 3D CME visualisation database has been created, allowing a detailed study of the low coronal and photospheric source regions of CMEs with additional help of SOHO/MDI data. The database serves already within the SECCHI consortium as a tool for visualisation and research projects on CMEs, e.g. in collaboration with the NASA Solar System Visualisation Group at the Jet Propulsion Laboratory, Pasadena, CA, USA.
A future goal of the project is to establish a computer code that allows to directly test with help of the images received from STEREO SECCHI, whether the 3D structure of CMEs, their internal magnetic field configuration and near-Sun evolution matches the model predictions proposed by Cremades & Bothmer and Tripathi & Cremades & Bothmer, based on a detailed analysis of SOHO/LASCO/EIT/MDI observations (Astronomy & Astrophysics 2004).

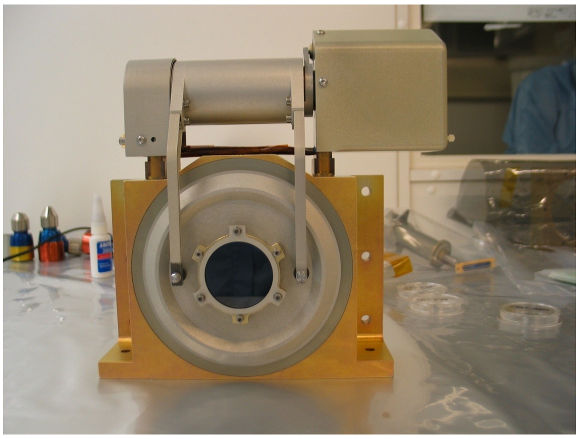

Fig. 50: SESAMe COR1 QM.

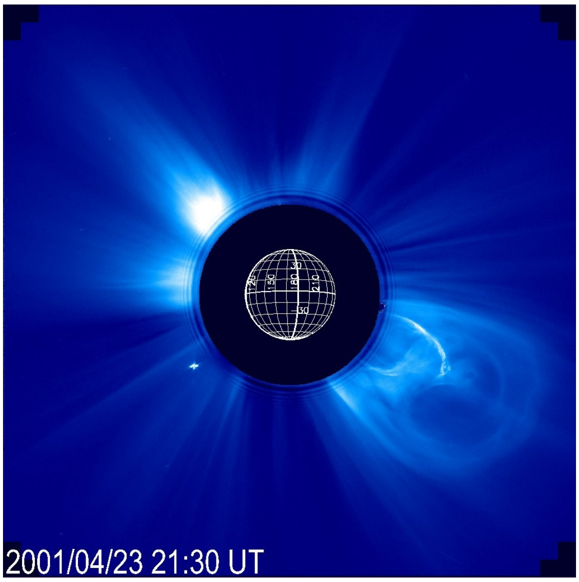

Fig. 51: Structured CME observed by SOHO/LASCO.

According to the presented scheme, the basic characteristics of CMEs can be deduced from correlated analyses of photospheric magnetic field, low coronal EUV and chromospheric H-alpha data by taking into account self-similar MHD expansion, pre-post coronal CME phenomena like flares, EUV dimmings, waves or arcades and the ambient coronal structure. As input data the code uses solar disk magnetic field and H-alpha observations from ground-based observatories and EUV images provided by the STEREO SECCHI Extreme Ultraviolet Imagers (EUVIs) to identify the CME source region. If possible SOHO/EIT or SDO/AIA measurements will be taken into account. The relevance of the EUV images as input parameters for the software code will depend on the changing perspectives with respect to the CME's place of origin. As output, the software code will yield the presumable 3D structure and evolution of CMEs for the distance range from about 1.5 to 6 solar radii. This synthetic 3D reconstruction of CMEs can directly be compared with the CMEs observations provided by the SECCHI COR 1 and COR 2 coronagraphs on board STEREO A and B. The predicted magnetic configuration and orientation of the CME inferred from the photospheric field and H-alpha data will be tested through *in situ* measurements of the solar wind and of energetic particles as provided by the STEREO and other suitably equipped and located spacecraft in the inner heliosphere. These studies can be interfaced with Space Weather Models.

To present the STEREO observations to a broader audience, the project includes the goal to establish the display of real-time images on flat LCD screens in the main entrance hall of the Planetarium Hamburg (www.planetarium-hamburg.de) as well as to use the location as a facilities for 3D visualisation. Of special interest are displays under the Planetarium dome. Hamburg currently has the most modern Planetarium of the world. The historic building, located in a park, has been renovated in 2003. The reopening occurred in October 2003. The Planetarium is visited by about 1000 people each weekend and serves as an ideal place for EPO activities. An information package has been established to introduce the STEREO mission.

The SECCHI/SCIP hardware and science contribution is supported by the German "Bundesministerium für Bildung und Forschung" through the "Deutsche Zentrum für Luft- und Raumfahrt e.V." (DLR, German Space Agency) through the project STEREO/Corona (FKZ 50 OC 0005).

(V. Bothmer, W. Boogaerts, H. Cremades, W. Deutsch, O. Hawacker, B. Inhester, H. Oberländer, B. Podlipnik, R. Schwenn, S.K. Solanki, D. Tripathi, T. Wiegelmann.)

Solar Orbiter: A high-resolution mission to the Sun and inner heliosphere

Scientific goals and orbit design

The Solar Orbiter mission was conceived and proposed by a European team led by MPAe scientists. After a successful assessment study it was selected by the ESA executive in September 2000 as ESA's next solar physics mission with a possible launch in 2013 – 2014.

Solar Orbiter will provide, at very high spatial and temporal resolution, novel observations of the solar atmosphere and unexplored inner heliosphere. The main science goals of the Solar Orbiter are to

- determine the properties, dynamics and interactions of plasma, fields and particles in the near-Sun heliosphere,

- investigate the links between the solar surface, corona and inner heliosphere,
- explore, at all latitudes, the energetics, dynamics and fine-scale structure of the Sun's magnetized atmosphere,
- probe the solar dynamo by observing the Sun's high-latitude field, flows and seismic waves.

The underlying basic questions which are relevant to astrophysics in general are: *Why does the Sun vary and how does the solar dynamo work? What are the fundamental physical processes at work in the solar atmosphere and in the heliosphere? What are the links between the magnetic-field-dominated regime in the solar corona and the particle-dominated regime in the heliosphere?*

The Solar Orbiter will, through its novel orbital design, for the first time

- explore the uncharted innermost regions of our solar system,
- study the Sun from close-up (45 solar radii or 0.2 AU),
- fly by the Sun tuned to its rotation and examine the solar surface and the space above from a co-rotating vantage point,
- provide images of the Sun's polar regions from heliographic latitudes in excess of 30°.

These four important new aspects to the Solar Orbiter mission will allow unique science investigations to be performed. The near-Sun interplanetary measurements together with simultaneous remote sensing observations of the Sun will permit us to disentangle spatial and temporal variations during the co-rotational phases. They will allow us to understand the characteristics of the solar wind and energetic particles in close linkage with the plasma conditions in their source regions on the Sun. By approaching as close as 45 solar radii, the Solar Orbiter will view the solar atmosphere with unprecedented spatial resolution. Over extended periods the Solar Orbiter will deliver the first images of the polar regions and the side of the Sun not visible from Earth.

The Solar Orbiter scientific requirements define the basic outline of the mission, in terms of orbital parameters, launch windows and payload mass. A strategy based on low-thrust electrical propulsion and planetary gravity assists is baselined. The celestial constellation of the Sun, Venus and Earth leads to a launch window of 3 weeks in every 19 months. The ecliptic projection of the Solar Orbiter trajectory is shown in Fig. 52. The selected orbit assures that the design of the spacecraft is still thermally feasible.The total S/C mass of the Solar Orbiter is compatible with a Soyuz-Fregat launch from Baikonur.

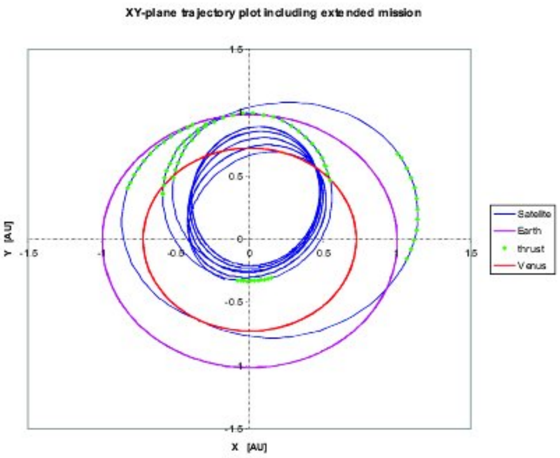

Fig. 52: Orbit design of Solar Orbiter: Ecliptic projection of the spacecraft trajectory.

The Solar Orbiter mission will have variable transmission phases, the durations of which vary with distance from Earth. Three scientific observation periods (each ten days long) are considered per S/C revolution about the Sun, with the strategy that these periods are centred on the passages through maximum southern and northern latitude and perihelion.

The spacecraft will be 3-axis stabilised and always Sun-pointed. Given the extreme thermal conditions at 45 solar radii (25 solar constants), the thermal design of the spacecraft has been considered in detail during the ESA assessment study, and viable solutions for the instrumentation have been identified, also by the help of industrial studies.

Baseline payload and political issues

MPAe has been a major player in the design of this mission and its objectives, and continued this role by contributions to the working groups activities. Two Payload Working Groups (PWGs) were established by ESA in 2002, with the task to address payload-related challenges, to study instrument feasibility, and produce a Payload Definition Document (PDD). It was delivered to ESA in May/June 2003 and contains a number of recommendations concerning, e.g. thermal loads, telemetry, low-mass options, and detectors. The institute intends to participate in the mission with key instrumentation for imaging and spectroscopy in visible and extreme ultraviolet light.

A Science Definition Team (SDT) was appointed by ESA (Chair: E. Marsch) to review the scientific goals of the mission as presently understood, to refine them where needed, to prioritise them in order to achieve a well-balanced and highly-focused mission, and to define the sets of measurements required. As a result of these activities, the payload for a baseline mission was designed (thereby taking into account the output of the PWG), which is able to achieve the main scientific goals. The Science Requirements Document (SRD) was completed by the SDT in December 2003.

The Solar Orbiter will achieve its wide-ranging aims with a suite of sophisticated instruments, which are optimised to meet the main solar and heliospheric science objectives. The baseline payload has a total mass of 140.5 kg, a power consumption of 128 W, and a telemetry rate of 88.5 kbs. The instrumentation consists of:

- Plasma Package (SWA)
- Fields Package (MAG + RPW + CRS)
- Particles Package (EPD, including Neutrons, gammas and dust)
- Visible Light Imager and Magnetograph (VIM)
- EUV Imager (EUI, encompassing 3 telescopes)
- EUV Spectrometer (EUS)
- Spectrometer/Telescope Imaging X-rays (STIX)
- Coronagraph (COR)

There was strong European as well as US support in the PWGs and SDT, anticipating some US-led instrumentation as NASA contribution to the mission. Solar Orbiter was highlighted as important for the US community in a number of documents, such as the Sun-Earth connection roadmap and the decadal report of the National Science Foundation. Solar Orbiter will be ESA's prime contribution to the International Living with a Star (ILWS) programme, which will start in 2007 and involve NASA, ESA, ISAS and perhaps other agencies.

(E. Marsch)

Technological pre-studies for the Solar Orbiter VIM instrument

The Visible Imager and Magnetograph (VIM) is a baseline instrument for ESAs Solar Orbiter mission. To identify potential technological risks and study the feasibility of the strawman payload, ESA created a payload working group, consisting of scientists with instrumental background. The MPAe was strongly represented in this group. MPAe led three technological pre-studies with industry to demonstrate feasibility of the VIM concept. The main targets of these studies were related to the question how the enormous heat load entering a 25 cm telescope at 0.2 AU affects the performance of the optical system. Two optical configurations were investigated, a closed telescope with a dielectric entrance filter, as well as an open telescope with a hot primary mirror. Both configurations proved to withstand the thermally critical situation during near-Sun orbital phases. This removes the largest question mark regarding the feasibility of such an instrument.

(A. Gandorfer, U. Schühle, in collaboration with M. Sigwarth (KIS, Freiburg), and V. Martínez Pillet (IAC, Tenerife))

Stars and solar-stellar connections

Understanding solar variability as groundwork for planet transit detection

Detection of planetary transits holds the greatest promise for the search of extrasolar terrestrial planets. However, intrinsic stellar variability can mask real transits or lead to 'false' planet transit detections. Understanding the origin of stellar variability can help to estimate the minimum sizes of planets detectable with this technique around different types of stars and to identify the best wavelength range for such measurements. The only star for which data with sufficient photometric accuracy and temporal sampling exist is the Sun. Solar variability on timescales relevant for planetary transits (hours to several days) is modelled using a variety of components, such as granulation, network (supergranulation), faculae and sunspots. Variability on time scales of a day and longer and on shorter time scales is analysed separately, since it has different physical causes.

Timescales of hours and longer:
A model based on the assumption that all irradiance changes on timescales of days to years are entirely due to the evolution of the solar magnetic flux on the surface was constructed. The excellent agreement between the model and data leads to the conclusion that the main driver of the solar irradiance variability at time scales of a day up to, at least, a solar cycle is the magnetic field at the solar surface. The magnetic field also provides significant contribution at timescales of a few hours.

Timescales from minutes to several hours:
A simple semi-empirical model computing the irradiance variability of the roughly 10^6 granules on the solar surface was constructed. It showed that granule lifetime and diameters, relative fractions of splitting and dissolving granules as well as thickness of inter-

granular lanes are important factors determining the amplitude and the shape of the irradiance power spectrum at periods shorter than several hours. Total number of granules, N_{tot}, and the brightness contrast between granule and intergranular lanes only affect the total power, but do not influence the slope or shape of the power spectrum.

The crossover between magnetic and convective signatures coincides with the frequency band of greatest interest for planetary transit observations. Good agreement between the combined irradiance (long period reconstructed irradiance and short period model output) and Virgo data confirms that our approach is correct: Solar irradiance can be reconstructed using two separate driving agents, magnetic field and granulation. There is, in particular, no need to explicitly introduce mesogranular and supergranular convective cells in order to reproduce solar irradiance variations.

(A.D. Seleznyov, S.K. Solanki, N.A. Krivova)

Stellar wind regime at the orbit of close-in extrasolar planets

Since 1995 approximately 120 extrasolar planets have been discovered. In contrast to the solar system, with Mercury as the closest planet to the Sun with a semi-major axis of 0.387 AU ($\sim$ 83 $R_\odot$), about 40 % of the extrasolar planets are closer to their star by a factor of 10 and more (e.g. OGLE-TR-56 b $\sim$ 5 $R_\star$). These extremely small distances put focus on the star-planet interaction in a so far unknown parameter regime. Having in mind the known solar-planetary interaction in the solar system, magnetic processes in these planetary systems are of specific interest, which is supported by observational evidence of chromospheric heating.

The main problem for modelling such a planetary system is the limited range of observed parameters. As the stars are classified as solar-like, wind velocities and densities are estimated on the basis of the solar wind models of Parker and Weber & Davis. Other parameters than the observable, e.g. stellar masses and radii, are varied so that a plausible range is taken into account. Fig. 53 shows the results obtained with Parker's model for an isothermal corona. For hot coronae the first can be used as an upper limit and for cooler coronae it gives a lower limit for the wind velocities. The red curves mark the locations of the sonic points, so for most cases the wind velocity is supersonic. But inclusion of magnetic fields suggests that the wind velocity at the planetary orbits is sub-Alfvénic. As a result the stellar wind interaction with extrasolar planets will take place in a different way from the one known in case of the the solar system, where the super-Alfvénic case prevails. Special numerical simulation efforts are started right now to investigate the stellar wind interactions in extrasolar planetary systems.

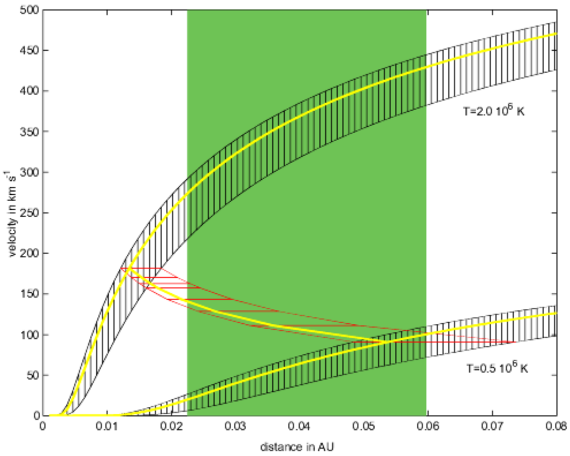

Fig. 53: Stellar wind velocities for 11 stars hosting close-in extrasolar planets for coronal temperatures of $0.5 \cdot 10^6$ K and $2.0 \cdot 10^6$ K with Parker's solar wind model. The width of the curves (shaded in black) show the range of solutions due to the varying stellar masses and radii. The planetary orbits lie within the green patch. Also, in yellow the solutions for the Sun and in red the locations of the sonic points are given.

(S. Preusse, J. Büchner, in collaboration with U. Motschmann, TU Braunschweig)

Constraints set by the Sun and degenerate stars on new couplings between electromagnetism and gravity

The unification of quantum field theory and general relativity is a fundamental goal of modern physics. In many cases, theoretical efforts to achieve this goal introduce auxiliary gravitational fields, ones in addition to the familiar symmetric second-rank tensor potential of general relativity, and lead to non-metric theories because of direct couplings between these auxiliary fields and matter. We have considered an example of a metric-affine gauge theory of gravity in which torsion couples non-minimally to the electromagnetic field. This coupling causes a phase difference to accumulate between different polarization states of light as they propagate through the metric-affine gravitational field. Solar spectropolarimetric observations were used to set strong constraints on the relevant coupling constant k: $k^2 < (2.5\text{km})^2$. Even stronger constraints were provided by a magnetic white dwarf with a mass close to the Chandrasekhar limit. Under conservative assumptions regarding the distribution of the magnetic field and the production of polarized radiation at the white dwarf's surface an upper limit of $k^2 < (0.05\text{km})^2$ was obtained.

(O. Preuss, S.K. Solanki and A. Gandorfer in collaboration with M.P. Haugan, Purdue University, West Lafayette, USA, H.P. Povel, P. Steiner and K. Stucki, ETH Zürich, P.N. Bernasconi, Johns Hopkins University, USA and D. Soltau, Kiepenheuer-Institut für Sonnenphysik, Freiburg)

Asteroseismology: Determination of cool star rotation properties

Asteroseismology provides us with the possibility of determining information on the rotation of a star. Besides the rotation frequency Ω, another important parameter that can be determined is the angle, i, between the direction of the rotation axis of a pulsating Sun-like star and the line of sight. A knowledge of i is important not just for obtaining improved stellar parameters, but also in order to determine the true masses of extrasolar planets detected from the radial velocity shifts of their central stars. The radial velocity measurements only provide $m_p \sin j$, where m_p is the planet's mass and j is the inclination of the orbital plane normal to the line of sight. For $j \approx i$ a knowledge of i then gives m_p. By means of Monte Carlo simulations, we estimate the precision of the measurement of i and other stellar parameters assuming noise levels and time series lengths achievable with upcoming space missions. We find that the inclination angle can be retrieved accurately when $i \gtrsim 30°$ for stars that rotate twice as fast as the Sun, or faster. An example is shown in Fig. 54.

In a second step we considered the possibility of determining the strength of the stellar differential rotation from low degree p-modes. A knowledge of differential rotation is important for an understanding of stellar dynamos. The signature of differential rotation is considerably weaker than of rotation itself, but it is nonetheless possible to set constraints on $\Delta\Omega$, the difference between Ω at the equator and at a latitude of 45°, for rapidly rotating stars ($\Omega \gtrsim 6\ \Omega_\odot$, where $\Omega_\odot$ is the solar rotation frequency). For such stars it is possible to distinguish between the cases $\Delta\Omega \sim \Omega$ and $\Delta\Omega$ = const.

(S.K. Solanki in collaboration with L. Gizon, Stanford University, USA)

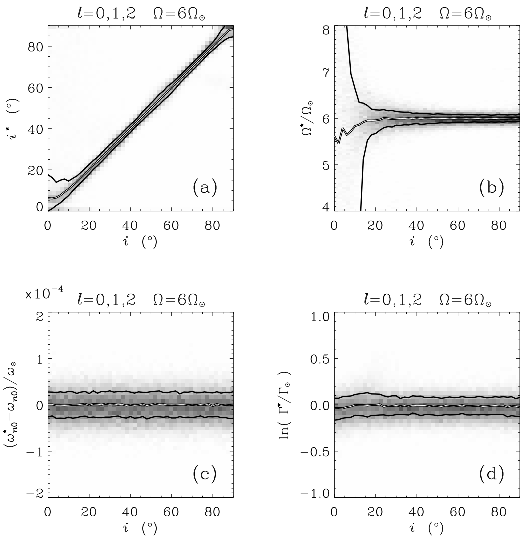

Fig. 54: Inclination angle of the stellar rotation axis i^*, rotation frequency Ω^*, relative error in mode frequency, ω^*_{n0}, and damping parameter Γ^* (normalized) estimated from a Monte-Carlo simulation of the oscillations on a star with true rotation frequency $\Omega = 6\ \Omega_\odot$. Note the high accuracy with which the inclination angle is recovered.

Spot sizes on Sun-like stars

The fractional coverage of stellar surface area by starspots is of interest for a variety of reasons, but most techniques only provide rough estimates of this important quantity. In particular, spot coverages obtained from photometry and Doppler imaging are often considerably lower than those deduced from the strengths of molecular bands. A possible source of this discrepancy was identified as part of the reported work. Sunspot areas exhibit a lognormal size distribution irrespective of the phase of the activity cycle, implying that most sunspots are small. We explored the consequences under the assumption that starspot areas are similarly distributed. The solar data allow for an increase in the fraction of larger sunspots with increasing activity. Taking this difference between the size distribution at sunspot maximum and minimum, we extrapolated to higher activity levels, adopting different dependences of the parameters of the lognormal distribution on total spot coverage. We found that, even for very heavily spotted (hypothetical) stars, a large fraction of the spots are smaller than the current resolution limit of Doppler images and hence might be missed on traditional Doppler maps. This result could explain the discrepancy of the spot coverages obtained from Doppler images and TiO spectra.

(S.K. Solanki in collaboration with Y.C. Unruh, Imperial College, London, UK)

Magnetically trapped circumstellar matter around hot stars

Spectroscopic observations indicate the presence of corotating circumstellar matter around chemically peculiar stars (helium-strong, helium-weak, and Ap/Bp stars) with strong magnetic fields. Presumably this matter is magnetically confined in regions of closed field lines. In the case of aligned rotators, for which the magnetic axis and the rotation axis coincide, the trapped matter accumulates near the equatorial plane.

We have considered the general case and studied the force equilibrium and the stability of circumstellar matter in the closed magnetosphere of an oblique rotator. Assuming that the magnetic energy density is much larger than the kinetic energy density of rotation, which, in turn, is much larger than the thermal energy density of the plasma, we can assume the magnetic field to be fixed and ignore the thermal pressure. The equilibrium problem is then reduced to finding the locations where the (vector) sum of the gravitational and the centrifugal force is perpendicular to a given magnetic field line. We find the following distribution of matter accumulating, e.g. from a stellar wind:

1. A disk-like structure roughly aligned with the magnetic equatorial plane, and
2. two locations above and below the disk, coarsely aligned with the axis of rotation.

The latter stable equilibrium regions are most prominent for large obliquity of the axes (perpendicular rotator). They provide hitherto unknown locations for the accumulation of circumstellar matter, which could explain some observations of rapidly rotating magnetic stars.

(O. Preuss, V. Holzwarth, M. Schüssler, S.K. Solanki)

Weak magnetic fields in white dwarfs

The major goal of this work is a better understanding of the role played by magnetic fields in the formation and evolution of stars. Only a small fraction of white dwarfs are known to have a magnetic field, while we expect at some low level all stars to have a field. Spectropolarimetry is the most promising technique for successful detections of weak magnetic fields. Spectropolarimetric observations of a sample of 12 normal DA white dwarfs were carried out using FORS1 at the 8 m Unit Telescope 1 of the Very Large Telescope, “Antu”. Spectra were acquired in the spectral range 340 – 600 nm, covering all H I Balmer lines from Hβ to the Balmer jump simultaneously. In this work we have used the spectropolarimetric capability of the FORS1 instrument, together with the light collecting power of the VLT, in order to investigate the presence of magnetic fields in the range 1 – 10 kG for our sample of white dwarfs.

We have detected longitudinal magnetic fields between 2 and 4 kG in three white dwarfs of our sample (WD 0446 – 790, WD 1105 – 048, WD 2359 – 434) by applying a χ^2–minimization procedure between their observed circular polarization spectra and the (V/I) spectra predicted by the weak-field approximation. With the exception of 40 Eri B (4 kG) these are the first positive detections of magnetic fields in white dwarfs below 30 kG. Although suspected, it was not clear whether a significant fraction of white dwarfs contain magnetic fields at this level. These fields may be explained as fossil relics from magnetic fields in the main-sequence progenitors considerably enhanced by magnetic flux conservation during the shrinkage of the core. A detection rate of 25% (3/12) may indicate now for the first time that a substantial fraction of white dwarfs have a weak magnetic field. This result, if confirmed by future observations, would form a cornerstone for our understanding on the evolution of stellar magnetic fields. Therefore, a larger sample of observations of weak magnetic fields is needed to clarify the long-standing question, how many white dwarfs have up to now undetected weak fields and to what extent magnetic flux is converted during stellar evolution. Such observations will be acquired during 2004 using FORS1 on VLT.

(R. Aznar Cuadrado, S. K. Solanki, in collaboration with S. Jordan, Eberhard-Karls-Universität Tübingen, R. Napiwotzki, University of Leicester, UK, H. M. Schmid, ETH-Zürich, Switzerland, and G. Mathys, European Southern Observatory, Santiago, Chile)

A stream of particles from the β Pictoris disc

Recently, a stream of particles originating from the direction of β Pictoris, a young main sequence star surrounded by a dust disc, has been reported (Baggaley 2000, JGR, **105**, 10353). Standard mechanisms of particle ejection from a disc fail to reproduce the properties of this stream: The particles are large, fast and their flux is high. Ejection of dust by radiation pressure from comets in eccentric orbits has been proposed by Grün & Landgraf (2001, Space Sci. Rev., **99**, 151). We propose another mechanism – scattering of dust by gravity of a hypothetical planet in the disc. We reexamine observational data and consider both theoretical scenarios, in order to test whether they can explain quantitatively the masses, the speeds and the fluxes.

Our analysis of the stream geometry and kinematics confirms that β Pic is the most likely source of the stream and suggests that an intensive dust ejection phase took place $\sim$ 0.7 Myr ago. Our dynamical simulations show that high observed ejection speeds can be explained by both planetary and radiation pressure mechanisms, providing, however, several important constraints. In the planetary ejection scenario, only a 'hot Jupiter'-type planet with a semimajor axis of less that 1 AU can be responsible for the stream, and only if the disc was dynamically heated by a more distant massive planet. The radiation pressure scenario also requires the presence of a relatively massive planet at several AU or more. Finally, the dust flux at Earth can be brought into reasonable agreement with both scenarios, provided that β Pic's protoplanetary disc recently passed through an intensive short-lasting ($\sim$ 0.1 Myr) clearance stage by nascent giant planets, similar to what took place in the early Solar System.

Our work also indicates that protoplanetary dust discs form a potentially rich source of large interstellar grains, as widely detected in the Solar System.

(N. A. Krivova and S. K. Solanki, in collaboration with A. V. Krivov, Univ. Potsdam and V. B. Titov, Univ. St. Petersburg)

2. *Planeten, ihre natürlichen Satelliten und Kometen/*
Planets, their moons and comets

Schwerpunktthema:

SMART-1 – Europas Mission zum Mond

(English version see 60)

Seit am 14. Dezember 1972 die Besatzung der Apollo-17-Mission das Taurus-Littrow-Tal am südöstlichen Rand des Mare Serenitatis mit dem Ziel Erde verließ, hat die Menschheit die Mondoberfläche nicht mehr betreten. Nach über 30 Jahren wird nun eine neue Initiative für eine weitere Phase der Erforschung und der Nutzung des Mondes in den USA eingeläutet. In den letzten Jahren haben jedoch einige Nationen bereits wieder angefangen, mittels satelliten-gestützter Fernerkundung offene Fragen der Mondforschung anzugehen. Unter den zurzeit laufenden Missionen wird die europäische Mission SMART-1 (Small Advanced Research Missions) als nächste den Mond erreichen. Obwohl SMART-Missionen eigentlich Technologien entwickeln sollen, die dann bei den großen Europäischen Cornerstone-Missionen zum Einsatz kommen sollen, will die Europäische Weltraumorganisation ESA mit der SMART-1-Mission auch noch ein altes Versprechen einlösen, nämlich einen europäischen Beitrag zur weiteren Erforschung des Mondes zu leisten.

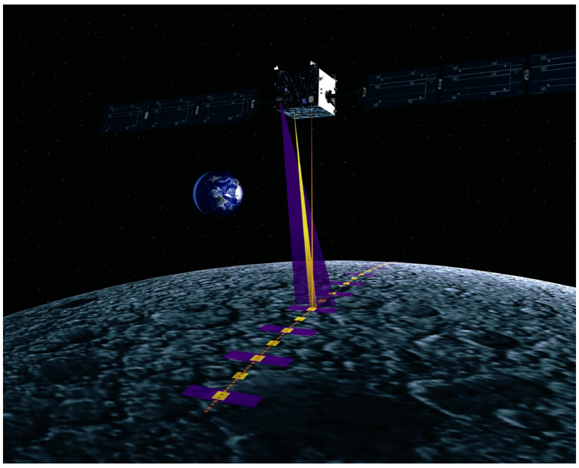

Abb. 55: Die Sonde SMART-1 tastet mit ihren Fernerkundungsinstrumenten die Mondoberfläche ab.

Man kann sich an dieser Stelle fragen, warum der Mond, den die Menschheit als einzigen Himmelskörper direkt besucht hat und von dem über 380 kg Gesteinsproben in irdischen Labors minutiös untersucht wurden, immer noch wissenschaftliches Interesse findet.

Das Interesse am Mond beruht unter anderem auf folgenden Tatsachen: Verglichen mit den terrestrischen Planeten ist der Mond einzigartig, was seine Größe, Dichte und seinen Ursprung angeht. Die Bildung des Erd-Mond-Systems muss nach wie vor als eine offene Frage betrachtet werden. Von den zur Auswahl stehenden Theorien scheint nur die Einschlagstheorie akzeptabel zu sein, die im wesentlichen besagt, dass die Erde mit einem sehr großen Objekt (in etwa von der Größe des Mars) kollidierte, und dass der Mond aus dem „ausgeschlagenen“ Material besteht. Die starke Präferenz für diese Theorie muss aber vor dem Hintergrund gesehen werden, dass all die anderen Theorien zu viele unplausible Annahmen machen müssen. Um diese Fragestellung klar beantworten zu können, müssen wir zwangsläufig mehr über die innere Struktur, die chemische Zusammensetzung und den Wärmefluss des Mondes wissen.

Der Mond unterlag wie alle terrestrischen Planeten im Laufe seiner Geschichte einem Abkühlungs- und Entgasungsprozess. In Planeten lassen radioaktive und andere Prozesse im Inneren Wärme entstehen, die dann nach außen abgeführt wird. Im Gesteinsmantel erfolgt der Wärmetransport durch Wärmeleitung und Konvektion. Diese Prozesse laufen bei den verschiedenen Planeten ganz unterschiedlich ab. Bei der Erde zum Beispiel erfolgt der Wärmefluss an der Oberfläche zu 65% durch Produktion, Migration und Subduktion lithosphärischer Platten, zu 20% durch Wärmeleitung und zu 15% durch den Zerfall radioaktiver Elemente in der Kruste, während beim Mond gar keine Plattenbewegung vorliegt. Gerade das Fehlen einer Plattentektonik und die Tatsache, dass wir für den Mond ein einzigartiges Datenarchiv haben, was die Geologie, Geochemie, Mineralogie, Petrologie und die Chronologie angeht, welches in seinem Umfang nur noch mit dem uns für die Erde vorliegenden vergleichbar ist, gibt dem Mond eine Sonderstellung in der vergleichenden Planetologie. Die Ein-Platten-Tektonik macht den Mond nämlich zu einem relativ einfach strukturierten Planeten. Es besteht deshalb die Hoffnung, dass wir beim Mond Einsichten in die Zusammenhänge zwischen geologischer Evolution und der internen sowie thermischen Entwicklung eines Planeten gewinnen können, die zu unserem generellen Verständnis der Entwicklung von Planeten beitragen.

Die Hoffnung eines europäischen Beitrages zum Studium dieser Fragen liegt nun auf der am 28. September 2003 mit einer Ariane 5 gestarteten SMART-1-Mission, deren primäres technologisches Ziel es ist, eine mit einem Ionen-Antrieb ausgestattete Raumsonde auf einer 16 Monate währenden Flugphase zum Mond zu testen. Die Raumsonde trägt eine aus 6 Instrumenten bestehende Nutzlast, die 10 verschiedene wissenschaftliche und technische Experimente umfasst.

Der wissenschaftliche Beitrag des MPI für Aeronomie zu SMART-1

Weil es wie bei der Erde auch beim Mond möglich ist, die Zusammensetzung des Mondinneren und damit die Zusammensetzung des Silikatanteils des Mondes aus bestimmten Mineralien an der Mondoberfläche abzuschätzen, zählt die Bestimmung der chemischen Zusammensetzung der Mondoberfläche zu den wichtigsten Aufgabenstellungen in der Mondforschung. An Bord der Raumsonde SMART-1 befindet sich daher eine Kamera, ein im Röntgenbereich empfindliches Spektrometer und ein vom Max-Planck-Institut für Aeronomie (MPAe) in Katlenburg-Lindau entwickeltes Spektrometer für das nahe Infrarot. Während spektroskopische Messmethoden von Gesteinen generell geeignet sind, um Mineralien zu identifizieren, zählt die Nahinfrarotspektroskopie zu den besonders geeigneten Methoden, um die Oberflächenzusammensetzung von Planeten und kleinen Körpern zu bestimmen. Das vom MPAe gebaute SMART-1-Infrarot-Spektrometer (SIR) (Abb. 56) misst das von der Sonne an einzelnen Mineralien reflektierte Licht in einem Wellenlängenbereich von 0,9 – 2,4 μm. Da einzelne Mineralien das Licht in diesem Bereich an ganz spezifischen Stellen absorbieren, kann man an Hand von einem Reflexionsspektrum aus der Lage und Stärke der Absorptionen im Spektrum einzelne Mineralien identifizieren.

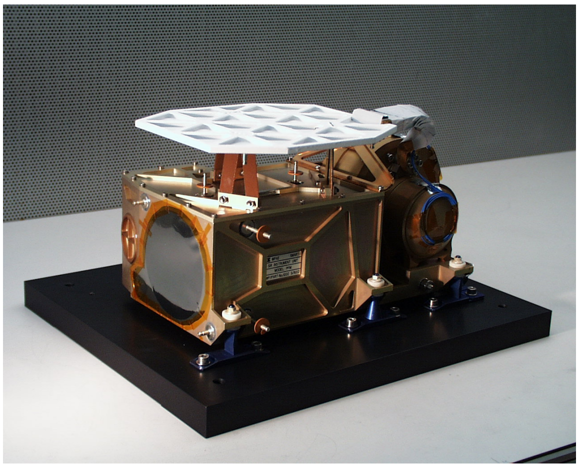

Abb. 56: Das am MPAe gebaute SIR-Instrument steht zur Montage bereit.

Von der Erde aus wurden natürlich schon Infrarot-Beobachtungen des Mondes vorgenommen. Doch solche Messungen haben zwei Nachteile. Erstens beschränken sich diese Messungen auf die der Erde zugewandte Mondseite, und zweitens werden diese Messungen durch die Atmosphäre der Erde gestört. Messungen, die aus einer Mondumlaufbahn gemacht werden, haben dagegen den Vorteil, dass erstens der ganze vom Instrument messbare Infrarotbereich ungestört von dem Einfluss der Atmosphäre aufgezeichnet und zweitens auch die Rückseite des Mondes analysiert werden kann. Dort befindet sich auch das nahe dem Südpol des Mondes gelegene Aitken Basin, ein Kratergebiet, das wegen seiner gewaltigen Ausmaße als größter bekannter Krater im Sonnensystem gilt. Bei einem Durchmesser von 2500 km und einer Tiefe von 13 km wird erwartet, dass an dieser Stelle Material aus dem Mondmantel sichtbar wird. Im Vorfeld für künftige Mondmissionen erwarten wir, dass SIR eine wichtige Rolle bei der Untersuchung dieses Gebietes leisten wird. Neben der Untersuchung von bisher kaum studierten Gebieten werden ferner bei Messungen, die aus einer Mondumlaufbahn gemacht werden, auch die räumliche Auflösung durch die Mondnähe verbessert. In der Tat ist SIR nicht das erste Infrarot-Spektrometer, das den Mond untersucht. Während frühere Spektrometer das Spektrum nur an einzelnen Stellen mittels Filtern abtasten konnten, misst das neue Instrument den ganzen Spektralbereich durchgängig zwischen 0,9 und 2,4 μm. Aus diesem Grund und wegen seiner guten spektralen Auflösung von 6 nm hat SIR grundsätzlich auch die Möglichkeit, das viel diskutierte Eis auf dem Mond nachzuweisen, sofern es wirklich vorhanden ist.

Dass das Wasser für die Entstehung von Leben wie wir es kennen eine unabdingbare Voraussetzung ist, bedarf keiner besonderen Erläuterung. Dass Wasser aber im Falle des Mondes zu einem Thema wurde, verdankt es einer Arbeit von Kenneth Watson und Kollegen, die 1961 bemerkten, dass die äquatoriale Ebene des Mondes nur um 1,5 Grad zur Ekliptik geneigt ist und deshalb Krater, die in den Polgebieten liegen, im Innern Gebiete aufweisen, die ständig im Schatten liegen. Wegen der extrem niedrigen Temperaturen von ca. -200 Grad Celsius in diesen Schattengebieten sollte dort das Wasser, sofern es einmal welches gab, noch als Eis vorliegen. Ob überhaupt Eis vorhanden ist und mittels welcher Mechanismen Wasser an diese Stellen überhaupt kommen konnte, steht nun seit geraumer Zeit im Zentrum des wissenschaftlichen Interesses und der Diskussion.

Seit die Raumsonde Lunar Prospector den Mond im Jahre 1998 besucht hat, verfechten einige Wissenschaftler die These, dass kein Zweifel daran bestehe, dass sie Eis mittels eines Neutronenmonitors wirklich beobachtet hätten. Trifft nämlich die kosmische Strahlung auf die Mondoberfläche, so werden Neutronen aus der Mondoberfläche, dem Regolith, geschlagen, die in weiteren Kollisionen mit den Atomen des Mondgesteines zunehmend Energie verlieren. Infolge dieser Kollisionen werden solche mehr oder minder moderierten Neutronen auch in den Raum oberhalb der Mondoberfläche gestreut, wo sie von einem auf einem Satelliten sich befindlichen Neutronenmonitor auch registriert werden können. Treffen die Neutronen auf Stoßpartner, die fast die gleiche Masse wie sie selber haben, zum Beispiel Wasserstoff, dann können sie in diesen Stößen besonders viel Energie abgeben. Aus der Messung eines Neutronenspektrums kann also auf die atomaren Stoßpartner oder auf das makroskopische Material geschlossen werden, auf das die Neutronen treffen.

In der Tat zeigt die Analyse der Lunar-Prospector-Messungen, dass es an den Polen besonders viel wasserstoffhaltiges Material zu geben scheint. Die Tatsache, dass dieses Material nun gerade in den Kratern, die im Schatten liegen, besonders konzentriert zu sein scheint, ist der wesentliche Punkt der Argumentation. Verglichen mit der Methode der Neutronenstreuung hat nun die Beobachtung von Eis mittels des Nahen Infrarotes einen besonders interessanten Aspekt. Während die Neutronenstreuung zwangsmäßig eine dicke Regolith-Schicht untersucht, beobachtet man mittels des Infraroten, da es sich um Reflexionsspektroskopie handelt, nur gerade die oberste Schicht. Da sich Eis, wegen seiner besonders schön ausgeprägten Absorptionsspektren im Infraroten, dort besonders leicht identifizieren lässt, würden erfolgreiche SMART-1-Beobachtungen sehr direkt und ohne weitere Annahmen beweisen, dass die von der Sonde überflogenen Oberflächen wirklich aus Eis bestehen. Im Hinblick auf die nun beschlossene Initiative, eine permanente bemannte Mondbasis zu errichten, erhält die Suche nach Wasser nun eine ganz neue Dimension.

(U. Mall)

Highlight:

SMART-1 – Europe's Mission to the Moon

On 14 December 1972, when Gene Cernan and Harrison Schmitt blasted off from the Taurus Littrow valley, on the south-eastern shore of Mare Serenitatis, at the end of the highly successful Apollo 17 mission, nobody thought that mankind would not visit the Moon again. Now more than 30 years later a new initiative in lunar research and utilisation has been launched in the US. In the last past years a few nations have started again to revisit some of the open questions in lunar science using remote sensing satellites. Among the currently operated missions SMART-1 (Small Advanced Research Missions) will visit the Moon next. Although SMART missions are intended to develop and test new technologies which should be used in future European cornerstone missions, the European Space Agency (ESA) will fulfill an old promise: To deliver a European contribution to enhance our understanding of lunar science.

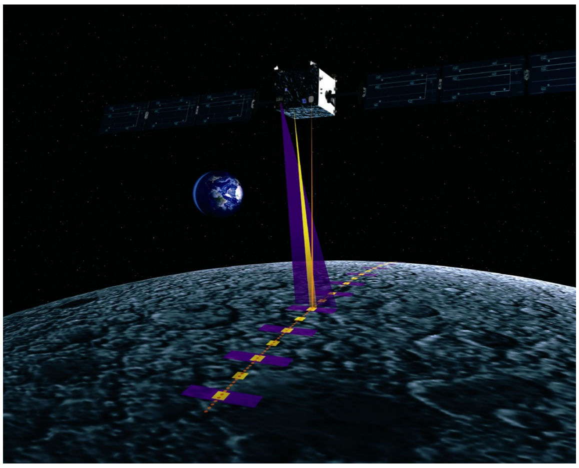

Fig. 55: The SMART-1 spacecraft surveying the lunar surface with its payload.

One may wonder why the Moon, which was visited as the only planetary body by mankind and from which we have collected more than 380 kg of samples, which were accurately analysed in our laboratories, is still of scientific interest. The interest in the Moon, among other reasons, is based on the following facts: Compared with other planets the Moon is unique in terms of its size, density and its origin. The formation is still considered an open question. Among the proposed theories, only the giant impact theory seems to be acceptable. This theory states that the proto-Earth collided with a massive object (of the size of Mars) and that a fraction of that debris went into orbit around the Earth and aggregated into the Moon. The strong preference which is given to this theory is based on the fact that the giant impact theory does not need additional artificial assumptions. However, to clearly answer the question of how the Moon originated, we need to know more about the inner structure, the chemical composition and the heat flux of the Moon.

The Moon, like all the terrestrial planets, was subject to cooling and outgassing processes. Radioactive and other processes generate heat which is then dispersed from within the core to the outside. In the mantel heat conduction and the heat convection are the basic heat transport mechanisms. In the different planets these processes contribute differently to the heat transport. In the case of the Earth, the heat flux at the surface is carried to 65% through the production, migration and subduction of lithospheric plates, to 20% through heat conduction, and to 15% through the decay of radioactive elements in the crust, while in the case of the Moon there does not exist any plate movement. It is just the absence of the plate tectonics and the fact that we have a unique data archive for geology, geochemistry, mineralogy, petrology and chronology, which gives the Moon its special position in the field of comparative planetology. The one plate tectonic makes the Moon a relatively simple structured planet. It is this fact which gives us hope that with the Moon we can gain insight into the relationship between geological evolution, internal and thermal development of a planet. This insight should ultimately lead us to a general understanding of planetary evolution.

Our hope for a European contribution to the unravelling of some of those questions relies now on the SMART-1 mission, which was launched on 28/09/2003 with an Ariane 5 rocket. The primary goal of SMART-1 is, however, the testing of a new ion electric propulsion system on a 16-month long flight to the Moon. The satellite carries 6 instruments, which perform 10 different scientific and technological experiments.

The scientific contribution of the MPI für Aeronomie to SMART-1

The determination of the chemical composition of the lunar surface remains one of the most important tasks in lunar science, since, as is the case with the Earth, it is possible to estimate the interior composition of the Moon from a knowledge of the mineral composition of the surface. On board the SMART-1 satellite one can therefore find a camera, an X-ray spectrometer and an near-infrared spectrometer which was developed at the Max-Planck-Institut für Aeronomie (MPAe) in Katlenburg-Lindau. While spectroscopic measurement methods are generally suitable for identifying minerals, the near-infrared spectroscopy is a particularly powerful method to determine the surface composition of planets and small bodies. The near-infrared spectrometer (SIR) measures the solar light which is reflected by individual minerals in the wavelength range between 0.9 and 2.4 μm. Since minerals absorb the light at very specific wavelength positions, one is able to determine from the position and the depth of the absorption features in the reflected spectra individual minerals.

Indeed, one has made infrared observations of the Moon already from Earth. However, such observations have distinct disadvantages. First, such measurements can only be made on the lunar near side and second, such measurements are disturbed by the Earth's atmosphere. Measurements which are made from a lunar orbit have the advantage that the instrument can record the whole measured infrared range measured without the influence of the atmosphere and second, that one can also analyse the lunar far side.

There you also find, close to the South Pole, the Aitken Basin. The South Polar Aitken Basin is the largest, oldest preserved lunar basin in the solar system. With a diameter of 2500 km and a depth of 13 km one expects that material from the lunar mantle becomes visible. We expect that in view of the upcoming lunar missions, SIR is going to contribute significantly to the investigation in this area. Aside from research in lunar regions, where hardly any research has been done, measurements taken from a lunar orbit are going to improve the spatial resolution. Indeed, SIR is not the first infrared spectrometer investigating the Moon. However, while older measurements could only sample the infrared spectral region at selected bands with the help of filters, our new instrument SIR measures the infrared region between 0.9 and 2.4 μm continuously. For this reason and because of its good spectral resolution of 6 nm, SIR has the possibility to discover the much discussed ice on the Moon, assuming that it really exists.

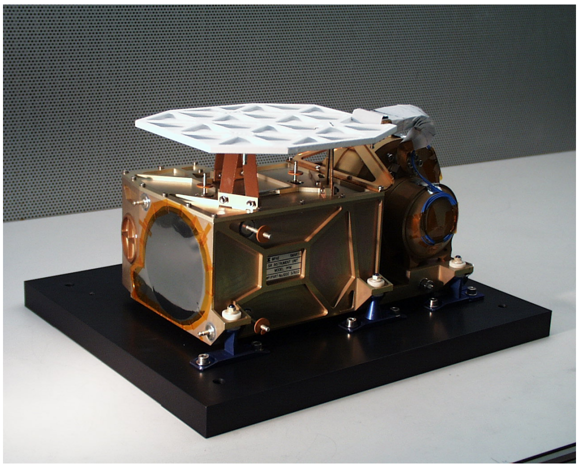

Fig. 56: The SIR instrument built by the MPAe ready for shipping to ESA's launch site.

The fact that water is an absolutely necessary condition for evolution of life is widely known. The fact that water has become a topic in lunar science goes back to a paper by Kenneth Watson and colleagues, who recognized in 1961 that the equatorial plane is inclined by 1.5 degrees to the ecliptic and, therefore, craters which are located close to the poles have regions in their interior which are permanently shadowed. Because of the extremely low temperatures of -200 degrees Celsius in these regions, any water which could have existed in these shadowed regions should still be present in the form of ice. Whether ice is really there and through which mechanisms water was transported to these shadowed regions has been at the centre of an intense and ongoing scientific debate.

Since the spacecraft Lunar Prospector visited the Moon in 1998, a group of scientists claim that there is no doubt that ice was observed with Lunar Prospector's neutron monitor. When cosmic rays strike the lunar surface, neutrons are released from the surface material of the Moon, the lunar regolith. The released neutrons lose their energy in subsequent collisions with the atoms of the lunar surface. A fraction of these moderated neutrons are scattered into the lunar exosphere where they can be observed with a neutron monitor located on a spacecraft. When neutrons collide with targets which have nearly the same mass, as for example, hydrogen atoms, they can lose a particular large fraction of their energy. By measuring a neutron spectrum one can therefore gain insight into the collisions patterns of the neutrons or the macroscopic material with which the neutrons collide.

Indeed, the analysis of the Lunar Prospector data show that there seems to exits large amounts of hydrogen rich material in the polar regions. The fact that this material looks to be concentrated in the craters which are permanently shadowed, is the important point in the scientific argument. Compared to the method of neutron scattering, the measurement of ice using the near-infrared has a particular interesting aspect. While neutrons can only probe a thick layer of material, near-infrared reflection spectroscopy investigates only the uppermost layer of any material. Since ice, with it clear absorption signatures, allows for a beautiful identification of its presence, successful SMART-1 SIR observations would directly and without any further assumptions prove that the spacecraft has flown over ice. With the prospect of the newly announced initiative to go back to the Moon and establish a permanent lunar base, the search for water has acquired a new dimension.

(U. Mall)

Wissenschaftliche Einzelberichte/ *Individual scientific reports*

(nur in Englisch)

Terrestrial planets research – Venus

Analyser of Space Plasmas and Energetic Atoms ASPERA-4 for Venus Express

The solar wind – Venus interaction is very similar to the one at Mars. Both planets do not possess an internal global magnetic field. This opens their atmosphere to the direct exposure of the solar wind. The solar wind particles interacting with the upper atmospheres can, via charge-exchange reaction, be converted to energetic neutral atoms (ENAs) which can be used to remotely study the interaction process and the plasma and neutral gas parameters. ASPERA-4 on Venus Express comprises a sophisticated ENA detection and imaging system with plasma sensors and a magnetometer. ASPERA-4 will allow to determine the instantaneous global distributions of plasma and neutral gas near the planet and to study the plasma induced atmospheric escape via detection of ENAs produced by charge – exchanging planetary ions. Furthermore, with ASPERA-4 we can investigate the atmospheric modification by ion sputtering via detection of the backscattering ENAs and the energy deposition to the atmosphere via detection of the precipitating ENAs. The MPAe is participating in the development and fabrication of ASPERA-4. The launch of Venus Express is scheduled for November 2005.

(J. Woch, N. Krupp, in collaboration with TU Braunschweig and IRF, Kiruna)

Terrestrial planets research – Earth

Power requirement of planetary dynamos

The energy flux needed to overcome ohmic dissipation in the Earth's core must be provided by slow secular cooling of the core, possibly by decay of radioisotopes such as ^{40}K, and by the gravitational energy released upon the growth of the solid inner core, which is depleted in light alloying elements compared to the liquid outer core. Estimates for the ohmic dissipation cover a wide range from 0.1 to 3 TW or roughly 0.3 – 10% of the Earth's surface heat flow, with recently preferred values exceeding 1 TW. The energy requirement of the dynamo sets constraints for the thermal budget and evolution of the core through Earth's history and may provide clues for explaining the presence or absence of magnetic fields in other planets.

Current dynamo models can reproduce the main characteristics of the geomagnetic field, but for numerical reasons some of the control parameters are far from Earth-like. In order to derive robust scaling laws we calculate the magnetic dissipation time, defined as the ratio of magnetic energy to ohmic dissipation, for a large set of numerical dynamo models covering a substantial range in key parameters. We find a simple inverse relation between the dissipation time and the magnetic Reynolds number, a measure for the ratio of advection to diffusion of the magnetic field. The numerical results permit also an additional dependence on the hydrodynamic Reynolds number, which describes the degree of turbulence of the flow. Although this dependence would be weak, its application to the Earth's core requires an extrapolation over six orders of magnitude in the Reynolds number and changes the estimate for the ohmic dissipation by an order of magnitude. To resolve this uncertainty we analyse the ohmic dissipation in the Karlsruhe dynamo experiment, where liquid sodium is pumped through a system of pipes. In this experiment the hydrodynamic Reynolds number is far larger than in the numerical models and the flow is turbulent. The experimental result agrees well with the simpler scaling law, suggesting that it also applies under the turbulent flow conditions in the Earth's core.

Using this result, we estimate that the power needed to run the geodynamo is in the range of 0.2 – 0.5 TW. This rather moderate power requirement removes the need for strong radioactive heating in the core. The age of the solid inner core, calculated to be only 1 Gyr when the dynamo needs more than 1 TW, could exceed 2.5 Gyr with our new estimate. An old inner core is more easily reconciled with evidence for the existence of the geomagnetic field with approximately the present-day strength over the past several billion years.

(U. Christensen in collaboration with A. Tilgner, University of Göttingen)

Stochastic resonance in a bistable geodynamo model

Recently a periodic signal with a period of 100 kyr in the distribution of residence times between reversals of the geomagnetic field has been suggested as signature of stochastic resonance. This period has also been found in other geomagnetic quantities. We tested the suggestion of stochastic resonance by applying periodic disturbances to a model of the geodynamo as a bistable oscillator, where stochastic fluctuations of the induction effect (multiplicative noise) lead to random transitions between the two polarity states of the supercritically excited fundamental axial dipole mode. By adding a weak periodic component either to the dynamo effect (multiplicative periodic term) or as a source term to the dynamo equation (additive periodic term) we demonstrate the signatures of stochastic resonance in the distribution of residence times. Depending on the multiplicative (additive) character of the periodic term, we find peaks at integer (half-integer) values of the applied period, superposed the otherwise Poissonian distribution, demonstrating the increased reversal rates at the resonance frequencies. A prominent and sharp peak at the forcing frequency shows up in the power spectrum of the dipole moment only in the case of an additive periodic component. The absence of this peak for the geomagnetic reversal record hints towards a multiplicative periodic component in the geodynamo. Especially the optimum resonance conditions for various mean times between reversals and various periodicities are derived. The periodic terms need to be about 0.1 in amplitude compared to the other terms in the dynamo equation to show the observed signatures of the magnetic field of the Earth. It is yet unclear what may cause such an effect to the geodynamo.

(D. Schmitt, in cooperation with S. Lorito, G. Consolini and P. De Michelis, Rome and P. Hoyng, Utrecht)

Comparison of mean-field theory with direct numerical dynamo calculations

Many features of the Earth's magnetic field have been successfully reproduced by non-linear three-dimensional simulations of the magnetohydrodynamics (MHD) in the Earth's core. Although some model parameters do not reach realistic values, the simulations exhibit a dipole dominated magnetic field that is maintained over several magnetic diffusion times. In addition, the time dependence of the dipole moment, including secular variation, excursions and reversals, resembles the observed Earth's magnetic field.

Despite this success in the case of the geodynamo, global dynamo calculations applied to various other astronomical objects make use of the so-called mean-field theory. Its idea is based on a scale separation where attention is focused only on mean, i.e. large-scale fields. Using an azimuthal average and defining mean fields as the axisymmetric parts of the actual magnetic field, it is possible to reduce the intrinsically three-dimensional dynamo problem to a two-dimensional one. The non-axisymmetric or residual parts need not to be known in detail. Only certain averages of them are relevant and appear as an additional term, the mean electromotive force, in the induction equation for the mean magnetic field.

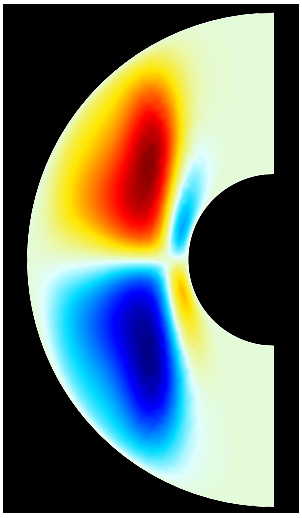

Fig. 57: Contour plot of $\alpha_{\phi\phi}$ in the meridional plane, derived for the benchmark 1 geodynamo model. Red and blue represent positive and negative values, respectively, with maximum amplitude of ±6 m/s.

Since both approaches are available in the case of the geodynamo, a detailed comparison of mean-field theory with direct numerical simulations can be done for the first time. One aim of our work is to get an estimation on the validity and reliability of mean-field theory. On the other hand, mean-field concepts help to improve the conceptual understanding of the geodynamo in the outer core.

Whether a mean-field model shows dynamo action or not depends strongly on the mean electromotive force which scales linearly and homogeneously with the mean magnetic field. In order to solve the induction equation for the mean magnetic field one has to extract this dependence by a series expansion of the electromotive force. The resulting tensorial mean-field coefficients α and β are inserted in the mean-field model equations. While α is interpreted as an inductive term, β contributes to the diffusion of the mean magnetic field. Unfortunately neither the 9 components of the α-tensor nor the 27 components of the β-tensor are known in general. Usually they are assumed in some reasonable way.

Making use of direct numerical simulations of the geodynamo we developed a method to determine these mean-field coefficients. For the first time we are able to present full α- and β-tensors.

Finally we inserted these calculated mean-field coefficients in a two-dimensional mean-field model and are now able to compare its dynamo action with three-dimensional MHD-calculations.

(M. Schrinner, U. Christensen, D. Schmitt, in cooperation with K.-H. Rädler, Potsdam)

Tomography and geodynamic models of the Eifel Plume

The Eifel in Western Germany is a region of recently active volcanism, probably associated with the rise of a thermal plume from greater depth in the mantle. To examine the subsurface structure a seismic network consisting of about 250 stations was operated in 1998. The tomographic inversion of the recorded teleseismic traveltime data for P- and S-waves show a well-resolved, plume-like velocity anomaly underneath the Eifel reaching to a depth of at least 400 km.

In an ongoing study we refine the model and try to extend it to a depth of 800 km by using additional data from previous experiments in the Rheingraben and Massif Central area. The shallow lithospheric structure is poorly constrained by the tomography experiment and additional information on crustal properties and from gravity anomalies can give a better control on it, which will help to improve the resolution and significance of the deep plume structure. The final combined inversion should provide a reliable image of the seismic transition zone beneath the Eifel and help to clarify the source depth of small mantle plumes.

Furthermore, we use fluid-dynamical models to better constrain the structure of the Eifel plume in a geodynamically consistent way. We want to derive estimates for the physical parameters of the plume and the surrounding mantle underneath the Eifel region such as position, radius, and excess temperature of the plume, the shape of the plume head in dependence of the surface motion of the Eurasian plate, and mantle rheology. We calculate a suite of numerical plume models and perform ray-tracing for the source-receiver configurations of the Eifel experiment through the synthetic plume structures. The plume parameters are varied until a best fit to the observed travel times is found. The observed data are influenced by mantle structures unrelated to the plume and we are working on methods to avoid that the inversion for plume parameters is corrupted by such unrelated structures. First results suggest that it is possible to constrain key parameters of the plume.

(U. Wüllner, M. Jordan, A. Barth, R. Olejniczak, U. Christensen in collaboration with J. Ritter, Karlsruhe)

Terrestrial planets research – Mars

Three-dimensional evolution models of convection in the Martian mantle

On Mars volcanism, tectonic activity and anomalies in the gravity field are concentrated in only one region, the Tharsis region. These observations suggest that thermal convection in the Martian mantle differs from that in the Earth's mantle. Models have shown that convection in the Martian mantle may be dominated by only one single plume under the Tharsis region. A possible reason for this greatly simplified convective pattern compared to the Earth can be the endothermic phase transition in the mineral structure from γ-spinel to perovskite and magnesiowüstite, which may appear close to the core-mantle boundary (CMB).

We now adopt an existing 3-D numerical convection code to the specific features on Mars, trying to make it more realistic than the existing models and aiming at modelling the total thermal evolution of the planet. We include the endothermic phase boundary from γ-spinel to perovskite and magnesiowüstite close to the CMB. The viscosity is depth-dependent and varies with the radial averaged temperature following an Arrhenius term. According to changes in the temperature the viscosity varies with time, which allows to simulate the thickening of the lithosphere. The model also includes cooling of the core, whose temperature is now determined by the heat lost to the mantle.

First results of these more realistic models confirm that the presence of the endothermic phase boundary near to the CMB causes a strong reduction of the number of upwellings. A two-plume pattern is reached after 4.5 billion years. In addition, the phase boundary affects the cooling of the core. Without the phase boundary the core cools by 500 K in 4.5 billion years, which drops slightly when the phase boundary is included. The influence of the transition on the thickness of the lithosphere after 4.5 billion years is only small. The thickness in all models is about 150 km.

(M. Buske and U. Christensen)

Mars Climate Simulator: Investigation of the current and ancient Martian climate, its stability and mechanisms of changes by means of a modular planet simulator model

Celestial-mechanical computations show that, even stronger than for Earth, Mars is subject to Milanković cycles, that is, quasi-periodic variations of the orbital parameters obliquity, eccentricity and precession. Consequently, solar insolation varies on time-scales of $10^4 - 10^5$ years. It has long been suspected that this entails climatic cycles like the terrestrial glacial-interglacial cycles. This hypothesis is supported by the light-dark layered deposits of the north- and south-polar caps indicating a strongly varying dust content of the ice due to varying climate conditions in the past.

To investigate the climate variability of Mars, a modular planet simulator model is developed. A general circulation model (GCM) of the atmosphere and a dynamic/thermodynamic ice-sheet model – both inherited from models for Earth – are adapted to Martian conditions. Eventually, these models will be coupled to asses the interaction between the atmosphere and the polar caps.

The GCM is based on the Portable University Model of the Atmosphere (PUMA). The result of a Mars simulation is shown in Fig. 58.

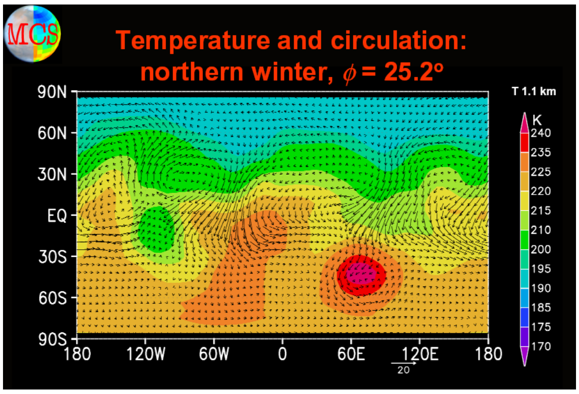

Fig. 58: Near surface daily mean temperature and wind at 1.1 km altitude as simulated with the Mars version of PUMA for the present obliquity of 25.2°.

The ice-sheet model SICOPOLIS (SImulation COde for POLythermal Ice Sheet) computes three dimensionally the temporal evolution of ice extent, thickness, velocity, temperature, and water content as a response to external forcing. The forcing is specified by the mean annual air temperature above the ice, the surface mass balance – which is ice accumulation (snow fall, condensation) minus ablation (melting, evaporation, erosion) –, and the geothermal heat flux entering the ice mass from below. Simulations have been carried out to study the evolution of the north polar cap of Mars under steady-state scenarios as well as transient scenarios over climate cycles, cf. Fig. 59.

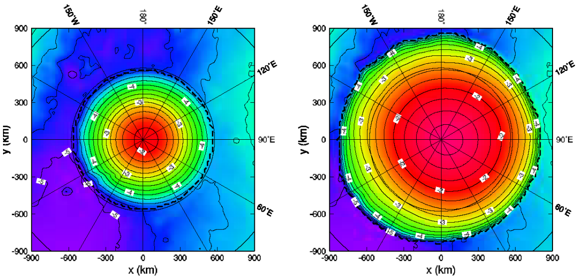

Fig. 59: Shape of the north-polar cap of Mars as simulated with the ice-sheet model SICOPOLIS, started from inital conditions with no ice. Left: Shape after 30 Ma, resembling the present polar cap. Right: Equilibrium shape after 500 Ma.

It is found that the north-polar cap is most likely not in a steady state with respect to the present climate.

(B. Grieger)

Mesoscale modelling of Martian fog formation

The simulation of Martian fogs is implemented with the Mars MM5. This model is based on the Pennsylvania State University (PSU)/National Center for Atmosphere Research (NCAR) Mesoscale Model Version 5 (MM5) and converted for use on Mars. It has been developed to research atmospheric dynamics on scales of a few hundreds meters to a few hundreds of kilometers, so that it is the most suitable model to study fog formation. The surface topography is taken from MGS Mars Orbiter Laser Altimeter (MOLA) high-resolution data set. Boundary conditions are provided by the GFDL Mars GCM.

For this study, we add the codes of microphysical processes to the Mars MM5. This enables the mesoscale atmospheric model to better simulate the water ice cycle. The microphysical processes of heterogenous nucleation, condensation, sublimation and sedimentation are included. Coagulation due to sedimentation will be added in the future. Brownian coagulation is negligible because it affects only small particles with r less than 0.01 μm, where r is particle radius. The nucleation rate is a function of the radius of nuclei particles, with nucleation on large dust particles being faster than that on small particles. All dust particles are assumed to act as nuclei. Since there are typically many large dust particles near the surface, little nucleation occurs on particles with $r < 1.0$ μm.

The radii of formed ice particles depends on the pre-existing dust particles which are active as nuclei. When fog is formed, the size distribution of aerosols is bimodal with the peaks of dust and fog particles because small dust is not covered by water-ice. Since water ice particles are segregated to the surface during the formation phase of the seasonal cap, large dust particles which act as nucleation cores of water ice particles are removed from the atmosphere.

High Resolution Stereo Camera (HRSC) onboard Mars Express has provided images of water ice clouds / haze since January 2004. The mesoscale model with the microphysical processes will be used to study the water ice in the atmosphere by comparing with the observed data. The wavelength dependence on the reflectance of clouds / haze will provide the information of the size of particles. The panchromatic bands are for a nadir, two photometric, and two stereo channels. Using the shadow and stereo methods the optical depth of clouds / haze are estimated. Furthermore, the height of ice condensed level will be given by analysing stereo images.

(A. Inada, W.J. Markiewicz, H.U. Keller)

Development of the LTE version of the general circulation and climate model of the Martian atmosphere MART-ACC

Future microwave experiments operating in the mm- and submm range will strongly improve the knowledge about the structure, dynamics and chemistry of the Martian atmosphere. Limb sounders in low orbits will provide highly resolved altitudinal profiles of temperature, wind, water vapour and minor species from ground to far above 100 km and therefore make an important contribution for a better understanding of the general circulation and the climate on short and long time scales. The complexity of the atmospheric interactions makes a simple interpretation of the experimental data difficult. Therefore, the numerical model MART-ACC (Martian Atmosphere – Circulation and Climate Model) describing the general circulation in the altitudinal range of 0 – 130 km is being to become upgraded.

The initial version of MART-ACC consisted in a three-dimensional Eulerian grid-point model with horizontal resolution of 22^o longitude versus 5.6^o latitude. The atmosphere was considered to be in local thermodynamic equilibrium.

2002 – 2003 the heating and cooling rates introduced into the LTE version of MART-ACC were essentially improved.

The temperature profiles and the wind velocities of the Martian atmosphere were better fitted to observational results obtained by the Thermal Emission Spectrometer (TES) of Mars Global Surveyor (MGS).

Basing on the vertical grid refinement (vertical steps of 1 km) a temporal and londitudinal analysis of the exitation of tidal waves in the atmosphere was performed.

(P. Hartogh, C. Jarchow, C.-V. Meister, R. Saito, G. Villanueva, in collaboration with U. Berger, G. Sonnemann, Leibniz-Institute for Physics of the Atmosphere, Kühlungsborn, A. Feofilov and A. Kutepov, Institute for Astronomy and Astrophysics, University Munich, and H. Elbern, Institute for Geophysics and Meteorology, University Köln)

Implementation of non-LTE radiation transport into the general circulation and climate model of the Martian atmosphere MART-ACC

Under conditions of local thermodynamic equilibrium (LTE), the level populations of the atmospheric components follow the Boltzmann law. In case of Mars, such conditions exist in the lower atmosphere.

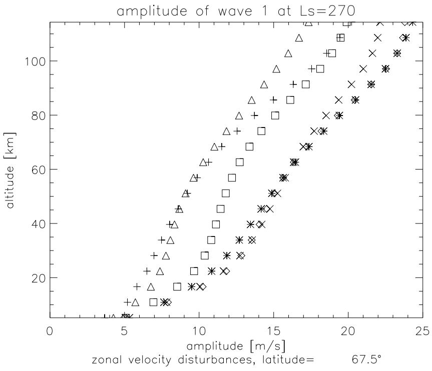

Fig. 60: Amplitudes of wave 1 of the zonal wind velocity in the Martian atmosphere at northern winter solstice calculated by MART-ACC. Equal symbols designate wave amplitudes at the same time. Time steps of 17700 sec are considered, that means the presented five altitudinal profiles show the behaviour during one Martian day of 88500 sec.

But, with decreasing particle densities, at altitudes of 50 – 80 km above the planetary surface, even although the velocity distributions of the particles may be assumed to be maxwellian ones, the radiational and collisional transitions between the energy levels of the carbon-dioxide isotopes cannot be considered separately. Consequently, the level populations of the carbon dioxide deviate from the Boltzmann law, and one has to describe the radiation transport problems within the frame of the non-LTE approximation.

Thus, for the altitudinal temperature and pressure profiles found by the LTE-version of the numerical model MART-ACC, profiles of the heating and cooling rates of the atmosphere are calculated (Fig. 61). Therefore, the radiation transport equation and the statistical equilibrium equation for the population densities of the energy levels of carbon dioxide are solved using the ALIRET line-by-line algorithm for the multilevel and multimolecular rotational-vibrational non-LTE problem. As trace gases causing the collisional transitions between the energy levels of carbon dioxide, atomar oxygen, carbon monoxide and molecular nitrogen are taken into account. It is shown that the non-LTE heating and cooling rates strongly depend on the atmospheric altitude, the solar zenit angle and the chemical components, but also on the chosen top of the atmospheric model.

The obtained non-LTE rates are finally introduced into the MART-ACC programme to recalculate the temperature, pressure and wind velocity profiles.

(C.-V. Meister, P. Hartogh in collaboration with A. Feofilov and A. Kutepov, Institute for Astronomy and

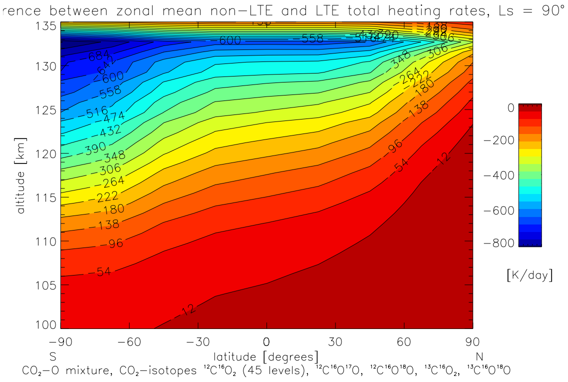

Fig. 61: Difference between non-LTE and LTE heating rates of the Martian atmosphere at northern summer solstice ($L_s = 90^o$) as function of latitude and altitude. The altitudes are found for an atmosphere model with constant height scale of 10 km. In models with temperature and gravity dependent height scales, the altitudes are about 25 km larger (the atmospheric pressure is $1-2$ orders smaller). 45 vibrational levels of the carbon-dioxide isotope $^{12}C^{16}O_2$ are considered. Further, the isotopes $^{12}C^{16}O^{17}O$, $^{12}C^{16}O^{18}O$, $^{13}C^{16}O_2$, and $^{13}C^{16}O^{18}O$ are taken into account.

Astrophysics, University Munich)

LTE radiative heating rates based on MGS/TES nadir temperature measurements

To compare the temperature profiles and the total heating rates obtained by the general circulation and climate model MART-ACC of the Martian atmosphere with experimental results, a detailed analysis of the diurnal and seasonal behaviour of the TES nadir temperature data published in the MGS Data Archives is performed (Fig. 62). Besides, basing on the experimental temperature profiles, the total LTE heating rates in the spectral range of $1-20$ μm are calculated using a line-by-line code which is equal to the description of the initial solution of the ALIRET programme for non-LTE investigations (Fig. 63). An additional non-LTE analysis shows that non-LTE effects are negligible in the considered altitudinal region.

(C.-V. Meister in collaboration with A. Feofilov and A. Kutepov, Institute for Astronomy and Astrophysics, University Munich)

Analyser of Space Plasmas and Energetic Atoms ASPERA-3 for Mars Express

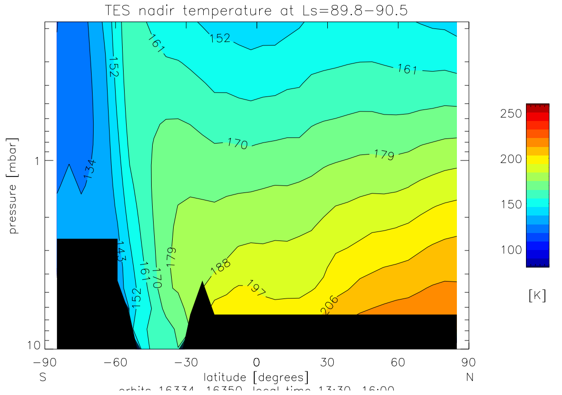

Fig. 62: TES nadir temperatures at northern summer solstice in the daytime.

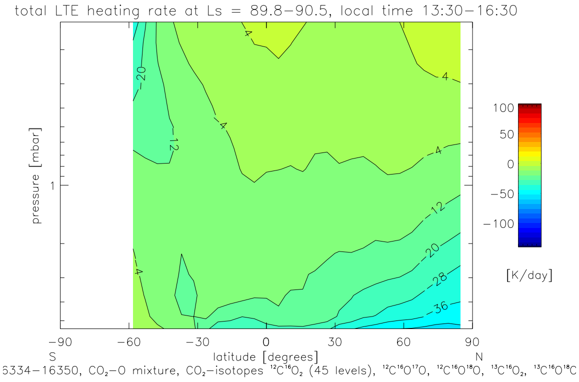

Fig. 63: Total LTE heating rates at northern summer solstice in the daytime. At the south pole, the quality of the data is not sufficient to calculate the rates.

The near-Mars environment is very different from near-Earth space. In its early history Mars is thought to have had substantial amounts of water and a much thicker atmosphere. It is believed that due to the absence of an intrinsic magnetic field the Martian atmosphere is exposed to a continuous erosion process, because any ionized component is effectively removed by the ion pickup process. Already the first results of the Phobos-2 mission have indicated a net outflow of about ~1 kg/s of matter from the Martian upper ionosphere/exosphere, indeed sufficient to cause a significant erosion of the atmosphere over cosmological time scales. The general scientific objective of the ASPERA-3 instrument on Mars Express is the study of the interaction of the Martian atmosphere with the interplanetary medium. The investigations to be performed will address the fundamental question, how strongly does the solar wind and electromagnetic fields affect the planetary atmosphere? It directly relates to the basic problem of Martian dehydration and the question of whether or not life existed on Mars in the past.

If the water was lost due to the direct exposure of the atmosphere to the solar wind, what are the mecha-

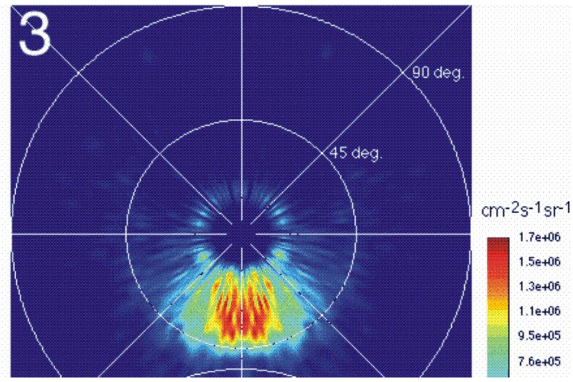

Fig. 64: Simulated ENA image of the solar wind plasma near Mars in the fish-eye projection. The polar axis is looking towards the Sun.

nisms of scavenging planetary matter? The answer to this fundamental question requires not only a search of water traces on the planetary surface (the important task of Mars Surveyor missions) but also the study of mechanisms for water outflow. On the other hand, the solar wind (Fig. 64) not only carries away atmospheric constituents, but can also deposit its matter into the atmosphere. The global objective of the ASPERA-3 investigation is to provide a coherent picture how energy is transferred from the solar wind to surrounding regions of the planet and to clarify its environmental effects on the planetary atmosphere. The MPAe has participated in the development and fabrication of ASPERA-3. The instrument was successfully tested after launch. In the next three years, we are aiming to develop a model of the escape of the planetary atmosphere, by combining theory, observations and simulations.

(J. Woch, E. Dubinin, M. Fränz, N. Krupp, in collaboration with TU Braunschweig and IRF, Kiruna)

Outer planets research – General

Zonal flow in gas planets

The origin of the strong zonal jets at the surface of the Jupiter and Saturn, which leads to their banded appearance, is discussed controversially. One theory maintains that this flow is driven by deep-reaching convection in the molecular hydrogen envelope, powered by the internal heat of the planets. Our previous numerical modelling work on thermal convection of a Boussinesq (incompressible) fluid in a rapidly rotating spherical shell has shown that strong zonal winds can be excited in this setting. It takes the form of nearly geostrophic flow in differentially rotating cylinders. Scaling relations derived from the numerical results successfully predict the characteristic velocity of the zonal winds. However, the model has difficulties to explain the number and characteristic spacing of the jets. We are currently working on making the model more realistic in two respects. We use a simplified 2-dimensional model in Cartesian geometry to explore the effects of various degrees of coupling of the flow to the underlying regions (the metallic hydrogen core).

Multiple jets are obtained for appropriate values of viscous boundary friction. To bridge the gap to the 3-D models, we are currently extending it to include boundary curvature.

Furthermore, the density changes strongly with depth across the molecular hydrogen layer. Therefore we are currently modifying our code to include the effects of compressibility in the anelastic approximation.

(U. Christensen, J. Rotvig, D. Tortorella, partly in collaboration with C. Jones, Exeter, England)

Outer planets research – Jupiter

Observations of inner satellites of Jupiter

Jupiter's small inner moons Thebe, Amalthea, Adrastea, and Metis revolve around the planet at distances of 3.11 R_J, 2.54 R_J, 1.81 R_J, and 1.79 R_J respectively (Thomas et al. 1998). Amalthea, the largest of the small inner moons, was discovered by Edward Barnard in 1892. The three others were first detected on Voyager images in 1980. These moons are interesting targets for regolith studies as they move in a rather harsh environment close to the giant planet Jupiter. On the other hand they are challenging objects for ground-based observations because of their proximity to the bright disk of their parent planet. Observations of the inner Jovian satellites Thebe, Amalthea and Metis have been conducted with the Two-Channel Focal Reducer of the Max Planck Institute for Aeronomy attached to the 2-m RCC telescope at Terskol Observatory (Pik Terskol, Northern Caucasus) from October 1999 to January 2002. Astrometric and photometric observations were performed. The photometric measurements are described here in somewhat more detail. The observations were taken through a filter with central wavelength 0.887 μm which coincides with a methane band of reduced brightness of the Jovian disk. All three satellites exhibit significant opposition brightening, but the strength of this effect, measured as the ratio of intensities at phase angles $\alpha_1 = 1.6^\circ$ and $\alpha_2 = 6.7^\circ$ does not vary significantly among these satellites. In order to measure the opposition surge parameters the empirical law proposed by Karkoschka and Hapke's model were used. The values of geometric albedos calculated with best-fit Hapke parameters are 0.096, 0.157, and 0.24 for Thebe, Amalthea, and Metis respectively. As the moons have synchronous rotation, one can speak of their leading and trailing sides as compared to their motion around Jupiter. We found that the average leading/trailing ratios of surface reflectance at the measured phase angles are 1.53 ± 0.05, 1.25 ± 0.04, 1.04 ± 0.08 for Amalthea, Thebe, and Metis. The systematic trend of increasing darkness of the trailing sides of the satellites with increasing distance from Jupiter may be caused by pollution of their trailing sides with sulphur ions released from the Galilean satellite Io.

(I. Kulyk, K. Jockers)

In situ observations of the Jovian magnetosphere

The Jupiter *in situ* research in the years 2002/2003 was based on the data analysis mainly from the Energetic Particles Detector (EPD) on board the Galileo spacecraft, which was the first spacecraft orbiting an outer planet. EPD was partly built at the institute and consists of two double-headed detector systems. EPD uses typical dE/dx versus E telescope and Time-Of-Flight techniques to separate different ion species and electrons in an energy range between tens of keV and several MeV. The whole instrument is mounted on top of a turntable so that its rotation combined with the spacecraft spin allows measurements from all directions in the three dimensional space.

In addition the Cassini flyby at Jupiter (October 2000 – April 2001) was also subject of further investigation of the Jovian system. Especially the Magnetospheric Imaging Instrument (MIMI) provided an excellent data set during that time period. MIMI consists of the three detectors INCA, CHEMS and LEMMS (designed and built at the institute) to detect neutral and charged particles, including information about ion charge states, energies and directions of motion in planetary magnetospheres. The measurable particle energy of the MIMI detectors range from keV to 160 MeV.

Analysis of *in situ* measurements inside the Jovian magnetosphere: Galileo/EPD results

Energetic Particle characteristics in the inner part of the Jovian magnetosphere and their relation to auroral emissions

Based on 33 Galileo passages through the inner part of the Jovian magnetosphere the properties of the energetic charged particle population are investigated. Pronounced changes in the particle intensities, and in their energy and pitch angle distributions (PAD) are

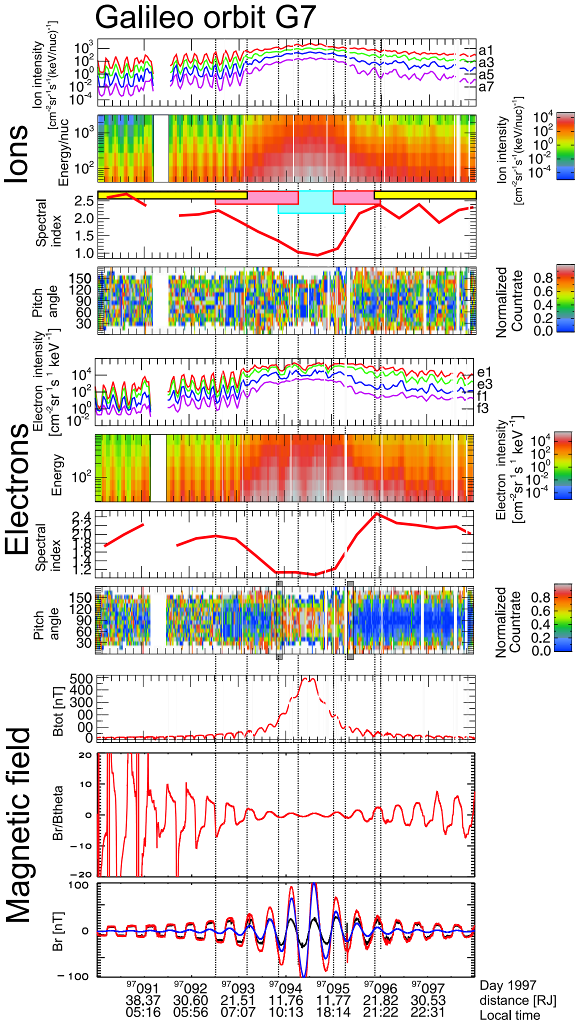

Fig. 65: Characteristic parameters of energetic particles and magnetic field components during orbit Galileo G7 in April 1997, days 90 – 98. Top to bottom: Ion intensity at four selected energy channels between 42 and 3200 keV; energy-time spectrograms, 1-hour averages; energy spectral slope for protons, 10-hour averages; normalized pitch angle distribution (PAD) for protons (80 – 220 keV), 30-minute averages); electron parameters in the same format as for the ions (energies between 29 and 884 keV), electron pitch angle distributions (304 – 527 keV); total magnetic field magnitude; ratio between radial and north-south components of the magnetic field; measured radial component of the field (red); internal field model O6 (blue) and the residual (black). Time, distance to the planet and local time are indicated at the bottom.

generally observed. Measurements from orbit G7 are shown as an example in Fig. 65.

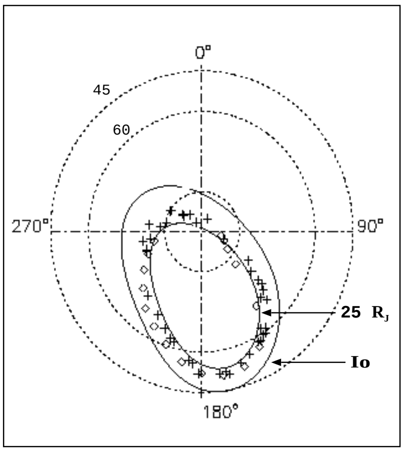

Fig. 66: Polar view of the Jovian north auroral zone. The different symbol correspond to: + – ionospheric footpoints of the pitch angle boundary, ◇ – HST secondary oval. For reference the footpoints of Io and 25 R_J (obtained with the magnetic field model VIP4 of Jupiter) are shown by solid lines.

The good coverage in local time and radial distance provided by Galileo allowed to trace the location of the most distinct changes within the equatorial plane. Independent on local time they occur at distances between 10 and 30 Jovian radii (R_J). Within this region particle intensities drop by several orders of magnitude and the energy spectra softens considerably. However, most prominent is a change of the electron pitch angle distribution from a pancake or trapped (maximum at 90 degrees) to a distribution which maximizes at other pitch angle values (bi-directional or butterfly distributions). The change occurs rapidly, usually within the time resolution of the measurements, giving rise to a sharp and distinct boundary. This boundary is located dependent on the orbit between 10 and 17 R_J. The PAD transition most probably reflects an enhanced ionospheric precipitation flux and therefore the relation between the PAD boundary and some of the observed structures in the Jovian aurora is studied. A comparison between the Hubble Space Telescope observations and the predicted ionospheric footprints of the PAD boundary (as given by the magnetic field model VIP4), indicates a good conjunction with the secondary oval, a discrete belt of emissions equatorward of the main auroral oval (see Fig. 66).

A possible explanation for the PAD change is the enhanced scattering of trapped particles towards smaller pitch angles caused by wave particle interaction, which would lead the distribution to the strong pitch angle diffusion limit and consequent enhanced precipitation. This assumption was verified by estimating the pitch angle diffusion coefficient for the measured whistler waves in the PAD boundary region of the magnetosphere. Furthermore, the precipitation energy flux estimated from the energetic electron distribution at the PAD boundary, under the assumption of strong diffusion, is compatible with the brightness range of the secondary oval auroral emissions.

(A. Tomas, J. Woch, N. Krupp, A. Lagg in collaborations with Imperial College London, UK; University of Iowa, USA; Applied Physics Laboratory/The Johns Hopkins University, USA; University of California Los Angeles, USA; Technical University Braunschweig)

Plasma Ccomposition in the magnetosphere of Jupiter

Galileo provides the opportunity to study globally the relative ion abundances of the Jovian magnetosphere by using the most complete data set of EPD. Relative abundance ratios maps of S/O, S/He, O/He and H/He at various energy/nuc ranges in the Jovian magnetosphere could be derived. Fig. 67 shows the global maps of S/O-ratio as one example.

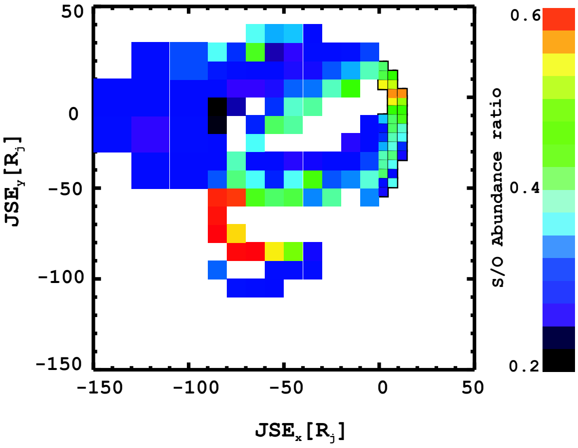

Fig. 67: Colour-coded values of S/O relative abundance ratio, calculated at 39 keV/nuc as projected along Galileo's orbits in the x-y plane of Jupiter Solar Ecliptic (JSE) coordinate. The data are averaged in time over distance [2min/distance(R_J)] and within boxes of 5, 10 and 20 R_J

Based on 15 Galileo orbits the EPD data were time averaged and spatially binned. We find S/O-ratio values around 0.5 consistent with the origin of sulfur and oxygen from the dissociation of SO_2 molecules from the moon Io. The ratio is relatively stable in radial distance and local time and is in good agreement with previous measurements from the Voyager spacecraft. An exception is orbit G2 where the ratio is higher by a factor of 2 compared to the average value. One possible interpretation is the highly dynamical nature of the predawn Jovian magnetosphere in combination with radially outward/anti-sunward flow bursts have been observed. In these substorm-like events (see below) particles are accelerated dependent on energy and mass changing the composition of the plasma in the vicinity.

Other derived abundance ratios (S/He, O/He, and H/He) show a pronounced energy dependence indicative of different sources for heavy ions (S, O from the moon Io) and Helium as well as protons from the solar wind and the ionosphere/atmosphere of Jupiter. These ratios do also vary more pronounced than the S/O-ratio in time, local time and distance from the planet.

(A. Radioti, J. Woch, N. Krupp, A. Lagg in collaborations with Applied Physics Laboratory/The Johns Hopkins University, USA; Technical University Braunschweig)

Substorms at Jupiter

Galileo has also provided evidence that the Jovian magnetotail is subject to global reconfiguration processes which in their basic properties resemble terrestrial magnetospheric substorms. We observe a thinning of the plasma sheet, break down of the corotation and particle bursts as evidence of reconnection in the Jovian magnetotail. Bulk flow events in combination with characteristic perturbations of the magnetic field topology indicate the release of plasmoids and field-aligned ion beams. These large-scale events are associated with the intensification of auroral emissions. However, the energy source and driving mechanism of these events are yet unclear. We find 23 substorm-like events in the Jovian magnetotail. One example is presented in Fig. 68.

The sketch of these two different states of Jovian magnetotail is shown in Fig. 69.

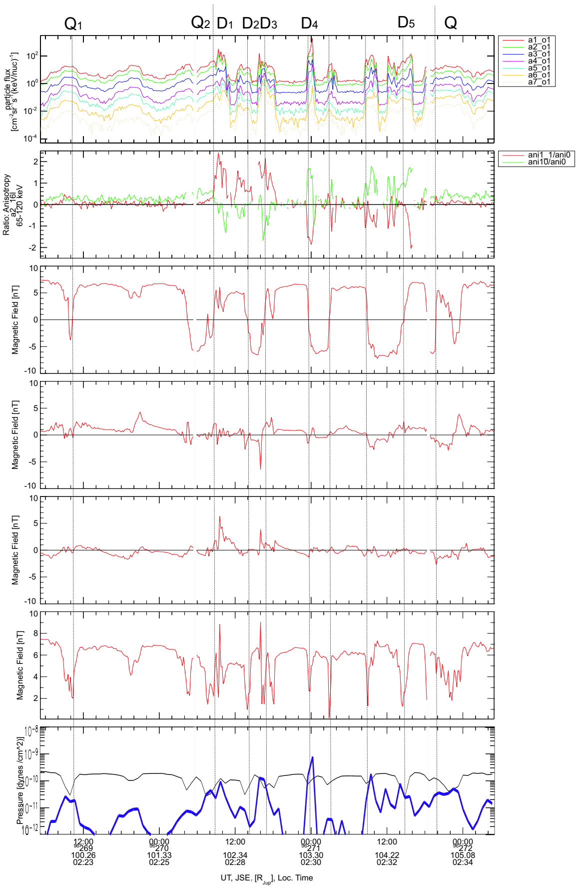

Fig. 68: Time profiles for days 269, 05:00 –– 272, 05:00 in 1996 of ion intensities (0.042 – 3.2 MeV) (first panel); first order anisotropies in the radial (red) (positive is outward) and corotational (green) direction (second panel); the magnetic field components (third -– fifth panels) in JSE coordinates (x towards Sun, y towards dusk, z towards north) and its magnitude (sixth panel) as measured by EPD and MAG on Galileo orbit G8; the magnetic field pressure (black) and the plasma pressure (blue).

The presented scheme shows the reconnection process in the Jovian magnetosphere with a transition from a quiet state to a disturbed topology and back to a quiet state. In the quiet state the plasma sheet is thick without a distinct plasma sheet/lobe boundary and the plasma flow is corotational. The pressure profiles show that the plasma pressure gradually increases and reaches the same values as the magnetic pressure at substorm onset. In the disturbed phase a neutral line forms and a strongly confined boundary layer between the current sheet and lobe is observed. In the boundary layer collimated accelerated plasma beams are observed which in the beginning of the event are streaming radially outward. In the course of the event after the time when the x-line crosses the position of the spacecraft inward moving is observed. The plasma pressure exceeds the magnetic pressure and is concentrated in the boundary layer. The whole reconnection process developed within 30 hours.

(E. Kronberg, J. Woch, N. Krupp, A. Lagg in collaborations with Applied Physics Laboratory/The Johns Hopkins University, USA; Technical University Braunschweig)

In situ observations of a neutral gas torus at Europa

A persistent pattern in the pitch angle distributions of energetic protons near the orbit of Europa has been observed with EPD on board the Galileo spacecraft

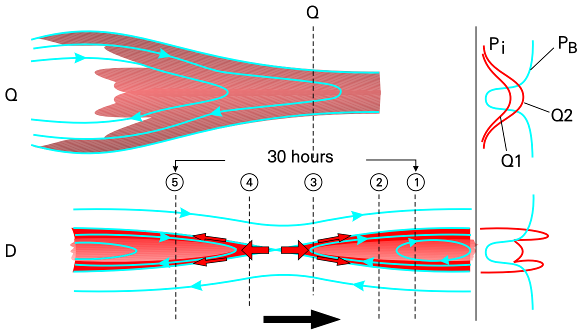

Fig. 69: A sketch of the inferred two states of the Jovian magnetotail with plasma and magnetic pressure profiles. Top: quiet state of the plasma sheet. Bottom: disturbed state.

during each of the Europa orbit crossings in the last 7 years. The evidence is shown in Fig. 70. The proton fluxes at energies larger than 220 keV peak at 90 degree pitch angle whereas fluxes of lower energy protons (80 – 220 keV) at this pitch angle are depleted.

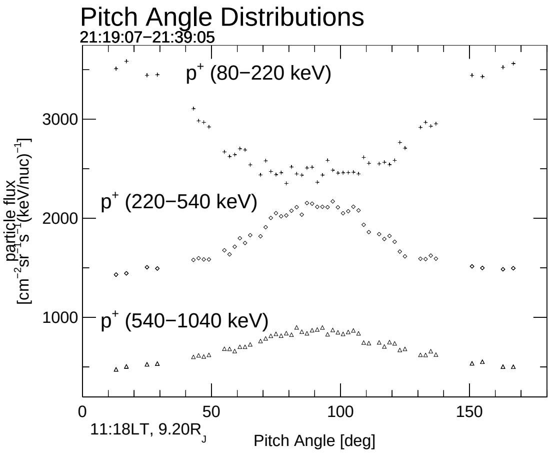

Fig. 70: Pitch angle distribution of protons inside the Jovian magnetosphere during the crossing of the Europa orbit.

Aware of other mechanisms (especially wave-particle interactions) we concentrated our discussion on the presence of a neutral gas torus which can account for this depletion signature due to charge exchange interactions. Assuming a radial diffusion coefficient of less than $2 \cdot 10^{-5} R_J^2 s^{-1}$ and a radial and latitudinal (magnetic) extension of 3 R_J and ± 15 degrees respectively a neutral number density of 20 to 50 particles per cm^3 is required to produce the observed depletion. Additionally, sulfur and oxygen ions must be dominantly multiply charged in order to maintain the observed normal pitch angle distribution. The high neutral number density results in an enhanced flux of Energetic Neutral Atoms (ENA). The Ion and Neutral Camera (INCA) on board the Cassini spacecraft did indeed measure ENA-fluxes which are an order of magnitude higher than the previously predicted values. This enhanced ENA-flux was interpreted as an emission originating from a neutral Europa torus with a number density of 40 per cm^3 and agrees perfectly with our results.

(A. Lagg, N. Krupp, J. Woch in collaborations with Applied Physics Laboratory/The Johns Hopkins University, USA)

Jupiter flyby of the Cassini spacecraft

A nebula of gases surrounding Jupiter

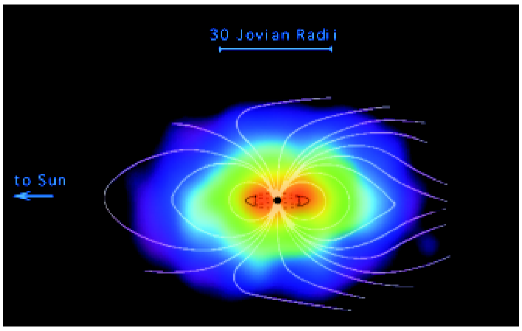

Fig. 71: Energetic neutral atom image of Jupiter's magnetosphere as viewed from the dusk meridian soon after Cassini's closest approach on 30 December 2000. The image was generated by neutrals in the range 50 – 80 keV per nucleon, assuming the species to be hydrogen. The location of Io's plasma torus has been sketched in (dark lines, centre) and Jupiter's magnetic field (white lines) superimposed on the image for reference.

The ion and neutral camera (INCA), one sensor of the MIMI instrument on board the Cassini spacecraft, detected for the first time directly fast and hot magnetospheric particles released from the Jovian system as a neutral wind. Thus a 'nebula' is created that extends outwards over hundreds of Jovian radii. INCA is specifically designed to detect and 'image' such energetic neutral atoms emanating from planetary magnetospheres. A sample of these images is shown in Fig. 71.

These neutral particles get singly charged by photo ionization and get picked up by the solar wind electric field. Even if their origin is Jupiter they are detected from the solar wind direction. The charge energy and mass spectrometer CHEMS, the second detector of MIMI on board Cassini, detected these singly charged ions which is another indication of the neutral gas nebula around Jupiter.

(N. Krupp, A. Lagg, J. Woch in collaborations with Applied Physics Laboratory/The Johns Hopkins University, USA; University of Maryland, USA)

Energetic particle observations in the vicinity of Jupiter: Cassini MIMI/LEMMS results

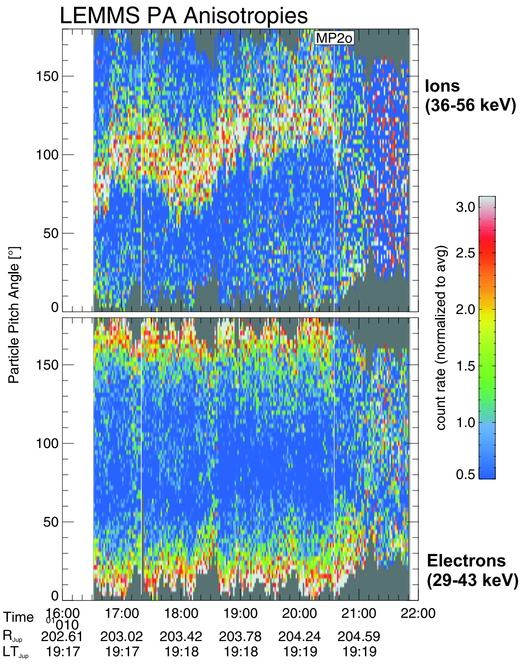

Fig. 72: Normalized pitch angle distributions as a function of time inside the Jovian magnetosphere on day 10, 2001 during the Cassini swing-by. The distributions are shown for ions (36 – 52 keV) on the top and for electrons (29 – 42 keV) on the bottom. Solid white line indicates the magnetopause (MP) crossing. The intensity at a certain pitch angle is colour-coded and normalized to the scan-averaged (= 86 s) intensity for each LEMMS rotation.

Cassini's unexpected entrance into the Jovian magnetosphere during the flyby occurred at distances of more than 200 R_J from the planet at about 19:19 local time. From data of the Low Energy Magnetospheric Measurement System LEMMS (detector 3 of the MIMI instrument), shown in Fig. 72, it could be concluded that electrons were observed bi-directionally along the magnetic field direction (0 and 180 degrees pitch angles) on a closed magnetic field configuration. Most of the ions move nearly perpendicular (pitch angles between 90 and 150 degrees) to the magnetic field direction.

After leaving the magnetosphere through the magnetopause the magnetic field connection back to planet (0 degree-pitch angle) remains for about 20 minutes with clear signatures of electrons streaming along the magnetic field. The other end of the field line lost their connection to the planet during the crossing and the bi-directional electron pitch angle distribution disappeared. Thereafter magnetic connection to Jupiter is lost and an isotropic distribution is observed. The left-hand side of Fig. 73 shows the measured electron intensities in several energy channels between 15 keV up to several MeV inside the magnetosphere including the magnetopause crossing. The intensities inside show quasi-periodic variations.

A Fast Fourier frequency analysis of the data is shown on the right-hand side of Fig. 73. The main peak in the derived power spectrum is found at around 40 minutes, a period which has been observed within the Jovian system in plasma wave, relativistic electron and x-ray data before. A possible explanation could be explosive merging processes taking place throughout the magnetosphere reaching to the magnetopause, indicative of a global phenomenon.

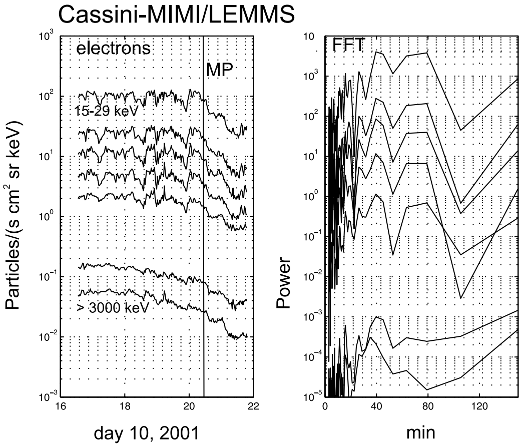

Fig. 73: Electron measurements inside the Jovian magnetosphere on day 10, 2001 by the MIMI/LEMMS instrument onboard Cassini. Left: electron intensities; right: result of Fast Fourier Transformation for various electron channels.

After leaving the magnetosphere LEMMS observed relativistic electrons downstream from the planet leaking out of the Jovian system. The sketch in Fig. 74 gives a possible scenario to explain these energetic electron observations.

The interplanetary magnetic field (IMF) is dragged around the obstacle into the duskside downstream magnetosheath. Under the assumption that a source region due to (patchy) continuous reconnection exists on the dayside some of the field lines can connect this source region with the spacecraft location. Electrons released from the source region travelling along the magnetic field lines could then be observed by Cassini. The fact that the energetic electrons were predominantly observed when the north-south component of the magnetic field was small or zero could then mean

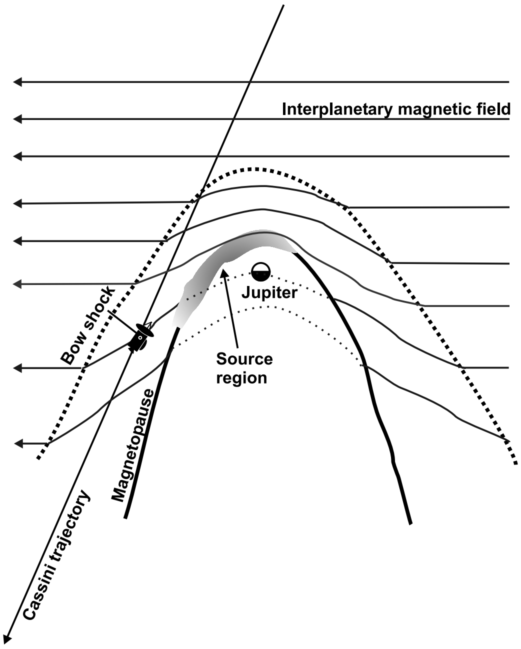

Fig. 74: Equatorial view of magnetic field lines dragged around the Jovian magnetosphere. In addition the trajectory of Cassini is shown.

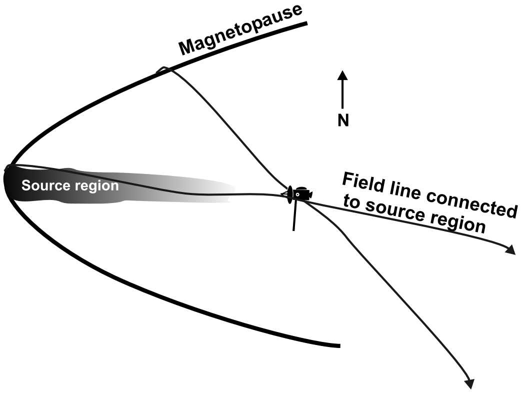

Fig. 75: A north-south view of the Jovian magnetosphere from the dusk side towards the planet. Magnetic field lines with small or zero north-south components connect an equatorial source region with the spacecraft.

that the source region was restricted in latitude or more effective close to the Jovian equator as illustrated in Fig. 75.

We believe that the observed relativistic electrons downstream from the planet are at least one source of those particles observed throughout the heliosphere.

(N. Krupp, J. Woch, A. Lagg in collaborations with Imperial College London; Applied Physics Laboratory/The Johns Hopkins University, USA)

Outer planets research – Saturn

The Descent Imager/Spectral Radiometer (DISR) aboard the Huygens probe

Among the large moons in the solar system, Saturn's satellite Titan is quite remarkable. It is the only moon with a condsiderable atmosphere, exhibiting a surface pressure 50% larger than Earth's. The Cassini mission – launched in 1997 – will explore Saturn, its rings, and its moons for several years after its arrival in July 2004. Cassini carries with it the European built Huygens probe which will descent through Titan's atmosphere in January 2005. One of Huygens' instruments is the Descent Imager/Spectral Radiometer (DISR), the focal plane of which was developed and built by MPAe.

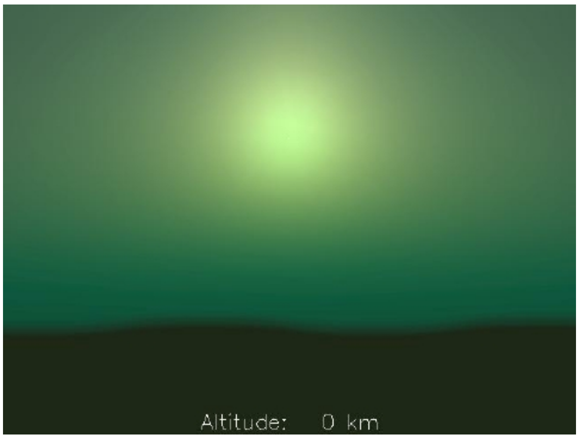

Fig. 76: The colour of Titan's sky as seen from the surface, resultant from radiative transfer computations.

During Huygens' descent, the DISR will take images and spectral measurements to investigate the atmosphere and the surface of Titan. In order to evaluate these data, it is neccessary to understand the light scattering in the optically thick atmosphere. Based on the optical properties derived from the microphysics of aerosol formation and gaseous scattering and absorption, the radiance intensity for each wavelength can be predicted by radiative transfer computations, cf. Fig. 76.

A comprehensive numerical model of radiative transfer taking into account the spherical geometry of the atmosphere has been developed to compute the polarization that may be observed by the DISR (Salinas, 2003).

The retrieval of the optical properties of the atmosphere from radiance measurements requires an inverse approach. Consequently, the Titan Inverse Radiation Model (TIRM) has been developed. It allows to retrieve all optical properties – i. e. extinction coefficient, single scattering albedo, and phase function – from the combined use of data from different subinstruments of the DISR (Grieger, 2003-002; Grieger, 2003-159). Besides tests with simulated DISR data, TIRM has been applied to radiance measurements taken by the spectrophotometers aboard the Venera 13 and 14 probes during their descent through Venus' atmosphere in 1982, cf. Fig. 77 (Grieger, 2004-009).

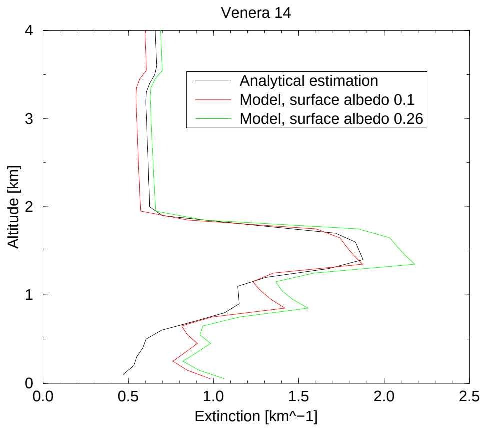

Fig. 77: Indication of a near surface cloud layer on Venus from Venera 14 spectrophotometer data. An approximative analytical estimation (which is only applicable on Venus but not on Titan) is confirmed by computations with TIRM, a model developed for Titan and DISR data.

This is an example for the kind of results that will be obtained for Titan's atmosphere from DISR data in January 2005.

(B. Grieger)

D/H ratio determination

The deuterium in the universe was produced shortly after the big bang. The process $^{2}\mathrm{H} + {}^{1}\mathrm{H} \rightarrow {}^{3}\mathrm{He} + \gamma$ depletes the deuterium in the universe as it cycles its way through star formation, astration, and interstellar injection. As a consequence, the ratio of deuterium to hydrogen in the interstellar medium is decreasing. It's current value is about $2 \cdot 10^{-5}$. Measurements of the deuterium to hydrogen ratio in the solar system reveal two distinct reservoirs of deuterium. Both of them are believed to predate the solar system itself:

- interstellar grains (D enriched),
- solar gas nebula.

The observations of Saturn's and Titan's D/H ratio is the most important goal for the CASSINI-UVIS/HDAC instrument built at MPAe. A precise determination of the D/H ratio will be a major clue to the understanding of the formation and history of Titan and the whole Saturnian system and thus for a better understanding of the evolution of the entire solar system.

The absorptions cells have been tested during the cruise phase observing interplanetary Lyman-α. It turned out that their filter characteristics are not as good as expected from the pre-flight calibration. So, it is not sure whether the instrument will be able to determine the D/H ratio in Titan's atmosphere.

Another goal of HDAC will be to study the distribution of interplanetary hydrogen and the hydrogen distribution in the Saturnian system. The instrument will do this in its photometer mode by measuring Lyman-α scattered by the hydrogen. Measurements of interplanetary Lyman-α are made during Cassini's cruise phase. The instrument's sensitivity has reached its maximum during the year 2002 remaining almost stable since then.

Data from HDAC measurements in photometer mode during Cassini's Earth swingby in August 1999 were analysed to investigate the distribution of exospheric hydrogen in Earth's geocorona.

More information about the Cassini mission and the HDAC instrument can be found at:
`http://www.linmpi.mpg.de/english/projekte/cassini`
and
`http://www.linmpi.mpg.de/english//projekte/cassini/HDAC`.

Some technical remarks:
The UVIS (Ultraviolet Imaging Spectrograph Investigation) experiment on board Cassini consists of two spectrographs (EUV, 56 – 118 nm; FUV, 110 – 190 nm), a high speed photometer (HSP), and a hydrogen-deuterium absorption cell (HDAC) which was built at MPAe. The HDAC is designed to measure the deuterium-hydrogen ratio of Titan's and Saturn's atmospheres.

The CASSINI-UVIS/HDAC channel consists of two absorption cell filters (a hydrogen cell and a deuterium cell) and a channel electron multiplier detector. The cells are separated by MgF_2 windows. In the hydrogen and deuterium cells a hot tungsten filament dissociates the H_2 and D_2 molecules into atoms producing an atomic density dependent on the filament temperature. These atoms resonantly absorb the hydrogen and deuterium Lyman-α lines, located at 121.567 nm and 121.534 nm, resp., passing through the cells. Cycling the filaments on and off and comparing the differences in signal gives a direct measurement of the relative hydrogen and deuterium signal.

If both filaments are turned off, the instrument is in photometer mode measuring at wavelengths between 110 and 230 nm.

(H.U. Keller, A. Korth, H. Lauche, S. Werner in cooperation with LASP/Boulder, USA, and the DLR Institute for Space Sensor Technology/Berlin-Adlershof)

Cometary research – Ground based

Ground-based observations of comets

The Two-Channel Focal Reducer of the MPAe is a device to be used at astronomical telescopes. It allows to take images in two spectral windows of the wavelength range 350 – 1000 nm simultaneously. It shrinks the image available at the Cassegrain focus of a reflecting F/8 telescope by a factor 2.86 and in this way provides a better adaptation of the telescope to average seeing conditions and to the object angular size. The Focal Reducer has special features for comet observations as it has an offset guider which is movable by stepping motors to guide observations of non-sidereally moving objects. It allows narrow band imaging through Fabry-Perot etalons and imaging polarimetry. A coronagraph setup is available for observations of faint sources close to bright objects.

In 1996 the Two-Channel Focal Reducer was brought to Pik Terskol Observatory in the Northern Caucasus. A contract granted 40 observing nights per year for MPAe scientists at the 2m-Zeiss-Telescope of Pik Terskol Observatory. At the end of 2002 this contract ended. Customs regulations demanded the return of the device to Germany. New, more stringent, customs regulations did not allow re-importation of the device into the Russian Federation. This led to the end of a very fruitful cooperation with the International Center for Astronomical, Medical and Ecological Research which runs Pik Terskol Observatory. In November 2003 the Two-Channel Focal Reducer was brought to the Bulgarian National Observatory Rozhen operated by the Astronomical Institute of the Bulgarian Academy of Science, Sofia, for use at their 2m-Zeiss-Telescope. This telescope is an earlier version of the 2m-telescope on Pik Terskol. Like the Pik Terskol telescope, it belongs to the series of 2m-Ritchey-Chrétien telescopes built by the Zeiss Jena company in the times of the German Democratic Republic.

Comet 46P/Wirtanen at Pik Terskol Observatory

Comet 46P/Wirtanen, the former target comet of the Rosetta mission, was observed on Pik Terskol from August 12 – 20, 2002 shortly before perihelion passage, which occurred at a heliocentric distance of 1.06 AU on August 27. The observations took place in morning twilight, as the solar elongation of the comet was less than 40°. They aimed at the determination of the rotation rate. In the blue channel of the Two-Channel Focal Reducer the gas coma of this gas-rich comet was recorded through a wide-band blue filter. At the same time in the red channel the dust coma was imaged through a filter centered at 853 nm. The images display the spherical gas coma and the rather narrow dust tail extended in the anti-solar direction. By chance some images of comet C/2002 O4 (Hoenig), discovered by a German amateur astronomer, were also obtained.

(K. Jockers, I. Kulyk)

Comet 2P/Encke at the Bulgarian National Observatory and SMTO, Arizona, USA

The study of ageing of comets is important, as only understanding of ageing will allow conclusions about the primordial solar system material. The ageing process is also of interest by itself, as it reveals details on the structure and evolution of these ancient ice-dust mixtures which represent cometary nuclei. Comet 2P/Encke with its perihelion distance of 0.34 AU is perhaps the most processed comet known. It was observed with the Two-Channel Focal Reducer at the Bulgarian National Observatory Rozhen from November 18 – 25 (Fig. 78) and with the Heinrich Hertz Telescope of the Submillimeter Observatory, a collaboration between Steward Observatory and MPI für Radioastronomie, November 19 – 30, 2003. The observations aimed at simultaneous observation of the mother molecule HCN in the submillimeter wavelength range and its dissociation product CN in the near-UV wavelength range. Also the observation techniques were complementary: Images with the focal reducer show the spatial extent of the CN coma in the plane of the sky while the radio observations provide the line profile, i.e. the radial velocity distribution of the gas driving the jets and fans.

With such observations we hope to further restrain the properties of the sunward fan, observed in this comet already for centuries, and its modulation by comet nucleus rotation and solar incidence angle. We also intend to verify the rotation state of the nucleus of this comet and to determine the ratio of HCN parent to CN daughter molecules in order to investigate the possi-

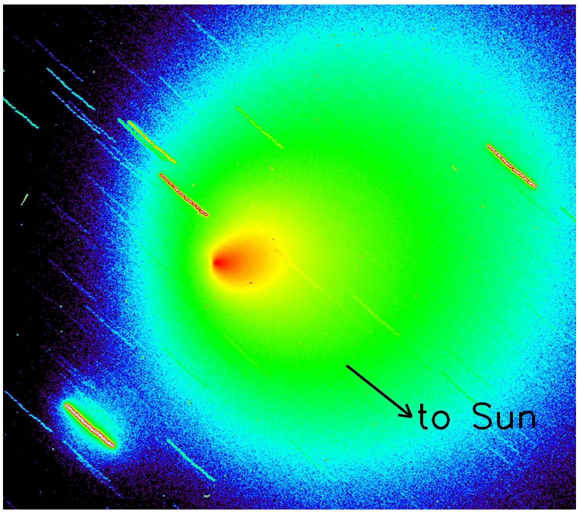

Fig. 78: Comet 2P/Encke as observed in the light of the CN radical at the Bulgarian National Observatory on November 25, 17 UT. The CN coma is strongly asymmetric.

bility of other molecules being parents of CN. A further aim of the optical observations was investigation of the dust content of this very gas-rich comet and its polarization. While the gas coma of most gas-rich comets like comet Wirtanen is spherically symmetric, in Comet Encke it is strongly asymmetric in the direction toward the Sun. In the continuum filters comet Encke is exceedingly faint and the shape of the coma is very similar to the gas coma. At the time of this writing it is unclear if there is a dust coma at all, i.e. if the "continuum" images show light scattered on cometary dust grains or if they show faint molecular emission transmitted by the "continuum" filters.

(K. Jockers, T. Bonev, S. Szutowicz)

Results of previous observations

The disintegration of comet C/1999 S4

Cometary nuclei are fragile. Sometimes cometary nuclei split into several subnuclei. These subnuclei may continue their outgassing. In this case several smaller comets with fully-grown tails form out of a larger comet. An example is comet Shoemaker-Levy 9 which split into about 20 subcomets, which 1994 fell into Jupiter. Sometimes the subnuclei stop to be active and the comet disintegrates. This was the case with comet C/1999 S4 in July 2000, a few days after the comet went through its perihelion at 0.77 AU. Comet C/1999 S4 was observed with the 2m-Telescopes of Pik Terskol Observatory, Northern Caucasus, Russia, and the Bulgarian National Observatory in the days before and during the time of its disintegration. Maps of the dust brightness and colour were constructed from images obtained in red and blue continuum windows, free from cometary molecular emissions. We analysed the dust environment of comet C/1999 S4 (LINEAR) taking into account the observed changes apparent in the brightness and colour images. The brightness and colour of individual dust particles, which is needed to interpret the observations is determined from calculations of the light scattering properties of randomly oriented oblate spheroids. Also the motion of the dust grains under solar radiation pressure was investigated.

The dust of comet C/1999 S4 (LINEAR) is strongly reddened, with reddening values up to 30% 100 nm in some locations. Often the reddening is higher in envelopes further away from the nucleus. We observed two outbursts of the comet with brightness peaks on July 14 and just before July 24, 2000, when the final disintegration of the comet started. During both outbursts an excess of small particles is released. Shortly after both outbursts the dust coma "turns blue". After the first outburst the whole coma is affected, after the second one only a narrow band of reduced colour close to the tail axis is formed. This difference is explained by different terminal ejection speeds, which were much lower than normal in case of the second outburst. In particular in the second, final outburst the excess small particles could originate from fragmentation of "fresh" larger particles.

(T. Bonev, K. Jockers, E. Petrova, M. Delva, G. Borisov, A. Ivanova)

Intensity, colour, and polarization of the dust coma of comet C/2000 WM1

Comet C/LINEAR (2000 WM1) was observed with the focal reducer of the Max Planck Institute for Aeronomy at the 2m-telescope of the Pik Terskol Observatory from November 10 to December 9, 2001, when the phase angle Sun-comet-Earth varied between 13° and 62° and the heliocentric distance from 1.5 – 1.1 AU. Narrow-band imaging photometry and polarimetry of the dust continuum was done in three spectral windows, free from cometary emissions, centered at 526, 713, and 853 nm, respectively. The images were calibrated to absolute intensities and used to construct intensity, colour and polarization maps of the dust continuum.

The polarization maps are featureless. The inversion angle (where the polarization changes sign) within measurement accuracy does not depend on wavelength. This contradicts the simple idea that cometary dust particles might be aggregates consisting of monomers having a narrow size range.

The dust coma of comet C/LINEAR (2000 WM1) exhibits red colour with mean reddening of about 15%

100 nm. The spatial distribution of this reddening is different in the different spectral ranges. We consider the observed features as a consequence of the combined influence of the size dependent light scattering properties of the dust particles, their motion under the influence of the solar radiation, and of the variations of distribution of the particle size normalized to the wavelength of the filter.

The intensity distribution of the dust coma of comet C/2000 WM1 was calculated using models of dust release from the cometary nucleus and of dust motion under the repulsive force of solar radiation pressure. Of particular interest were images obtained at November 20, when the Earth went through the cometary orbit plane. At this time the comet displayed a so-called anti-tail and particles emitted a long time before the observation are visible in the image. To make the models fit the observations, one must take into account that cometary dust grains fragment during acceleration by gas drag after release from the nucleus. Because of the fragmentation process the final speed of fragmented dust particles is much smaller than the speed of particles of the same size released directly from the nucleus because the fragmented particles retain the low speed of their large parent dust grains.

(K. Jockers, T. Bonev, I. Kulyk)

Near Earth Asteroid 33342 (1998 WT24)

Observations of NEA 33342 (1998 WT24) were performed at the Pik Terskol Observatory, the Crimean Astrophysical Observatory and the Chuguev Observational Station between December 2 – 19, 2001. The polarimetric (polarization minimum $P_{min} = -0.25\%$ and polarimetric slope $h = 0.039\%$ per degree) and photometric (the phase coefficient $\beta = 0.021$ mag/deg) results indicate that asteroid 33342 is one of the rare E-type asteroids. The E-type asteroid synthetic polarization curve consists of two parts: A narrow peak centered at $\alpha \approx 1.5^\circ$, superimposed on the regular negative polarization branch which converts to the positive polarization branch at $\alpha = 18^\circ$. The maximum of positive polarization is 1.6% – 1.8% at the phase angle range $72^\circ - 80^\circ$ for the BVRI bands. The albedo and the size of asteroid 33342 are 0.43 and 0.42×0.33 km, respectively.

(N. N. Kiselev, K. Jockers, V. K. Rosenbush, F. P. Velichko, M. N. Shakhovskoj, Y. S. Efimov, D. F. Lupishko, V. V. Rumyantsev)

CN, NH_2 and dust in the atmosphere of comet C/1999 J3

Observations of comet C/1999 J3 (LINEAR) were made at the 2-m-telescope of the Pik Terskol Observatory on September 19, 1999. Narrow-band CCD images of the CN, NH_2, and dust atmospheres have been recorded using the two-channel focal reducer of the Max Planck Institute for Aeronomy. To fit distributions of the CN and NH_2 molecules in the comet atmosphere a Monte Carlo model was adopted. For the CN atmosphere the best agreement between observed and calculated surface profiles was gained with the CN photodissociation lifetime $\tau_{\mathrm{CN}} = 1.5 \times 10^5$ s and with the photodissociation lifetime $\tau_{\mathrm{CN}parent} = 3.2 \times 10^4$ s for its parent. This result indicates that HCN is the main source of the CN radicals in the atmosphere of comet C/1999 J3 (LINEAR). As to the NH_2 radicals there is no doubt that NH_3 is the dominant source of this species in the comet atmosphere. The lifetimes $\tau_{\mathrm{NH}_2} = 1.0 \times 10^5$ s for NH_2 and $\tau_{\mathrm{NH}_2 parent} = 5.0 \times 10^3$ s for its parent are close to theoretical calculations. Also, the gas-production rates of CN, $Q(CN)=3.8\times10^{25}$ mol s^{-1}, and NH_2, $Q(NH_2)=1.3\times10^{25}$ mol s^{-1}, have been determined. Appearance and obtained data evidence that the comet is a gaseous one. The albedo-filling factor-distance product $Af\rho = 21.6$ cm for the blue spectral window and = 23.4 cm for the red one. The normalized spectral gradient of the cometary dust is low, 3.8% per 100 nm. The ratio $\log((Af\rho)_{443}/Q(CN)) = -24.25$ exhibits a very low ratio of dust to gas as well.

(P.P. Korsun, K. Jockers)

Cometary research – Rosetta

Microwave Instrument for the Rosetta-Orbiter (MIRO)

The scientific objectives of MIRO are to characterise the abundances of major volatile species and key isotopic ratios of the comet, to study the processes controlling the outgassing in the surface layer of the nucleus and the development of the inner coma, to globally characterise the nucleus subsurface to depth of a few centimetres or more and to search for low gas levels in the asteroid environment.

MIRO is a heterodyne spectrometer detecting the molecular and surface emissions at 0.5 and 1.6 mm wavelength. MIRO is the first of a new class of instruments, so to speak a miniaturised radio telescope. The key component of MIRO is the Chirp Transform Spectrometer (CTS), which has been developed at the MPAe and is unique in terms of power consumption

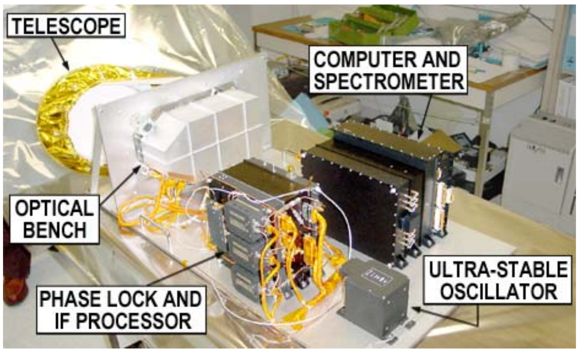

Fig. 79: The MIRO instrument during tests in the laboratory

and mass per spectrometer channel. MIRO will be switched on about 4 weeks after the launch in the first quarter of 2004. First science operations are planned for March 2005.

(P. Hartogh, C. Jarchow, L. Song, E. Steinmetz)

General studies

An equatorial dipole dynamo

Bodies in the solar system exhibit a wealth of different magnetic field morphologies. On the Earth, Jupiter, Saturn, and probably Mercury, a magnetic dipole aligned with the axis of rotation is the dominant feature. On Uranus and Neptune the dipole axes are tilted at 50 and 47 degrees respectively, and multipoles gain more relative importance. Computer simulations of magnetic field generation in planetary cores allow to explore the conditions under which one or the other geometries may be favoured. As shown in Fig. 80, a fluid flow made of vortices aligned with the axis of rotation (blue when rotating clockwise, red when rotating counter-clockwise) can stretch and fold the magnetic field lines just like rubber-bands, thus producing magnetic field. We have found that such a flow supports both axial and equatorial magnetic dipole geometries. In the latter case though, the equatorial magnetic lines of force are in conflict with the shearing motion of the axial vortices. The result is a dynamo whose equilibrium magnetic energy is much lower than that of its axial counterpart. This might explain why the amplitude of the magnetic field on Uranus and Neptune is lower than what is expected from the application of models working on the Earth, Jupiter and Saturn.

(J. Aubert, J. Wicht)

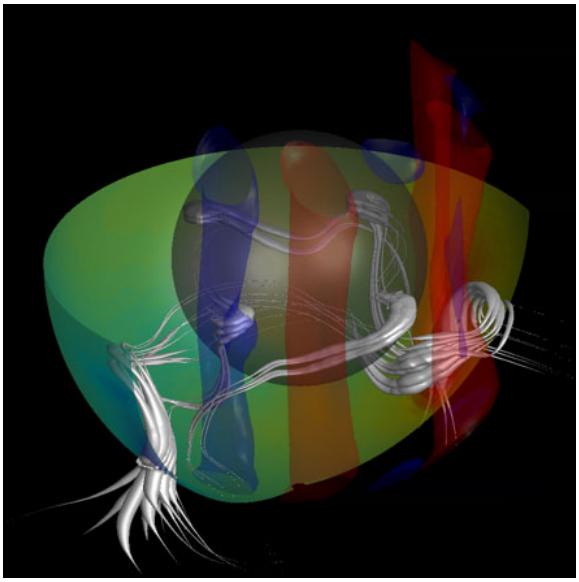

Fig. 80: Representation of an equatorial dipole dynamo. Equatorial magnetic lines of force (in grey) are stretched and folded by axial flow vortices (clockwise in blue and counterclockwise in red).

Magnetic field reversals

Field reversals are the most dramatic events in the geomagnetic history. The sequence of polarity changes has been recorded in volcanic rocks and compacted sediments. The Earth's ocean floors preserve the succession of reversals during the last 180 Myr as stripes of alternating magnetisation directions. Similar magnetisation patters have been identified in the Martian crust. Though these polarity sequence provide a fascinating view into the history of planetary tectonics and the internal dynamo mechanism, little is known about the reversals process itself. Unfortunately, paleomagnetic data provide only limited information about the internal dynamics. Thus, dynamo simulations prove indispensable in providing a link between external observations and interior processes.

Fig. 81: Comparison of polarity sequences from paleomagnetic data and a numerical dynano simulation, each covering roughly 20 Mill. years.

We have numerically simulated field reversals with a dynamo code that models convective flow and magnetic field production in a spherical shell. Careful analysis of numerous calculations has considerably advanced the understanding of the reversal process (see below). The involved long time scales and the large variations in reversal frequency (between no reversals and 4 reversals / Myr years) call for extremely long simulations. Fig. 81 shows a comparison of the paleomagnetic reversal sequence for the last 20 Myr and a comparable long sequence from a numerical simulation.

(J. Wicht, C. Kutzner, U. Christensen)

Detailed analysis of reversal dynamics

The complex interwoven nature of magnetic field, fluid flow and buoyancy complicates the interpretation of the internal processes in dynamo simulations. A rather simple nearly-periodically reversing dynamo model has therefore been selected for a first complete exploration of the reversal dynamics. Several 2d and 3d animations finally enabled us to unravel the details of the reversal sequence. Fig. 82 shows the changes in the poloidal field polarity during one reversal. Despite the fact that the model in rather simple, many of its features may nevertheless apply to geomagnetic reversals. Important findings are:

- The helicity associated with plume like upwellings inside and at the tangent cylinder are essential for creating inverse field. Such features are thought to also exist inside the tangent cylinders of the Earth, which suggest that reversals could start in these regions.
- Upwelling in the plumes transport the inverse field to the core mantle boundary. When the inverse patches reach the core surface the reversal process becomes 'visible' for an outside observer. This oberver would see only a smaller section of the total process.
- The inverse field is advected along the core-mantle boundary until the reversal is completed, i.e. normal polarity field has been replaced. This suggest that the fluid velocities close to the CMB determine the duration of the reversal at the CMB. Using typical westward drift values arrives at an estimated duration of a few thousand years for the Earth. This agrees well with paleomagnetic results.
- The dynamo is close to a kinematic solution. This suggests that the velocity field is not responsible for triggering the reversal. Oscillatory fields are a primary solution of the dynamo problem. However, since the velocity field is not stationary in the simulation, the interpretation is complicated.

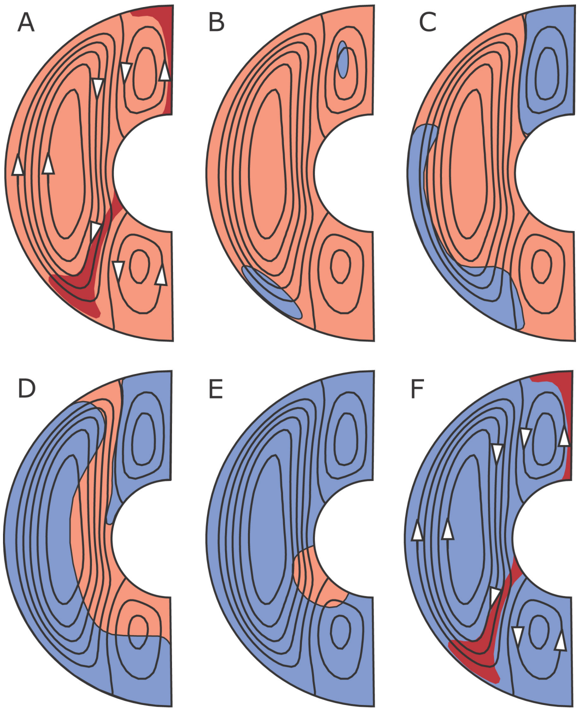

Fig. 82: Dynamics of a mangetic field reversal. Red and blue stand for normal and reversed polarity of the poloidal magnetic field. Contour lines are streamlines of the axisymmetric meridional circulation, which distributes the inverse field along the core-mantle boundary and thoughout the core. The inverse field is produced in rising plumes marked with darker colours in the first and last panel.

(J. Wicht in cooperation with P. Olson, Johns-Hopkins University, Baltimore, USA)

How long does a reversal take?

Paleomagnetists commonly infer the properties of geomagnetic excursions and reversals from magnetic sequences of one site only. However, dynamo simulations show that the relative dipole contribution is lower during reversals and excursion than in stable epochs. Thus, local field features will become more important and the magnetic signatures will therefore depend on the data site. This translates to all estimates of reversal and excursion properties. I have used numerical dynamo simulations to test and quantify this site dependence. The results show that the magnetic signature of the same event can indeed differ significantly from site to site. This has several consequences: Duration estimates can vary by an order of magnitude. This also holds for the duration of larger excursions. The mean length of reversals and excursions is of the order of 10 000 years, which is in rough agreement with paleomagnetic findings. Moreover, excursion are not necessarily global phenomena. An excursion that shows a large latitude swing at one site may not exceed normal secular variation at another sites.

(J. Wicht)

Simulated geomagnetic reversals and preferred VGP paths

The question whether virtual geomagnetic poles (VGPs) recorded during reversals and excursions show a longitudinal preference is discussed controversially in the palaeomagnetic community (VGPs are a way of interpreting local magnetic field sequences as if they where caused by a 'virtual' dipole component only). One possible mechanism for such VGP clustering is the heterogeneity of heat flux at the core-mantle boundary (CMB). We use three-dimensional convection-driven numerical dynamo models with imposed non-uniform CMB heat flow that show stochastic reversals of the dipole field. We calculate transitional VGPs for a large number of token sites at the Earth's surface. In a model with a simple heat flux variation given by a Y_{22} harmonic, the VGP density maps for individual reversals differ substantially from each other but the VGPs have a tendency to fall around a longitude of high heat flow. The mean VGP density for many reversals and excursions shows a statistically significant correlation with the heat flow. In a model with an imposed heat flux pattern derived from seismic tomography we find maxima of the mean VGP density at American and East Asian longitudes, roughly consistent with the VGP paths seen in several palaeomagnetic studies. We find that low-latitude regions of high heat flow are centres of magnetic activity where intense magnetic flux bundles are generated. They contribute to the equatorial dipole component and bias its orientation in longitude. During reversals the equatorial dipole part is not necessarily dominant at the Earth's surface, but is strong enough to explain the longitudinal preference of VGPs as seen from different sites.

(C. Kutzner, U. Christensen)

Regolith on atmosphereless bodies of the solar system

Theory

The surfaces of solar system bodies (planets, natural satellites, asteroids and comets) are covered with fractured minerals (rubble, soil). Such a layer is called regolith. The processes forming regolith on solar system bodies other than the Earth are very different from those on Earth, where water exists in liquid form. The structure and size distribution of the fractured minerals affects the observable quantities of the surface of the body like brightness and polarization and its wavelength and phase dependence.

If we want to extract information about the minerals forming the surface of a solid solar system body and about the processes shaping its surface (like bombardment with meteoritic particles or with solar wind ions and cosmic ray particles) we must understand the scattered and thermal radiation coming from regolith of various kinds and, even more difficult, we must be able to deduce properties of the regolith from the observed radiation. A theoretical study of this kind has become possible through support by the DFG in the framework of its special program No. 1115 "Mars and the terrestrial planets". In this study agglomerates of spheres were taken as model regolith grains.

The angular dependence of brightness and linear polarization of randomly oriented aggregates has been investigated in order to find rules connecting their scattering properties with their structure, packing density, complex refractive index, and number and size of the spheres forming the aggregate. Our study was based on an interpretation in terms of successive orders of scattering, in particular on the analysis of the contribution of the interference and near-field effects. Such an approach allowed us to explain and interrelate the main peculiarities of the angular dependence of the intensity and polarization displayed by aggregates. Of special interest are the aggregates showing a so-called negative branch of linear polarization of light scattered into angles close to the backscattering direction. It has been shown that the enhancement of intensity and the negative polarization in this angular range are mainly caused by the interference of multiply scattered waves as well as by near-field effects.

If the number of particles in the aggregate is large enough and its size is comparable to the wavelength, the backscattering enhancement is caused by the particles in the surface layers of the aggregate, where the radiation field is mostly homogeneous, while the negative branch is mainly generated by the deeper layers of particles, where the radiation field is inhomogeneous with chaotic changes of amplitudes and phases. This results in a rather weak dependence of the negative polarization on particle location in the deeper layers of the aggregate and on particle number but not on packing density.

(V. Tishkovets, E. Petrova, K. Jockers)

Herschel Space Observatory (former Far Infrared Space Telescope – FIRST)

The Herschel Space Observatory – the mission formerly known as FIRST – will perform photometry and spectroscopy in the 60 – 670 μm range. It will have a radiatively cooled telescope and carry a science payload complement of three instruments housed inside a superfluid helium cryostat. It will be operated as an observatory for a minimum of three years following launch and transit into an orbit around the Lagrangian point L2 in the year 2007. Herschel is the cornerstone number 4 (CS 4) in the ESA "Horizon 2000" science plan. It will be implemented together with the Planck mission (selected as M3) as a single project.

Fig. 83: Herschel Space Observatory

Herschel has the potential of discovering the earliest epoch-galaxies, revealing the cosmologically evolving AGN-starburst symbiosis, and unravelling the mechanisms involved in the formation of stars and planetary system bodies. The key science objectives emphasise specially the formation of stars and galaxies, and the interrelation between the two, but also includes the physics of the interstellar medium, astrochemistry and solar system studies.

The three instruments on the Herschel Space Observatory are PACS (Photodetector Array Camera & Spectrometer, SPIRE (Spectral and Photometric Imaging Receiver) and HIFI (Heterodyne Instrument for the Far-Infrared).

HIFI

As far as the solar system is concerned, HIFI will focus on the exploration of planetary and cometary atmospheres. A core program has been proposed to investigate the external water of the four giant planets and Titan in combination with PACS and SPIRE and to repeat this measurements over the mission lifetime in order to get knowledge about a possible temporal variability. Another program will be dedicated to the Martian atmosphere. It is proposed to monitor the water vapour and to determine accurately it's isotopic ratios. A number of specific species (O_2, O_3, OH, H_2 and H_2O_2) will be searched for. In addition a deep line survey over the whole HIFI spectral range is proposed. Furthermore it is proposed to study water in a significant sample of comets over a large range of heliocentric distances. The topics are: Evolution of water and kinematics by observing the 557 GHz water line; water excitation and physical conditions by observing several water lines; the deuterium isotopic ratio by searching for HDO.

The MPAe will have a leading role in the planetary science guaranteed time key program and manage the planetary observation program from 2004 on.

Our hardware involvement in HIFI started in 2000 and concerns the Wide Band Spectrometer (WBS) Readout Electronic (WBE) and the WBS Intermediate Frequency Processor (WBI).

(P. Hartogh, H. Bitterlich, P. Börner, W. Boogaerts, M. Clement, R. Enge, I. Héjja, C. Jarchow, K. Jockers, A. Loose, M. Monecke, C. Römer, L. Song, H. Schüddekopf, E. Steinmetz, U. Strohmeyer, W. Wunderlich)

Stratospheric Observatory for Infrared Astronomy (SOFIA)

SOFIA will open a new era in science: It will offer astronomers a unique platform, providing regular access to the entire MIR/FIR and submillimeter wavelength range between 5 μm and 600 μm, part of which is otherwise inaccessible from the ground.

As demonstrated by the KAO (Kuiper Airborne Observatory), IRAS (Infrared Astronomical Satellite) and ISO (Infrared Space Observatory), infrared and submillimeter radiation characterizes a multitude of rich and varied physical processes, and reveals astronomical phenomena occurring in otherwise hidden regions of the cosmos. SOFIA will exploit and extend this scientific legacy by means of sensitive, high spectral and spatial resolution observations spanning the

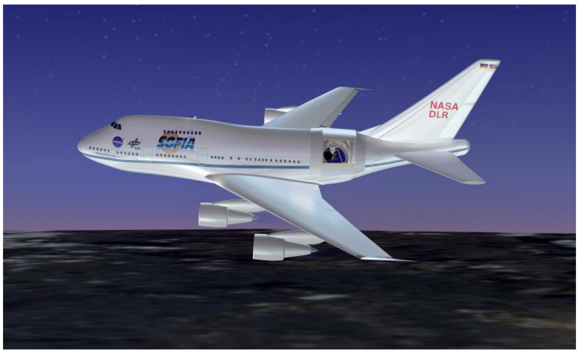

Fig. 84: Sofia

infrared and submillimeter domain. Topics to be addressed by SOFIA users include:

- Interstellar cloud physics and star formation in our galaxy.
- Proto-planetary disks and planet formation in nearby star systems.
- Origin and evolution of biogenic atoms, molecules, and solids.
- Composition and structure of planetary atmospheres and rings, and comets.
- Star formation, dynamics, and chemical content of other galaxies.
- The dynamic activity in the center of the Milky Way.
- Ultra-luminous IR Galaxies (ULIRGS) as a key component of the early universe.

Besides this contribution to science progress, SOFIA will be a major factor in the development of observational techniques, of new instrumentations and in the education of young scientists and teachers in the discipline of infrared astronomy.

German Receiver for THz Astronomy (GREAT)

GREAT is developed in cooperation with MPIfR in Bonn (PI), the University of Cologne and DLR-WS in Berlin-Adlershof. It will operate in three bands between 1.4 and 5 THz. Our contribution are the high resolution Chirp Transform Spectrometers (CTS) and the local oscillator unit (LOU) for the intermediate frequency processor (IFP). Fig. 85 shows one open CTS-unit. This spectrometer has been developed in the framework of a PhD thesis. The application for GREAT has required several new technical developments compared to former spectrometers being built at MPAe: A digital harmonic chirp generator, stripline filters, a new digital preprocessing unit (taking advantage of the MPAe microwave back end ASIC) and finally a built-in computer which performs process control items, postprocesses spectra, transfers data and communicates with the outside world via an ethernet link. The units provided by MPAe are planned to be delivered in 2004.

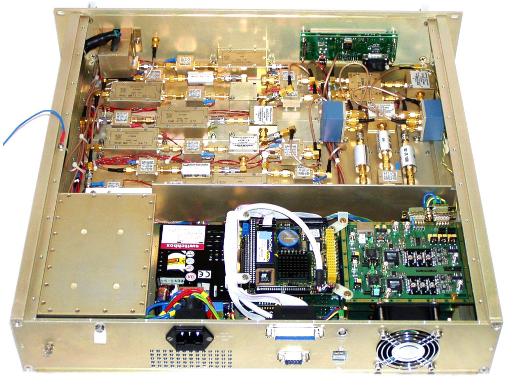

Fig. 85: Chirp Transform Spectrometer for the GREAT instrument

Since GREAT will be able to measure water vapour in space we plan to determine vertical water vapour profiles in the atmospheres of Mars and the giant planets, investigate its isotopic ratios and seasonal variation. Furthermore we will work on cometary observations, again mainly of water and its isotopes. Part of the anticipated work should be understood as a preparation of and support for the Herschel Space Observatory.

(P. Hartogh, G. Villanueva, M. Clement, C. Jarchow, C. Römer, E. Steinmetz)

3. *Atmosphäre, Ionosphäre und Magnetosphäre der Erde/*
Terrestrial Atmosphere, Ionosphere, Magnetosphere

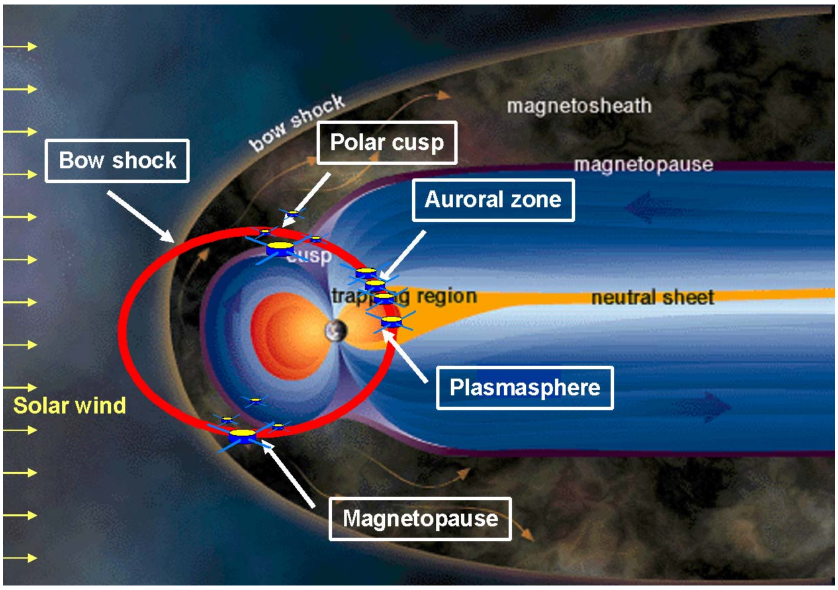

Abb. 86: Regionen der Erdmagnetosphäre, die von den Cluster-Satelliten untersucht werden: Sonnenwind, Bugstoßwelle (*Bowshock*), Kompressionsregion (*Magnetosheath*), Magnetopause, Polarer Scheitel (*Cusp*), Plasmasphäre und Aurora-Region (letztere durch Fernerkundung).

Schwerpunktthema der Magnetosphärenforschung:

Räumliche Plasma-Strukturen – Cluster Ergebnisse

(English version see page 91)

Die Erdmagnetosphäre im Sonnenwind

Durch die Aufheizung der Sonnenkorona auf über 1 Million Grad Kelvin werden kontinuierlich Ionen in das Vakuum des interplanetaren Raumes geblasen. Der so entstehendende Ionenfluss wird *Sonnenwind* genannt und hat eine geringe Dichte von nur wenigen tausend Teilchen pro m^3, aber eine hohe Geschwindigkeit von mehr als 300 km/s und eine thermische Energie von mehr als 10^5 K.

Die Ionen des Sonnenwindes tragen die magnetische Struktur der solaren Chromosphäre mit sich, wodurch *das interplanetare Magnetfeld* entsteht. Ein ionisiertes Gas wird *stoßfreies Plasma* genannt, wenn seine Dichte so gering ist, dass Stöße zwischen den Ionen so selten auftreten, dass akustische Wellenausbreitung nicht möglich ist. Dies ist beim Sonnenwind der Fall. Dagegen ist im Plasma eine Ausbreitung elektromagnetischer Wellen möglich, wie auch von Wellen, die sich über eine Änderung von Dichte und Richtung des im Plasma verankerten Magnetfeldes ausbreiten. Letztere sind sogenannte *magneto-akustische* und *Alfvén-Wellen*, die sich mit typischen Geschwindigkeiten von 30 – 100 km/s im Sonnenwind ausbreiten.

Die Sonnenwindionen werden am Magnetfeld der Erde abgelenkt. Die durch die Wechselwirkung des Sonnenwindes und des Erdmagnetfeldes entstehende Magnetosphäre ist in Abb. 86 dargestellt. Die Grenzschicht, an der der Druck des irdischen Magnetfeldes dem Druck des anströmenden Windes gleich ist, wird *Magnetopause* genannt. Diese wird in Abständen von 5 – 10 Erdradien je nach Sonnenwinddruck beobachtet.

Da der Sonnenwind relativ zur Erde mit einer Geschwindigkeit strömt, die höher ist als die der Wellen im Plasma, entsteht ähnlich wie bei einem Überschallflugzeug eine Bugstoßwelle (*bow shock*) stromaufwärts der Magnetopause. An dieser Stoßwelle wird die Strömungsenergie des Windes in thermische Energie umgewandelt, so dass die Strömungsgeschwindigkeit kleiner wird als die Wellengeschwindigkeit. Zugleich mit der Aufheizung wird der Sonnenwind in der Region zwischen Bugstoßwelle und Magnetopause komprimiert. Diese Region wird *Magnetosheath* genannt.

Innerhalb der Magnetopause wird die Magnetosphäre im Wesentlichen durch das Dipolfeld der Erde be-

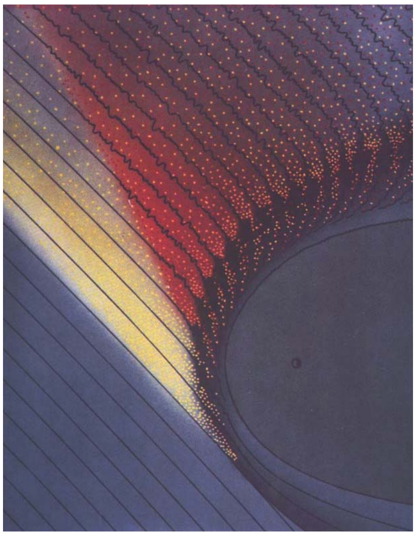

Abb. 87: Sonnenwindionen werden an der Bugstoßwelle reflektiert und laufen entlang des Magnetfeldes zurück. Dabei können Elektronen (gelb) und Protonen (rot) unterschiedliche Regionen erreichen und Plasmawellen anregen.

stimmt, allerdings strömt auch hier aus der Ionosphäre in Höhen von mehr als 200 km Plasma ab, das zunächst noch mit der Atmosphäre korotiert (*Plasmasphäre*), aber am magnetosphärischen Äquator eine Stromschicht bildet, die sogenannte Neutralschicht (*neutral sheet*). Diese kann sich weit in den Schweif der Magnetosphäre (*magnetotail*) ausdehnen. Am Scheitel des Dipolfeldes (*cusp*) können einerseits Ionen aus der Magnetosheath bis zur Ionosphäre eindringen oder umgekehrt ionosphärische Teilchen entweichen.

Während diese globale Struktur der Magnetosphäre recht gut durch die Näherung einer magnetisierten Flüssigkeit (*Magnetohydrodynamik – MHD*) beschrieben werden kann, versagt eine solche Beschreibung schon dann, wenn man die zeitliche Änderung der Struktur oder die Plasmawechselwirkung an den verschiedenen Grenzflächen beschreiben möchte. Hier spielt die genaue Energie- und Richtungsverteilung der Ionen eine entscheidende Rolle, und die Physik der Wechselwirkung läßt sich durch lineare Modelle nicht mehr beschreiben.

Aus diesem Grunde wurde eine Satellitenmission entworfen, die es erlaubt, zeitliche und räumliche Plasmaveränderungen zu unterscheiden – die Cluster-Mission. Diese besteht aus vier Satelliten, die die Erde seit August 2000 in einer Tetraeder-Formation auf einem polaren Orbit mit einer Periode von 56 Stunden in einem Abstand von 4 – 20 Erdradien umkreisen. Ein typischer Orbit ist in Abb. 86 rot dargestellt. Wie man sieht, erfassen die Satelliten auf ihrem Orbit wesentliche Wechselwirkungsregionen der Magnetosphäre. Das Ende der Datenerfassung ist für 2006 geplant.

Das MPAe ist an der wissenschaftlichen Konzeption und Ausstattung der Cluster-Mission mit zwei Instrumenten beteiligt: den Ionenspektrometern CIS und RAPID. Das CIS-Instrument benutzt unterschiedliche Sensoren, um Ladung und Masse (CODIF-Sensor) und Strömungsparameter (HIA-Sensor) thermischer positiver Ionen zu bestimmen. Das RAPID-Instrument bestimmt Strömungsparameter von Elektronen und Ionen im supra-thermischen Bereich (oberhalb 30 keV). Daneben besteht ein reger wissenschaftlicher Austausch mit den anderen Teams der Cluster-Mission. Im Folgenden stellen wir einige herausragende Ergebnisse dieser Zusammenarbeit vor.

Plasmawellen vor der Bugstoßwelle

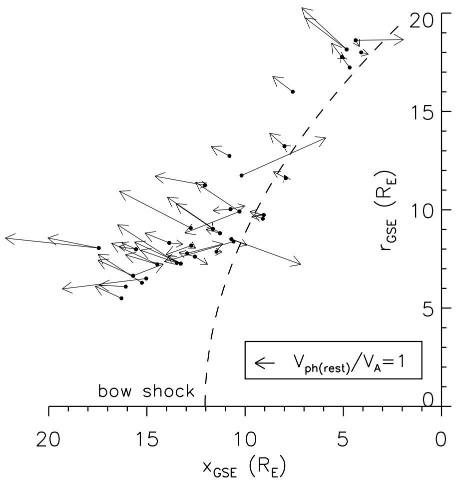

Abb. 88: Ion-Zyklotron-Wellen in der Foreshock-Region: Gezeigt wird die Projektion der Wellenvektoren auf die Radial-Vertikal-Ebene der Magnetosphäre.

Ein Teil der Sonnenwindionen wird an der Bugstoßwelle der Magnetosphäre reflektiert und läuft entlang des interplanetaren Magnetfeldes dem anströmenden Sonnenwind entgegen. Dabei werden Elektronen aufgrund ihrer höheren Geschwindigkeit weniger als Protonen vom anströmenden Wind abgelenkt. Dies führt zur Ausbildung des Elektronen- und Ionen-*Foreshocks* (Abb. 87). Mit Daten des CIS-Instrumentes ist es der Gruppe um Eberhard Möbius (Univ. New Hampshire) erstmals gelungen, die Intensität des reflektierten Strahls in Abhängigkeit von Parametern der Bugstoßwelle zu bestimmen.

Die Wechselwirkung der reflektierten Ionen mit dem anströmenden Plasma des Sonnenwindes führt

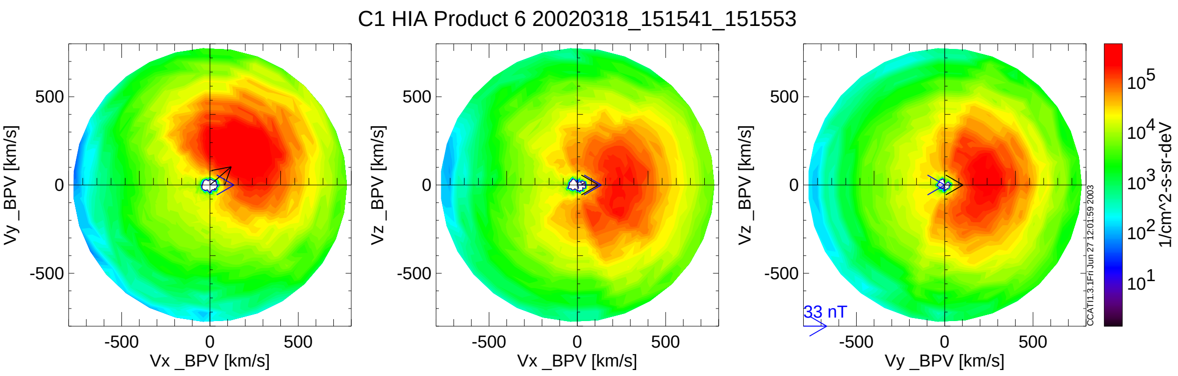

Abb. 90: Schnittebenen durch die räumliche Verteilung der Ionen, gemessen mit dem CIS-Sensor auf C1 entlang der Koordinatenachsen in einem feld-parallelen System. Pfeile bezeichnen die Magnetfeldrichtung (blau) und die Flussrichtung (schwarz).

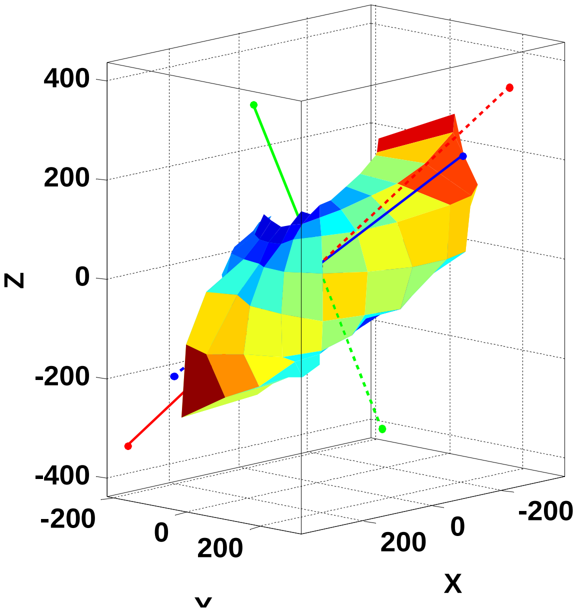

Abb. 89: Räumliche Form einer Mirrormode-Plasmawelle, gemessen aus der 4-Satelliten-Korrelation der Cluster-Magnetometer: Farbe und Ausdehnung der Fläche bezeichnen die Korrelationslänge in der jeweiligen Raumrichtung, Linien bezeichnen Magnetfeld (blau), Plasmageschwindigkeit (rot) und Magnetopausen-Normale (grün).

zur Anregung von Plasmawellen, sogenannten *Ion-Zyklotronwellen*. Die Tetraeder-Konfiguration der Cluster-Satelliten erlaubt es, die Ausbreitungsrichtung und Geschwindigkeit der Wellen für unterschiedliche Frequenzen zu bestimmen. Das Magnetometer-Team an der TU Braunschweig hat dazu die sogenannte Wellenteleskop-Methode entwickelt. Die Abb. 88 zeigt die Projektion der Foreshock-Wellenvektoren auf die Radial-Vertikal-Ebene der Magnetosphäre aus einer Arbeit von Yasuhito Narita, TU Braunschweig. Man sieht, dass die Wellenausbreitung im allgemeinen senkrecht zur Bugstoßwelle erfolgt. Zur Transformation der Messungen in ein Referenzsystem, das sich mit dem Plasma bewegt, waren unsere CIS-Messungen wesentlich.

Plasmawellen in der Magnetosheath

In den Kompressionsregionen planetarer Magnetosphären hat man schon vor 25 Jahren ein Wellenphänomen beobachtet, das sich durch ein abruptes – also nicht sinusförmiges – Abfallen der Magnetfeldstärke auszeichnet. Man hat auch schon früh beobachtet, dass dieses Phänomen mit einem Ansteigen des Ionendruckes senkrecht zum Magnetfeld (*Vertikaldruck*) einhergeht. Dies hat zu dem Modell der sogenannten *Mirrormode-Welle* geführt: Ionen werden von Zonen größerer Feldstärke abgelenkt (gespiegelt), nehmen dabei aber Energie aus dem Feld auf, so dass sich Zonen niederer Feldstärke bilden. So entsteht ein nicht-linearer Resonanzeffekt. Der genaue Mechanismus konnte aber bisher nicht erklärt werden. Mit Cluster ist es nun erstmals möglich, die räumliche Struktur dieser Wellen zu vermessen. Die Abb. 89 zeigt die Korrelationslängen des Magnetfeldes in verschiedenen Raumrichtungen über eine Sequenz von Mirrormode-Wellen, bestimmt von Tim Horbury, Imperial College, London. Das erstaunliche Ergebnis dieser Analyse ist, dass die magnetische Struktur der Welle nicht symmetrisch zum mittleren Feldvektor ist, sondern eine Neigung von etwa 30 Grad aufweist.

Das CIS-Instrument erlaubt die Messung der räumlichen Ionendruckverteilung in einer Mirrormode-Welle. Es lag daher nahe zu untersuchen, ob die Druckverteilung der magnetischen Struktur folgt. Die Abb. 90 zeigt drei räumliche Schnitte durch die Ionenflussverteilung in einer Mirrormode-Welle aus einer Arbeit von Markus Fränz. Man sieht, dass die Ionenverteilung sich völlig symmetrisch zum mittleren

Feldvektor (blau) ausrichtet, also eine Abweichung von 30 Grad nicht zu beobachten ist. Eine Interpretation dieses Ergebnisses ist Gegenstand der Forschung.

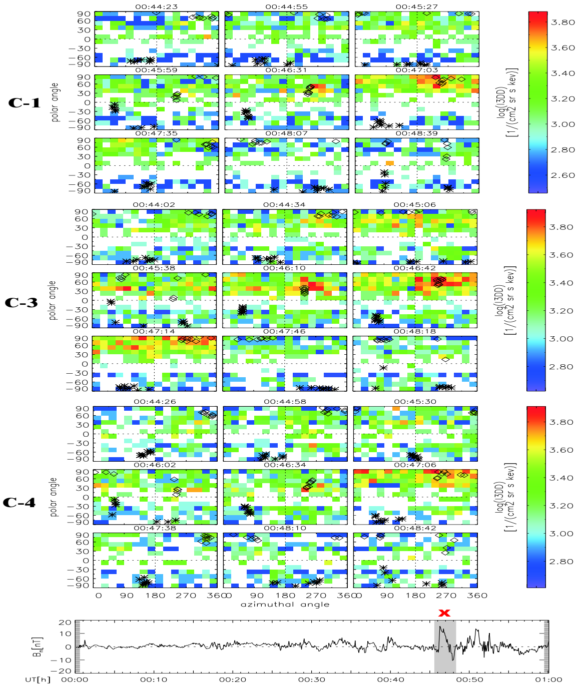

Abb. 91: Azimuthale und polare Flüsse energiereicher Ionen (30 – 68 keV), gemessen durch Cluster-RAPID auf den Satelliten C1, C3 und C4, gemessen zwischen 00:44 und 00:48 UT am 3.3.2001. Die Kreuze bezeichnen die jeweilige Magnetfeldrichtung im 4-Sekunden-Abstand (Spinperiode der Satelliten). Das Fluss-Transfer-Ereignis geschah im Wesentlichen um 00:46 UT, die Messungen lassen magnetfeld-parallele Ionenstrahlen durch die Magnetopause erkennen.

Physik der Erdmagnetopause

Als Magnetopause bezeichnet man die Grenze zwischen abgebremstem Sonnenwind, der Magnetosheath, und der Magnetosphäre. Das Verständnis, wo, auf welche Weise und in welchem Maße sich diese Grenzschicht öffnet, bietet uns den Schlüssel für ein Verständnis der Wirkung des solaren Plasmas auf die Erdumgebung. Aus früheren Weltraumexperimenten ist bekannt, dass die Physik der Magnetopausenöffnung wesentlich von den zeitlich und räumlich stark variablen lokalen Feld- und Plasmaverhältnissen abhängt. Gleichzeitige Messungen mit den vier Cluster-Satelliten bieten nun erstmals die Möglichkeit, die Öffnung aufzuklären. Während dies mit Einzelsatelliten in der Vergangenheit in der Regel nicht realisierbar war, erlaubt es die 4-Satelliten-Konstellation von Cluster zum ersten Mal, Dicke und Geschwindigkeit der Magnetopause unabhängig voneinander zu bestimmen. In Arbeiten von Jörg Büchner und Bernd Nikutowski wurden in Kooperation mit der Technischen Universität Braunschweig (K.-H. Glaßmeier) mit Hilfe von Magnetfeldmessungen Schichtdicken und Geschwindigkeiten der Magnetopause bestimmt (siehe separaten Beitrag). So gelang es z.B., Größe (etwa 700 km) und Bewegungsgeschwindigkeit (etwa 40 km/s) sogenannter *Fluss-Transfer-Ereignisse (FTE)* unabhängig voneinander zu bestimmen. In der unteren Grafik der Abb. 91 ist die typische Magnetfeldsignatur des FTE vom 3.3.2001, 00:46 UT, eine bipolare Schwingung, durch ein rotes Kreuz gekennzeichnet. In den Abbildungen darüber sieht man, wie das Ionenspektrometer RAPID auf den drei Cluster-Satelliten C1, C3, C4 verschiedene energiereiche Ionenstrahlen feststellte. Ursache ist das FTE, das eine Bresche durch die Magnetopause geschlagen hat und am Rand der transferierten Magnetflussröhre parallel zum Magnetfeld energiereiche Ionen aus der Magnetosphäre ausströmen läßt.

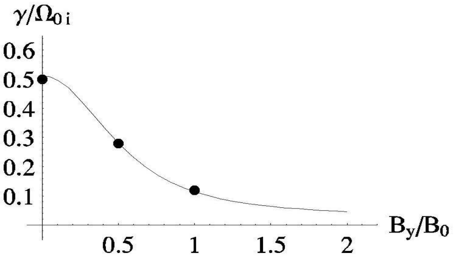

Abb. 92: Abhängigkeit der auf die Ionengyrofrequenz normierten Anstiegsrate der Plasmawelleninstabilität vom Rotationswinkel des Magnetfeldes durch die Magnetopause.

Zum Verständnis dieser Untersuchungen führten Jörg Büchner und Ilya Silin kinetische Plasmasimulationen durch. Insbesondere wurde der Unterschied zwischen dem Fall antiparalleler Magnetfelder und solchen mit einem endlichen Führungsfeld in Stromrichtung untersucht, um die Abhängigkeit der Öffnung der Magnetopause von der Rotation des Magnetfeldes zu erforschen. Während im ersten Fall durch mikroskopische Ionenresonanz Plasmawellen instabil angeregt werden, schwächt sich diese Instabilität mit wachsender Rotation (Parameter B_y/B_0 in Abb. 92) ab. Der mikrophysikalische Mechanismus und die Effizienz der beobachteten Magnetopausenöffnung mit Magnetfeldrotationen ungleich 180 Grad (sogenannte *Komponenten-Rekonnexion*) bleibt damit vorerst ungeklärt.

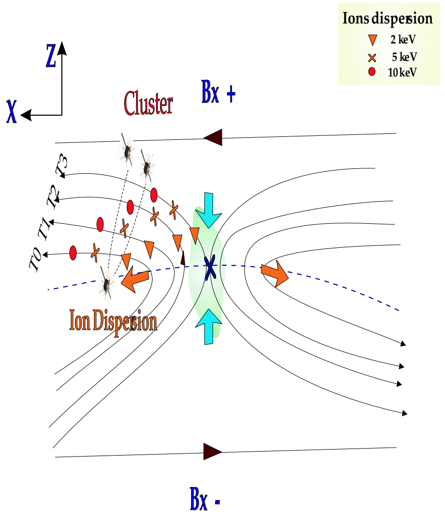

Abb. 93: Schematik eines Rekonnexionsprozesses im Magnetschweif der Erde. Pfeile markieren die Bewegung der Feldlinien, die übrigen Symbole die Ausbreitung der Ionen in Abhängigkeit von ihrer Energie.

Schwingungen des Erdschweifs, dünne Stromschichten und magnetische Rekonnexion

Wenn der Druck des Sonnenwindes auf die Erdmagnetosphäre ansteigt, werden durch die Kompression inm Bereich der Plasmasphäre und Ionosphäre elektrische Ströme erzeugt. Diese führen zu einem erhöhten Plasmaabfluss in die Plasmaschicht des Magnetosphärenschweifs. Wenn die Dichte der Plasmaschicht soweit ansteigt, dass das Plasma vom Magnetfeld nicht mehr gehalten werden kann, kommt es zur Ablösung von Plasmawolken (*Plasmoiden*) in sogenannten *Teilstürmen*. Am Abschnürpunkt der Plasmoide verbinden sich entgegengesetzte Magnetfelder, um die Magnetosphäre zu schließen (*Rekonnexion*). Bei der Rekonnexion werden plötzlich große Mengen von Feldenergie frei, die zu einer lokalen Heizung des Plasmas führen (Abb. 93).

Eine Schlüsselrolle für die Rekonnexion im Schweif spielt offenbar seine zentrale Stromschicht. Die vier Cluster-Satelliten halfen uns, durch Trennung räumlicher und zeitlicher Variationen erstmals nachzuweisen, dass eine Verdünnung der Schicht schließlich zu einer explosionsartigen Energiefreisetzung führt. Von Jörg Büchner und Bernd Nikutowski wurde gemeinsam mit der TU Braunschweig (K.-H. Glaßmeier) auf diese Weise ermittelt, dass die Schweifstromschicht zunächst mit einer Amplitude von mehreren Tausend Kilometern auf und ab schwingt (Abb. 94) und sich dabei immer weiter verdünnt (Abb. 95). Durch die Autoren konnte dabei gezeigt werden, dass die Schichtdicke bis auf einen Ionen-Gyroradius absinkt, bevor sie in heftige Oszillationen übergeht, die durch Anregung von Plasmawellen in Stromrichtung hervorgerufen werden. Anschließend erfolgt eine starke Störung der Teilchenflüsse, während in Erdnähe Teilstürme beobachtet werden. Mit Hilfe von numerischen Simulationen konnte Jörg Büchner dazu zeigen, wie die Wellenanregung in verdünnten Stromschichten des Schweifs zu Rekonnexion führt (Abb. 96). Da die Rekonnexion zu einer katapultähnlichen Beschleunigung von Teilchen und Plasma in Erd- und in Schweifrichtung führt und das Plasma heizt, erklärt sie die wichtigsten Signaturen von Teilstürmen.

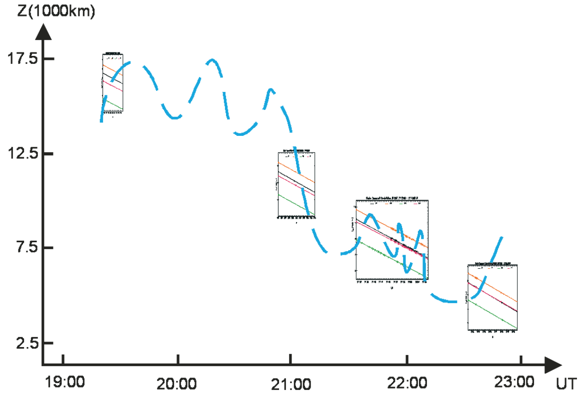

Abb. 94: Schwingung der magnetosphärischen Schweif-Stromschicht (blaue Linie), abgeleitet aus den Durchgängen der Schicht durch die vier Cluster-Satelliten entlang ihrer – farblich gekennzeichneten – Bahnen zwischen 19:00 und 23:00 UT am 7.9.2001. Z bezeichnet den Abstand von der nominellen Äquatorebene der Erdmagnetosphäre.

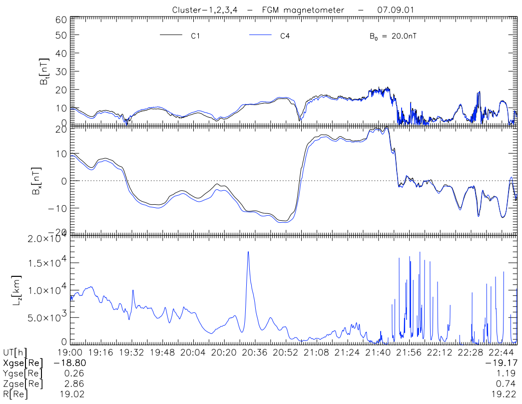

Abb. 95: Total- (oben) und Bx-Komponente des Magnetfeldes im Schweif zwischen 19:00 und 23:00 UT am 7.9.2001. Am Vorzeichenwechsel von Bx deutlich erkennbar ist der Magnetopausendurchgang um 21:00 Uhr. Die untere Kurve verdeutlicht, wie die Stromschichtdicke bis 21:00 ständig abnimmt, um danach in heftige Oszillationen überzugehen.

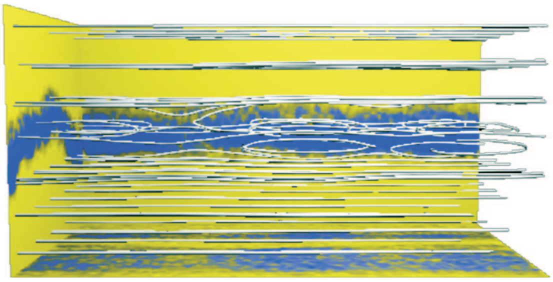

Abb. 96: Kinetisch am MPAe simulierte Knick-Instabilität der magnetosphärischen Schweifstromschicht (blaues Band auf der Boxwand), die nach der beobachteten starken Verdünnung der Stromschicht einsetzt und zu Rekonnexion, d.h. zu Neuverbindung des Magnetfelds – neue Feldlinientopologie (Abb. 93) – führt, die eine Freisetzung magnetischer Energie und Plasmabeschleunigung einleitet.

Globale Teilchenströme

Durch die Heizung des Plasmas während Teilstürmen entstehen Ionenstrahlen, die sich global in der Magnetosphäre ausbreiten können. Die Abb. 97 zeigt Messungen des CIS-Codif Sensors über 30 Minuten zu Beginn eines Teilsturms aus einer Arbeit von Axel Korth und Markus Fränz. Panel b zeigt das Intensitätsspektrum von Sauerstoffionen als Funktion der Energie. Man sieht, dass sich oberhalb von 5 keV ein anhaltender Ionenstrahl ausbildet, dessen mittlere Energie von 40 keV auf 10 keV abfällt. Als Ursprung dieser Ionen nehmen wir eine Rekonnexionsregion im Magnetschweif an, wie sie in Abb. 93 skizziert ist. Unterhalb von 1 keV sieht man kurzzeitige Ioneninjektionen. Diese interpretieren wir als Ionenabfluss aus der Ionosphäre.

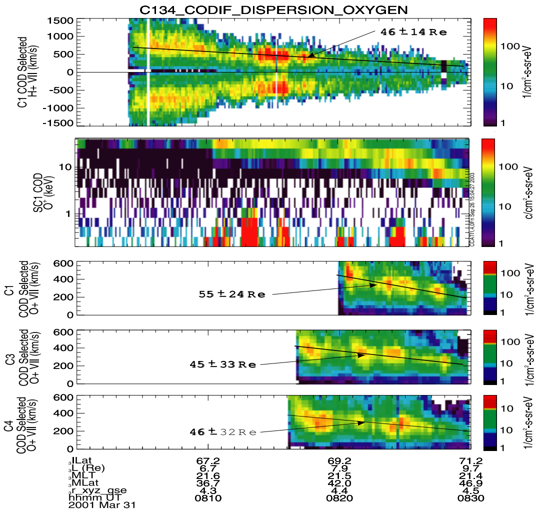

Abb. 97: Ionenströme während eines Teilsturms: Flussintensitäts-Spektrogramme als Funktion der Zeit und der parallelen Protonengeschwindigkeit bei C1 (a), der Sauerstoffenergie bei C1 (b), der parallelen Sauerstoffgeschwindigkeit bei C1, C3 und C4 (c,d,e).

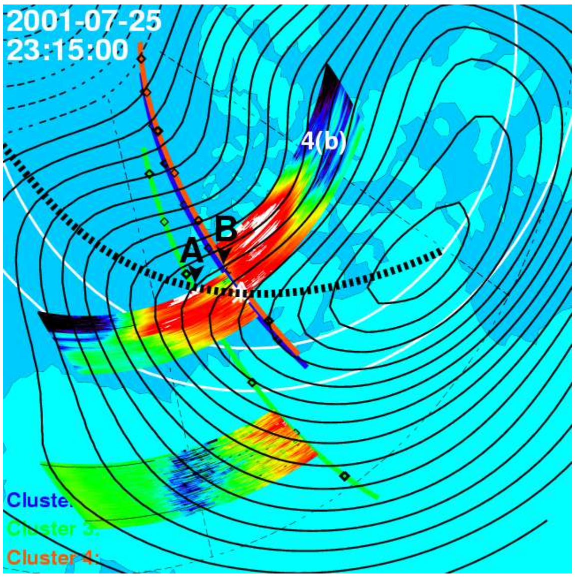

Abb. 98: Teilchenströme zwischen der Cusp und der Ionosphäre: Dargestellt sind Ionenspektrogramme der CIS-Instrumente auf C1, C3 und C4 entlang der magnetischen Fußpunkte der Satelliten in der Ionosphäre über Kanada. Darunter liegt das Profil der ionosphärischen Konvektionsströme aus SuperDARN-Radarmessungen. Die gestrichelte Linie bezeichnet die Grenze zwischen offenen und geschlossenen Feldlinien.

Die Richtungsauflösung des CIS-Sensors erlaubt es nun, für jede Energie die Ionengeschwindigkeit parallel zum Magnetfeld ($V_{||}$) zu berechnen. Panel a zeigt das so gewonnene $V_{||}$-Spektrogramm für den Protonenstrahl, Panel c, d, und e für die Sauerstoffstrahlen auf C1, C3 und C4. Eine lineare Regression durch den positiven Ast der $V_{||}$-Spektrogramme bestimmt die Ionenankunftsverzögerung in Abhängigkeit von ihrer Geschwindigkeit (*Dispersion*). Daraus läßt sich direkt der Abstand der Ionenquelle berechnen. Die berechneten Abstände von 45 – 55 Erdradien sind in der Abbildung eingetragen. Damit ist es erstmals möglich, eine relativ präzise Lokalisierung einer Rekonnexionsregion im Magnetschweif zu geben.

Seit vielen Jahren werden die Ionenflüsse in der Ionosphäre durch bodengebundene Radarmessungen bestimmt. Unser Institut ist bis heute in diesem Bereich federführend tätig. Mit der Cluster-Mission ist es nun möglich zu erforschen, wie sich diese Ionenflüsse in die äußere Magnetosphäre fortsetzen. Die Abb. 98 zeigt die Konvektionsströme in der Ionosphäre über dem nördlichen Kanada während eines magnetischen

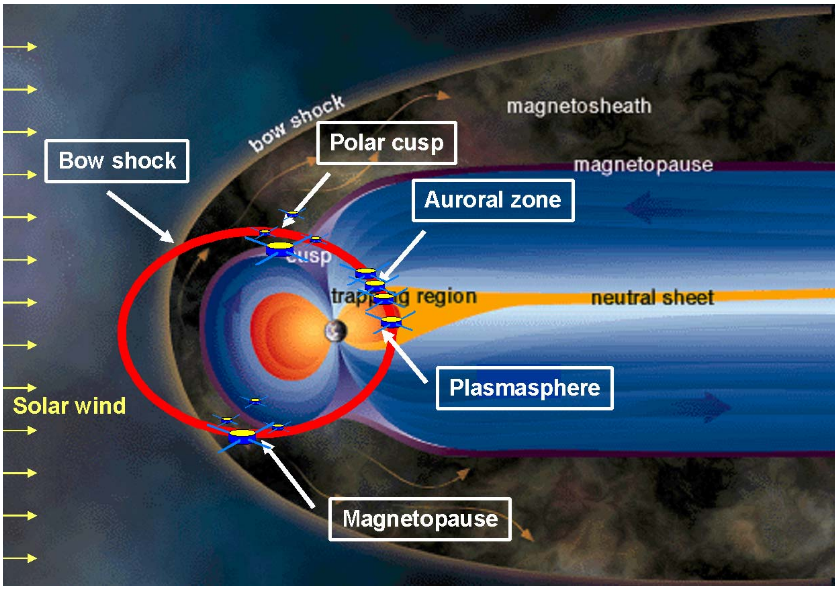

Fig. 86: Regions of the Earth magnetosphere investigated by the Cluster satellites: Solar wind, bowshock, magnetosheath, magnetopause, polar cusp, plasmasphere and aurora region (the later by remote sensing).

Sturmes, gemessen mit der SuperDARN-Radaranlage aus einer Arbeit von Karl-Heinz Trattner (Lockheed-Martin, Palo-Alto, 2002 zu Gast am MPAe). Darüber gelegt sind entlang der Trajektorien von drei Cluster-Satelliten die CIS-Intensitätsspektrogramme von Protonen. Aus dem Einsetzen der Ionenströme bei Cluster läßt sich die Grenze zwischen geschlossenen und offenen Feldlinien der Magnetosphäre bestimmen. Die Projektion dieser Linie auf die Ionosphäre (gestrichelt) zeigt, dass diese Grenze mit der Linie des stärksten Gradienten in den Konvektionsströmen übereinstimmt. Die Messungen erlauben darüber hinaus, die Dynamik der Ströme über die Sturmperiode zu bestimmen.

Highlight of magnetospheric research:

Spatial structure of magnetospheric plasma – Cluster results

The Earth magnetosphere in the solar wind

The solar corona is heated up to a temperature of more than 1 million degree kelvin. This heating causes ions to be blown continuously into the vacuum of interplanetary space. This ion outflow is called *solar wind* and has a density of only a few thousand particles per m^3, but a velocity of more than 300 km/s and a thermal energy of more than 10^5 K.

The solar wind ions carry with them the magnetic structure of the solar chromosphere, thus causing the *interplanetary magnetic field*. An ionized gas is called a *collisionless plasma* if collisions between ions are so rare that acoustic waves cannot propagate. This is the case for the solar wind. Electromagnetic waves on the other hand can propagate through the plasma, as well as waves which propagate as changes in density and direction of the magnetic field which is bound to the plasma. The latter are called *magneto-acoustic* and Alfvén waves. They have a typical velocity of 30 – 100 km/s in the solar wind.

Solar wind ions are deflected by the Earth magnetic field. The Earth magnetosphere defined by the interaction of solar wind and Earth magnetic field is shown in Fig. 86. The boundary at which the pressure of the Earth magnetic field equalizes the pressure of the inflowing wind is called *magnetopause*. This boundary is observed at distances between 5 – 10 Earth radii depending on solar wind pressure.

Since the solar wind streams relative to Earth with a speed which is higher than the speed of waves in the plasma, a *bow shock* builds up upstream of the magnetosphere similar as for a super-sonic aircraft. At the bow shock the energy of the bulk motion of the solar wind is converted to thermal energy such that the bulk motion becomes smaller than the wave velocity. While the plasma is heated it is also compressed in the region between bow shock and magnetopause. This region is called *magnetosheath*.

Inside the magnetopause the magnetosphere is essentially dominated by the dipolar magnetic field of the

Earth. But even here plasma escapes from the *ionosphere* (at a height of about 200 km above the atmosphere) and builds the corotating *plasmasphere*. At the magnetospheric equator plasma can escape further to build the equatorial *neutral sheet*. This can stretch anti-sunward into the *magnetotail*. At the *polar cusp* magnetosheath ions can intrude down to the ionosphere causing the aurora. But ionospheric ions can as well escape through the cusp.

While this global structure of the magnetosphere can be described fairly accurate by a magnetized fluid model (*magneto-hydrodynamics, MHD*), such a model already breaks down if we try to describe the temporal change or the plasma interaction at the boundaries. Here the distribution of energy and propagation directions of the ions play an essential role and linear fluid models are misleading.

For that reason a satellite mission was developed which would allow to separate temporal and spatial changes of the magnetospheric plasma – the *Cluster mission*. This consists out of four satellites which fly around Earth since August 2002 in a tetrahedral formation on a polar orbit with a period of 56 hours and a distance of 4 – 20 Earth radii. A typical orbit is shown in red in Fig. 86. One can see that the satellites cover the most important regions of plasma interaction in the magnetosphere. End of data reception is planned for 2006.

The MPAe took part in the design and construction of the Cluster mission with two instruments: the ion-spectrometers CIS and RAPID. The CIS-instrument uses different sensors to determine charge and mass (CODIF-sensor) and stream parameters (HIA-sensor) of positive ions at thermal energies. The RAPID-instrument determines stream parameters of electrons and positive ions in the supra-thermal energy-range (above 30 keV). There is also an active scientific collaboration with other teams of the Cluster mission. In the following we present some outstanding results of this collaboration.

Plasma waves at the bow shock

Part of the solar wind ions is reflected at the bow shock of the magnetosphere and travels along the interplanetary field against the solar wind stream. Back-streaming electrons have a higher velocity and are thus deflected less by the solar wind than back-streaming protons. So the electron- and ion-*foreshocks* are formed (Fig. 87). Using the data of the CIS-instrument the group of Eberhard Möbius (Univ. New Hampshire) could for the first time determine how the intensity of the reflected ion-beam depends on parameters of the bow shock.

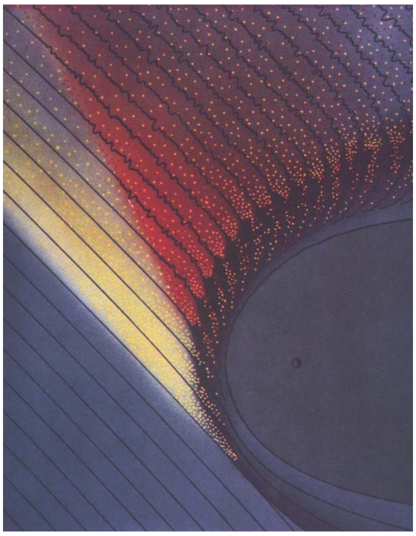

Fig. 87: Solar wind ions are reflected at the bow shock and travel back along the interplanetary field. Electrons (yellow) and protons (red) can reach different foreshock regions and excite waves.

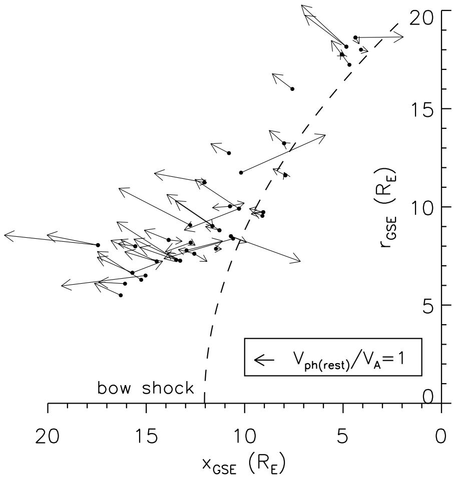

Fig. 88: Ion-cyclotron waves in the foreshock region: Projection of wave vectors onto the radial-vertical plane of the magnetosphere.

The interaction of reflected ions with the solar wind plasma excites plasma waves – so called *ion-cyclotron waves*. The tetrahedral configuration of the Cluster satellites allows to determine propagation direction and velocity for different frequencies of these waves. The magnetometer team at the Technical University of Braunschweig developed the *wave-telescope method* for that purpose. Fig. 88 shows the projection of the foreshock wave vectors onto the radial-vertical plane of the magnetosphere from a paper by Yasuhito Narita, TU Braunschweig. One can see that the propagation

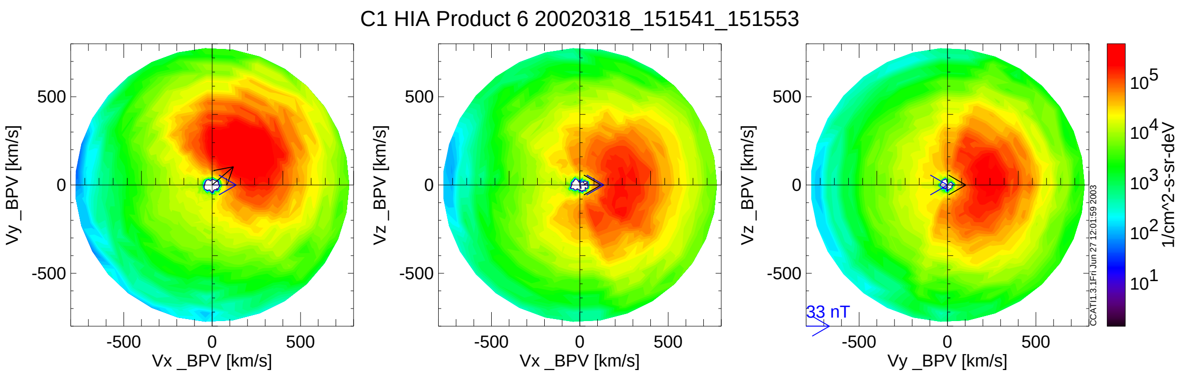

Fig. 90: Planar cuts through the ion distribution in velocity space along the coordinate axes of a field-parallel system obtained by the CIS-HIA-sensor. Arrows indicate the direction of the magnetic field vector (blue) and bulk speed (black).

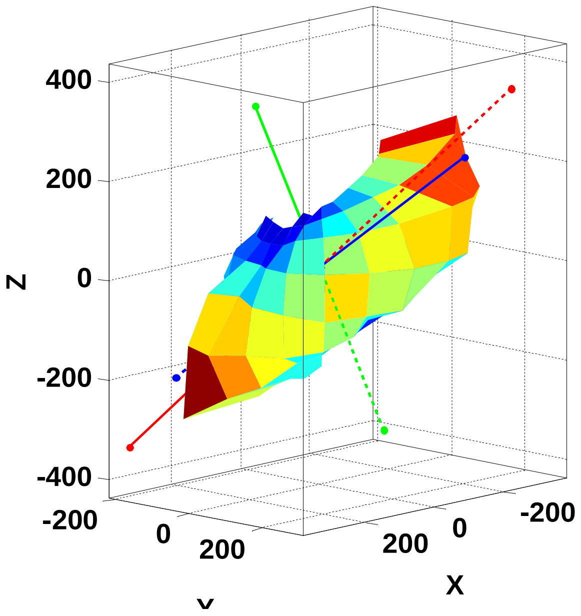

Fig. 89: Spatial shape of a mirror-mode wave obtained by correlating observations of the 4 Cluster magnetometers: Colour and extension of the surface indicate the correlation length in each direction. Lines indicate the mean magnetic field (blue), the plasma velocity (red) and the magnetopause normal (green).

is generally perpendicular to the bow shock. For the transformation of these observations into a reference system which moves with the plasma our CIS-data were essential.

Plasma waves in the magnetosheath

In the compression regions of planetary magnetospheres one has observed already 25 years ago a wave phenomenon that is marked by sudden – non-sinusoidal – drops of the magnetic field strength. At that time it was also observed that this phenomenon is related to an increase in the ion pressure perpendicular to the magnetic field. This did lead to the model of a so called *mirror-mode wave*: Ions are reflected by regions of higher field strength but in the process absorb some energy from the field. Thus regions of lower field strength build up in a non-linear resonance process. But the exact mechanism could not be explained so far. With Cluster it was possible for the first time to measure the spatial structure of these waves. Fig. 89 shows the correlation lengths of the magnetic field in different spatial directions over a sequence of mirror-mode waves from a paper by Tim Horbury, Imperial College, London. The surprising result of this analysis is that the magnetic structure of the wave is not symmetric to the mean field vector but shows an inclination of about 30 degrees.

The CIS-instrument allows to determine the spatial distribution of the ion pressure in a mirror-mode wave. So it was intriguing to investigate whether this distribution shows the same inclination as the magnetic structure. Fig. 90 shows three cuts through the ion-intensity distribution during a mirror mode wave from a paper by Markus Fränz. One can see that the ion distribution is completely symmetric to the mean field vector (blue). There is no 30 degree deviation visible. This result could also be confirmed quantitatively by calculation of the so-called pressure tensor orientation. An interpretation of the discrepancy of the field and ion observation is the subject of current research.

Physics of the magnetopause

Magnetopause we call the boundary between the shocked solar wind, the magnetosheath, and the magnetosphere. Understanding where, how and how much this boundary opens is a key for understanding the influence of solar plasma on the space environment of Earth. From previous space missions it is known that the physics of magnetopause opening crucially depend on the variable local field and plasma conditions. Simultaneous observations of the four Cluster satellites for the first time give the opportunity to explore these physics. Using the four-satellite configuration we can specifically determine thickness and speed of the magnetopause independently. In papers by Jörg Büchner and Bernd Nikutowski we determined in cooperation with the TU Braunschweig (K.-H. Glaßmeier) these parameters (see separate article). This way it was for example possible to measure size (typical 700 km) and speed (typical 40 km/s) of so-called *flux-transfer events – FTEs* (see separate article).

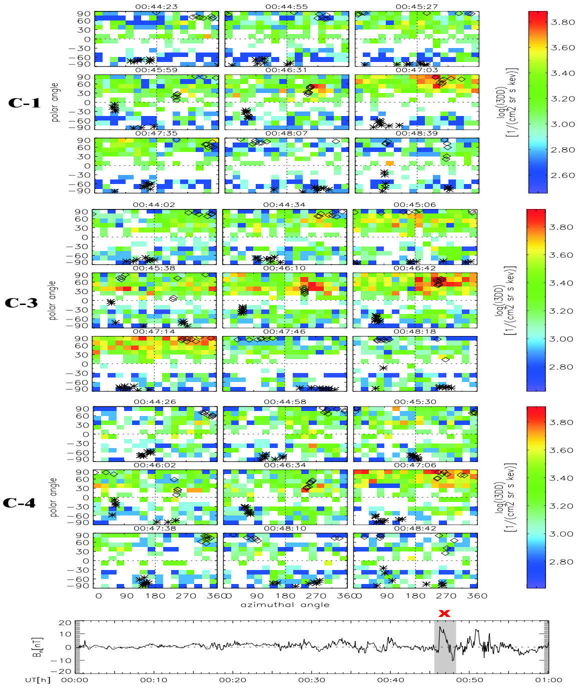

Fig. 91: Azimuthal and polar fluxes of energetic ions (30 – 68 keV) observed by Cluster-RAPID on satellites C1, C3 and C4 between 00:44 and 00:48 UT on 3 March 2001. The crosses mark the magnetic field direction in 4 s steps (spin periods of the satellites). The flux-transfer event happend at 00:46 UT where one can observe field-parallel ion beams through the magnetopause.

The lowest panel of Fig. 91 shows a typical magnetic signature of a FTE observed on 3 March 2001 at 00:46 UT: A bipolar wave (marked by the red cross). The upper panels show that the RAPID-spectrometer did observe separate energetic ion beams. We explain this by an outflow of energetic ions from the magnetosphere parallel to the magnetic field at the boundary of a transferred flux-tube after the FTE opened the magnetopause.

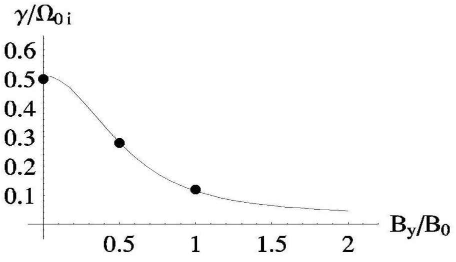

Fig. 92: Dependence of the growth rate of a plasma instability on the rotation angle of the magnetic field through the magnetopause (normalized to the ion gyro-frequency).

To improve the understanding of these observations Jörg Büchner and Ilya Silin did kinetic plasma simulations. Specifically they investigated the difference between the case of anti-parallel magnetic fields and the case of a finite lead-field in the direction of plasma streaming to clarify the dependene of the magnetopause opening on the rotation of the magnetic field. While in the first case microscopic ion resonances excite plasma waves, this instability is dampened with growing rotation angle (parameter B_y/B_0 in Fig. 92). The micro-physical mechanism and the efficiency of the observed magnetopause opening with field rotation different from 180 degrees (so-called *component-reconnection*) remain so far unexplained.

Oscillations of the magnetotail, thin current sheets and magnetic reconnection

When the solar wind pressure on the magnetosphere increases, electric currents are generated by the compression in the plasmasphere and ionosphere. This can lead to an increased outflow of plasma into the plasma sheet in the magnetotail. If the plasma density in the plasma sheet increases to a level where the magnetic field can no longer hold back the corotating plasma, plasma clouds (*plasmoids*) can separate from the plasmasphere in so-called *substorms*. At the point of separation opposite magnetic fields can re-connect to close the magnetospheric field (*reconnection*). During reconnection large amounts of field energy can be converted into thermal ion energy producing energetic particle beams (Fig. 93).

A key role for the reconnection process plays the equatorial current sheet. The four Cluster satellites did help us to prove that a thinning of the current sheet leads to a sudden energy release. Jörg Büchner and Bernd Nikutowski together with the team of K.-H. Glaßmeier (TU Braunschweig) discovered that the magnetotail current sheet oscillates with an amplitude of several thousand kilometers (Fig. 94) while its thickness decreases (Fig. 95). The authors could show that only when the thickness reaches the order of an ion gyro-

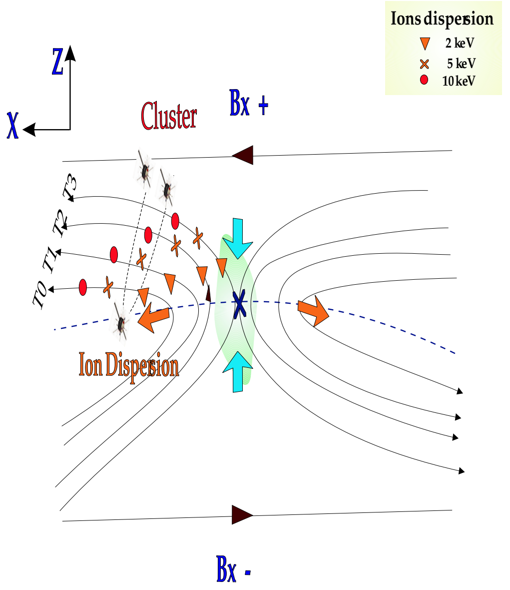

Fig. 93: Outline of a reconnection process in the Earth magnetotail. Arrows indicate the motion of field lines, the other symbols indicate the propagation of ions dependent on their energy.

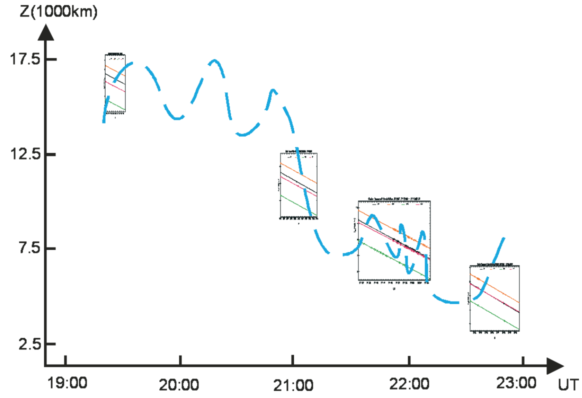

Fig. 94: Oscillation of the magnetotail current sheet (blue line) inferred from the crossing of the current sheet by the four Cluster satellites along their orbits (coloured) between 19:00 and 23:00 UT on 7 September 2001. Z is the distance from a nominal equatorial plane of the magnetosphere.

radius plasma waves in current direction cause additional oscillations of the sheet. Then particle fluxes get disturbed while near-Earth substorms are observed. With numerical simulations Jörg Büchner could also show that wave excitation in thin current sheets of the magnetotail can lead to reconnection (see Fig. 96). Since reconnection leads to a sudden tail- and earthward acceleration of particles and plasma heating, it can explain the main features of substorms.

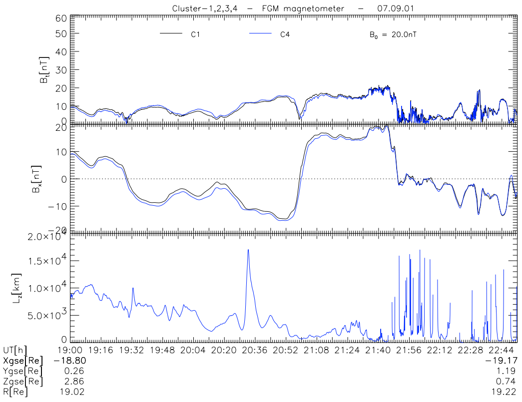

Fig. 95: Total value and B_x component of the magnetic field between 19:00 and 23:00 UT on 7 September 2001. The change in sign of B_x indicates the magnetopause crossing at 21:00 UT. The bottom panel shows how the current sheet thickness decreases continuously before strong oscillations start.

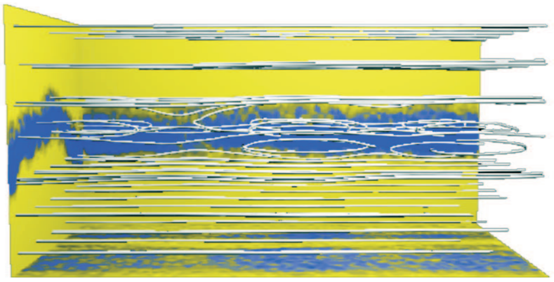

Fig. 96: Kinetic simulation of the kink-instability at the magnetotail current sheet (blue ribbon at the border of the box) developed at MPAe. The instability takes off after the observed thinning of the current sheet and leads to reconnection and a new field topology (see Fig. 93). Magnetic energy is released and plasma accelerated.

Global particle beams

The ion heating during substorms leads to beams of ions which can travel through the magnetosphere on a global scale. Fig. 97 shows observations of the CIS-CODIF sensors over 30 minutes after a substorm onset from a paper by Axel Korth and Markus Fränz. Panel b shows intensity spectra of oxygen ions as a function of energy. One can observe a continuous ion beam above 5 keV with a mean energy decreasing from 40 keV to 10 keV. They assume that the origin of these ions is a reconnection region in the magnetotail as shown schematically in Fig. 93. Below 1 keV one can see short-time ion injections which they interpret as ion outflow from the ionosphere.

The spatial resolution of the CIS-sensors allows to cal-

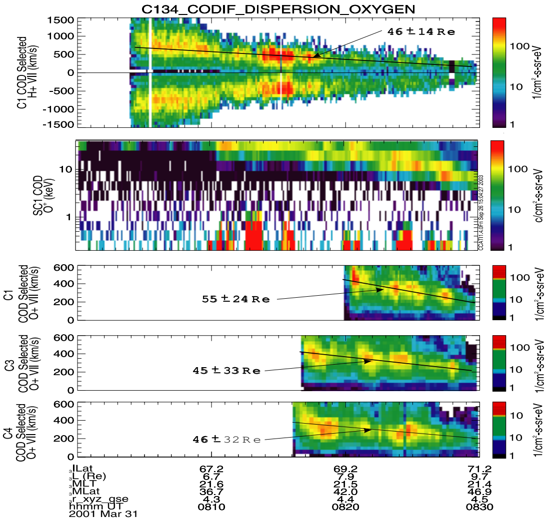

Fig. 97: Ion beams during a substorm from top to bottom: Intensity spectrograms as a function of time and (a) the parallel proton speed at C1, (b) the oxygen energy at C1, (c,d,e) the parallel oxygen speed at C1, C3, C4.

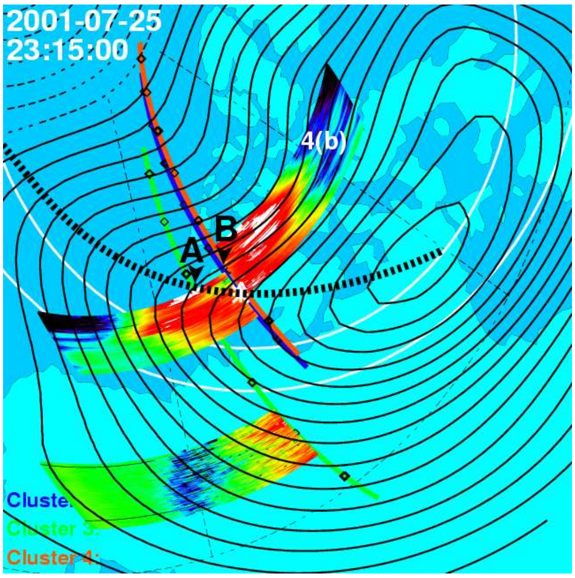

Fig. 98: Ion beams between cusp and ionosphere: Ion spectrograms observed by the CIS-instruments on C1, C3 and C4 along the magnetic foot-points of the satellites in the ionosphere over Canada. Underneath is plotted the pattern of ionospheric convection observed by the SuperDARN-radar. The dashed line indicates the boundary between open and closed magnetic field lines.

culate for each energy bin the respective ion velocity parallel to the local magnetic field ($V_{||}$). Panel a shows the $V_{||}$-spectrogram for the proton beam on C1, panel c, d , and e for the oxygen beams on C1, C3 and C4. A linear regression through the positive branch of the $V_{||}$-spectrograms determines the delay in arrival time dependent on the ion speed (*dispersion*). From that immediately follows the distance of the ion source. The derived distances of 45 – 55 Earth radii are shown in the figure. Thus it is possible for the first time to give a rather precise localisation of a reconnection region in the magnetotail by remote sensing.

For many years ion fluxes in the ionosphere are observed by ground-based radar. Our institute is up to this day a leader of research in that field. With the Cluster mission it is now possible to investigate how these ion fluxes map into the magnetosphere. Fig. 98 shows convection patterns in the ionosphere over northern Canada during a magnetic substorm observed by the SuperDARN-Radar from a paper by Karl-Heinz Trattner (Lockheed-Martin, Palo-Alto, visiting MPAe in 2002). On top of these observations you can see CIS-proton intensity spectrograms plotted along the trajectories of three Cluster satellites. From the onset of the ion beams at Cluster one can determine the boundary between open and closed magnetospheric field lines. The projection of this boundary onto the ionosphere (dashed) shows that the boundary coincides with the line of largest gradient in the convection pattern. The observations also allow to determine the temporal change of the ion streams during substorms.

(M. Fränz, J. Büchner, P. W. Daly, A. Korth, B. Nikutowski)

Wissenschaftliche Einzelberichte/ *Individual scientific reports*

(nur in Englisch)

Research projects in the neutral atmosphere

Trace gases in the atmosphere

Cryogenic sampling in the stratosphere

Between 1977 and 1999, a total of 27 balloon flights was carried out at Gap and Aire sur l'Adour (France, 44° N), Kiruna (Sweden, 68° N) and Hyderabad (India, 17.5° N) yielding vertical profiles of up to 30 compounds for tropical, middle and high northern latitudes. To create a reliable database for public access, a special procedure was used to detect and eliminate uncertainties in absolute calibrations for a number of halocarbons along with CH_4 and N_2O and the replacement substances HFC-134a, HCFC-141b and HCFC-142b. With a suitable regression applied to the profiles, respective tropospheric mixing ratios were derived and compared with available data from various surface monitoring programs. It turned out that these agreed, with few exceptions, within the absolute calibration uncertainties. Thus a consistent database for all constituents could be established showing their changing abundances and the growing chlorine and bromine input into the stratosphere over the years.

(R. Borchers in cooperation with P. Fabian, Technical University of Munich)

Reactive gases

In atmospheric chemistry hydrogen chloride (HCl) is a very interesting compound. In the stratosphere it belongs to the so called reservoir substances with concentrations in the ppb range (10^{-9}), in the troposphere it is emitted by volcanoes with varying concentrations of up to several percent and finally it can be a natural and anthropogenic combustion product. Due to its reactivity HCl cannot be measured using cryogenic sampling and subsequent gas chromatographic analysis. *In situ* measurement in the stratosphere so far have been done using complicated infrared or microwave spectrometer.

A new attempt has been made to measure HCl at ppb-level using gas chromatographic methods in order to get an easy to handle instrument with high sensitivity. In principle two different methods are possible: a) direct gas chromatographic separation with a suitable detector for HCl, b) conversion of HCl into a less critical gas (derivatisation) followed by normal gas chromatographic separation and detection. So far the latter method has been chosen although adsorption effects due to the high polarity of the HCl molecule create additional problems. Apropriate choice of materials, type of column and detector are main topics.

(R. Borchers)

Structure and dynamics of the polar mesopause region

Recently, lidar observations of polar mesospheric clouds (PMC) have been performed at the South Pole (*Chu et al.*, Geophys. Res. Lett. **28**, 1937, 2001) indicating that the clouds occur 2 – 4 km above typical PMC heights. The mean diurnal variations of the maximum backscatter ratio, the centroid height and the total backscatter coefficient are dominated by a 12-h component. To explain the observed PMC properties, the diurnal variations have been simulated as well as possible by varying eight parameters of the MPAe PMC model which describes the temperature of the neutral gas and of the cloud particles, the H_2O mixing ratio and the meteoric dust size distribution.

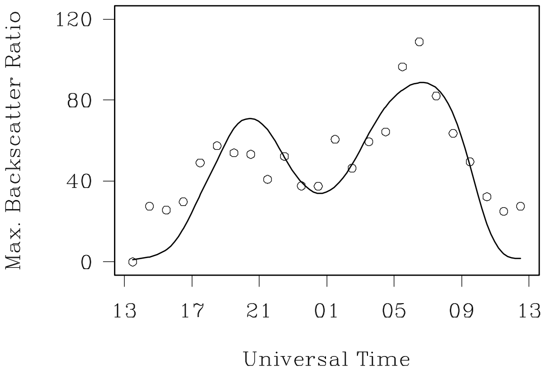

Fig. 99: Diurnal variations of observed (circles) and computed (continuous line) maximum backscatter ratios.

Fig. 99 shows, for example, a comparison between the observed and the computed diurnal variations of the maximum backscatter ratio. The results indicate that (1) at constant heights near 85 km, the neutral gas temperature increases with increasing geographic latitude; (2) the semidiurnal tide has a temperature amplitude near 2.5 K; (3) the H_2O mixing ratio is considerably larger than hitherto assumed in PMC simulations; (4) the meteoric dust concentration in the antarctic summer mesosphere is much smaller than in the arctic one. With the exception of (2), all findings are in good agreement with earlier studies. The existence of a semidiurnal tide with a non-zero temperature amplitude, however, is at odds with the presently accepted explanation of the semidiurnal tide at the poles.

(J. Klostermeyer)

The WASPAM experiment

The WASPAM (Wasserdampf- und Spurengasmessungen in der Atmosphäre mit Mikrowellen) experiment is located at the Artic Lidar Observatory for Middle Atmospheric Research (ALOMAR) in Northern Norway since 1995. It provides water vapour profiles from 40 to 85 km altitude. In 2002 the instrument has been maintained and refurbished. Among other things we added the MIRO high resolution spectrometer development model in order to test the long term behaviour of this instrument and to learn about possible long term changes. We anticipate to use the expected results for the calibration of the MIRO flight model high resolution spectrometer.

Since development model covers a larger bandwidth of the microwave spectrum we could extent the lower boundary of the WASPAM altitude coverage from 40 to 30 km.

In 2002 we discovered that WASPAM is able to detect exhaust plumes from rockets, especially from the space shuttle. Once in about 110 km altitude, the space shuttle is flying almost horizontally for some time, burning more than 300 tons of liquid hydrogen and oxygen. The resulting exhaust plume consists of nearly pure water vapour, has a diameter of about 3 km and is more than 1500 km long.

In case this exhaust plume passes the footprint of the WASPAM antenna beam in the lower thermosphere, it creates a significant and very narrow peak in one spectrometer channel. We cannot determine the exact altitude of the source of this signal by retrieval calculations, however we can deduce from atmospheric models the descent speed of the plume and extrapolated the altitude to 100 km. It is amazing that space shuttle exhaust plumes can be transported from Florida to northern Norway in a little more than 1 day. We investigated all space shuttle launches and got in about 40% of the cases a significant signal, mainly in summer and fall. We derived average lower thermospheric wind speeds ranging from 15 to 50 m/s. Meanwhile it turned out that the plumes can create artificial noctilucent clouds (NLC). Taking into account the water vapour transported into the lower thermosphere due to space traffic, the NLC statistics may be considerably deteriorated and care has to be taken in drawing conclusions about climate changes based on the analysis of NLC-statistics.

(P. Hartogh, C. Jarchow, L. Song)

Ionospheric research: EISCAT and Heating research

HF effects on PMSE echoes

That HF-enhanced electron temperature can make polar mesospheric summer echoes (PMSE) seen by VHF radars weaker, was discovered in 1999 and has been used to learn more about why such echoes are seen at relatively short VHF wavelengths. In 2003 a new phenomenon, the PMSE overshoot effect, was discovered. In this effect, which was predicted by O. Havnes, when the powerful HF-wave is on for a short time and then off for a long enough time for the dusty plasma to return to its undisturbed conditions, the PMSE strength, when the heater is switched off, can increase by a large factor compared to what it was directly before the heater was switched on. By analysing the shape of the overshoot characteristic curve as the PMSE varies, weakening as the heater is switched on, overshooting as it is switched off and then relaxing back to an undisturbed level, it is possible to obtain a considerable amount of information on the state of the PMSE dusty plasma. This will be investigated in subsequent campaigns.

(M.T. Rietveld in collaboration with E. Belova, S. Kirkwood, Swedish Institute of Space Physics; P. Chilson, University of Colorado, USA, O. Havnes, C. la Hoz, L. Næsheim, University of Tromsø, Norway)

Artificial auroral rings

The EISCAT low-gain HF facility has been used repeatedly since 1999 to produce artificially stimulated optical emissions in the F-layer ionosphere over northern Scandinavia. For HF pumping using the high-gain antenna close to the 4th gyro-harmonic, and only for the pump beam tilted 9° S, unstable annular optical structures form, which collapse into blobs whilst descending in altitude as shown in Fig. 100. The morphology and time development of the enhanced radar ion-acoustic echoes, which are a proxy for Langmuir turbulence, are similar to the optical signature, at least in the north-south meridian. The pump frequency being close to a gyro-harmonic is consistent with suppression of upper-hybrid turbulence, although no direct observations of this are available. The experiment provides observational evidence that artificial optical emissions may result from Langmuir turbulence at

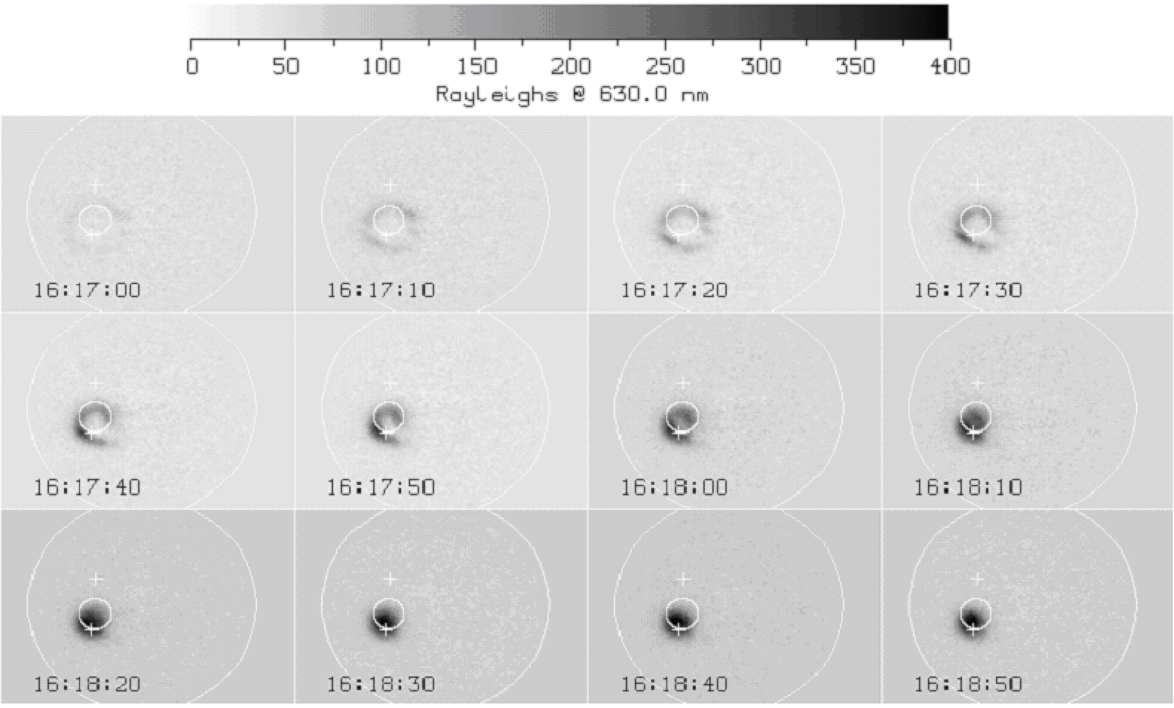

Fig. 100: A sequence of images showing the development of the artificial optical structure on 12 November 2001. The images are calibrated into Rayleighs at 630 nm and have 10 s integration. North and east are to the top and right, respectively. Each image is taken in the zenith from Skibotn and has a 50° field of view (large circle). The HF pump turns on at 16:17:00 UT and off at 16:19:00 UT, after which the optical blob simply fades away. The -3 dB locus of the pump beam is shown as a small circle (beamwidth = 7.4°), projected at 235 km altitude and tilted 9° south of the HF facility at Ramfjordmoen. The upper cross shows the location of the HF transmitter whilst the lower cross shows the magnetic field line direction (12.8° S), both projected at 235 km.

high latitudes. The unstable annular structures and the need to tilt the HF beam 9° S remains unexplained.

(M.T. Rietveld, in collaboration with M. Kosch, A. Senior and F. Honary, University of Lancaster, B. Isham, EISCAT, I. McRea, RAL, UK)

Multi-wavelength artificial optical emissions

The relative roles played by Langmuir turbulence and upper hybrid turbulence in energising electrons by powerful HF radio waves is not fully known. By studying the response of multiple optical emissions to powerful HF-pumping, the energy spectrum of the energised electrons can be determined, and thereby the acceleration mechanism can be studied. The 557.7 to 630.0 nm intensity ratio of 0.3 – 0.4 implies that the excitation is caused by a non-thermal electron population. Recently emissions at 844.6 and 427.8 nm have also been measured and are being analysed together with the EISCAT measurements of electron temperature. Such measurements which were made during gyrofrequency stepping experiments should help determine the nature of the acceleration mechanism when one is close to or away from a gyrofrequency harmonic.

(M.T. Rietveld, in collaboration with M. Kosch, U. Lancaster, B. Isham, EISCAT, B. Gustavsson, T.B. Leyser, B.U.E. Brändström, Å. Steen, and T. Sergienko, Swedish Institute of Space Physics, K. Kaila and H. Holma, University of Oulu, Finland)

Electron densities from CHAMP and EISCAT

To get a comprehensive view on high latitude processes using different observation techniques, the SIRCUS (Satellite and Incoherent scatter Radar Cusp Studies) campaign was initiated in 2001/2002. Electron density profiles derived from radio occultation data on the German CHAMP satellite were compared with those measured with the EISCAT facility. Since ionospheric profiling with the help of space-based GPS receivers is a relatively new technique, validations with established independent instruments are of crucial importance. It was found that the majority of profile comparisons in electron density peak value and height as well as in TEC lie within the error ranges of the two methods. Differences in the ionospheric quantities do not necessarily occur when the location of the occultation and of the radar site are far apart. Differences are more pronounced when the ionosphere is remarkably structured.

(M.T. Rietveld and K. Schlegel in cooperation with C. Stolle, University of Leipzig, N. Jakowski, DLR, Neustrelitz)

HF-effects in the E region using STARE

The spectral width of HF-induced backscatter observed with the Norwegian STARE 140 MHz coherent radar was measured for the first time and found to be about 50 Hz from which an upper limit of the turbulent diffusion coefficient was derived. Software was developed to display the backscatter intensity of the same radar in near-real-time at the EISCAT heater site with the aim of performing harmonic gyro-frequency heating experiments. Like so many HF-induced phenomena, it is expected that artificial E-region irregularities also show a dependence of the HF wave on the proximity to a gyro-harmonic which would confirm that upper-hybrid instability plays an important role. The first experiments have been performed but further measurements are necessary to give a conclusive result.

(E. Nielsen, M.T. Rietveld and M. Bruns in cooperation with W. Schmidt, Finnish Meteorological Institute)

Magnetospheric response to HF-heating

Using HF diagnostic techniques to probe irregularities above Tromsø, in addition to the many other auroral instruments available in northern Scandinavia, the response of the mildly disturbed ionosphere-magnetosphere to HF heating is being investigated. Possible perturbations to aurora and magnetospheric echoing effects have been found.

(M.T. Rietveld, in cooperation with N. Blagoveshchenskaya, V. Kornienko, Arctic and Antarctic Research Institute, St. Petersburg, and B. Thidé, Swedish Institute of Space Physics)

Magnetosphere

Survey of energetic particles in the magnetosphere – RAPID data

The RAPID instrument on board the 4 Cluster satellites measures energetic electrons and ions ($E > 28$ keV) in all regions of the Earth's magnetosphere. As of June 2002, Cluster data coverage was increased from 50% to 100%, permitting a complete survey of the magnetosphere as the polar orbit traverses all local times during the course of one year.

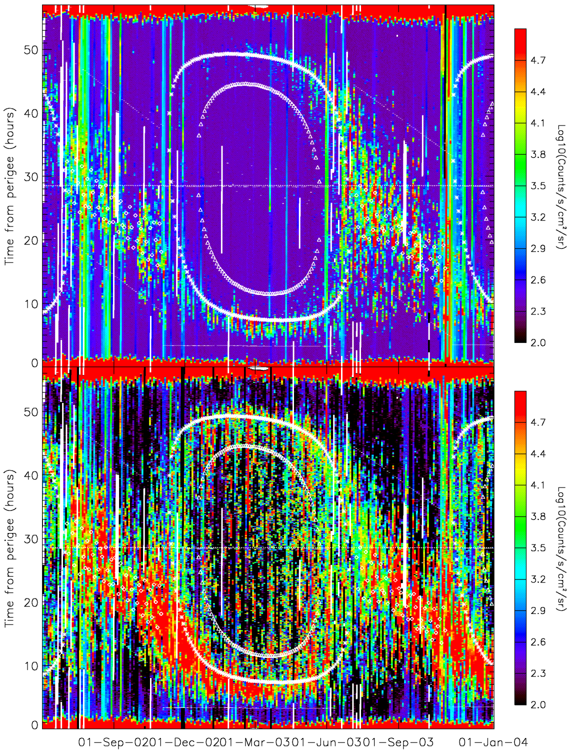

Fig. 101: Energetic electrons (upper) and protons (lower panel) distributions in the magnetosphere, as measured by RAPID on Cluster 2 from June 2002 to January 2004. See text for explanation. (This plot was prepared by J. Davies of the Rutherford Appleton Laboratory.)

Figure 101 presents a graphical overview of the results from $1\frac{1}{2}$ years of data, with the electron (upper) and proton (lower panel) fluxes plotted on the so-called Bryant representation. One orbit (57 hours) is drawn as a vertical line from perigee to perigee, with apogee in the middle. The next orbit is plotted to right, so time goes from left to right as usual. The white crosses and triangles forming the ovals in the center indicate the theoretical positions of the magnetopause and bow shock, respectively, while the white circles between the ovals mark the expected locations of the neutral sheet in the geomagnetic tail.

From the upper panel, one sees that the electrons are to be found exclusively inside the magnetosphere, predominantly in the plasmasheet and at the magnetopause, rarely in the magnetosheath (area between the ovals), and never in the solar wind (area inside the central oval). The protons also paint the plasmasheet very well, are at the magnetopause, inside the magnetosheath, and occur in the solar wind. The dawn-dusk asymmetry caused by gradient drift is also clearly visible for both species. The eastward drifting electrons are seen more on the dawn side (to the right of the magnetopause oval) while the westward drifting protons are more numerous on the dusk (left) side.

This work is a collaboration with the RAPID colleagues at the Rutherford Appleton Laboratory in the UK.

(P. W. Daly)

Lower hybrid waves observed at thin current sheets by the Interball spacecraft

Our kinetic numerical simulations of the instabilities of thin current layers have revealed the importance of lower-hybrid drift (LHD) waves caused by pressure gradients (see sections “Collisionless reconnection due to unstable lower habrid waves”). In order to search for LHD waves we have analysed Interball-1 observations of thin current sheets. As an example Fig. 102 shows the electric field oscillations in the range 0.1 – 10 Hz at 04:41:31 UT on August 26, 1995. At that time the Interball-1 s/c was crossing a turbulent boundary layer (TBL) diagnosed, e.g. by magnetic field measurements in the frequency range 0 – 2 Hz. Between 04:41:31 and 04:41:34 UT the estimated magnetic field gradient inferred a current sheet thickness of about one ion gyro radius (30 km, a calibration bar of 15 km width obtained from a dual spacecraft comparison between Interball-1 and its subsatellite Magion-4 is shown in the left lower part of the Figure). The observed electric field fluctuations with amplitudes up to 5 mV/m correspond to characteristic spatial scales of the order of the electron gyroradius (marked in the middle of Fig. 102). Just before their appearance (see left hand side of Fig. 102, an ellipse outlines this region) lower amplitude fluctuations are observed at about ten times the local ion gyrofrequency while high-amplitude lower-hybrid waves peak during the earlier encounter of the main magnetopause current sheet at 04:39:13 UT. In the developed structures the time scales are of the order of inverse proton cyclotron frequency, while the scales spread down to the electron gyro-radius ones, which is a characteristic feature of the low-hybrid turbulence.

(J. Büchner, together with S. Savine, IKI Moscow)

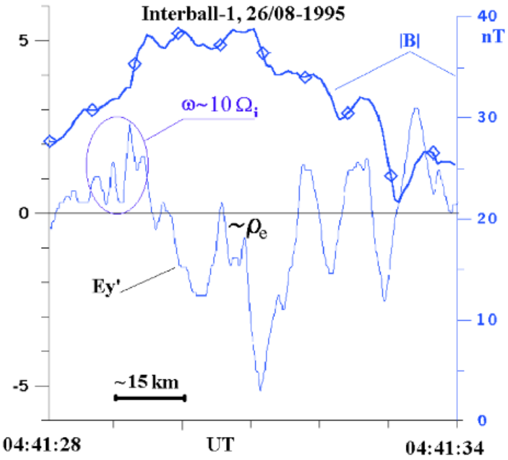

Fig. 102: Electric field fluctuations (Ey’) and magnetic field variations (B) during a thin current layer crossing observed by Interball-1 on August 28th, 1995.

Collisionless reconnection due to unstable lower hybrid drift waves

In the past it was suggested that a collisionless tearing mode instability could cause reconnection, responsible, e.g. for substorms in the Earth’s magnetosphere. The two-dimensional linear electron tearing mode instability is, however, too slow to explain, e.g. the rapid, almost explosive dynamics of substorms. There must be some process which enhances reconnection through current sheets. One of the possibilities would be a lower-hybrid drift (LHD) instability which is encountered in regions of sufficiently sharp pressure gradients. In order to investigate the possible role of unstable LHD waves for magnetic reconnection we used our newly developed three-dimensional Vlasov code. We could show that LHD-waves initially excited at the current sheet edges, in their non-linear evolution penetrate towards the current sheet center. There the LHD waves get in Landau resonance with current-carrying ions and the coupling of the two independent waves from the opposite sides of the current sheet leads to a global instability which can be either symmetric or anti-symmetric. We have shown that the wavelength and oscillation frequency of the resulting reconnection are inherited from LHD waves, while the growth and reconnection rate are proportional to the ion cyclotron frequency. Magnetic reconnection in the presence of current-aligned drift waves becomes intrinsically three-dimensional. Since the growth rate of the waves exceeds that of tearing-mode instability they eventually prevail and lead to reconnection enhancement through the direct coupling of reconnection electric fields with the quasi-electrostatic fields of LHD waves. Fig. 103 demonstrates the three-dimensional structure of the resulting small-scale reconnection by depicting the reconnected magnetic field components across the current sheet midplane. The change of polarity along the X-axis (reconnection-direction) corresponds to locally two-dimensional reconnection while the profile in the Y-direction is due to the LHD-oscillations. The observed direct coupling of LHD instability and reconnection accounts for the enhancement of the reconnection rate up to one order of magnitude higher as compared to the linear electron tearing mode instability.

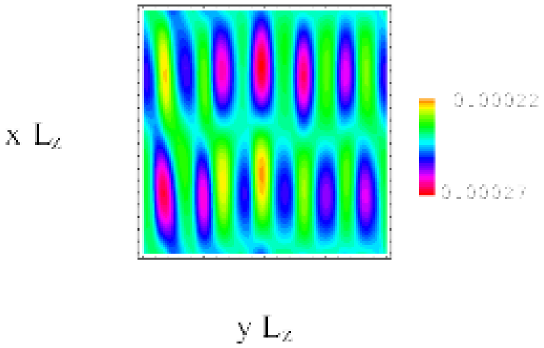

Fig. 103: The reconnection magnetic field through a thin current sheet resulting from a Lower Hybrid Drift wave moving from left to right.

(J. Büchner, I. Silin)

Development and parallelization of a 3D Vlasov-code for collisionless plasma simulation

Non-linear and non-local plasma effects have to be taken into account if one wants to understand the basic physical transport processes governing the evolution of macroscopic plasma systems and energy transformation leading to observable reconfigurations, radiation etc. Since analytical theories usually fail to solve these problems one utilizes numerical plasma simulation methods. For this sake in the past we had developed in MPAe a two-dimensional (2D) Vlasov code in order to simulate the microphysical processes determining the instabilities of current sheets leading to reconnection. We found that unstable waves in the current direction are growing considerably faster due to resonant wave-interaction than the tearing-mode instability which corresponds to 2D reconnection. The question arose whether in a realistic naturally 3D system where the two orthogonal modes can couple, the reconnection processes can be accelerated. In order to investigate this question and possible non-linear coupling effects it was necessary to develop the code to carry out simulations in the fully three-dimensional configuration space. It appeared that this task poses extremely high requirements on computer resources. Such simulations can be tackled only on massively parallel computers with dozens of CPU and dozens of GBytes of memory. In order to extend the Vlasov-code to three spatial dimensions on PC clusters with distributed memory a domain decomposition along the X-axis introduced using the Message-Passing Interface (MPI). Further the OpenMP parallelization standards were utilized for systems with shared memory. The selection between these two architectures or their combination allows an efficient execution of the code on practically any parallel computer, such as IBM p690 or IBM SP6000 (shared memory) or on a PC cluster with distributed memory. Some results about the efficiency of the parallelization using different memory load are depicted in Fig. 104, namely the time (in seconds) required for running the same program cycle on different number of processors and with different amount of memory (MPI and OpenMP architecture with 800 Mb memory executed on an IBM RS6000-SP with (blue lines) and OpenMP version with 800 Mb, 8 GBytes and 30 GBytes (red, green and cyan lines, respectively) executed on IBM p690 machine. The solid and dashed lines correspond to the full time of the cycle and to its parallel part, respectively. It turned out, e.g. that for tasks with 800 MBytes of global variables the use of larger number of CPUs leads to slower overall execution, while for production runs with large memory it is reasonable to use the largest possible number of CPUs. This and other results of the Vlasov-code parallelization effort were added to the knowledge database of the GWDG and provide the basis for the further kinetic plasma simulation work.

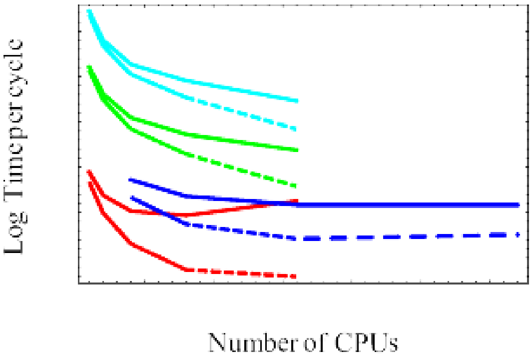

Fig. 104: Time per one cycle of 3D Vlasov-code simulation on different number of CPUs for several values of global memory: red and blue – 800 Mb, green – 8 Gb, cyan – 30 Gb.

(J. Büchner, I. Silin)

Component merging – collisionless reconnection in the presence of a magnetic guide field

Magnetic reconnection opens tangential discontinuities – the boundaries between magnetized plasmas – like, e.g. the magnetopause between solar wind and the Earth's magnetosphere. Since magnetic fields from the two sides of the interaction region are not always antiparallel, as assumed in the case of traditional reconnection theories, the question arose, whether so called component merging for non-antiparallel fields is possible and, if so, how efficient it is. To the lowest order a non-antiparallel configuration can be represented by adding a constant magnetic field, a so-called guide field, perpendicular to the anti-parallel fields. In order to understand how a guide field affects the reconnection process we utilized our newly developed 3D Vlasov-simulation code. As a result it appeared that, on the one hand, the addition of a guide field weakens the growth of the tearing-mode instability, while on the other hand it leads to the generation of new modes of oblique unstable waves. We found that due to the oblique propagation of lower-hybrid drift (LHD) waves fewer resonant particles participate in the wave coupling to reconnection and that the overall efficiency of the inverse Landau damping decreases. The growth rate of the LHD instability becomes proportionally to the density of resonant ions and decreases by almost an order of magnitude for a magnetic field shear angle of 90°. On the other hand, sheared LHD waves do still penetrate to the current sheet center and, this way, cause stochastic reconnection of magnetic field lines from the opposite sides. Contrary to the reconnection in anti-parallel magnetic fields, no classical X- or O-line forms in the presence of guide fields. Instead, the field lines from the opposite sides of the current sheet bread around one another and allow the percolation of magetic flux, plasma and particles through the current sheet as shown in Fig. 105.

(J. Büchner, I. Silin)

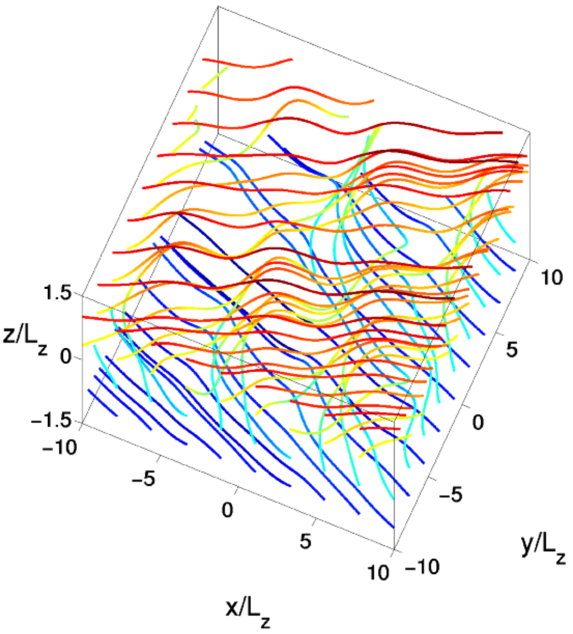

Fig. 105: Stochastic magnetic reconnection in the presence of $B_y/B_0 = 0.25$ guide field

Oscillitons – a new concept in non-linear space plasma physics

Indroduction

It is generally held that instabilities in space plasmas lead to the generation of many plasma eigenmodes which grow out of the thermal noise. Recent significant progress in satellite observations of wave phenomena, with high temporal/spatial resolution measurements exhibit the wave forms of 'plasma turbulence'. It is often the case that broad-frequency emission observed in power-frequency-time spectrograms actually consist of coherent wave structures, many of which are reminiscent of solitons or quasi-monochromatic wave packets. Some selected examples include (a) electrostatic solitons (electron holes) on the auroral field lines and near the magnetopause, (b) the so called broad-band electrostatic noise which, in reality, consist of a series of solitary pulses, (c) bursts of narrow-band coherent whistler and lower-hybrid emissions (d) slow mode solitons in the magnetospheric boundary layer, (e) coherent wave emissions in the form of wave packets in multi-ion plasmas (comets, Mars, Io, Titan).

In several of our papers since 2001 it is shown that observations of almost coherent waves in the form of wave packets are related with the existence of a new specific class of non-linear waves, called oscillitons, because they reveal both solitary and oscillatory features. These strongly non-linear wave structures can be driven by the solar wind flow when the bulk speed matches the specific values or by different type of instabilities in non-equilibrium space plasmas. In the first case, such waves can be the important element of the structures of shocks and other type of discontinuities in the solar wind. Hybrid and PIC simulations, recently published in literature, confirm the existence of electron whistler oscillitons at the bow shock foot. Ion whistler oscillitons, which exhibit themselves as coherently gyrating ion beams in the foreshock, are excited by beam-plasma instability. An exact solution for such structures has also been obtained. It is important that the linear instability works as a driver of non-linearly stationary solutions. The numerical and analytical results are in a good agreement as with the previous observations on ISEE and AMPTE satellites as well as with the more comprehensive measurements on Cluster. It is believed that ion whistler oscillitons is a key element of quasi-parallel and parallel shocks. This subject will be studied in future in more detail.

A very simple diagnostic tool, based on the dispersive wave characteristics, which allows predict the possible existence of oscilliton structures in different space plasmas is found even for the cases when the exact solutions of strongly non-linear equations (e.g. Vlasov equations) is not possible. It occurs that in many cases instabilities, or collisionless damping, modify the dispersion curves creating inflection points at (omega-k) diagrams. These inflection point determine the wavelength of the oscillating core imbedded to the oscilliton structure.

It is important to note that the solar wind itself is an interesting multi-ion object. The arising new types of solitary waves have been studied. It has been shown that even a small addition of alpha-particles can strongly modify the dispersion of low-frequency waves and hence the structure of solitons. In addition, oscillitons may appear. This fact probably shed light on the absence of very thin subcritical shocks in the solar wind.

A more detailed description of the oscilliton concept and its relevance to observations in space plasmas are given in the following.

Necessary soliton/oscilliton conditions:

The linear dispersion theory can be used to determine what type of solitary waves may exist in a given plasma configuration. Fig. 106 shows examples of dispersion curves of different types of plasma waves. The top figures of each panel depict the dispersion curves in the frequency – wavenumber ($k-\omega$) space. On bottom the related phase speed – wavenumber ($\omega/k-k$) diagrams are shown.

Panel (a) presents the well known case of the dispersion of low-frequency electromagnetic waves propagating in a warm plasma ($\beta = 3$) at 80° to the magnetic field. Negative dispersion of the Alfvén wave mode (the lower curve) can balance the effects of nonlinear wave steepening providing conditions for soliton existence. The soliton speed lies in the region which represents the gap between the curves corresponding to the propagating waves. Such solitons may have a close relationship to the so-called magnetic holes often observed in space plasmas.

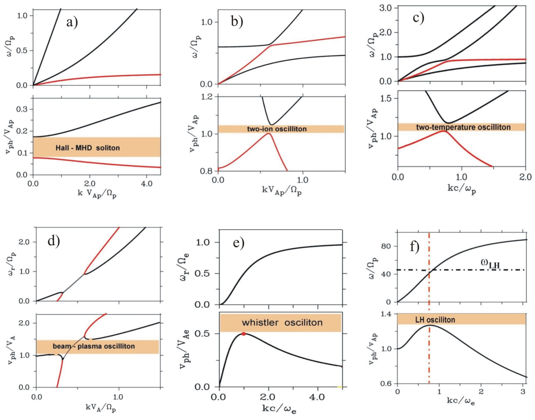

Fig. 106: Dispersion of waves in different plasma configurations: a) LF waves in a warm single-ion plasma, oblique propagation, Ω_p is the proton cyclotron frequency, V_{Ap} is the proton Alfvén velocity: $\theta = 80°$, $\beta = 3.0$; b) LF waves in a cold plasma containing protons and 25% α-particles: $\theta = 30°$; c) LF waves in a plasma with two proton populations of different temperature; d) unstable LF waves in a beam-plasma, coupling between R and beam mode: $n_b = 0.01$, $V_b = 3.0$; e) whistlers in a cold plasma, parallel propagation; f) lower-hybrid waves: $\theta = 87°$.

In plasmas consisting of two sorts of ions the dispersion strongly changes and inflection points (where phase- and group-velocities coincide: $\omega/k = \partial\omega/\partial k$) appear at the cross-over frequencies (panel b). As the result, the sign of dispersion changes at a certain wavenumber. This leads to the dramatic changes of the properties of non-linear waves and solitons. A new type of solitary waves (oscilliton) which combines the features of classical solitons and periodic waves can exist. Fig. 106c illustrates the example of the dispersion in plasma which contains two proton populations with different temperatures. Such situation is realized, for example, near Mars where the solar wind is loaded by the protons originated from the extended hydrogen exosphere. It is seen that in this case the dispersion has also inflection points corresponding to the extrema on the curves of the phase speeds. It is found that oscilliton structures can exist in such a plasma configuration. The recent observations by Mars Global Surveyor bring us a lot of examples of oscillatory structures upstream of the bow shock.

Another situation, where we meet with a change of sign of the dispersion and therefore can also expect the existence of oscillitons, is the well known wave phenomenon – whistlers (panel 1 e). Indeed, the wave forms of whistler waves observed in the magnetosheath (the region between the bow shock and the magnetosphere) often look like as almost monochromatic wave packets (‘lion roars’). Such strongly nonlinear wave structures represent oscillitons generated in a temperature-anisotropic plasma. The same dispersion feature is conserved when the magnetosonic wave propagates almost perpendicular to the magnetic field (Fig. 106f). The characteristic frequency of oscillations in the localized wave packet (oscilliton) occurs close to the low-hybrid frequency. Relevant structures were observed on the auroral field lines by Freja satellite and did not get an adequate explanation till now. Inflection points can not only be intrinsic features of the wave dispersion in equilibrium plasmas. It occurs that such points may appear due to modifications of dispersive curves due to some linear instabilities. For example, they arise in the configuration where an ion beam propagates along the magnetic field (panel 1d).

Cluster observations:

This situation is realized in many space plasmas, for example, in the ion foreshock where solar wind ions reflected at the bow shock propagate upstream along the magnetic field lines. It occurs that sometimes the behaviour of the ion beam is very puzzling. It exhibits large amplitude coherent wave rotations (phase-bunched gyrating ions) accompanied by the generation of an almost monochromatic wave packet in the ULF frequency range and the shifted in phase coherent 'gyration' of the solar wind. Fig. 107 shows an example of such a foreshock event in the Cluster ion and magnetic field measurements. It is clearly seen that the appearance of LF coherent waves is accompanied by significant changes in the ion spectra. A strictly field-aligned beam only exist outside the disturbed region. This unusual phenomenon can be understood as an oscilliton which represents the self-generated non-linear structure in a beam-plasma system.

Oscilliton profiles:

Results of solving the stationary, fully non-linear set of ordinary differential equations which describe the beam-plasma interaction are shown in Fig. 108. From top to bottom the transverse magnetic field component B_y (and the magnitude B-1, dashed line), the transverse beam velocity v_{by} (and the velocity change in x direction $V_b - v_{bx}$), and the corresponding solar wind velocity v_{py} (and v_{px}) are plotted. There is obviously a good agreement with the experimental signatures from Cluster shown in Fig. 107. From the hodograms on the left side one can see the transverse rotation of the three quantities which have only a field-aligned component outside the oscilliton. The rotation is right-handed and results from the non-linear momentum coupling between the beam and the main plasma (solar wind) via the self-generated electromagnetic field.

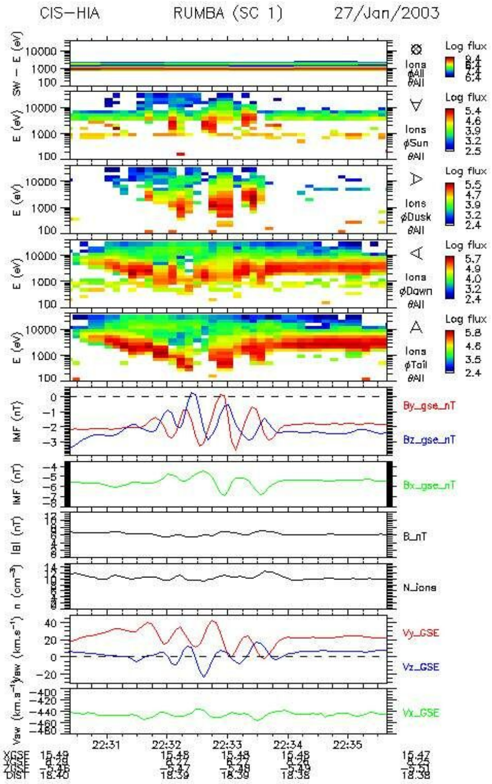

Fig. 107: Cluster measurements in the foreshock. From top to bottom: Energy-time spectrograms for different ion populations from CIS/HIA, magnetic field components and magnitude, ion density and bulk velocities, alpha-particle density.

We believe that the oscilliton concept is of general importance for the interpretation of many other observations where coherent emission in form of wave packets is seen in different plasma environments and frequency regimes, up to the electron plasma frequency where wave packets with ms duration have recently been resolved.

(K. Sauer, E. Dubinin in collaboration with J.F. McKenzie and Ch. Mazelle, Toulouse)

Non-linear electrostatic structures in the auroral magnetosphere

Recently, using high-resolution technical equipment on rockets and satellites localized electrostatic structures and waves have been registered in various areas of space plasma. For example, such structures have been found by the satellites VIKING, FREIA, FAST, and POLAR in the auroral magnetosphere. Now, in the connection with, e.g. planetary atmospheres and interstellar clouds, also a growing interest

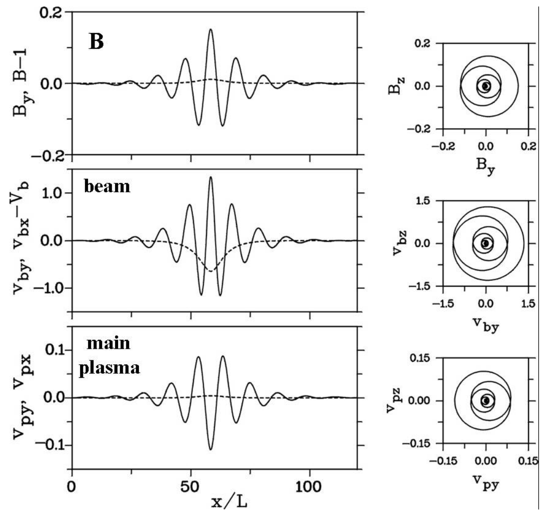

Fig. 108: Oscilliton in a beam-plasma, outcome of stationary, fully non-linear two-fluid description: Transverse components of the magnetic field and of both ion velocities (b: beam, p: plasma) within the oscilliton propagating with the velocity U=1.28 in the same direction as the beam (n_b=0.005, V_b=3.0). Dashed lines show the magnetic field value and the longitudinal ion velocities. Left panels depict the hodograms of the transverse oscilliton components.

in the problem of formation of electrostatic structures in dusty plasmas exists. Thus, two three-dimensional non-linear theoretical models of electrostatic solitary waves are investigated within the frame of magnetohydrodynamics. Both times, a multi-component plasma is considered, which consists of hot electrons with a rather flexible velocity distribution function.

Additionally, cold ion beams are taken into account in the model to study ion beam-acoustic structures (IAS), and in the model to investigate electron beam-acoustic structures (EAS) cold electrons are included. Dust-acoustic structures (DAS) are analysed considering dust grains, the charge of which is determined by the local electron and ion currents. The numerical results of the considered models allow to conclude that electrostatic structures with negative potential are formed both in the IAS model and EAS model, but structures with negative potential (of compressional type) are formed in the IAS model only. The non-linear electrostatic structures obtained by the POLAR satellite seem to correspond to the EAS model.

(C.-V. Meister in collaboration with A. Volosevich, State University Mogilev, Belarus)

III. Abteilung Rosenbauer/Department Rosenbauer

(English version see page 112)

Der Berichtszeitraum war hauptsächlich durch folgende Arbeiten bzw. Ereignisse gekennzeichnet:

Abschließende Arbeiten und Tests an unseren Rosetta-Hardware-Beteiligungen, insbesondere dem Rosetta Lander Philae

Wie bei Weltraumprojekten üblich, mussten vor dem Start, der damals noch für Januar 2003 vorgesehen war, viele Tests durchgeführt und dazugehörende Protokolle und Dokumente erstellt werden. Für alle Subsysteme und Instrumente waren auch noch sogenannte „Ground Reference Models“ zu erstellen, um das Verhalten von Geräten im Flug mit diesen „Standards“ auf dem Boden vergleichen zu können.

Außerdem musste an diversen Projekt-Treffen und Telefonkonferenzen teilgenommen, Kurse zur Kommandogabe und Datenübertragung besucht und mit dem sich nähernden Starttermin auch immer mehr Zeit für die Befriedigung des Interesses von Presse, Rundfunk und Fernsehen aufgewandt werden.

Unsere bereits stark geschrumpfte Mannschaft war als Beisteller von vielen Subsystemen, wie der Leistungsversorgung, dem Bordcomputer, den Harpunen, der mechanischen Orbiter-Lander-Verbindung, dem Abstoßmechanismus, unserem COSAC-Experiment und vor allem dem Landegestell über lange Zeit extrem belastet. Das Landegestell allein enthält ja eine ganze Reihe komplexer und kritischer Funktionseinheiten wie u.a. Dämpfungsmechanismus, Bein-Entfaltungsaktuator, Hebe-, Dreh- und Kippmechanismus, zentrales steuerbares Schaltgetriebe, lösbare Verriegelungen für die Startphase, einstellbare Lamellen-Reibkupplungen für das Kardangelenk und Eisschrauben mit Rücklaufsperre.

Zudem musste am bzw. im Landegestell die gesamte Sensorik und Verkabelung des SESAME-Experiments untergebracht werden, und die „Startrampen“ für die Harpunen zur Verankerung auf dem Kometen waren so zu befestigen, dass die Rückstoßbeschleunigung von über 1000 g nicht zu Schäden am Lander und seiner Nutzlast führt.

Doch nicht nur die Funktionalität der Subsysteme in unserem Verantwortungsbereich musste getestet und gegebenenfalls verbessert werden; unsere Verantwortlichkeit erstreckte sich wegen der von uns wahrgenommenen Funktionen „Payload Engineer“ (Hemmerich) und „Lead Scientist“ (Rosenbauer in Zusammenarbeit mit Bibring) zum Teil auch auf die auf dem Lander untergebrachte wissenschaftliche Nutzlast und die „Betreuung“ der Experimentatoren.

Die Umstellung auf den neuen Zielkometen 67 P/Churyumov-Gerasimenko

Wegen des Fehlstarts einer Ariane-5-Rakete und der daraus resultierenden Notwendigkeit, von Seiten Arianespace das gesamte Ariane-5-System zu untersuchen und teilweise zu verbessern, konnte der Start zum Kometen Wirtanen nicht rechtzeitig realisiert werden. Deshalb musste ein geeigneter neuer Komet als Missionsziel gefunden werden. „Geeignet“ heißt in diesem Zusammenhang, dass sein Orbit stabil und gut bekannt ist und dass es möglich ist, diesen Orbit mit der Ariane-5G+ in Rendezvous-Art außerhalb eines Sonnenabstandes von 3 AU zu erreichen. Die letztere Forderung ergibt sich daraus, dass beim ersten Rendezvous der Kometenkern an seiner Oberfläche noch kalt sein soll, so dass größere Gas- und Staubausbrüche unwahrscheinlich sind. Außerdem sollte, wegen der schon eingetretenen Startverzögerung durch den Ariane-Fehlschlag, ein Start in naher Zukunft möglich sein. Eine weitere wichtige Forderung war, dass der Kern des neuen Zielkometen in seiner Größe bzw. Masse nicht stark von der des ursprünglich ausgewählten (46 P/Wirtanen) abweicht, weil das Landemanöver und das Landegestell für diesen, d.h. für eine Auftreffgeschwindigkeit von etwa 0,5 m/s ausgelegt sind. Wenn der neue „Target“-Komet sehr viel massereicher ist als 46 P/Wirtanen, führt dies wegen der größeren Schwerkraftwirkung zu einer höheren Auftreffgeschwindigkeit, und damit vergrößert sich sowohl die Gefahr eines tiefen Einsinkens (bei weichem Untergrund) als auch die des Rückpralls (bei hartem Untergrund). Zusätzlich nimmt auch noch die Gefahr des Umkippens zu, wenn der Lander auf einem schiefen Hang aufkommt.

Verständlicherweise gibt es im gewünschten Zeit- und Ortsraum nicht viele „brauchbare“ Kometen. Nach langen Rechnungen und Erörterungen entschied man sich für 67 P/Churyumov-Gerasimenko, der fast allen Forderungen zufriedenstellend entsprach, außer dass er sich als deutlich größer (und damit wahrscheinlich massereicher) herausstellte als Wirtanen.

Wir mussten uns also auf den schlechtesten Fall, d.h. eine gegenüber einer Landung auf Wirtanen deutlich höhere Auftreffgeschwindigkeit, einzustellen versuchen.

Zuerst wurde erwogen, die Rückprallgefahr durch Versteifung der Beine des Landegestells zu verringern. Dies stellte sich wegen der festgelegten Gesamtmasse und Massenverteilung des Landers als nicht sinnvoll machbar heraus. Wir versuchten deshalb, das an Bord befindliche Kaltgassystem (ADS) so umzubauen, dass die Auftreffgeschwindigkeit ferngesteuert verringert werden kann. Dieser „Königsweg“, der die für den Wirtanen-Fall vorbereiteten und getesteten Landeverhältnisse weitgehend wiederhergestellt hätte, wurde uns von der ESA, wegen aus ihrer Sicht nicht mehr ausreichender Zeit zum Testen, untersagt.

Wir waren deshalb auf kleine Korrekturen am Landegestell, nämlich eine teilweise Versteifung des Kardan-Gelenks und eine Reduktion des maximalen Kippwinkels auf 5° beschränkt. Damit wird aber auch die für die wissenschaftlichen Experimente wichtige Kippsicherheit des Landers reduziert. Ob diese, auf Anraten der Firma Astrium dann doch durchgeführten Änderungen aber tatsächlich einen nennenswerten positiven Effekt haben, konnte nur mehr mittels Simulationen und Tests mit dem Qualifikationsmodell ermittelt werden, da der Lander bereits am Satelliten integriert war.

Wir müssen deshalb leider in Kauf nehmen, dass wahrscheinlich die Landung auf dem „neuen“ Kometen riskanter ist als es eine Landung auf Wirtanen gewesen wäre, weil sowohl die Wahrscheinlichkeit des tiefen Einsinkens und des Rückpralls als auch die des Umkippens voraussichtlich höher sein werden als bei einer Landung mit kleinerer Geschwindigkeit, wie sie bei Wirtanen zu erwarten gewesen wäre.

Experimente und Experimentbeteiligungen in unterschiedlichen Phasen der Durchführung

COSAC

Unser wichtigstes Experiment COSAC muss weiterhin sporadisch bezüglich seiner Einsatzfähigkeit überprüft werden. Es ist außerdem eines der wenigen Rosetta-Experimente, das, wenn das System nicht im „Schlafzustand“ ist, bereits vor der Landung nützliche Daten (über das umgebende Gas) liefern kann.

(H. Rosenbauer, F. Goesmann, R. Roll, M. Hilchenbach, H. Böhnhardt)

Beiträge zum Landegerät „Beagle 2“ der Mars-Express-Mission

Entsprechend unserem Interesse haben wir uns an dem Bodenanalysegerät (GAP = Gas Analysis Package) von Beagle 2 mit der Beistellung des sog. Sample Handling, Acquisition and Distribution System (SHADS), bestehend aus „Karussell“, „Tapping Stations“ und 12 bis zu einer Temperatur von 800°C hochheizbaren „Öfen“ aus Platin beteiligt und uns damit die uneingeschränkte Mitwirkung bei der Datenanalyse erworben.

Wie bekannt ist, ist aber die Landung von Beagle 2 leider misslungen bzw. eine Kommunikation zum Mars Express Orbiter oder anderen möglichen Empfangsstationen nicht zustande gekommen. Es ist ein kleiner Trost für uns, dass wir von den Kollegen der Open University eingeladen wurden, uns an Beagle 3 zu beteiligen, über dessen Realisierung zur Zeit diskutiert wird.

(R. Roll, F. Goesmann, H. Böhnhardt).

COSIMA

Seit April 2003 ist unser Institut auch das neue Zuhause eines weiteren Rosetta-PI-Instrumentes, des kometaren Sekundärionen-Massenspektrometers COSIMA. Dieses Instrument misst die Zusammensetzung des Kometenstaubes in der Umgebung des Kometenkernes auf dessen Weg zum Perihel. COSIMA wurde am Max-Planck-Institut für extraterrestrische Physik, Garching, mit dem Hauptkontraktor, der Firma von Hoerner und Sulger, Schwetzingen, unter der Leitung des COSIMA-PI Dr. Jochen Kissel gebaut. Jochen Kissel ist seit dem 1. April 2003 an unserem Institut, und hier werden in den kommenden Jahren zusammen mit den COSIMA-Wissenschaftlern auch die Kalibrationen mit dem Referenzmodell durchgeführt und das COSIMA-Flugmodell betreut werden.

Die wissenschaftlichen Fragen, welche mit COSIMA untersucht werden sollen, sind:

- Woraus bestehen die Staubteilchen, die vom Kometenkern kommen?
- Welche Effekte bewirkt die Staubfreisetzung, und wie ändert sich der Staub auf seiner Flugbahn durch die Kometenkoma?

- Welche Isotopenverhältnisse kommen vor, und was können wir aus diesen über die Geschichte der kometaren Materie lernen?

- In welchem chemischen Zustand sind die organische und die mineralische Phase?

Um diese Fragen beantworten zu können, müssen die Staubteilchen chemisch analysiert werden; dazu muss man die kleinsten Teile davon, also Atome oder Moleküle, in elektrisch geladenem Zustand abtrennen. Die Masse dieser Ionen wird dann in einem Flugzeit-Massenspektrometer bestimmt. Bei der bisher einzigen solchen Analyse am Kometen 1P/Halley (1986) wurden ionisierte Atome und Moleküle durch den Einschlag schneller Staubteilchen (relative Geschindigkeit von über 69 km/s) erzeugt. Bei COSIMA übernehmen diese Aufgabe Indium-Ionen aus einer speziellen Ionenquelle, mit denen eingefangene Staubteilchen beschossen werden. Die Massen der freigesetzten Ionen geben die Auskunft über die chemische Zusammensetzung der getroffenen Partikel, die wir zur Beantwortung der wissenschaftlichen Fragen benötigen. Labormessungen an Vergleichsmaterialien werden helfen, den Abtrennprozess der Ionen besser zu verstehen.

(J. Kissel, M. Hilchenbach, H. Böhnhardt)

NPD (Neutral Particle Detektor)

Das Instrument NPD ist ein Neutralgas-Massenspektrometer, das die Temperatur des neutralen Sonnenwindes messen kann. Es soll ein Teil der erweiterten Nutzlast des Solar Orbiters werden.

(M. Hilchenbach, E. Marsch)

GAS

Das Experiment GAS auf Ulysses, mit dem die Flüssigkeitsparameter des neutralen interstellaren Heliums mit zunehmender Messdauer immer genauer bestimmt werden können, wird von der NASA weiter unterstützt und liefert immer noch perfekte Daten, die jetzt wegen der Langlebigkeit des Instrumentes auch unter dem Gesichtspunkt ausgewertet werden, dass sich der Fluss des lokalen interstellaren Mediums relativ zum Sonnensystem verändern könnte, z.B. wenn „fremde“ Lokalgasströme in unser „LISM“ eindringen.

(H. Rosenbauer, M. Witte).

CELIAS

CELIAS, eine Kombination eines Ionen-Massenspektrometers mit einem UV-Spektrometer auf SOHO, liefert seit 8 Jahren Daten und wird in der Heliosphärenforschung („Terminationsschock“) und Sonnenforschung (energetische Teilchen) eingesetzt.

(M. Hilchenbach)

MIRAS

MIRAS ist ein RAMAN-Spektrometer, dessen Entwicklung gemeinsam mit der Universität Jena betrieben wird. Erste „Breadboard“-Modelle wurden im Rahmen eines DLR-Projekts gefertigt und mineralogische Untersuchungen publiziert.

(M. Hilchenbach)

PATIB (Planetary Deep Driller)

PATIB soll zusammen mit der Industrie für die Erforschung planetarer und anderer Oberflächen entwickelt werden.

(M. Hilchenbach)

MORE

MORE ist ein Projekt in der Konstruktionsphase, an dessen Entwicklung sowohl unsere Abteilung als auch die Industrie interessiert sind, und das eine verbesserte Version des COSAC-Experiments beinhaltet. MORE ist Teil der Modellnutzlast eines geplanten großen Exobiologie-Projekts der ESA, eines Rovers auf der Marsoberfläche.

(F. Goesmann, R. Roll, M. Hilchenbach)

Weitere Datenauswertungsrechte

Aufgrund unserer Verantwortlichkeit (zusammen mit dem französischen Lead Scientist) für die gesamten wissenschaftlichen Belange der Lander-Mission haben wir uneingeschränkte Rechte der Datennutzung, insbesondere von Lander-Experimenten. Dies entspricht in etwa den Ergebnissen von 8 weiteren wissenschaftlichen Experimenten.

Verringerung des Abteilungspersonals

Wegen meines herannahenden Emeritierungstermins (30. Juni 2004) wurden in meiner Abteilung – den Weisungen des Präsidenten entsprechend – keine neuen Projekte mit nennenswertem Bedarf an Personal oder anderen Ressourcen mehr begonnen; vielmehr wurde, in Absprache mit den Kollegen, das Personal aus meiner Abteilung sukzessive an die jüngeren Kollegen oder, im Falle von technischen Kräften, an Werkstätten oder Labor abgegeben. Zur Zeit steht mir praktisch nur noch die Hilfe meiner Sekretärin zur Verfügung, die ich wegen meiner noch andauernden Verpflichtungen für den Rosetta-Lander Philae und des eventuell zustande kommenden Einstiegs in das ECOS-Projekt noch auf unbestimmte Zeit als Minimalhilfe benötigen werde.

Sicherung von Langzeitbetreuung und Wissenserhalt

Da der Flug zum „Rendezvous“ mit dem Ziel-Kometen Churyumov-Gerasimenko fast 10 Jahre dauern wird und der Lander, wie wir hoffen, dann noch für einige Zeit – im optimalen Fall für einige Jahre – Daten liefern wird, ist die Gesamtmission ungewöhnlich lang. Bei einem solchen Projekt ist der Wissenserhalt ein nicht triviales Problem, auf das bisher viel – aber sicher noch nicht genug – Zeit verwandt wurde. Es besteht auch weitgehend Einigkeit darüber, dass die schriftliche Dokumentation in manchen Fällen nicht ausreicht und die Erinnerungsfähigkeit der Konstrukteure und Erbauer des Landers und der Nutzlast wichtig wird. Das bedeutet aber, dass langfristig gesicherte Stellen vorhanden sein müssen. Das konnte durch das gemeinsame Engagement der MPG und des DLR weitgehend erreicht werden. Auch ausreichend erfahrene und – voraussichtlich langfristig verfügbare – Mitarbeiter konnten gefunden werden.

Simulationsrechnungen zur Landung auf dem Kometen

Simulationsrechnungen zum Verhalten des Landers bei und unmittelbar nach der Landung sind schon seit langem durchgeführt worden (M. Hilchenbach). Sie mussten aber an den neuen Zielkometen, d.h. an eine deutlich höhere Landegeschwindigkeit als bei Wirtanen erwartet, angepasst werden.

Vorbereitende Überlegungen und Rechnungen zum ins Auge gefassten Projekt ECOS

Das Projekt hat nur geringe Fortschritte gemacht, weil während der Vorbereitungen zum Rosetta-Start praktisch kein freies Personal vorhanden war. Wegen der meiner Meinung nach hohen gesellschaftlichen Relevanz des Themas habe ich die Arbeit an einem schriftlichen Projektvorschlag unmittelbar nach dem Rosetta-Start aufgenommen und hoffe nach dessen Fertigstellung (abhängig von meiner Belastung durch das Rosetta-Projekt) auf eine zügige Bearbeitung durch die zuständigen Gremien der Max-Planck-Gesellschaft.

Nachwort und Danksagung

Ich möchte die Ablieferung dieses möglicherweise letzten Tätigkeitsberichts aus meiner Abteilung zum Anlass nehmen, mich bei allen meinen Mitarbeiterinnen und Mitarbeitern für die immer freundliche, intensive und häufig inspirierende Zusammenarbeit ganz herzlich zu bedanken. Dies gilt auch für die Mitarbeiter aus den Werkstätten, der Konstruktion, der Haustechnik, den Sekretariaten, der Verwaltung und für die vielen anderen Dienste, ohne die ein Institut wie das unsrige nicht funktionieren könnte, vom Einkauf über die Raumreinigung, die Reisestelle und die Arbeiten zur Aufrechterhaltung des Telefonnetzes, des Computernetzwerks bis hin zur Hausbewachung.

Einen besonderen Dank aussprechen möchte ich aber den Kolleginnen und Kollegen, die direkt mit mir zusammengearbeitet haben. Ohne Ihr Können, Ihre Einsatzfreude und Gewissenhaftigkeit wären viele der Geräte, die in unserer kleinen Gruppe entworfen und gebaut wurden, nicht zustande gekommen und die entsprechenden wissenschaftlichen Ziele könnten wahrscheinlich nicht erreicht werden.

Ich habe mich über die Zusammenarbeit mit Ihnen allen immer gefreut und hoffe, dass auch Sie sie in guter Erinnerung behalten werden.

Speziellen Dank schulde ich meiner stets freundlichen, gewissenhaften und nimmermüden Sekretärin Susanne Kaufmann.

Postskriptum (16.04.2004):

Der Start der Rosetta-Mission fand am 02.03.04 von Kourou / Frz. Guyana aus statt und war zu 100% erfolgreich. Die „Commissioning“-Aktivitäten sind schon fast beendet, und bisher ist kein Fehler entdeckt worden.

Ihr Helmut Rosenbauer, April 2004

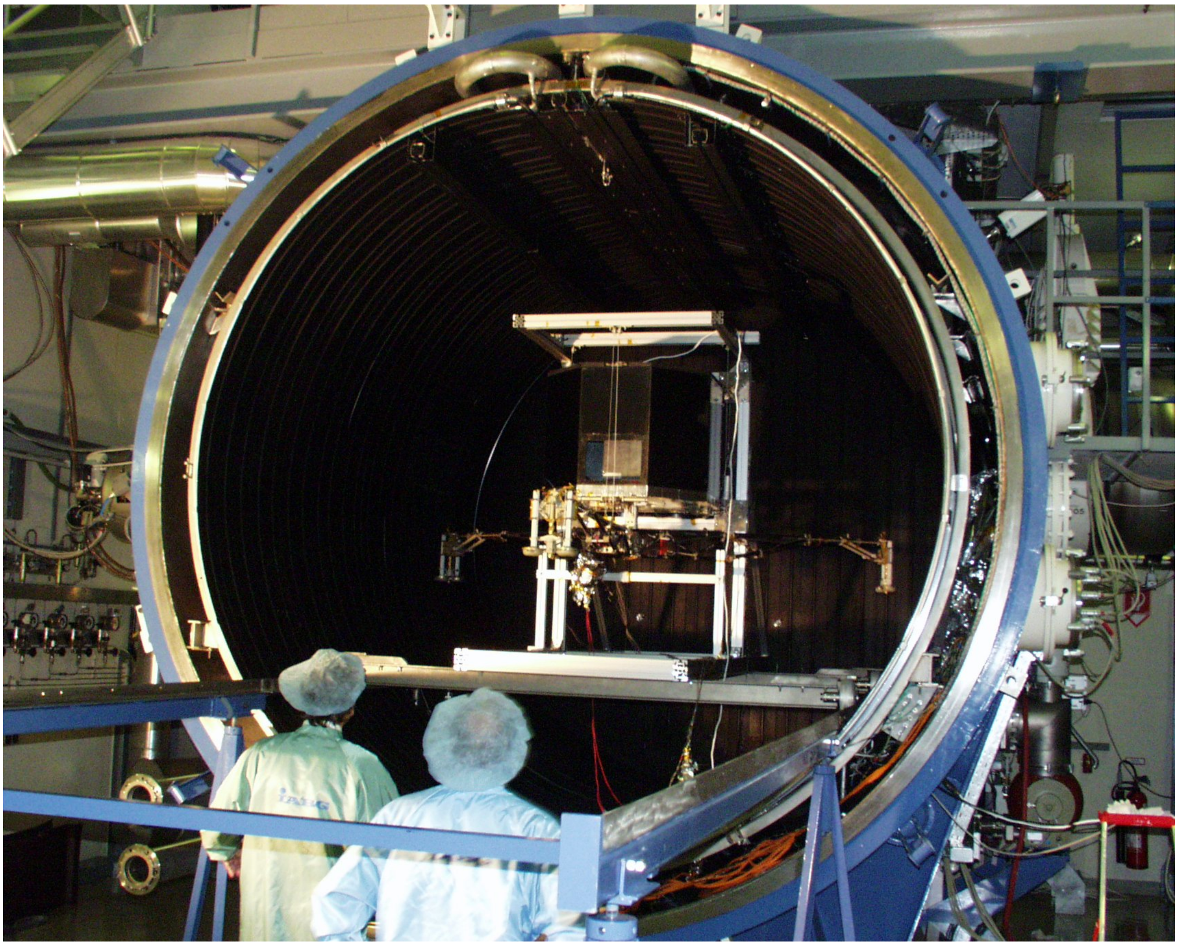

Abb. 109: Der Rosetta-Lander Philae in der geöffneten Vakuumtestkammer der IABG in Ottobrunn / *The Rosetta Lander Philae in the open vacuum test chamber at IABG/Ottobrunn*

The report period was mainly characterized by the following activities and events, respectively:

Completion and testing of our hardware contributions to the Rosetta Mission; in particular the Rosetta Lander Philae

As usual for space projects, the time period before launch (launch was then still planned for January 2003) was rather hectic because many tests had still to be performed and all documents established. So-called "Ground Reference Models" had to be designed, constructed and tested for all subsystems and instruments, in order to enable comparisons between the instruments and subsystems in flight with functionally identical "standards" on ground.

In addition, participation in many project meetings and tele-conferences was necessary, experience in commanding and data transmission had to be established by participating in several courses. With the launch date approaching, increasingly more time had to be spent for satisfying the interests of press, radio and TV reporters.

Our team which had already been reduced substantially, had over a long period been suffering from high work load, due to its responsibility for many hardware units, as complicated as the power subsystem, the onboard computer ("CDMS"), the anchoring subsystem, the mechanical orbiter-lander connection, the push-off mechanism and, in particular, the COSAC experiment and the Landing Gear.

That latter device alone contains a bunch of complex and critical devices, as the damping mechanism, actuators for unfolding of the legs and "feet", the lower and upper launch locks, the lift-, turn- and tilt-mechanisms, the central gear box, adjustable friction clutches, fixation and release devices between the lower side of the base plate and the upper side of the central structure, and free-wheeling ice screws.

On top of this, all the sensors and emitters, including cabling, of the SESAME experiment had to be routed through and fixed to the Landing Gear. The "launch pads" had to be fixed to the Landing Gear's central structure in such a way that the launch pad and its surroundings would withstand accelerations higher than 1000 g, and on the other hand, the mechanical shock generated at harpoon launch is absorbed by the Landing Gear's structure to an extent that delicate devices on the Lander are not damaged or destroyed.

However, not only the functioning of the subsystems under our reponsibility had to be tested and improved, if necessary; in addition, our responsibility included, because of our tasks as "Payload Engineer" (Hemmerich) and "Lead Scientist" (Rosenbauer in collaboration with a French colleague), in part also the Lander's scientific payload.

Change to a new target comet: 67 P/Churyumov-Gerasimenko

Because of the failure of an Ariane 5 launcher and the resulting necessity for Arianespace to investigate the whole system and partially improve it, the flight to comet 46 P/Wirtanen could not be realised on time. Therefore, a suitable new target comet had to be looked for and selected. In this context, "suitable" means that the comet's orbit is stable and wellknown and that this orbit can be reached by means of an Ariane 5G+ such that a rendezvous outside of a solar distance of 3 AU is possible.

The latter requirement must be fulfilled because the nucleus to be visited should still be "cold" at the time of landing so that major gas and dust bursts are unlikely to happen. An additional requirement asks for a launch as early as possible because the previous launch delays should at least partially be compensated.

A further important requirement was that the nucleus of the new target comet does not differ greatly in size or mass, respectively, from the original target 46 P/Wirtanen because the landing manoeuvre and the Landing Gear are optimized for an impact speed of about 0.5 m/s. If the new target comet would be much more massive than 46 P/Wirtanen, a considerable higher impact speed would result because of the higher gravitational attraction, and thus, the risk of deep sinking-in (in case of a soft ground at the landing site) as well as a strong rebound (in case of a hard ground) would be increased. In addition, the risk of overturning at landing on a steep slope would be increased.

Considering the many requirements given above, one can easily understand that there are not many "good" comets which fit the requirements and are in the right place at the right time. After lengthy calculations and considerations, a decision in favour of 67 P/Churyumov-Gerasimenko was made which did fit most of the requirements reasonably well, except that it turned out to be larger by a relatively high factor than Wirtanen (and therefore must be expected to be also correspondingly more massive).

Therefore, we had to get ourselves (and the Lander) prepared for a much higher impact speed than the 0.5 m/s the Lander was made for. We therefore had to get prepared for the worst case, namely a considerably higher impact velocity compared to a landing on the nucleus of comet Wirtanen.

First, we considered to reduce the risk of rebound by increasing the stiffness of the legs of the Landing Gear. This turned out to be not feasible because the total mass of the Lander as well its mass distribution were fixed and stiffening without changing the mass and mass distribution was just impossible. Therefore, we tried to modify the cold gas system (ADS) on board such that the impact velocity could be adjusted to a suitably small value by ground command.

This would have been an ideal solution since we could have simulated the landing conditions on Wirtanen which we had intensely studied both by means of computer simulation and hardware tests. If we could have employed this "silver bullet", we could have been well off. However, ESA was opposed to this solution because they assumed that there might not be enough time for sufficient testing.

We were, therefore, restricted to small changes of the Landing Gear, namely a partial stiffening of the cardanic joint and a reduction of the maximum tilt angle to 5°. Unfortunately, this restriction affects correspondingly the angle over which samples for scientific analysis can be taken. Nevertheless, we followed the advice of the Astrium company to introduce the changes. Whether the changes would have had a positive or negative effect, could only be determined by simulations and ground tests with the qualification model, since the lander was already integrated and attached to the spacecraft.

Therefore, we must accept that all three risks (rebound, deep sinking-in and turnover) are probably higher than they would have been at a landing on the nucleus of comet Wirtanen.

Experiments and experiment contributions in different phases of realisation

COSAC

Our most important experiment, COSAC, further needs to be checked sporadically with respect to its flawless functioning. This is the more important as it is one of the rare Rosetta experiments which can deliver useful data (about the surrounding gas) all the time the system is not in "sleeping" mode.

(H. Rosenbauer, F. Goesmann, R. Roll, M. Hilchenbach, H. Böhnhardt).

Hardware contributions to the Martian Lander Beagle 2

In accord with our interest, we have contributed to the device for soil analysis GAP (=Gas Analysis Package) of Beagle 2 by delivering the so-called Sample Handling, Acquisition and Distribution System (SHADS), consisting of a "carousel", "tapping stations" and 12 "ovens" made of platinum which can be heated up to 800°C. Thereby, we have established rights for unlimited participation in data analysis.

Unfortunately, the landing of Beagle 2 was not successful or communication to the Mars Express Orbiter or other receiving stations could not be established. In this situation, we are grateful to the colleagues from the Open University who invited us to contribute to Beagle 3, the realisation of which is presently under discussion.

(R. Roll, F. Goesmann, H. Böhnhardt)

COSIMA

Since April 2003, our institute is the new home of another Rosetta PI instrument, the cometary secondary ion mass analyser COSIMA. The purpose of this instrument is to analyse the cometary dust in the vicinity of the comet's nucleus on its approach to perihelion. COSIMA was built at the Max-Planck-Institute für extraterrestrische Physik, Garching, with the prime industrial contractor von Hoerner and Sulger, Schwetzingen, under the guidance of the COSIMA PI Dr. Jochen Kissel, who joined our institute in April 2003. The institute will be involved, within the COSIMA science team, in the calibration of the ground reference model and operation of the flight model.

(J. Kissel, M. Hilchenbach, H. Böhnhardt)

NPD (Neutral Particle Detector)

NPD is a neutral gas mass spectrometer which measures the temperature of the neutral solar wind. It is part of the extended model payload of the Solar Orbiter.

(M. Hilchenbach, E. Marsch)

GAS

The GAS experiment on Ulysses, by which the fluid parameters of the neutral interstellar helium can be determined increasingly accurately with measurement time growing, is still supported by NASA and carries on to deliver perfect data which – due to the longevity of the instrument – are evaluated also taking into consideration the aspect that the flow of the local interstellar medium could change relative to that of the solar system, which could occur for example when external local gas streams infiltrate our „LISM“.

(H. Rosenbauer, M. Witte).

CELIAS

CELIAS, a combination of an ion mass spectrometer with a UV-spectrometer on-board of SOHO, is delivering data since 1996. The data delivered are used for publications in heliospheric research (e.g. on the termination shock) and solar energetic particle physics.

(M. Hilchenbach)

MIRAS

MIRAS is a RAMAN spectrometer which is being developed jointy with the University of Jena. First breadboards have been developed in the frame of a DLR project and mineralogical research papers are being published.

(M. Hilchenbach)

PATIB (Planetary Deep Driller)

PATIB shall be developed together with industry for the investigation of planetary and other solid celestial surfaces.

(M. Hilchenbach)

MORE

MORE is a project in the construction phase. Both our department, as well as industry, are interested in its development. It includes an improved version of the COSAC experiment and is part of the model payload of a planned large exobiology project of ESA, a rover operating on the Martian surface.

(F. Goesmann, R. Roll, M. Hilchenbach)

Further rights in data evaluation

Because of our responsibility (together with a French colleague) for all scientific aspects of the Lander mission, we have unlimited rights in data utilisation. This corresponds to the results of approximately 8 additional scientific experiments.

Reduction of manpower

Because my retirement is approaching quickly (30 June 2004), I have, according to the presidential rules, not used any noticeable amount of the institute's resources. Rather, in agreement with my colleagues, the personnel of my department was stepwise transferred to the younger colleagues or, in case of technical personnel, distributed to the workshops and the electronics lab. At present, I have left only the support of my secretary which I will need for still a while because of the continuation of my responsibilities for the Rosetta Lander (Philae) and the chance that the ECOS project might be started.

Ensuring of long-term care-taking and maintenance of expert knowledge

As the trip of the Rosetta Orbiter to the rendezvous with the target comet Churyumov-Gerasimenko will last approximately 10 years and we hope that the Lander will deliver data for some time – in the optimum case for some years –, the overall mission is exceptionally long. Within such a project, the maintenance of expert knowledge is not a trivial problem, rather one to which up to now much, but yet not enough, time has been spent. There is a wide agreement that written documentation in not sufficient in some cases and that the knowledge and recollection of the Lander designers and constructors may become important. This also means that a sufficient number of permanent positions have to be available. This could largely be accomplished by joint commitments of MPG and DLR. Also, sufficiently experienced staff which is expected to be available for a long period, could be found.

Support of the landing activities for Philae by means of mathematical simulation of the landing process

Mathematical simulations of the Lander's behaviour during and directly after the landing have been performed since long (M. Hilchenbach). However, they had to be adjusted to the new target comet, i.a. to a considerably higher landing velocity than in the case of Wirtanen.

(M. Hilchenbach in collaboration with ESOC)

Preliminary considerations and calculations in support of the envisaged ECOS project

The project has made only little progress because there was practically no personnel available during the preparations for the Rosetta launch. Because of the fact that I am of the opinion that the subject is of high social relevance, I have started to work on a written project proposal shortly after the Rosetta launch and hope that after my completion of this proposal the responsible boards of the Max Planck society will deal with and respond to it in due time.

For my expression of thanks, please see the German version.

Postscript:

The launch of the Rosetta mission took place on 2 March 2004 from Kourou / French Guyana and was 100% successful. The commissioning activities have almost been completed, and up to now, there have been no failures.

Helmut Rosenbauer, April 2004

IV. International Max Planck Research School on Physical Processes in the Solar System and Beyond at the Universities of Braunschweig and Göttingen

Übersicht / Overview

Die “International Max Planck Research School on Physical Processes in the Solar System and Beyond at the Universities of Braunschweig and Göttingen” wurde 2002 als gemeinsame Inititative des Max-Planck-Instituts für Aeronomie in Katlenburg-Lindau und der physikalischen Fakultäten der Universität Göttingen (Universitäts-Sternwarte, Institut für Geophysik) und der Technischen Universität Braunschweig (Institut für Geophysik und Meteorologie, Institut für Theoretische Physik) gegründet. Sie bietet in- und ausländischen Studenten Gelegenheiten, auf dem Gebiet der Physik des Sonnensystems zu promovieren.

Die Schule bietet ein forschungsintensives dreijähriges Promotionsstudium. Voraussetzung ist ein Diplom oder ein Master of Science in Physik. Die Abschlüsse (PhD oder Dr. rer. nat.) können an den beteiligten Universitäten Braunschweig oder Göttingen oder an der Heimatuniversität angestrebt werden.

Das Lehrprogramm beinhaltet die gesamte Physik des Sonnensystems von der Geophysik über Planetenphysik zur Sonnenphysik. Es garantiert eine breite, interdisziplinäre und fundierte wissenschaftliche Ausbildung. Das wissenschaftliche Programm wird durch Kurse in numerischer Physik, Weltraumtechnologie und Projektmanagement ergänzt. Das Lehrangebot ist in englischer Sprache.

Die Forschungsmöglichkeiten für Doktoranden reichen von Instrumentierung und Beobachtung über Datenanalyse und -interpretation zu numerischen Simulationen und theoretischer Modellierung. Eine klare wissenschaftliche Schwerpunktbildung sorgt für eine thematische Verzahnung der einzelnen Promotionen. Durch die Bearbeitung gemeinsamer Themen und die enge Zusammenarbeit der Doktoranden in Forscherteams entsteht ein wissenschaftlicher Mehrwert.

In den Jahren 2002 und 2003 nahmen insgesamt 50 Doktoranden an der Schule teil, davon haben 7 ihre Promotion erfolgreich abgeschlossen. Die Teilnehmer kommen aus insgesamt 16 Ländern, 64% sind ausländischer Nationalität, 36% sind weiblich. Über 500 Bewerbungen in den ersten beiden Jahren der Research School zeigen die Attraktivität dieses internationalen Programms für junge Wissenschaftler.

The “International Max Planck Research School on Physical Processes in the Solar System and Beyond at the Universities of Braunschweig and Göttingen” was founded in 2002 as a joint venture of the Max Planck Institute for Aeronomy with the University of Göttingen (University Observatory, Institute of Geophysics) and the Technical University Braunschweig (Institute of Geophysics and Meteorology, Institute of Theoretical Physics). The participating institutes are uniquely positioned in the fields of solar system physics and together form a center of scientific excellence in an innovative and interdisciplinary research area.

The School offers graduate students from many countries attractive conditions for education and research. A prerequisite is a diploma or masters degree in physics. The PhD degree can be obtained either from the Universities of Braunschweig or Göttingen or the home university of the student.

The program covers the full range of physics inherent in the rapidly growing field of solar system science from geophysics and planetary science to solar physics, as well as the underlying fundamental physics. It ensures a broad, interdisciplinary, and well-founded education for a career in science. The science program is complemented by training in computational physics, space technology and project management, which considerably widens the career opportunities for the students.

High-profile space missions and projects for ground-based instruments, data analysis as well as theoretical and large-scale numerical modeling provide a wide range of research possibilities for PhD students.

In 2002 and 2003 altogether 50 students took part in the program, from which 7 successfully finished their PhD. The students came from 16 countries, 64% were of foreign nationality, 36% were female. More than

Fig. 110: Offizielle Eröffnung der Research School am 20. März 2002 / *Official opening of the Research School on 20 March 2002.*
Von links nach rechts / *From left to right:* Prof. Kern, Prof. Gruss, F. Kolesnikov, A. Tomas, Prof. Litterst, Minister Oppermann, Prof. Solanki, Dr. Schmitt

500 applications in the first two years of operation of the Research School show the attraction of this international program for young scientists.

Vorstand / *Chair:*

U. Christensen (MPAe), K.-H. Glassmeier (Technische Universität Braunschweig), F. Kneer (Universität Göttingen), U. Motschmann (Technische Universität Braunschweig), S. K. Solanki (MPAe, Vorsitz/Chair), A. Tilgner (Universität Göttingen), D. Schmitt (MPAe, Koordinator/Coordinator)

Lehrveranstaltungen / *Lectures* 2002 – 2003:

Introductory Course, 18 – 22 Febuary 2002 (Christensen, Glassmeier, Jockers, Kneer, Marsch, Motschmann, Schmitt, Schüssler, Schwenn, Solanki, Tilgner, Thomas, Wilhelm)

Inverse Problems in Space Physics, May 2002 (Inhester)

Planetary Atmospheres, 24 – 28 June 2002 (Basilevsky, Rodin, Titov)

Plasma Physics, 24 – 28 June 2002 (Schmitt, Schüssler)

Solar Corona and Heliosphere, 28 October – 1 November 2002 (Marsch, Schwenn)

Stellar Physics, 28 October – 1 November 2002 (Glatzel)

Small Bodies of the Solar System, 3 – 7 March 2003 (Jockers)

Dynamo Theory, 3 – 7 March 2003 (Christensen, Rädler, Schmitt, Schüssler, Tilgner)

Space Plasma Physics, 23 – 27 June 2003 (Marsch)

Space Instrumentation, 23 – 27 June 2003 (Schwenn, Curdt, Gandorfer, Hilchenbach, Hoekzema, Pardowitz, Richter, Schühle)

Planetary Surfaces and Interiors, 17 – 21 November 2003 (Christensen, Grieger, Küppers, Mall, Markievicz, Nathues)

Stellar Atmospheres and Radiative Transfer, 17 – 21

Fig. 111: Unsere Studenten während einer Seminarwoche auf der Burg Bodenstein / *Group of students during a lecture week at Burg Bodenstein*

November 2003 (Dreizler)

Solar System Seminar, 22 seminar days with 62 talks by students and 20 tutorial talks by guests (Schmitt)

Abgeschlossene Dissertationen / *Finished PhDs:*

Volkmar Holzwarth: Dynamik magnetischer Flussröhren in Riesensternen und engen Doppelsternen, Universität Göttingen, 2002

Oliver Preuß: Astronomical Tests of the Einstein Equivalence Principle, Universität Bielefeld, 2002

Katja Janßen: Struktur und Dynamik kleinskaliger Magnetfelder der Sonnenatmosphäre, Universitäts-Sternwarte, Universität Göttingen, 2003

Santo Valentin Salinas Cortijo: Multi-dimensional Polarized Radiative Transfer Modeling of Titan's Atmosphere, Universität Göttingen, 2003

Alexander Vögler: Three-dimensional simulations of magneto-convection in the solar atmosphere, Universität Göttingen, 2003

Maren Wunnenberg: Untersuchung kurzperiodischer akustischer Wellen in der Sonnenatmosphäre mit Hilfe der Wavelet-Transformation, Universitäts-Sternwarte, Universität Göttingen, 2003

Lidong Xia: Equatorial Coronal Holes and Their Relation to the High-Speed Solar Wind Streams, Universität Göttingen, 2003

Laufende Dissertationen / *Ongoing PhDs:*

MPAe:

Ingo Jens Baumann: Simulation of magnetic flux transport on the Sun (Solanki/Schüssler)

Juan Manuel Borrero Santiago: Inversion of the Stokes profile (Solanki)

Monika Buske: Evolution models of the Martian interior (Christensen)

Mark Cheung: Numerical simulation of magnetoconvection (Schüssler)

Maria Hebe Cremades Fernandez: Magnetic field configurations in coronal mass ejections (Bothmer/Schwenn)

Yevgen Grynko: Reflection of light from atmosphereless solar system bodies and from cometary dust (Jockers)

Michael Heuer: Kinetic plasma processes in the solar corona and solar wind (Marsch).

Tra-Mi Ho: Data analysis and model calculations of cometary comae (Thomas)

Carsten Köllein: Numerical simulations of the structure of cometary nuclei (Thomas/Keller)

Fedor Kolesnikov: Vortex flows around magnetic flux tubes (Schüssler)

Maxim Kramar: Tomography of coronal magnetic fields (Inhester/Marsch)

Elena Kronberg: Dynamical processes in Jupiter's magnetosphere (Woch/Krupp)

Rupali Mahajan: Modeling of the Martian climate (Grieger/Keller)

Marilena Mierla: Dynamics of the solar corona (Schwenn)

Guadalupe Munoz Martinez: Coronal mass ejection acceleration, statistical and analytical evaluations (Schwenn)

Ganna Portyankina: Atmosphere-surface vapour exchange and ices in the Martian polar regions (Markiewicz/Keller)

Sabine Preusse: Computer modeling of plasma interactions in extrasolar planetary systems (Büchner/Motschmann).

Aikaterini Radioti: Plasma composition in the magnetosphere of Jupiter (Woch/Krupp)

Luciano Rodriguez Romboli: The heliosphere – Ulysses investigations (Woch/Krupp)

Ryu Saito: Development of a general circulation model for Titan's atmosphere (Hartogh)

Martin Schrinner: Modeling of the geodynamo (Christensen/Schmitt)

Andrey Seleznyov: The origin of solar variability, with an application to the search for extra-solar planets (Solanki)

Alina Semenova: Modelling of giant starspots on the poles of rapidly rotating stars (Solanki)

Sergey Shelyag: Simulations of solar magnetoconvection and their interpretation (Schüssler/Solanki)

Ilya Silin: Theory and simulation of kinetic plasma instabilities (Büchner)

Ana Teresa Monteiro Tomas: Planetary magnetospheres – Jupiter (Woch/Krupp)

Denise Tortorella: Compressible convection in gas giant planets (Christensen)

Durgesh Kumar Tripathi: Development of stereoscopic image processing methods for the STEREO mission (Bothmer/Schwenn)

Geronimo Villanueva: Radiometry of ozone and water vapour in the Earth atmosphere (Hartogh)

Vasily Zakharov: Investigation of phase diversity methods for the Sunrise project (Solanki)

Universität Göttingen:

Aleksandra Andjic: Waves in the solar atmosphere observed with high spatial and temporal resolution (Kneer)

Nazaret Bello Gonzalez: Magnetic fields in sunspots penumbrae (Kneer)

Itahiza Francisco Dominguez Cerdena: Quiet Sun magnetic fields (Kneer)

Oleg Okunev: Polar faculae of the Sun (Kneer)

Markus Sailer: High spatial resolution for solar observations with Multi Conjugated Adaptive Optics and Speckle reconstruction (Kneer)

Aveek Sarkar: Lattice-Boltzmann method applied to the dynamo problem (Tilgner)

Technische Universität Braunschweig:

Thorsten Bagdonat: Simulation of the solar wind interaction with comets (Motschmann)

Dragos Ovidiu Constantinescu: Magnetic mirror structures in the terrestrial magnetosphere (Glassmeier)

Jean-Mathias Grießmeier: Magnetospheres of extrasolar planets (Motschmann)

Yasuhito Narita: Magnetospheric physics – Cluster II data analysis (Glassmeier)

Michael Rost: Coagulation of magnetized dust in the early solar system (Glassmeier)

Anja Stadelmann: Studies on paleomagnetospheric processes (Glassmeier)

Jens Stadelmann: Diffusion of the geomagnetic secular variation through the heterogenuous mantle (Weidelt)

(D. Schmitt)

V. Rechenzentrum, Elektroniklabor und Werkstätten/ Computer Centre, Electronic Laboratory and Workshops

Rechenzentrum/Computer Centre

(I. Pardowitz und Mitarbeiter)

Internet und Sicherheit

Wie in den letzten Jahren hat das Internet in seinen verschiedenen Aspekten die Aktivitäten des Rechenzentrums wesentlich geprägt. Nach wie vor stehen neben den technischen Gesichtspunkten die Themen Sicherheit und die wissenschaftliche Nutzung im Vordergrund.

Die Ausfallsicherheit der Leitung nach Göttingen wurde durch die Inbetriebnahme einer zweiten 1-Gbit/s-Leitung wesentlich erhöht. Diese redundante Leitung wird für den Zugang aus dem ungesicherten Netzwerkbereich (z.B. für Gäste) ins Internet benutzt.

Dank des CISCO-Routers mit Sicherheitsfunktionalität, der schon im Jahre 2000 in Betrieb ging, sind keine Einbrüche aus dem Internet mehr vorgekommen. Dagegen haben die Probleme mit Viren in E-Mails und mit Spam-Mails drastisch zugenommen. Dieses Problem musste durch Einführung eines E-Mail-Virenscanners auf dem Eingangs-Mailserver gelöst werden.

Die Erfahrungen mit dem RAPID- und SUMER-Datenbankserver konnten weitergenutzt werden, um zunächst für das Projekt Sunrise eine webbasierte Dokumenten-Datenbank zu implementieren. Sie dient dazu, alle notwendigen Informationen in der Entstehungsphase eines Projektes zentral zu sammeln und den Projektbeteiligten zur Verfügung zu stellen. Wegen der internationalen Verflechtung dieses Projektes war eine solche webbasierte, platformunabhängige Lösung notwendig geworden.

Dieses System besteht im Kern aus einer MySQL-Datenbank, auf die mittels mehrerer Softwaremodule berechtigte Anwender von jedem Webbrowser aus dem Internet zugreifen können und damit Zugang zu den aktuellen Daten und Dokumenten des Projektes bekommen. Die Dokumente werden im PDF-Format abgespeichert, Daten in jedem beliebigen Format werden in zip-Containern in die Datenbank abgelegt. Solche Daten können z.B. Konstruktionszeichnungen und CAD-Daten, elektronische Schaltpläne, Onboard-Software u.Ä. sein. Inzwischen wird dieses System auch für die Dokumentation der Projekte STEREO, HIFI und VMC genutzt und verwaltet (derzeit rd. 500 Dokumente).

(M. Bruns, I. Pardowitz)

Ausstattung und Dienstleistungen

Die Server-Ausstattung des Rechenzentrums ist wie in den letzten Jahren weiter ausgebaut worden. Die Rechenkapazität des **Unix-Clusters** wurde durch die Anschaffung einer Sun Fire 280R mit zwei Prozessoren und 8-GB-Speicher wesentlich erweitert.

Das HSM-Archiv-System SAM-FS wurde Ende 2002 durch eine Overland Neo Tape-Library mit 26 Stellplätzen und zwei Super-DLT-Laufwerken erweitert. Damit wurde auch der Generationswechsel von DLT-IV zu Super-DLT-Medien vollzogen. Der Plattencache des HSM-Systems wurde in diesem Zuge ebenfalls durch ein weiteres Raid-System vergrößert. Dieses Archivsystem dient dazu, die Experiment-Daten sowohl für den laufenden Auswertebetrieb (auf dem Plattencache) zu halten als auch über sehr lange Zeiträume (auf den Magnetbändern) aufzubewahren.

Im **Windows-Bereich** wurde im Berichtszeitraum die Migration von der NT-4-Umgebung auf Windows 2000 Active Directory vollzogen. Mit dem primären Domänen-Controller der NT-4-Domäne wurde im März 2003 der letzte noch verbliebene NT-4-Server im Rechenzentrum außer Dienst gestellt. Parallel dazu wurde die Umstellung der Arbeitsplatzrechner von Windows 9x/NT auf Windows 2000/XP vorangetrieben. Diese Maßnahmen haben eine zentrale Verwaltung der Systeme erst möglich gemacht, so dass inzwischen auf der überwiegenden Anzahl der Workstations Betriebssystem, Service Packs, Sicherheits-Updates und Virenscanner zentral gesteuert auf dem aktuellen Stand gehalten werden.

Im Zuge der Migration zu Windows 2000 wurde auch der Exchange-Server von der Version 5.5 auf Exchange 2000 gebracht. Mit dem Tivoli Storage Manager (TSM) der Firma IBM wurde im Sommer 2003 ein sehr leistungsfähiges und flexibles

Backup-System in Dienst gestellt, das auch den Prozess des Restaurierens erheblich beschleunigt. TSM ist auf einer Doppel-Xeon-Maschine mit 2.4-GHz-Taktfrequenz und 4-GB-Hauptspeicher implementiert, die unter Windows Server 2003 läuft. Die Datensicherung erfolgt auf einem 2 TB umfassenden Plattenspeicher, der es ermöglicht, die Backups künftig vollständig online – und damit schnell zugreifbar – zu halten. Die Absicherung des Plattenbereichs geschieht mit einer SDLT-Bandbiblothek mit 26 Bandplätzen und einer unkomprimierten Gesamtkapazität von ca. 4 TB.

In den vergangenen Jahren ist die Anzahl der Windows-Dienste und damit – nach der in diesem Umfeld zumeist angewandten Regel "ein Dienst, ein Server" – die Anzahl der Server stark angestiegen. Zu den klassischen File, Print und Mail Services kamen Terminal Services, verschiedene Varianten des Fernzugriffs, zentrale Installationsserver und mehr. Viele dieser Dienste stellen nur geringe Anforderungen, etwa an die CPU-Leistung. Um eine hohe Verfügbarkeit zu gewährleisten, ist jedoch entsprechend redundant ausgelegte und somit kostspieligere Hardware erforderlich.

Konsolidierung verspricht hier die Virtualisierung von Servern unter VMware. Diese Software ermöglicht es, auf einer physikalischen Maschine (dem Host) eine Vielzahl unterschiedlicher und voneinander unabhängiger Betriebssystem-Instanzen (die Gäste) als virtuelle Maschinen (VM) parallel zu betreiben. Nach außen ist eine solche VM nicht von einem "real existierenden" PC zu unterscheiden. Leistungsfähige Hardware vorausgesetzt, kann auf einer einzigen Maschine ein vollständiges Netzwerk mit Windows- und Linux-Servern und unterschiedlichen Clients realisiert werden. Dadurch, dass eine VM sich lediglich in Form einiger Dateien manifestiert, eröffnen sich neue Möglichkeiten hinsichtlich Verfügbarkeit, Sicherung und Flexibilität.

Nachdem VMware im Test- und Evaluierungsbereich bereits seit 1999 ohne Probleme im Einsatz ist, wurden im vergangenen Jahr mehrere Dienste, darunter der Druckerdienst, erfolgreich als VM realisiert. Es ist daher geplant, im Zuge der Erneuerung alter Hardware in den kommenden Jahren – in Zusammenarbeit mit anderen Max-Planck-Instituten – verstärkt virtuelle Maschinen auf relativ wenigen leistungsfähigen Hosts einzusetzen.

(G. Kettmann)

Die **personellen Dienstleistungen** für die wissenschaftlichen Projekte spielen weiterhin neben dem Betrieb der Infrastruktur (Rechner, Netze, Peripherie) eine wichtige Rolle. Für die Projekte STARE, WIND, CELIAS und SUMER/SOHO, ULYSSES, RAPID und CIS/Cluster werden regelmäßig die eingehenden Daten aufbereitet und für die weitere wissenschaftliche Analyse bereitgestellt und archiviert.

(M. Bruns, H. Michels, C. Ludwieg)

Im Berichtszeitraum hat das Thema **Ausbildung** einen größeren Raum gegenüber den Vorjahren eingenommen. Die Zahl der **Praktikanten** im Rechenzentrum ist vom Jahr 2001 mit 67 Praktikumswochen auf 98 und 172 Praktikumswochen in den Jahren 2002 bzw. 2003 angestiegen. Es sind teils Schüler-Praktikanten aus Haupt-, Realschulen oder Gymnasien, teils Praktikanten im Rahmen eines Fachhochschul-Studiums und teils Praktikanten im Rahmen von Umschulungsmaßnahmen, die während ihres 2 bis 22 Wochen langen Aufenthalts im Institut allgemein den Betriebsalltag in einem Rechenzentrum kennen lernen oder anhand kleinerer Projekte und der Mitarbeit im Rechenzentrum praktische Erfahrungen für ihren späteren Beruf erwerben.

Im Jahre 2002 wurde im Rechenzentrum ein **Ausbildungsplatz** zum Fachinformatiker für Systemintegration eingerichtet, und im Herbst 2003 hat der erste Jugendliche im Rechenzentrum seine 3-jährige Ausbildung begonnen.

(G. Monecke)

Elektroniklabor/Electronic Laboratory

(I. Pardowitz)

Den größten Anteil an den personellen Aktivitäten während des Berichtszeitraums im Labor hatten Arbeiten vor und nach Abgabe der Rosetta-Instrumente. Mit den Instrumenten OSIRIS, RTOF, MIRO und CONSERT auf dem Rosetta-Orbiter sowie mit COSAC und den verschiedenen Subkomponenten des Landers hat das Elektronik-Labor und das gesamte Institut einen sehr gewichtigen Anteil an der Rosetta-Mission beigetragen. Gleichzeitig sind die Arbeiten an dem Sunrise-Projekt begonnen worden, für welches das Institut die Gesamtverantwortung trägt sowie mehrere zentrale Komponenten beitragen wird.

Weitere Projekte, an denen Mitarbeiter des Labors gearbeitet haben, waren die Beteiligungen an Instrumenten für die Missionen STEREO, HIFI, Venus Express und DAWN.

CCD-Board für Herschel

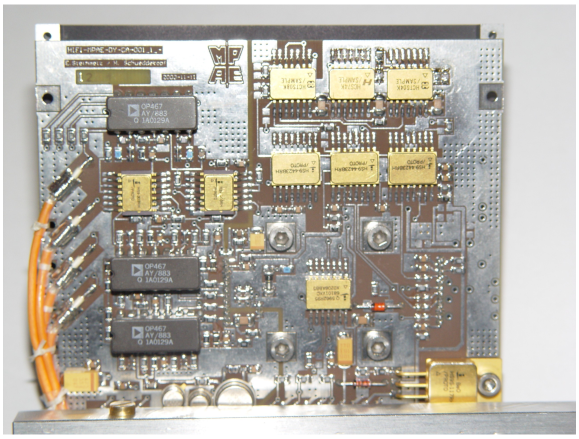

Abb. 112: CCD-Board für Herschel / *CCD-board for Herschel*

Das CCD-Board (Abb. 112) ist für ein 4-Linien-CCD für den Einsatz bei der Herschel-Mission entwickelt worden. Es beinhaltet die Verteilung und Filterung der Spannungsversorgung sowie die Erzeugung von sehr genauen Referenzspannungen. Ferner ist auf diesem Board eine Schaltung untergebracht, die es ermöglicht, die zeitliche Ablaufsteuerung des 4-Linien-CCDs zu justieren. Jede CCD-Linie hat zwei analoge Ausgänge, einen *even* und einen *odd* Ausgang. Die Ausgänge haben einen sehr hohen Gleichspannungsanteil (ca. +8,5 V). Dieser Gleichspannungsanteil wird von der Elektronik kompensiert und gleichzeitig das nutzbare Signal mit schnellen, rauscharmen Verstärkern um einen Faktor 3,5 verstärkt. Danach werden über einen Analogschalter die *even* und *odd* Signale auf eine Leitung zusammengeführt. Die so entstandenen 4 Videosignale, mit einer max. Amplitude von ca. +5 V, werden über 4 Koaxialleitungen zur nachfolgenden Elektronik geleitet. In dieser Elektronik befinden sich dann 4 schnelle 14-Bit-ADCs, welche die Videosignale konvertieren.

(E. Steinmetz, H. Schüddekopf, P. Börner)

SECCHI Experiment Sun Aperture Mechanism (SESAMe)

Die NASA–STEREO–Mission soll im Jahr 2005 mit zwei Raumsonden starten. Auf jeder Raumsonde sind zwei Coronographen (COR1, COR2) und ein Extrem Ultra-Violet Imager (EUVI) vorgesehen. Zum Schutz der Filter am EUVI und der Optiken an COR1 und COR2 wird am Max-Planck-Institut ein Türverschluss-Mechanismus gebaut, welcher auf Erfahrungen von LASCO beruht. Im Gegensatz zu LASCO sind bei STEREO die thermischen und mechanischen Anforderungen an die Mechanik und die Elektronik wesentlich höher, da sich die einzelnen Teleskope nicht in einer Box, sondern auf einer Platte befinden bzw. kein Thermalschild für den Türmechanismus vorhanden ist.

(W. Deutsch)

Neue Thermal-Vakuumkammern

Im Jahr 2003 wurden zwei neue Thermal-Vakuumkammern der Firma SGI in Betrieb genommen (Abb. 113). Diese Investition, die mit einem erheblichen Umbau der Kranhalle verbunden war, hatte zum Ziel, die z.T. 25 Jahre alten Test-Einrichtungen durch moderne, leistungsfähigere Geräte zu ersetzen. Die neuen Kammern haben einen Innenraum von 60 x 60 x 80 cm^3 und erlauben die Simulation von Weltraumbedingungen wie die Aufheizung bis 150°C sowie eine Abkühlung bis -190°C in einem Vakuum bis 10^{-5} mbar. Mit diesen computergesteuerten TV-Kammern können sowohl manuelle TV-Profile wie bisher als auch automatische Zyklen gefahren werden. Die TV-Kammern befinden sich in einem Reinraum der Klasse 50.000, die Be- und Entladung der Kammern kann unter Bedingungen der Klasse 10.000 erfolgen. Insbesondere bei Langzeittests, wie sie für die oben erwähnten SESAMe-Türen notwendig waren, hat sich die Leistungsfähigkeit der neuen Anlagen erwiesen.

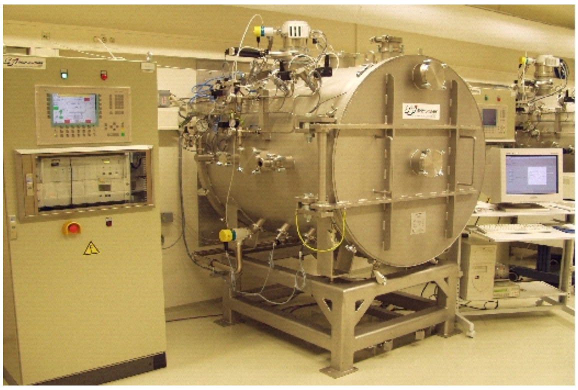

Abb. 113: Thermal-Vakuumkammer / *Thermal Vacuum Chamber*

CCD-Testeinrichtung/CCD Test Facility

Bildaufnehmende Sensoren müssen vor dem Einsatz in wissenschaftlichen Experimenten in umfassender Weise überprüft und charakterisiert werden. Häufig steht dafür die für den späteren Einsatz vorgesehene, spezifische Elektronik noch nicht zur Verfügung. In diesem Falle ist eine universelle Elektronik vorteilhaft, mit der beliebige Sensoren ohne größeren Adaptieraufwand betrieben werden können.
Das hier beschriebene Testgerät ist für CCDs wie auch

für andere Bildsensoren einsetzbar. Alle für den Betrieb erforderlichen Spannungen und Signale lassen sich per Software einstellen. Die aufgenommenen Daten werden zur weiteren Bearbeitung in Echtzeit in einen PC übertragen.

Imaging sensors used in scientific experiments have to be selected according to the actual application. In most instances, the dedicated experiment electronics is not yet available at that time. It is therefore useful to have a universal electronics, capable to operate the sensor in question without a significant adaptation effort.
An all-purpose test facility for CCDs and other detectors will be described here that has been developed to overcome this problem. It is reconfigurable by software. A fast data link to a PC is available for further data evaluation in real time.

Im Rahmen des OSIRIS-Projektes wurde ein Testsystem entwickelt, mit dem beliebige Bildaufnehmer, vorrangig aber CCDs, optisch und elektrisch vermessen werden können.
Sensoren verschiedener Produktfamilien oder verschiedener Hersteller unterscheiden sich in wesentlichen Parametern wie:

- Anzahl der Pixel (Spalten, Zeilen)
- Art und Anzahl der notwendigen Steuersignale
- Statische und dynamische Spannungspegel
- Anzahl und Dynamik der Analogkanäle
- Auslesegeschwindigkeit

Um den Aufwand zum Anpassen eines Sensors gering zu halten, wurde folgendes Konzept entwickelt:
Alle Analogspannungen, die zum Betrieb eines Sensors benötigt werden, lassen sich per Software einstellen. Ebenso sind die Impulsfolgen zum Ladungstransport innerhalb des Sensors in Amplitude und Signalform programmierbar. Für die Analogkanäle gibt es eine sensorunabhängige Schnittstelle.
Die Sensoranpassung beschränkt sich damit auf:

- Herstellen einer angepassten CCD-Aufnahme mit Vorverstärker.
- Eingabe der Impulsmuster – aus binären Zahlenfolgen 10110...
- Programmierung der vorgesehenen Betriebsspannungen.

Im Anschluss können damit die gewünschten Messungen durchgeführt werden.

Aufbau und Funktion

Das Testsystem (Abb. 114) wird von einem Digitalen-Signal-Prozessor (DSP) gesteuert.

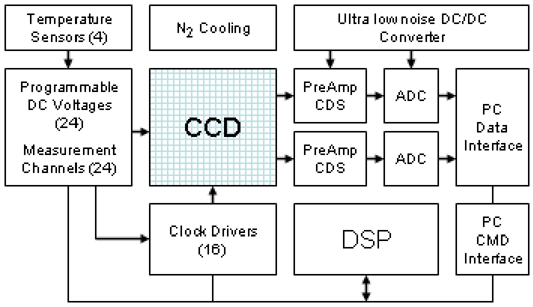

Abb. 114: Blockschaltbild des Testsystems / *Block diagram of the test system*

Über Digital-Analog-Wandler mit nachgeschalteten Boostern werden die verschiedenen Gleichspannungen zum Betrieb des Sensors bereitgestellt. Diese Spannungen, wie auch mehrere Temperaturkanäle, können als Housekeeping-Daten gemessen werden. Die Ablaufsteuerung zum Betrieb des Sensors übernimmt der DSP. Er gestattet es, Clocksignale im Raster von 80 ns zu erzeugen. Diese dienen sowohl zum Takten des Sensors als auch zum Steuern der Datenwandlung und der Übertragung der Bilddaten zum PC. Weiterhin stehen programmierbare Signale zur Verfügung, die z.B. für die bildsynchrone Ansteuerung eines Shutters vorgesehen sind.

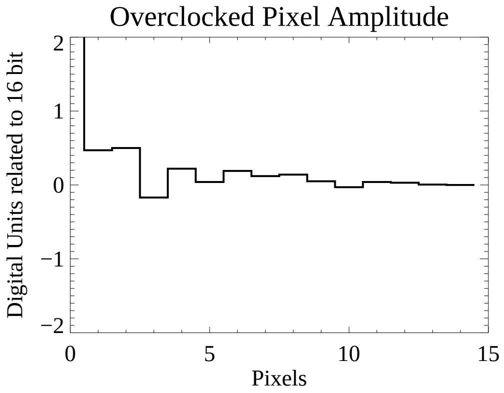

Abb. 115: Verhalten nach einem Signalsprung / *Signal response upon a test pulse*

Für die Programmierung des Testsystems wie auch für die Auswertung der Daten gibt es eine Reihe von IDL-Programmen. Alternativ kann auch eine andere Hochsprache, wie z.B. LabView, eingesetzt werden. Dazu steht eine Windows-DLL zur Verfügung, die die Verbindung zu den DSP-Routinen herstellt. Für die Stromversorgung der hochsensiblen Analogelektronik wurden extrem störungsarme Gleichspannungskonverter entwickelt. Im gegenwärtigen Aufbau sind zwei Analogkanäle mit 16-bit-ADCs und einer Abtastrate von 500 kS/s eingesetzt.

Zur Überprüfung des dynamischen Verhaltens der Signalkette wurde ein Signalsprung (Weiß-Schwarz-Übergang) über 95% des Dynamikbereiches in das Testsystem eingekoppelt. Das Ergebnis in Abb. 115 zeigt, dass das Signal praktisch unverfälscht verarbeitet und detektiert wird.

Der digitale Übertragungskanal zum PC ist galvanisch entkoppelt und hat eine Bandbreite von 12 MBytes/s. Die Abb. 116 und Abb. 117 zeigen das Testsystem, angeschlossen an einen Vakuumbehälter im CCD Labor. Damit sind CCD-Messungen bis unter 180 K möglich.

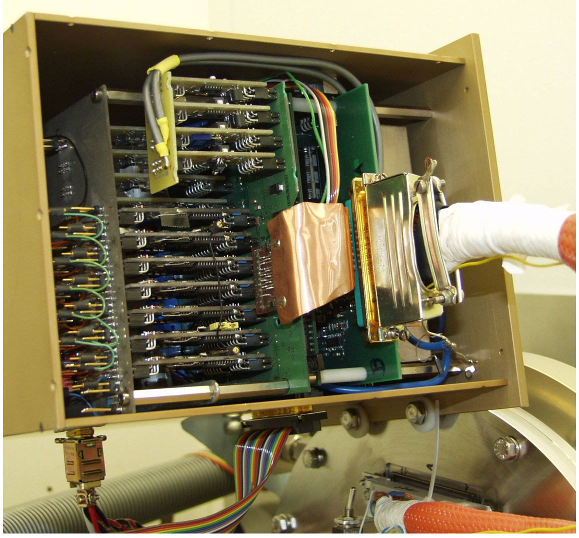

Abb. 116: Testsystem am Vakuumgefäß / *Test system at vacuum chamber*

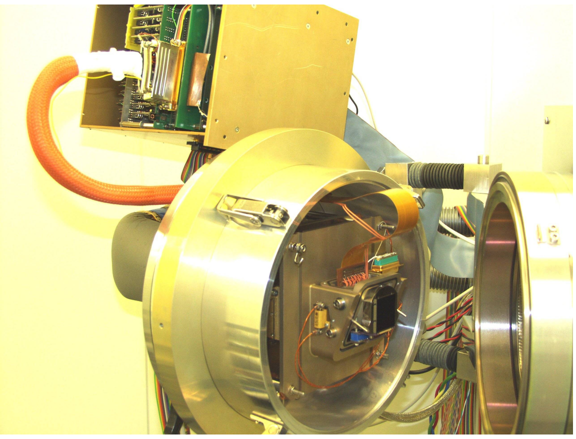

Abb. 117: Geöffnetes Vakuumgefäß mit CCD / *Open vacuum chamber with CCD*

Technische Daten:

- Steuerung durch TI-Signalprozessor TMS320C31
- Kommandierung und Auswertung über Hochsprache (IDL, LabView)
- Programmierbar sind:
  - 8 Sensorspannungen (-13,5 V bis +13,5 V bzw. 0 V bis +27 V)
  - 12 Clockpegel (-13,5 V bis +13,5 V, bis 500 mA)
  - 16 Clockpattern im Raster von 80 ns
  - Steuersignale Sampling, Shutter usw.
  - 24 Kanäle zur Spannungs- und Temperaturmessung (12 bit)
- Bildsignal A/D Wandlung: 2 Kanäle à 16 bit
- Sehr gutes dynamisches Verhalten (Abb. 115)
- Datenübertragung in Echtzeit zum PC (32 bit @ 3 MHz)

(G. Tomasch, H.U. Keller, R. Kramm, H. Sierks, T. Tzscheetzsch, H. Schüddekopf)

Mechanische Werkstätten, Haustechnik, Ausbildung/Engineering workshops, physical plant, training

(V. Thiel)

Werkstätten

Zu den mechanischen Werkstätten gehören die Abteilungen Feinmechanik, Schlosserei, Galvanik und Siebdruck. Die enge Zusammenarbeit mit den Wissenschaftlern, den Ingenieuren und der Konstruktion gewährleistet einen optimalen Fertigungsablauf für die oft sehr komplizierten Einzelteile, so dass auch Änderungswünsche rechtzeitig einfließen können. Von den 13 Mitarbeitern wurden eine Vielzahl von Einzelaufträgen für die im Institut laufenden Projekte, für Laborexperimente, für Testreihen, für die Unterhaltung der Messlabore sowie Reparatur- und Instandsetzungsarbeiten durchgeführt. Für 2002 und 2003 sind in den einzelnen Werkstätten folgende Hauptarbeiten zu nennen:

Feinmechanik

In der Feinmechanik-Werkstatt wurde schwerpunktmäßig für die Projekte Rosetta-Lander, STEREO, SIR, HIFI, VMC und Sunrise gearbeitet.

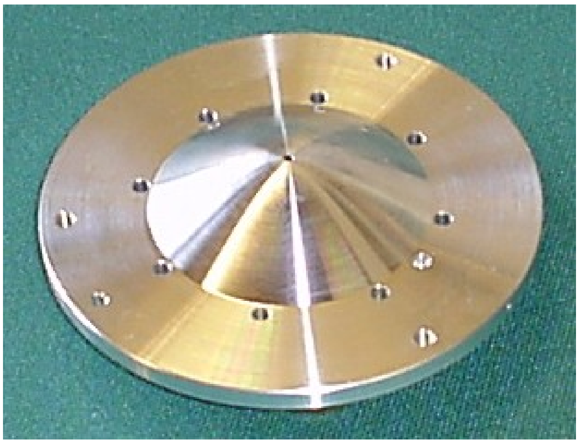

Abb. 118: Teil einer Ionenfalle / *Part of ion trap*

Die Einzelteilanfertigungen wie Elektronikbox, Ionenfalle (Abb. 118) Eject-Mechanismus, Bubble, Housing of Mirror, Cover Top, Transmissionshaft, Tür-Mechanismus (Abb. 119), Gehäuse und Frontplatten nahmen dabei einen breiten Raum ein. Außerdem wurden Vorrichtungen und Aufnahmen für Thermal-, Vakuum- und Vibrationstests sowie Einzelteile für das Projekt Bodenbeobachtungen von Kometen hergestellt. Umfangreiche feinmechanische Arbeiten mussten für den Lander durchgeführt werden, darunter auch der Eisbohrer (Abb. 120).

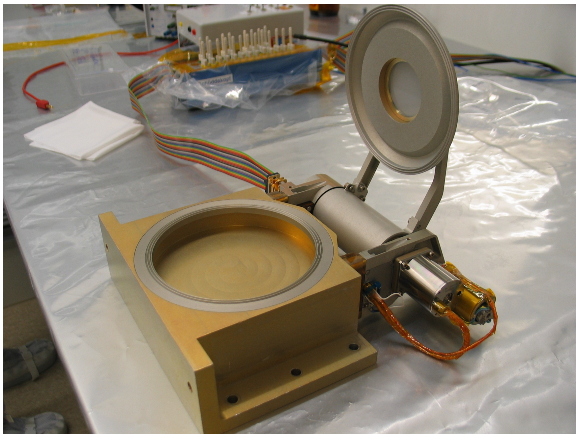

Abb. 119: Tür-Mechanismus für STEREO / *Port mechanism for STEREO*

Abb. 120: Eisbohrer für Rosetta / *Ice drill for Rosetta*

Für diese Arbeiten stehen den Facharbeitern der Feinmechanik-Werkstatt manuell zu bedienende Werkzeugmaschinen sowie 3-CNC-gesteuerte Fräsmaschinen und 2-CNC-gesteuerte Drehmaschinen zur Verfügung. Das Erreichen höchster Präzision steht dabei im Vordergrund.

Galvanik

Bevor die in der Feinmechanik-Werkstatt und die bei Fremdfirmen gefertigten Einzelteile zu Baugruppen integriert werden, wird in der Galvanik eine Oberflächenbehandlung durchgeführt. Zur Verarbeitung kommen überwiegend hochfeste Aluminiumlegierungen, wobei die Vorbehandlungen wie z.B. Entfetten und Beizen auf die jeweiligen Legierungen abgestimmt werden müssen. Gefordert werden Oberflächen, die je nach Anwendungsfall gut leitfähig, isolierend, glänzend, matt oder lichtabsorbierend sein müssen. Die hauptsächlichen Verfahren sind dabei Gelbchromatieren, Vergolden, Verkupfern, Vernickeln und Eloxieren. Kleinere Strukturen wie Blenden, Ablenkgitter oder Kontaktbleche, die nicht mehr maschinell herstellbar sind, werden durch Ätztechnik oder Galvanoformung hergestellt. Zum Aufgabengebiet der Galvanik gehört auch die Herstellung von Leiterplatten, außerdem besteht die Möglichkeit zur Darstellung der mikroskopischen Bilder auf einem Monitor oder Videoprinter.

Siebdruck

Im Berichtszeitraum nahm das Projekt STEREO einen Großteil der Arbeiten in Anspruch. Darunter fiel das Beschriften von Einzelteilen, die im Haus oder von Fremdfirmen gefertigt wurden. Hier kamen die Graviermaschine und der Multifunktionslaser zum Einsatz. Im Anschluss mussten die Teile auf der Messmaschine vermessen werden. Mit dem Laser wurden unterschiedliche Encoder-Scheiben aus Edelstahl und der Federteil aus Kupfer-Beryllium geschnitten, eloxierte Aluminiumteile beschriftet und Spezialbearbeitungen von Keramik, Metallen und Leiterplattenmaterialien durchgeführt. Mit dem Fotoplotter konnten für das Projekt HIFI Vorlagen von Leiterplatinen geplottet und anschließend in der Galvanik fertig gestellt werden. Auf der Diamantsäge wurden Glasplatten, Keramikrohre sowie Drehstähle auf Maß geschnitten. Zur Verfügung steht noch die Aufdampf- und Sputteranlage, mit der verschiedene Materialien mit Gold, Silber, Aluminium, Kupfer, Chrom oder Nickel beschichtet werden können.

Schlosserei

Zu den Aufgaben der Schlosserei gehören Aufbau und Betreuung der Großgeräte im Laborbereich, Wartung und Reparatur von Vakuumpumpen und -anlagen, umfangreiche Schweißarbeiten mit Edelstahl und Aluminium-Legierungen sowie Montagearbeiten für Antennenanlagen. Für das Projekt OSIRIS wurde eine Testkammer im Cleanraum umgebaut, umfangreiche Versorgungsleitungen für Stickstoff und Synthetische Luft aus Edelstahl angefertigt und verlegt sowie ein Kühlschlangensystem aus Kupferrohr gefertigt und montiert. Beim Projekt Rosetta-Lander wurde zwecks Ermittlung der Fallgeschwindigkeit des Landers eine Ausleger-Konstruktion aus U-Profilstahl gebaut, eine Vakuumkammer für Langzeittests des Landers umgebaut und ein Lasttestaufbau aus Aluminium hergestellt. In der Nähe von Tromsö wurden Reparaturarbeiten an der Rio-Imager-Antennenanlage durchgeführt, die durch Beschädigungen durch Schneelast erforderlich geworden waren. In der Schlosserei wird ein Metallbauer, Fachrichtung Konstruktionstechnik, ausgebildet.

Ausbildung

Im Institut wurden 2002 und 2003 bis zu 28 Lehrlinge ausgebildet. Der Schwerpunkt lag bei den Industriemechanikern (Fachrichtung Geräte- und Feinwerktechnik) und den Industrieelektronikern (Fachrichtung Gerätetechnik). Für diese beiden Berufe bestehen Lehrwerkstätten, für die jeweils ein Meister zuständig ist. Weitere Ausbildungsberufe waren: Metallbauer (Fachrichtung Konstruktionstechnik), Elektroinstallateur, Fachinformatiker (Fachrichtung Systemintegration) und Kauffrau für Bürokommunikation. Außerdem haben 32 Schülerpraktikanten und 18 Hochschulpraktikanten, drei Umschüler und ein Meister für Abiturienten (Northeimer Modell) in den einzelnen Werkstätten und der Rechenanlage ein Praktikum absolviert. In der Elektro-Lehrwerkstatt, in der 8 Ausbildungsplätze zur Verfügung stehen, werden innerhalb der 3,5-jährigen Ausbildungszeit praktische und theoretische Kenntnisse vermittelt.

Im Einzelnen sind das bei Beginn der Ausbildung einfache Verdrahtungen, Herstellen von Lötverbindungen, Überprüfen und Dokumentieren von Kennwerten elektronischer Bauelemente. Später werden auch Platinen mit SMD-Bauteilen bestückt und getestet.

Der Umgang mit dem PC ist ebenso selbstverständlich wie die Anwendung moderner Software zum Programmieren der Computerbausteine und die Herstellung der Platinenlayouts.

Einen weiteren Schwerpunkt stellt die Stromversorgung dar, wobei die Energie aus dem öffentlichen Netz aufbereitet werden muss, da Gleichstrom mit niedrigeren Spannungen zum Betreiben der elektronischen Komponenten benötigt wird. Viele dieser Aufgaben stellen sich oft in Verbindung mit den im Hause laufenden Projekten, so dass auch hier eine gewisse Abwechslung in den einzelnen Aufgabenstellungen eintritt und somit auch neue Techniken in die Ausbildung einfließen können. Als Beispiel für eine projektbezogende Aufgabe soll hier die Erzeugung einer hohen Wechselspannung zum Betrieb einer Ionenfalle in einem Massenspektrometer stehen (Abb. 121). Erzeugt wird eine hochfrequente Wechselspannung zwischen 400 – 500 Vss aus einer Gleichspannung von 12 V mit gutem Wirkungsgrad.

Die Ausgangsspannung ist sinusförmig und wird mit den Lastkapazitäten auf eine Resonanzfrequenz von 500 kHz abgestimmt. Ein geschlossener Regelkreis regelt mit einem P-I-Regler, der seinen Sollwert vom Analogausgang eines MC erhält, den Amplitudenwert der Ausgangsspannung.

In der Feinmechanik-Lehrwerkstatt (Abb. 122) werden neben den Grundfertigkeiten entsprechend dem Berufsbild intensiv Grundkenntnisse über das Programmieren von CNC-Fräs- und Drehmaschinen sowie den Aufbau von Pneumatikschaltungen durch ausreichende Unterweisung, Werkmaterial sowie Zwischenarbeiten und Zwischenprüfungen vermittelt.

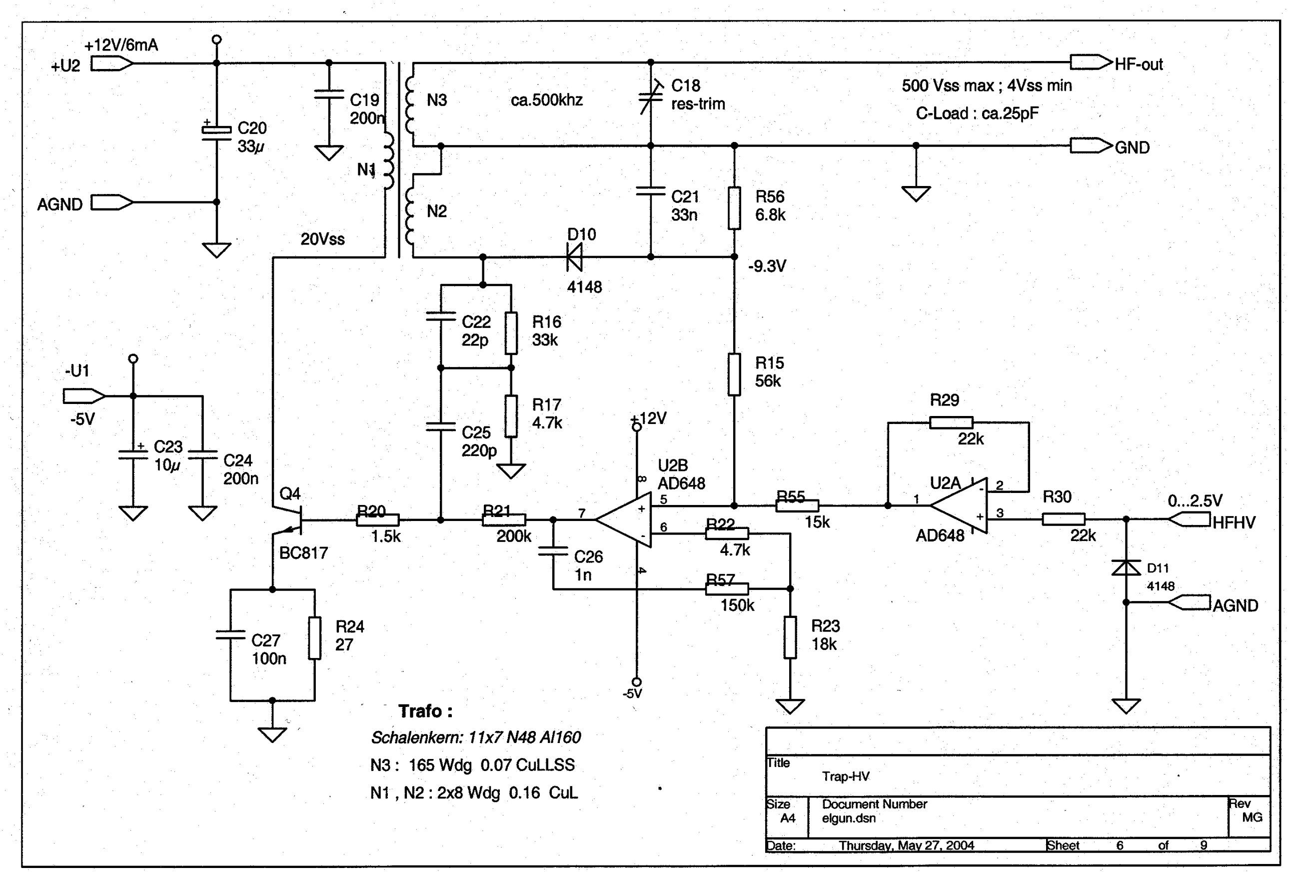

Abb. 121: Hochspannungs-HF-Versorgung für Ionenfalle / *High voltage HF power supply for iontrap*

Abb. 122: Feinmechanik Lehrwerkstatt / Precision mechanics training centre

Das 3. und 4. Lehrjahr wird je nach Kenntnisstand auch für Arbeiten der im Haus laufenden Projekte herangezogen. Hierbei waren hauptsächlich Einzelteilfertigungen für die Projekte Rosetta Lander, STEREO, HIFI, SIR und VMC durchzuführen.

Vor der Industrie- und Handelskammer haben folgende Mitarbeiter ihre Facharbeiterprüfung erfolgreich bestanden:

Industrieelektroniker: Torben Hillebrand, Daniel Hoffmann, Thomas Kerl, Henning Lohrengel, Dennis Weber

Industriemechaniker: David Enge, Marcel Gruschka, Sebastian Kliemann, Artur Mass, Christian Rust

Kauffrau für Bürokommunikation: Martina Schlemme, Nadine Teichmann

Haustechnik

In den vergangenen Jahren lagen die Schwerpunkte der Haustechnik in der Sanierung der Heizung und Erneuerung der Sanitär- und Elektroinstallation.
Alle Gebäude sind nun mit neuen Heizkörpern und einer neuen Steuerungs- und Regeltechnik ausgestattet. Eine neue, von der Haustechnik installierte Gebäudeleittechnik ermöglicht eine zentrale Überwachung und Regelung der Heizkreise und Lüftungsanlagen.
Die Mittel- und Niederspannungsverteilungen wurden durch neue Anlagen ersetzt und in die Gebäudeleittechnik eingebunden.
Der Hörsaal wurde rundum erneuert. Die Lüftung ist nun temperaturgeregelt und die Beleuchtung

kann auf verschiedene, den Erfordernissen angepasste Lichtzonen geschaltet werden. Eine komplett neue Audio- und Videotechnik ermöglicht jetzt auch Übertragungen aus dem Hörsaal in den Dieminger-Raum. Ein Ausbau für Videokonferenzschaltungen ist vorgesehen. Eine neue Bestuhlung und eine Erneuerung des Fußbodens und der Decke geben dem Hörsaal ein neues Aussehen (Abb. 123).

Abb. 123: Hörsaal / *Lecture room*

Ein weiterer Schwerpunkt lag in dem Neubau eines Kalibrationsraumes und des TV-Testraums in der Kranhalle. Der Kalibrationsraum wurde im Laborkeller gebaut. Die Besonderheit ist ein fast schwingungsfreier Boden, der optische Messungen ermöglicht. Dies wurde durch eine Betonplatte von 20 cm Stärke erreicht. Der Testraum und der Kalibrationsraum erfüllen die Reinraumanforderung der Klasse 100.000. Erreicht wurde dies durch den Einbau einer Lüftungsanlage mit den entsprechenden Filtern (Abb. 124). Ein Aktivkohlefilter im Kalibrationsraum soll bei Messungen mit der Ulbrichtkugel entstehende Ozongase ausfiltern .

Zusätzlich eingebaute Clean-Zelte in den beiden Räumen sorgen für Reinraum Klasse 100 zum Einbauen der Exponate in die Messkammern.

Die Eingangshalle bekam nach der Installation einer Brandschutzdecke ein neues Aussehen. Die gesamte Elektro- und Sanitärinstallation wurde dabei erneuert. Am Laborgebäude wurde die erforderliche Betonsanierung durchgeführt, die Fahrzeughalle bekam neue elektrisch betriebene Tore. Diese Maßnahmen verbesserten auch die Außenansicht des Instituts und sollen in den nächsten Jahren fortgesetzt werden.

Außerdem wurden die WC-Anlagen in allen Gebäuden und in der Kantine erneuert, wobei im Zuge der Erneuerung hier auch ein Behinderten-WC installiert werden konnte.

Den Mitarbeitern aus den Fachbereichen Elektro – Heizung/Sanitär, dem Tischler, Gärtner, Maler, Reinigungspersonal und Hausmeister gelang es, bei den haustechnischen Anlagen durch gute Wartungs- und Instandhaltungsarbeiten einen störungsfreien Betrieb zu gewährleisten.

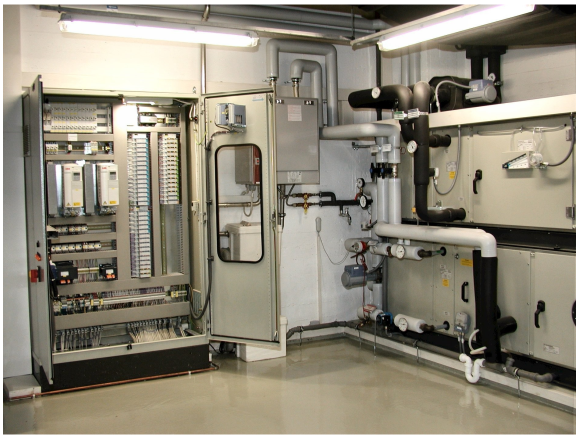

Abb. 124: Kontrollzentrum für Lüftungsanlage des Kalibrationsraumes / *Control centre ventilation system at calibration facility*

VI. **Personelle Gliederung/**Personnel

Kollegium, wissenschaftliche Mitglieder/Board of directors, scientific members

Prof. Dr. Ulrich R. Christensen
Dr. Helmut Rosenbauer
Prof. Dr. Sami K. Solanki
(Geschäftsführender Direktor/Managing director)
Prof. Dr. Vytenis M. Vasyliūnas

Emeritierte wissenschaftliche Mitglieder/Emeritus scientific members:
Prof. Sir Ian Axford, FRS
Prof. Dr. Tor Hagfors

Auswärtige wissenschaftliche Mitglieder/External scientific members:
Prof. Dr. Jules A. Fejer, University of California, La Jolla
(† 23.12.2002)
Prof. Dr. Albert A. Galeev, Moskau
Prof. Dr. Johannes Geiss, Universität Bern
Prof. Dr. Karl-Heinz Glaßmeier, Technische Universität Braunschweig
Prof. Dr. Erwin Schopper, Bad Soden

Technischer Geschäftsführer/Technical Manager: Dr. Iancu Pardowitz (seit 01.07.2003)
Geschäftsführer/Manager: Dr. Peter Czechowsky (bis 30.06.2003)

Wissenschaftliche und wissenschaftlich-technische Mitarbeiter/Scientific staff

Dr. Julien Aubert
Andreas Barth
Dr. Peter Barthol
Dipl.-Ing. Lothar Bemmann
Dipl.-Ing. Hartmut Bitterlich
Dr. Thomas Blümchen
Dipl.-Phys. Peter Börner
Dr. Reinhard Borchers
Dr. Volker Bothmer
Dr. habil. Jörg Büchner
Dr. Werner Curdt
Dr. Patrick W. Daly
Dipl.-Math. Ingolf Dammasch
Dr. Markus Fränz
Dr. Achim Gandorfer
Dr. Romain Garmier
Dr. Fred Goesmann
Dr. Björn Grieger
Dr. Paul Hartogh
Dipl.-Phys. Hermann Hartwig
Dr. Istvan Hejja
Dr. Martin Hilchenbach
Dr. Nico Hoekzema
Dr. Stubbe Hviid
Dr. Bernd Inhester
Prof. Dr. Wing-Huen Ip
Dr. Christopher Jarchow
Prof. Dr. Klaus Jockers
Dr. Michael Jordan
Dr. habil. Horst Uwe Keller
Dr. Georg Kettmann
Dr. Jochen Kissel
Dr. Jürgen Klostermeyer
Dr. Andreas Kopp
Dr. Axel Korth
Dr. Jörg-Rainer Kramm
Dr. Natalie Krivova
Dr. Norbert Krupp
Dr. Michael Küppers
Dr. Carsten Kutzner
Dr. Andreas Lagg
Dr. Stefano Livi
Dr. Urs Mall
Dr. Wojcieck Markiewicz
Dr. Davina Markiewicz-Innes
Prof. Dr. Eckart Marsch
Prof. Dr. James F. McKenzie
Dr. Claudia-Veronika Meister

Dipl.-Math. Helmut Michels
Dr. Andreas Nathues
Dr. Erling Nielsen
Dr. Bernd Nikutowski
Robert Olejniczak
Dr. Iancu Pardowitz
Dipl.-Ing. Borut Podlipnik
Dr. Fabrice Portier-Fozzani
Dr. Michael Richards
Dr. Arne K. Richter
Dr. Michael Rietveld
Dr. habil. Jürgen Röttger
Dr. Reinhard Roll
Dr. Jon Rotvig
Prof. Dr. Konrad Sauer
Prof. Dr. Kristian Schlegel
Dr. Dieter Schmitt
Dr. Udo Schühle
Prof. Dr. Manfred Schüssler
Prof. Dr. Rainer Schwenn
Dipl.-Phys. Ilse Sebastian
Dr. Joachim Segschneider
Dr. Holger Sierks
Dipl.-Ing. Li Song
Dr. Axel Steinhof
Dr. Dietrich Stratmann
Prof. Dr. Peter Stubbe
Dipl.-Ing. Istvan Szemerey
Dr. Nicolas Thomas
Dr. Hellmuth Timpl
Dr. Dmitri Titov
Dipl.-Ing. Georg Tomasch
Dr. Stefan Werner
Dr. Johannes Wicht
Dr. Thomas Wiegelmann
Dr. Klaus Wilhelm
Dr. Manfred Witte
Dr. Bernd Wöbke
Dr. Joachim Woch
Dr. Ursula Wüllner

Abteilung EDV/Computing department (Leitung/Management: Dr. Iancu Pardowitz)

Andreas Blome
Bernhard Brauner
Michael Bruns
Peter Fahlbusch
Lothar Graf
Terrance Ho
Dr. Georg Kettmann
Christine Ludwieg
Helmut Michels
Godehard Monecke
Adolf Piepenbrink
Jürgen Wallbrecht
Bernhard Wand

Auszubildender/Apprentice: Alexander Forsch

Laboratorien/Laboratories (Leitung/Management: Dr. Iancu Pardowitz, Helmut Zapf (bis 16.05.2003)
Sekretariat/Secretariat: Christiane Heise

Günther Auckthun
(abgeordnet vom MPI für Strömungsforschung)
Walter Böker
Waltherus Boogaerts
Dipl.-Ing. Irene Büttner
Eberhard-Michael Clement
Dipl.-Ing. Arne Dannenberg
Dipl.-Ing. Werner Deutsch
(abgeordnet vom MPI für Strömungsforschung)
Dipl.-Ing. Rainer Enge
Klaus-Dieter Eulig
Andreas Fischer
Dipl.-Ing. Henning Fischer
Dipl.-Ing. Dietmar Germerott
Klaus-Dieter Gräbig
Dipl.-Ing. Klaus Heerlein
Peter Hemmerich
Hendrick Jakob
Heinz Günter Kellner
Oliver Küchemann
Wolfgang Kühn
(abgeordnet vom MPI für Strömungsforschung)
Wolfgang Kühne
Dipl.-Ing. Alexander Loose
Olaf Matuschek
Dipl.-Ing. Reinhard Meller
Markus Monecke
Dipl.-Ing. Reinhard Müller
Wolfgang Neumann
Jürgen Nitsch

Dipl.-Ing. Henry Perplies
Dipl.-Ing. Borut Podlipnik
Klaus-Dieter Preschel
Waltraut Reich
Dipl.-Phys. Tino Riethmüller
Dipl.-Ing. Claudius Römer
Rolf Schäfer
Helmut Schild
Gustav-Adolf Schlemm
Dipl.-Ing. Jan Carsten Schröder
Helmut Schüddekopf
Dipl.-Ing. Hartmut Sommer
Michael Sperling
Dipl.-Ing. Eckhard Steinmetz
Ulrich Strohmeyer
Markus Thiele
Dipl.-Ing. Jörg Trautner
Thomas Tzscheetzsch
Daniel Windler
Wolfgang Wunderlich

Werkstätten, Haustechnik, Ausbildung:/Workshops, physical plant, training

Leitung: Dipl.-Ing. Volker Thiel
Stellvertreter Werkstatt: Egon Pinnecke
Stellvertreter Haustechnik: Horst Heise
Stellvertreter Ausbildung: Roland Mende
Sekretariat: Beatrix Hartung

Werkstatt/Workshops:

Feinmechanik:	Hermann Arnemann, Hans-Joachim Gebhardt, Ernst-Reinhold Heinrichs, Dietmar Hennecke, Detlef Jünemann, Roland Mende, Norbert Meyer, Thorsten Meyer, Egon Pinnecke, Werner Steinberg
Schlosserei:	Hans-Joachim Heinemeier
Galvanik:	Hans-Adolf Heinrichs, Walter Wächter
Siebdruck/Laser:	Joachim Weiß, Mathias Schwarz (abgeordnet vom MPI für Strömungsforschung)

Haustechnik/Physical plant:

Elektro:	Horst Heise, Michael Hilz, Peter Mutio, Mario Reich, Mario Strecker
Heizung-Sanitär:	Karl-Heinrich Deisel, Herbert Ellendorff, Werner Hundertmark
Tischlerei:	Helge Aue, Martin Heinrich
Gärtner:	Martin Schröter, Hans-Dieter Waitz
Reinigung:	Ilona Brandt, Monika Doucet-Hitscher, Oxana Dunkel, Cornelia Fahlbusch, Sinaida Großkopf, Jennifer Hagemann, Nana Heine, Ilona Hisgen, Astrid Karl, Monika Link, Anna Macke, Gudrun Müller, Maria Müller, Birgit Podritzki, Rosemarie Poppe, Lucia Ristau, Claudia Rudolph, Edeltraud Rümke, Margarete Schmidt, Maria Schmidt, Danuta Waßmann, Heidemarie Weber, Irmtraut Wolf
Küche:	Johannes Kohlrautz, Sylvia Aue, Marlis Borghold, Lilli Dargel, Beate Meyer

Ausbildung/Training of apprentices:

Feinmechanik: Roland Mende

Elektrotechnik: Manfred Güll

Auszubildende: Christian Biermann, André Bode, Robert Burkhardt, Albert Dargel, David Enge, Fabian Ernst, Julian Fellmann, Matthias Franke, Simon Geile, Marcel Gruschka, Gregor Hadasch, Philipp Haut, Marius Hellmold, Martin Hildebrand, Torben Hillebrand, Daniel Hoffmann, Stephan Kellner, Thomas Kerl, Arno Kiefert, Oliver Kliemand, Sebastian Kliemand, Martin Koch, Alexander Kornehl, Till Kremser, Sven Krenauer, Henning Lohrengel, Artur Mass, Fabian Maulhardt, Christian Menge, Fiete Paul Mieglitz, Sebastian Neumann, Sebastian Poppe, Christoph Ressel, Christian Risch, Christian Rust, Alexander Schmidt, Jan Wagner, Alex Weber, Dennis Weber, Marius Wittkowski, Christian Zinke.

Dokumentation, Konstruktion/Documentation, mechanical design:
Leitung: Bernd Chares (seit 01.10.2003), Wolfgang Engelhardt (bis 30.09.2003)
Anita Brandt, Bernhard Goll, Angelika Hilz, Marianne Krause, Jürgen Wedekind, Mona Wedemeier

Bibliothek/Library: Prof. Dr. Klaus Jockers (wissenschaftlicher Bibliotheksbeauftragter)
Inge Kraeter, Renate Meusel

Öffentlichkeitsarbeit/Public relations:
Dr. Norbert Krupp, Prof. Dr. Kristian Schlegel (bis 31.05.2002), Dr. Bernd Wöbke

Redaktion der Instituts-Informationen/Editor of the institute newsletter:
Dr. Reinhard Borchers

Direktionssekretärinnen/Secretaries of the directors:
Sabine Deutsch, Susanne Kaufmann, Karin Peschke, Rosemarie Röttger, Barbara Wieser

Sekretärinnen/Secretaries: Anja Behrens, Gerlinde Bierwirth, Marianne Ebbighausen, Marita Eickemeier, Petra Fahlbusch, Elke Hartmann, Karin Kellner, Helga Oberländer, Helga Reuter, Ingrid Schrader, Sibylla Siebert-Rust, Ute Spilker, Margit Steinmetz, Sabine Stelzer, Andrea Vogt

Verwaltung/ Administration: Andreas Poprawa (Verwaltungsleiter)
Andrea Macke, Bernhard Bleckert, Jürgen Bethe, Roswitha Komossa, Dorothee Schreiber

Auszubildende/Apprentices: Nadine Senger, Martina Schlemme (bis 31.08.2002), Jennifer Eckert (bis 31.10.2003)

Personalbüro/Personell office: Edith Deisel, Christiane Neu

Einkauf/Goods received: Klaus-Dieter Hagen, Monika Majunke, Ilse Schwarz, Christina Thomitzek, Bernhard Vogt, Martina Schlemme (bis 31.03.2003)

Buchhaltung/Book-keeping: Martina Heinemeier, Nadine Teichmann, Andrea Werner

Sonstige Dienste/Other services: Renate Heitkamp, Inge Reuter, Robert Uhde

Doktoranden/Ph.D. students

Doktoranden, die in den Jahren 2002 und 2003 im MPAe tätig gewesen sind; Hochschule, Betreuer an der Hochschule und am MPAe, Beginn und Thema der Arbeit in Klammern./
Ph.D. students at MPAe in 2002 and 2003; Highschool, supervisor at highschool and at MPAe, start and title of thesis in brackets.

Dipl.-Phys. *Ingo Jens Baumann* (Universität Göttingen, Göttingen Graduate School of Physics, Prof. Dr. F. Kneer – Prof. Dr. S. K. Solanki, Prof. Dr. M. Schüssler; 1. März 2002. Simulation of magnetic flux transport on the Sun).

Dipl.-Phys. *Juan Manuel Borrero-Santiago* (Universität Göttingen, Göttingen Graduate School of Physics, Prof. Dr. F. Kneer – Prof. Dr. S. K. Solanki; 3. September 2001. Inversion of the Stokes profile).

Dipl.-Phys. *Monika Buske* (Universität Göttingen, Prof. Dr. F. Kneer – Prof. Dr. U. R. Christensen; 1. Februar 2003. Evolution models of the Martian interior).

Dipl.-Phys. *Chung Ming Mark Cheung* (Universität Göttingen, Göttingen Graduate School of Physics, Prof. Dr. F. Kneer – Prof. Dr. M. Schüssler; 1. März 2003. Numerical simulation of magnetoconvection).

Dipl.-Ing. *Che-yi Chuang* (National Chiao Tuang Universität Taiwan – Dr. P. Hartogh; 8. Mai 2003. Development of space applicable, tunable IF preprocessor system for a subharmonical pumped 550 GHz double sideband Schottky receiver system).

Dipl.-Phys. *Kerstin Cierpka* (Universität Göttingen, Institut für Geophysik, Prof. Dr. U. R. Christensen – Prof. Dr. K. Schlegel; 20. März 1999. Auswertung und Interpretation von Fabry-Perot- und EISCAT-Daten).

Dipl.-Ing. *Maria Hebe Cremades Fernandez* (TU Braunschweig, Prof. Dr. K.-H. Glaßmeier – Dr. V. Bothmer, Prof. Dr. R. Schwenn; 15. Februar 2002. Magnetic field configurations in coronal mass ejections).

Dipl.-Phys. *Yevgen Grynko* (Universität Göttingen, Göttingen Graduate School of Physics – Prof. Dr. K. Jockers; 1. Februar 2002. Reflection of light from atmosphereless solar system bodies and from cometary dust).

Dipl.-Phys. *Michael Heuer* (Universität Göttingen, Prof. Dr. F. Kneer – Prof. Dr. E. Marsch; 1. April 2001. Kinetic plasma processes and wave-particle interactions of ions and electrons in the solar corona and solar wind – Theoretical investigations and data analysis of Helios observations).

Dipl.-Phys. *Tra-Mi Ho* (Universität Göttingen, Prof. Dr. F. Kneer - Dr. N. Thomas, Prof. K. Jockers; 1. Februar 2001 bis 31. März 2003. Data analysis and model calculations of cometary comae).

Dipl.-Phys. *Volkmar Holzwarth* (Universität Göttingen, Prof. Dr. K. Beuermann – Prof. Dr. M. Schüssler; 1. November 1999. Dynamik magnetischer Flussröhren in Riesensternen und engen Doppelsternen).

Dipl.-Phys. *Dilip Kumar Jana* (Universität Göttingen, Göttingen Graduate School of Physics – Prof. Dr. S. K. Solanki; 9. Februar 2002 bis 31. Januar 2003. Properties of solar photospheric magnetic features).

Dipl.-Phys. *Carsten Köllein* (Universität Göttingen, Göttingen Graduate School of Physics – Dr. N. Thomas; 1. April 2002. Numerical simulations of the structure of cometary nuclei).

Dipl.-Phys. *Fedor M. Kolesnikov* (Universität Göttingen, Göttingen Graduate School of Physics, Prof. Dr. F. Kneer – Prof. Dr. M. Schüssler; 1. Februar 2002. Vortex flows around magnetic flux tubes).

Dipl.-Phys. *Maxim Kramar* (Universität Göttingen, Prof. Dr. A. Tilgner – Dr. Inhester; 1. Februar 2002. Tomography of coronal magnetic field).

Dipl.-Phys. *Elena Kronberg* (TU Braunschweig, Prof. Dr. K.-H. Glaßmeier – Dr. J. Woch, Dr. N. Krupp; 1. Januar 2003. Dynamical processes in Jupiter's magnetosphere).

Dipl.-Phys. *Carsten Kutzner* (Universität Göttingen, Prof. Dr. U. Christensen – Prof. Dr. U. Christensen; 1. April 2003 bis 31. Juli 2003. Numerische Dynamo-Simulation).

Dipl.-Phys. *Rupali Mahajan* (Universität Göttingen; Prof. Dr. A. Tilgner – Dr. B. Grieger, Dr. H. U. Keller; 1. Mai 2002. Investigation of the current and ancient Martian climate, its stability and mechanisms of changes by means of a modular planet simulator model).

Dipl.- Phys. *Marilena Mierla* (Universität Göttingen, Prof. Dr. F. Kneer – Prof. Dr. R. Schwenn, 1. Februar 2002. Dynamics of the solar corona).

Dipl.-Phys. *Guadalupe Munoz Martinez* (Universität Göttingen, Göttingen Graduate School of Physics, Prof. Dr. F. Kneer – Prof. Dr. R. Schwenn; Coronal mass ejection acceleration, statistical and analytical evaluations).

Dipl.- Phys. *Ganna Portyankina* (Universität Göttingen, Göttingen Graduate School of Physics – Dr. W. Markiewicz, Dr. H. U. Keller; 1. Februar 2002. Atmosphere - surface vapour exchange and ices in the Martian polar regions).

Dipl.-Phys. *Oliver Preuß* (Universität Bielefeld, Prof. Dr. B. Peterson – Prof. Dr. S.K. Solanki; 1. Dezember 1999 bis 30. November 2003. Astronomische Tests von Gravitationstheorien).

Dipl.-Phys. *Sabine Preusse* (Universität Clausthal-Zellerfeld, Prof. Dr. U. Motschmann – Dr. J. Büchner; 1. November 2002. Computer modeling of plasma interactions in extrasolar planetary sytems).

Dipl.-Phys. *Aikaterini Radioti* (TU Braunschweig, Prof. Dr. K.-H. Glaßmeier – Dr. N. Krupp, Dr. J. Woch; 23. Januar 2003. Plasma composition in the magnetosphere of Jupiter).

Dipl.-Ing. *Luciano Rodriguez Romboli* (TU Braunschweig, Prof. Dr. K.-H. Glaßmeier – Dr. N. Krupp, Dr. J. Woch; 15. April 2002. Study of interplanetary coronal mass ejection seen by Ulysses).

Dipl.-Ing. *Ryu Saito* (– Dr. Hartogh; 1. April 2003. Development of a general circulation model for Titan's atmosphere).

Dipl.-Phys. *Santo Valentin Salinas Cortijo* (Universität Göttingen, Prof. Dr. F. Kneer – Dr. H. U. Keller, 27. April 2000 bis 26. April 2003. Multidimensional radiative transfer modelling of Titan's atmosphere).

Dipl.-Phys. *Martin Schrinner* (Universität Göttingen, Göttingen Graduate School of Physics, Prof. Dr. A. Tilgner – Prof. Dr. U. R. Christensen, Dr. D. Schmitt; 1. März 2002. Modeling of the geodynamo).

Dipl.-Phys. *Andrey D. Seleznyov* (Universität Göttingen, Göttingen Graduate School of Physics, Prof. Dr. F. Kneer – Prof. Dr. S.K. Solanki; 1. Februar 2002. The origin of solar variability, with an application to the search for extra-solar planets).

Dipl.-Phys. *Alina Semenova* (Universität Göttingen, Göttingen Graduate School of Physics, Prof. Dr. S. Dreizler – Prof. Dr. S.K. Solanki; 1. März 2003. Solar and stellar magnetic fields).

Dipl.-Phys. *Sergiy Shelyag* (Universität Göttingen, Göttingen Graduate School of Physics, Prof. Dr. F. Kneer – Prof. Dr. S.K. Solanki, Prof. Dr. M. Schüssler; 1. August 2001. Simulation of solar magnetoconvection and their interpretation).

Dipl.-Phys. *Ilya Silin* (Technische Universität Braunschweig, Prof. Dr. U. Motschmann – Dr. J. Büchner; 1. Oktober 2001 bis 30. September 2003. Theory and simulation of kinetic plasma instabilities).

Dipl.-Phys. *Ana Teresa Monteiro Tomas* (Technische Universität Braunschweig, Prof. Dr. K.-H. Glaßmeier – Dr. N. Krupp, Dr. J. Woch; 1. Februar 2002. Planetary Magnetospheres – Jupiter).

Dipl.-Phys. *Denise Tortorella* (Universität Göttingen, Göttingen Graduate School of Physics – Prof. Dr. U. R. Christensen; 1. Oktober 2001. Compressible convection in gas giant planets).

Dipl.-Phys. *Durgesh Tripathi* (Universität Göttingen; Prof. Dr. F. Kneer – Dr. V. Bothmer; 1. Februar 2002. Analysis of SOHO EUV coronographic observations of CME's - Development of stereoscopic image processing methods for the STEREO mission).

Dipl.-Ing. *Geronimo Villanueva* (Universität Clausthal-Zellerfeld, Prof. Dr. L. Reindel – Dr. P. Hartogh; 17. März 2001. High-resolution spectrometer for SOFIA).

Dipl.-Phys. *Alexander Vögler* (Universität Göttingen, Prof. Dr. F. Kneer – Prof. Dr. M. Schüssler; 1. Februar 2000. 3D-Simulation von solarer Magnetokonvektion).

Dipl.-Phys. *Peter Vollmöller* (Universität Göttingen, Prof. Dr. F. Kneer – Prof. Dr. M. Schüssler; 1. Februar 2000 bis 30. September 2002. Konvektion und Magnetfelder in der Photosphäre der Sonne).

Dipl.-Phys. *Lidong Xia* (Universität Göttingen, Prof. Dr. F. Kneer – Prof. Dr. E. Marsch; 1. Oktober 1999 bis 31. September 2002. MHD and particle processes for the acceleration of the solar wind by observations of SUMER/SOHO).

Dipl.-Phys. *Vasily Zakharov* (Universität Göttingen, Göttingen Graduate School of Physics – Prof. Dr. S.K. Solanki; 1. Januar 2003. Investigation of phase diversity methods for the SUNRISE project).

VII. Wissenschaftliche Zusammenarbeit/ Scientific Collaboration

Wissenschaftler, die als Gäste längere Zeit am MPAE tätig waren/ Scientific guests with long-term visits to MPAE

(Stipendiaten der MPG, des DAAD, der DFG, der Alexander von Humboldt-Stiftung/Friedrich-Wilhelm-Bessel-Preisträger, Postdocs und Honorarempfänger/ Stipend holders of the MPG, the DAAD, the DFG, the Alexander von Humboldt Foundation/Friedrich Wilhelm Bessel Research Award and Postdocs)

Dr. Julien Aubert, Institut für Geophysik der Universität Göttingen, Göttingen, 1. April 2003. Investigation of mechanisms in dynamo modelling, with planetary applications. Zusammenarbeit mit Prof. U. Christensen.

Dr. Regina Aznar Cuadrado, Osservatorio Astronomico di Capodimonte, Neapel, Italien, Postdoc, 1. Juni 2003 – 31. Dezember 2004. Magnetic fields of white dwarfs. Zusammenarbeit mit Prof. S.K. Solanki.

Dr. Tanyu Bonev, Institute of Astronomy, Bulgarian Academy of Sciences, Sofia, Bulgarien, 2. Juni – 31. Juli 2002, 3. September – 31. Dezember 2002, 1. April – 30. Juni 2003 und 15. September – 15. Dezember 2003. Farbe des Staubes von Komet C/1999 S4 (LINEAR). Zusammenarbeit mit Prof. K. Jockers.

Dr. Tamara K. Breus, Space Research Institute, Academy of Sciences, Moskau, Russland, 20. Mai – 1. Juli 2002. Zusammenarbeit mit Prof. W.I. Axford.

Dr. Robert Cameron, Uchida Laboratory, Science University of Tokyo, Japan, Postdoc, 15. März 2003. Zusammenarbeit mit Prof. M. Schüssler.

Dr. Andrzej Czechowski, Space Research Center, Polish Academy of Sciences, Warschau, Polen, 2. Juni – 31. Juli 2002. Solar wind modeling. Zusammenarbeit mit Prof. J.F. McKenzie.

Prof. T.B. Doyle, School of Pure and Applied Physics, University of Natal, Durban, Südafrika, 11. Juli – 30. August 2002. Multi-ion plasmas (solar wind, Mars, Venus). Zusammenarbeit mit Prof. J.F. McKenzie.

Prof. Ibrahim Eltayeb, Department of Mathematics and Statistics, Sultan Qaboos University, Muscat, Sultanat Oman, 15. Juli – 15. August 2002. Solar atmosphere. Zusammenarbeit mit Prof. J.F. McKenzie.

Dr. Francisco Frutos-Alfaro, Universidad de Costa Rica, Escuela de Fisica, San Pedro, Costa Rica, 15. März 2000 – 14. September 2002. Auswertung und Interpretation von Cluster-CIS Daten. Zusammenarbeit mit Dr. A. Korth.

Dr. Romain Garmier, Observatoire Midi–Pyrénées, Toulouse, Frankreich, 3. April 2002. Forschungsarbeiten Projekt MARSIS. Zusammenarbeit mit Prof. T. Hagfors.

Dr. *Istvan Hejja*, KFKI–AEKI, Budapest, Ungarn, 1. Oktober 2001 – 31. Mai 2003. Untersuchungen zur Spannungsversorgung des Massenspektrometers im Rahmen des Projekts COSAC. Zusammenarbeit mit Dr. H.U. Keller.

Dr. Nikolaj N. Karpov, International Center for Astronomical and Medico-Ecological Research, Kiew, Ukraine, 15. März 2003 – 15. Mai 2003. Arbeiten am Zweikanal-Fokalreduktor. Zusammenarbeit mit Prof. K. Jockers.

Prof. Dr. Zerefsan Kaymaz, Istanbul Technical University, Faculty of Aeronautics and Astronautics, Istanbul, Türkei, Stipendiatin der Alexander von Humboldt-Stiftung. 6. Juli 2002 – 29. Juni 2003. Zusammenarbeit mit Prof. V.M. Vasyliūnas.

Dr. Christoph Keller, National Solar Observatory, Tucson, AZ/USA, Friedrich-Wilhelm-Bessel-Preisträger der A.v.Humboldt-Stiftung, September 2003 – Mai 2004. Zusammenarbeit mit Prof. M. Schüssler und Prof. S.K. Solanki.

Dr. Nikolaj N. Kiselev, Astronomical Observatory, Kharkiv State University, Kharkiv, Ukraine, 11. April – 10. Juli 2002. Interpretation von Polarisationsmessungen von Kometenstaub. Zusammenarbeit mit Prof. K. Jockers.

Dr. Natalie Krivova, Astronomical Institute, St. Petersburg University, St. Petersburg, Russland,

1. August 1999 – 31. Juli 2002. Zusammenarbeit mit Dr. P. Hartogh, Dr. I. Mann und Prof. S.K. Solanki.

Dr. Carsten Kutzner, Institut für Geophysik der Universität Göttingen, Göttingen, 1. August 2003 – 31. Oktober 2003. Numerische Dynamo-Simulation. Zusammenarbeit mit Prof. U. Christensen.

Dr. Shibu K. Mathew, Indian Institute of Astrophysics, Bangalore, Indien, Postdoc, 1. September 2000 – 31. August 2003. Solar optical instrumentation. Zusammenarbeit mit Prof. R. Schwenn, Dr. U. Schühle und Prof. S.K. Solanki.

Dr. Zongjun Ning, Fudan University, Shanghai, VR China, Postdoc, 20. April 2002 – 31. Dezember 2003. Zusammenarbeit mit Prof. S.K. Solanki und Dr. D. Markiewicz-Innes.

Dr. K. Nykiri, Imperial College, London, UK, Januar 2002. Zusammenarbeit mit Dr. J. Büchner.

Prof. A. Otto, University of Alaska, Fairbanks, 27. März – 29. April 2002 und 16. März – 5. April 2003. Zusammenarbeit mit Dr. J. Büchner.

E. Panov, Institute for Space Research, Moscow, Russia, 10. September – 20. Dezember 2003. Zusammenarbeit mit Dr. J. Büchner.

Dr. Elena V. Petrova, Space Research Institute, Russian Academy of Sciences, Moskau, Russland, 15. Januar – 14. April 2002 und 12. Januar – 12. April 2003. DFG-Projekt zum Thema „Regolith on atmosphereless bodies of the solar system“. Zusammenarbeit mit Prof. K. Jockers.

Dr. Olena Podladchikova, National Kiev Polytechnique Institute, Electronic Faculty, Kiew, Ukraine, 16. August – 16. Dezember 2002 und 1. Februar – 31. Mai 2003. Statistical analysis of solar data by SVP and modelling of coronal heating by reconnection. Zusammenarbeit mit Dr. J. Büchner.

Dr. Fabrice Portier-Fozzani, Laboratoire d’Astronomie Spatiale (LAS), Marseille, Frankreich, Postdoc (DLR), 15. September 2000 – 15. September 2003. Stereoskopie. Zusammenarbeit mit Prof. R. Schwenn und Dr. B. Inhester.

Dr. Oliver Preuss, Universität Bielefeld, Postdoc, 1. Dezember 2002 – 30. November 2003. Constraints on gravity-induced birefringence in nonsymmetric gravitational theories by polarisation measurements of sprectral lines. Zusammenarbeit mit Prof. S.K. Solanki.

Dr. Nour-Eddine Raouafi, Observatorio Astronomico di Torino, Turin, Italien, Postdoc, 8. Januar 2002 – 31. Dezember 2004. Solare Polarimetrie. Zusammenarbeit mit Prof. S.K. Solanki.

Dr. Zongquan Qu, Yunnan Astronomical Observatory, Chinese Academy of Sciences, Kunming, VR China, 6. September 2002 – 19. November 2002. Infrared Stokes polarimetry of solar photospheric an chromospheric magnetic field. Zusammenarbeit mit Prof. S.K. Solanki.

Dr. Romana Ratkiewicz, Space Research Center, Polish Academy of Sciences, Warschau, Polen, 3. Juni – 31. August 2002. Solar wind. Zusammenarbeit mit Prof. J.F. McKenzie.

Dr. Santo Valentin Salinas Cortijo, National University of Singapore, Faculty of Science, 1. Juli 2003 – 31. August 2003. Multidimensional radiative transfer modelling of Titan’s atmosphere. Zusammenarbeit mit Dr. H.U. Keller.

Laurent Stehly, Ecole Normale Superieure de Lyon, ENS Lyon, Frankreich, 2. Mai – 20. August 2003. Simulation of dynamos with small inner cores. Zusammenarbeit mit Prof. U. Christensen.

Dr. Guillermo Stenborg, Instituto de Astronomia y Fisica, Ciudad Universitaria, Buenos Aires, Argentinien, 1. Januar 2001 – 31. Dezember 2002. Beobachtungen der Sonnenkorona mit dem MICA Koronagraph. Zusammenarbeit mit Prof. R. Schwenn.

Dr. Slawomira Szutowicz, Space Resarch Centre, Polish Academy of Sciences, Warschau, Polen, 15. September – 15. Dezember 2003. Gas-Jets am Kern des Kometen 2P/Encke, Messungen der Mikrowellenemission von HCN am Kometen Encke (gemeinsam mit G. Villanueva). Zusammenarbeit mit Dr. P. Hartogh und Prof. K. Jockers.

Dr. Luca Teriaca, Osservatorio Astrofisico di Arcetri, Florenz, Italien, 1. Februar 2003 – 31. Januar 2005. Large and small-scale dynamics of the Sun. Zusammenarbeit mit Prof. S.K. Solanki.

Dr. Viktor Tishkovets, Astronomical Institute, Kharkov National University, Kharkov, Ukraine, 15. November 2002 – 15. Mai 2003. DFG-Projekt zum Thema „Regolith on atmospherelss bodies of the solar system“. Zusammenarbeit mit Prof. K. Jockers.

Prof. C.-Y. Tu, Peking University, Beijing, China, 1. – 31. Januar 2002, 1. September – 31. Dezember 2002. 1. – 31. Januar 2003, 1. September – 31. Dezember 2003. Thema: Auswertung von Plasmadaten der Helios-Mission, Numerische Simulationen zur Beaminstabilität im Sonnenwind, Modellrechnungen zur Koronaheizung, und theoretische Arbeiten zur Zyklotronheizung von Ionen im Sonnenwind. Zusammenarbeit mit Prof. E. Marsch.

Prof. G. Vekstein, University of Manchester, UK, 4. – 10. November 2002. Zusammenarbeit mit Dr. J. Büchner.

Dr. Alexander Vögler, Postdoc, 1. August 2003. 3D-Simulation von solarer Magnetokonvektion. Zusammenarbeit mit Prof. S.K. Solanki.

Dr. Jingsong Wang, Department of Geophysics, Peking University, Beijing, VR China, Postdoc, 21. Februar 2001 – 30. April 2003. Mars Ionosphäre. Zusammenarbeit mit Dr. E. Nielsen.

Dr. Tongjiang Wang, National Astronomical Observatories, Beijing, VR China, Postdoc, 5. Juni 2001 – 31. Mai 2003. SUMER Datenanalyse. Zusammenarbeit mit Prof. S.K. Solanki und Dr. K. Wilhelm.

Dr. Lidong Xia, University of Science and Technology of China, Hefei, Anhui, VR China, 1. Mai 2003 – 31. Dezember 2003. Equatorial coronal holes and their relation to the high-speed solar wind streams. Zusammenarbeit mit Prof. E. Marsch.

Dr. Jun Zhang, National Astronomical Observatories, Beijing, VR China, 19. Juni 2001 –- 31. Mai 2002. Solare Magnetfelder und ihre koronale Manifestation. Zusammenarbeit mit Prof. S.K. Solanki und Dr. K. Wilhelm; 15. September 2003 – 15. Mai 2004. Ulysses Datenauswertung. Zusammenarbeit mit Prof. S.K. Solanki und Dr. J. Woch.

Wissenschaftler, die als Gäste nur kurzzeitig am MPAE tätig waren/ Scientific guests with short-term visits to MPAE

Dr. N. Andre, Imperial College, London, England, 1 Woche im November 2002 und 1 Woche im März 2003. Zusammenarbeit mit Dr. N. Krupp und Dr. J. Woch.

Dr. Ir. Willem A. Baan, Direktor, Westerbork Observatory, Dvingeloo, Niederlande, 13. September 2002. Diskussionen mit Prof. T. Hagfors u.a. sowie Seminarvortrag (The new radio astronomy installation, LOFAR).

Dr. M. Dougherty, Imperial College, London, England, 1 Woche im November 2002 und 1 Woche im März 2003. Zusammenarbeit mit Dr. N. Krupp und Dr. J. Woch.

Dr. B.N. Dwivedi, Banares Hindu University, Varanasi, Indien, Juni 2002 und Juni 2003. Zusammenarbeit mit Dr. W. Curdt.

Prof. Dr. A. Eviatar, Department of Geophysics and Planetary Sciences, The Raymond and Beverly Sackler Faculty of Exact Sciences, Tel Aviv University, Ramat Aviv, Israel, 21. – 26. April 2002 und 29. September – 4. Oktober 2002. Zusammenarbeit mit Prof. V.M. Vasyliūnas.

Dr. A. Hanlon, Imperial College, London, England, 1 Woche im November 2002 und 1 Woche im März 2003. Zusammenarbeit mit Dr. N. Krupp und Dr. J. Woch.

Dr. Peter Hoyng, SRON Laboratory for Space Research, Utrecht, The Netherlands, 26. – 28. Mai 2003. Zusammenarbeit mit Dr. D. Schmitt.

Dr. G. Mann, Astrophysikalisches Institut Potsdam, Observatorium für solare Radioastronomie, 9. – 10. April 2002, 18. – 22. November 2002, 16. – 17. Dezember 2002, 14. – 16. Mai 2003. Zusammenarbeit mit Prof. E. Marsch.

Prof. Andrei Mikhailov, IZMIRAN, Troitsk, Moscow Region, Russland, 2. – 31. März 2002. Ionosphere-thermosphere interaction. Zusammenarbeit mit Prof. K. Schlegel.

Prof. Fernando Moreno Insertis, Universität La Laguna, Spanien, 1. – 8. März 2003. Zusammenarbeit mit Prof. M. Schüssler.

Dr. Nichols, University of Leicester, England, 23. – 30. November 2003. Zusammenarbeit mit Dr. N. Krupp und Dr. J. Woch.

Prof. A. Nishida, JSPS, Tokyo, Japan, 5. – 17. Oktober 2003. Zusammenarbeit mit Dr. N. Krupp und Dr. J. Woch.

Dr. Mathieu Ossendrijver, Kiepenheuer Institut für Sonnenphysik, Freiburg, 26. – 28. Mai 2003. Zusammenarbeit mit Dr. D. Schmitt.

Dr. Franck Plunian, Grenoble, France, 26. – 28. Oktober 2003. Zusammenarbeit mit Dr. D. Schmitt.

Prof. Karl-Heinz Rädler, Astrophysikalisches Institut Potsdam, 25. Oktober 2002, 3. – 7. März 2003, 26. – 28. Oktober 2003. Zusammenarbeit mit Dr. D. Schmitt.

Dr. J. Saur, Applied Physics Laboratory, MD, USA, 22. – 27. Juni 2003. Zusammenarbeit mit Dr. N. Krupp und Dr. J. Woch.

Dr. S. Savine, Institute for Space Research, Moskau, Russland, 11. – 25. August 2002 und 11. – 25. August 2003. Zusammenarbeit mit Dr. J. Büchner.

Prof. R. Sydora, University of Edmonton, Alberta, Kanada, 5. – 7. November 2003. Zusammenarbeit mit Dr. J. Büchner.

Prof. L. Zelenyi, Institute for Space Research, Moskau, Russland, 6. – 19. Mai 2002 und 28. April – 24. Mai 2003. Zusammenarbeit mit Dr. J. Büchner.

A. Zhukov, November 2002. EU-INTAS–ESA Project 99-00727, "Geoeffective interplanetary structures: their origins on the Sun and in the solar wind". Zusammenarbeit mit Dr. V. Bothmer.

Wissenschaftler, die als Gäste am MPAE vom Deutschen Akademischen Austauschdienst (DAAD) gefördert worden sind/Scientific guests at MPAE sponsored by the DAAD

Ilya Silin, Moscow State University, Russland, PHD student, 2001 – 2004. Zusammenarbeit mit Dr. J. Büchner.

Lidong Xia, University of Science and Technology of China, Hefei, Anhui, VR China, Doktorand seit 1. Oktober 1999. Zusammenarbeit mit Prof. E. Marsch.

Längere Aufenthalte von Wissenschaftlern des MPAE an anderen Instituten/Long-term visits of MPAE scientists to other institutes

Dr. Volker Bothmer, Frequent short term visits of NRL, LMSAL, JPL in 2002 and 2003 for hardware and science collaborations within the STEREO/SECCHI project.

Prof. Klaus Jockers, Pik Terskol Observatorium (Nordkaukasus) des Internationalen Zentrums für Astronomische und Medizinisch-Ökologische Forschung (Goloseevo bei Kiew): 6. – 23. August 2002. Beobachtungen des Kometen 46P Wirtanen mit dem 2m Zeiss-RCC-Teleskop des Pik Terskol Observatoriums und dem Zweikanal-Fokalreduktor des MPAE. Astronomischen Observatorium Rojen in Bulgarien: 9. November – 5. Dezember 2003 und 25. Dezember 2003 – 8. Januar 2004, Beobachtungen des Kometen 2P Encke und der Saturnmonde mit dem 2m Zeiss-RCC-Teleskop des Bulgarischen Nationalobservatoriums Rojen und dem Zweikanal-Fokalreduktor des MPAE.

Dr. Michael Küppers, CSG, Kourou, Franz. Guayana, 2. – 14. September 2003, (Rosetta/OSIRIS Systemtests).

Dr. Michael T. Rietveld, 6 Monate pro Jahr bei EISCAT, Tromsø, Norwegen.

Prof. Kristian Schlegel, Department of Physics and Astronomy, University of Western Ontario, London, Ontario, Canada, 1. August – 31. Oktober 2003.

Dr. Dieter Schmitt, Astrophysikalisches Institut Potsdam, 30. September – 1. Oktober 2002; Istituto Nazionale di Geofisica e Vulcanologia, Rome, Italy, 27. September – 4. Oktober 2003.

Prof. Vytenis M. Vasyliūnas, University of Massachusetts Lowell, USA, 10. – 21. Juni 2003.

Projekte in Zusammenarbeit mit anderen Institutionen/Projects in collaboration with other institutions

Die Art der Zusammenarbeit des MPAE mit anderen Institutionen ist im einzelnen ziemlich unterschiedlich. Die folgende Aufzählung soll nur einen kurzen Überblick geben./The cooperation of MPAE with other institutions is extensive and varied. The following list only provides a brief overview.

Astronomical tests of gravitation theory.- O. Preuss und S.K. Solanki in Zusammenarbeit mit M. Haugan, Purdue University, West Lafayette, USA; D. Wickramasinghe, Australian National University, Canberra; S. Jordan, Universität Tübingen.

BOLD – Blind to Optical Light Detectors: Development of imaging arrays for solar UV observations based on wide band gap materials.- U. Schühle in Zusammenarbeit mit J.-F. Hochedez (Royal Observatory of Belgium, Brussels), J. L. Pau, C. Rivera, E. Muñoz, J. Alvarez (University of Madrid, Spain), J.-P. Kleider (LGEP-CNRS, Gif-sur-Yvette Cedex), P. Lemaire (Institut d´Astrophysique Spatiale, Orsay), T. Appourchaux, B. Fleck, A. Peacock (European Space Agency, Noordwijk), M. Richter, U. Kroth, A. Gottwald (Physikalisch-Technische Bundesanstalt, BESSY, Berlin), A. Deneuville, P. Muret (LEPES-CNRS, Grenoble), M. Nesladek (IMO, Diepenbeek), F. Omnès (CRHEA-CNES, Valbonne), J. John, C. Van Hoof (Interuniversity Microelectronics Centre, Leuven).

CASSINI-Mission MIMI Magnetospheric Imaging Instrument (MIMI) on the Cassini Mission to Saturn/Titan.- W.-H. Ip, E. Kirsch, N. Krupp und B. Wilken in Zusammenarbeit mit S.M. Krimigis (JHU, APL), D.G. Mitchell (JHU, APL), D.C. Hamilton (U.M.), S. Livi (JHU, APL), J. Dandouras (CESR), S. Jaskulek (JHU, APL), T.P. Armstrong (UKANS), J.D. Boldt (JHU, APL), A.F. Cheng (JHU, APL), G. Gloeckler (U.M.), J.R. Hayes (JHU, APL), K.C. Hsieh (U.A.), E.P. Keath (JHU, APL), L.J. Lanzerotti (BELL LABS), R. Lundgren (U.M.), B.H. Mauk (JHU, APL), R.W. McEntire (JHU, APL), E.C. Roelof (JHU, APL), C.E. Schlemm (JHU, APL), B.E. Tossman (JHU, APL), D.J. Williams (JHU, APL).

CASSINI-Mission UVIS (Ultraviolet Imaging Spectrometer CASSINI/HUYGENS Mission).- H.U. Keller, A. Korth, H. Lauche in Zusammenarbeit mit L.W. Esposito (PI), LASP, University of Colorado, Boulder, USA, University of Southern California, Los Angeles, USA, Jet Propulsion Laboratory, Pasadena, USA, California Institute of Technology, Pasadena, USA, Southwest Research Institute, Boulder, USA. Der erfolgreiche Start fand am 15. Oktober 1997 statt. Die Ankunft am Saturn wird im Juli 2004 erwartet.

CHAMP-Satellit (Geoforschungszentrum Potsdam).- Gemeinsame Experimente mit EISCAT, K. Schlegel und M.T. Rietveld.

CME driven shock wave.- B. Inhester, N.-E. Raouafi, S.K. Solanki und M. Mierla in Zusammenarbeit mit S. Manusco und C. Benna, Osservatorio Astronomico di Torino, Turin, Italien; J.P. Delaboudinière, Institut d'Astrophysique Spatiale, Orsay, Frankreich.

CONSERT auf Rosetta, Radio Tomography Project.- E. Nielsen, T. Hagfors in Zusammenarbeit mit Laboratoire de Planétologie, University of Grenoble; ESA.

Coronal holes studied with SUMER and CDS.- U. Schühle und S.K. Solanki in Zusammenarbeit mit K. Stucki, ETH Zürich, Schweiz.

Deep Space Mission 1 – PEPE.- K. Sauer, Co-Investigator.

Dust from the β Pictoris disk.- N.A. Krivova und S.K. Solanki in Zusammenarbeit mit A.V. Krivov, Universität Potsdam; V.B. Titov, Universität St. Petersburg, Ukraine.

EISCAT (European Incoherent Scatter Facility).- Das Projekt wird in internationaler Zusammenarbeit von Forschungsorganisationen in Deutschland, Finnland, Frankreich, Großbritannien, Japan, Norwegen und Schweden durchgeführt. In Deutschland ist die Max-Planck-Gesellschaft Trägerin von EISCAT; T. Hagfors, M.T. Rietveld, J. Röttger und K. Schlegel.

Energetische Neutralteilchen.- M. Hilchenbach in Zusammenarbeit mit A. Czechowski, Space Research Centre, Polish Academy of Sciences, Warschau, Polen; K.C. Hsieh, University of Arizona, Tucson, USA.

Energetische Teilchenereignisse von der Sonne und Heliosphäre.- M. Hilchenbach in Zusammenarbeit mit B. Klecker, Max-Planck-Institut für extraterrestrische Physik, Garching; K. Bamert, Physikalisches Institut der Universität Bern, Schweiz; R. Kallenbach International Space Science Institute, Bern, Schweiz.

Entwicklung und Charakterisierung einer VUV-Strahlungsquelle als Transfernormal für zukünftige Weltraummissionen.- U. Schühle in Zusammenarbeit mit M. Richter, A. Gottwald, F. Schulze (Physikalisch-Technische Bundesanstalt, BESSY, Berlin).

Equator-S Satellit: Experiment MAG.- Betriebsphase des MAG- und nach dem Start und ihre Datenauswertung. J. Büchner, B. Nikutowski, Zusammenarbeit mit Imperial College, London, UK University of New Hampshire, Durham, USA. University of Fairbanks, Alaska, USA

ESA-Mission Cluster 2 (Nachbau Cluster 1).- *Experiment CIS (Cluster Ion Spectrometer).* A. Korth, H. Rosenbauer, V.M. Vasyliūnas und P.W. Daly in Zusammenarbeit mit CESR Toulouse, Frankreich (federführend); MPI Garching; Universities of New Hampshire, Washington, Seattle, Berkeley, USA; IFSI/CNR, Frascati, Italien; Lockheed, Palo Alto, USA; SISP, Kiruna, Schweden.

EU-INTAS–ESA Project 99-00727 "Geoeffective interplanetary structures: their origins on the Sun and in the solar wind".- V. Bothmer in Zusammenarbeit mit Imperial College of Science, Technology, and Medicine, The Blackett Laboratory, London, United Kingdom, Institute of Terrestrial Magnetism, Ionosphere, and Radio Wave, Department of Magnetism of the Earth and Planets, Sector of Space Magnetoplasma Dynamics, IZMIRAN, Troitsk, Russia, Moscow State University, Institute of Nuclear Physics, Moscow, Russia.

EUV variations in the quiet Sun: short-term.- S.K. Solanki in Zusammenarbeit mit A. Brkovic, H. Peter, Kiepenheuer Institut für Sonnenphysik, Freiburg und I. Rüedi, PMOD/WRC, Davos, Schweiz.

Galileo-EPD (Energetic Particles Detector).- Datenauswertung. N. Krupp, A. Lagg und J. Woch in Zusammenarbeit mit D. Williams, APL, USA.

Galileo-PLS.-, V.M. Vasyliūnas in Zusammenarbeit mit der Universität Iowa, Iowa City, IA, USA.

GEOMAR (Universität Kiel) SFB 574: Volatiles and Fluids in Subduction Zones.- Am MPAE: Analyse vulkanischer Gasproben. R. Borchers in Zusammenarbeit mit Matthias Frische, Universität Kiel.

GGS-Mission: POLAR-Satellit.- *Experiment HYDRA und Experiment CEPPAD.* Betriebsphase des HYDRA- und des CEPPAD-Instruments nach dem Start und ihre Datenauswertung. A. Korth in Zusammenarbeit mit der University of Iowa (federführend), dem Goddard Space Flight Center, Greenbelt, der University of California, San Diego, der University of New Hampshire, Durham, der Aerospace Corporation, Los Angeles, dem Los Alamos National Laboratory, der Boston University, alle USA.

G.I.F.-Projekt/German-Israeli Foundation for Scientific Research & Development.- V.M. Vasyliūnas in Zusammenarbeit mit Prof. Dr. A. Eviatar, Universität Tel Aviv, Ramat Aviv, Israel.

Helio- and asteroseismology, with applications to extrasolar planets.- S.K. Solanki in Zusammenarbeit mit L. Gizon, Stanford University, USA.

HIFI–WBS (Heterodyne Instrument for FIRST – Wideband Spectrometer).- P. Hartogh, P. Börner und C. Jarchow in Zusammenarbeit mit T. de Graauw, H.J. Aarts, D.A. Beintema, J. Gao, H. Jacobs, W. Jellema, W. Luinge, P.R. Roelfsema, X. Tielens, H. van de Stadt, B. van Leeuwen, N.D. Whyborn, K.J. Wildeman (SRON, Utrecht, Niederlande), E. Van Dishoeck (Universität Leiden, Niederlande), R. Güsten, K. Menten (Max-Planck-Institut für Radioastronomie, Bonn), C.H. Honingh, K. Jacobs, R. Schieder, J. Stutzki (Universität Köln), A. Emrich (Omnisys, Göteborg, Schweden), S. Torchinsky (Chalmers, Göteborg, Schweden), M. Larsson (Universität Stockholm, Schweden), C. Rosolen (Arpeges, Observatoire de Paris, Meudon, Frankreich), G. Beaudin, (LERMA, Meudon, Frankreich), E. Caux, A. Cros (CESR, Toulouse, Frankreich), P. Cais (Bordeaux Observatory, Frankreich), E. Lellouch, T. Encrenaz (DESPA, Paris, Frankreich), C. Gry (LAS Marseille, Frankreich), N. Maurun (Graal, Montpellier, Frankreich), K. Schuster (IRAM, Grenoble, Frankreich), F. Boulanger (IAS, Orsay, Frankreich), L.T. Little (Kent University, UK), T. Miller (UMIST, UK), T.J.T. Moore (Liverpool-J. Moures, UK), S. Withington (MRAO Cambridge, UK), G.J. White (QMW London, UK), R. Cerrulli, R. Orfei, (IFSI Frascati, Italien), V. Natale, (CAISMI Florenz, Italien), J. Martin-Pintado (OAN, Alcala, Spanien), J.D.G. Puyol (Obs. Yebes, Spanien), M.J. Sarna, R. Szczerba (Coperinicus AC, Warschau, Polen), W.R. McGrath, J.C. Pearson, T.C. Gaier (JPL, Pasadena, USA), T.G. Phillips, J. Zmuidzinas (Caltech, Pasadena, USA), A.I. Harris (Maryland University, USA), E. Herbst (Ohio State University, USA), D.A. Neufeld (Johns Hopkins University, USA), N.R. Erickson (FCRAO, Amherst, MA, USA), S. Verghese (Lincoln Lab., MIT, USA), S. Kwok (Calgary University, Canada), D.A. Naylor (Lethbridge University, Canada), F. Lo (IAA Taiwan), H. Wang,(NTU, Taipeh, Taiwan), P. Zimmermann (RPG, Meckenheim).

2001 – 2003: INTAS 2000-465 Development of multi-point measurement techniques for a closely space group of spacecraft.- J. Büchner und B. Nikutowski in Zusammenarbeit mit G. Belmont, A. Roux, S. Perraut, B. Lembege, G. Chanteur, N. Cornilleau-Wehrlin (CETP/UVSQ, Velizy, France), K. Torkar (IWF Graz, Austria), S. Bedrich (KayserThrede GmbH, Munich, Germany), V.E. Korepanov (National Space Agency of the Ukraine, Lvov), V.E Kunitsin (Moscow State University).

2003 – 2005 INTAS 2003-51-4872 Ion and electron scales in mass and energy transfer: magnetospheric mapping, modelling and future missions.- J. Büchner in Zusammenarbeit mit J.L. Rauch, J.L. Pincon (LPCE, Orleans, France) E. Amata (ISI, Rome, Italy) J. Blecki (CBK Warsaw), L.M. Zelenyi, S. Savin, A. Skalsky, A. Veselov (IKI Moscow).

Interball.- Data analysis of the international magnetospheric plasma mission. J. Büchner in collaboration with the Space Research, Moscow, Russia, Dr. S. Savine.

Investigation of the current and ancient Martian climate, its stability and mechanisms of changes by means of a modular planet simulator model – Mars Climate Simulator.- DFG-Schwerpunktprogramm 1115 “Mars und die terrestrischen Planeten”. H.U. Keller, D. Titov, B. Grieger in Zusammenarbeit mit K. Fraedrich, Meteorologisches Institut der Universität Hamburg und R. Greve, Fachbereich Mechanik der Technischen Universität Darmstadt.

Kinetic plasma theory.- J. Büchner in collaboration with the Space Research, Moscow, Russia, Prof. L.M. Zelenyi.

LYRA -- LYman alpha RAdiometer: A Solar VUV radiometer on board ESA mission PROBA II.- U. Schühle in Zusammenarbeit mit J.-F. Hochedez, D. Berghmans, A. Ben Moussa (Royal Observatory of Belgium, Brussels), W.K. Schmutz, S. Koller, C. Wehrli, I. Rüedi (Physikalisch-Meteorologisches Observatorium Davos), M. Nesladek (IMO Diepenbeek), J.H. Lecat, J.M. Defise, Y. Stockman (Centre Spatiale de Liège), D. Gillotay (Belgian Institute for Space Aeronomy, Brussels), M. Kretzschmar (Istituto Fisica dello Spazio Interplanetario, Rome).

Magnetopause MHD simulation and Cluster data analysis.- J. Büchner in collaboration with the University of Alaska, Fairbanks, Institute for Geophysics, Prof. A. Otto.

MAOAM (The Martian Atmosphere: Observing And Modeling).- P. Hartogh, C. Jarchow, C.-V. Meister, R. Saito und G. Villanueva in Zusammenarbeit mit U. Berger, G. Sonnemann (IAP Kühlungsborn), A. Feofilov, A. Kutepov (IAA München), H. Elbern (Institut für Geophysik und Meteorologie, Köln),

M. Allen (JPL, Pasadena, USA), Gordon Chin (GSFC, Greenbelt, USA).

Mars-Express Experiment ASPERA-3.- (Analyzer of Space Plasmas and EneRgetic Atoms) Entwicklung und Bau des Experimentes. J. Woch und N. Krupp in Zusammenarbeit mit dem IRF Kiruna, Schweden (federführend) und weiteren europäischen und amerikanischen Institutionen.

MARSIS.- E. Nielsen, T. Hagfors in Zusammenarbeit mit INFO-COM Dept., University of Rome, Italien; Jet Propulsion Laboratory, Pasadena, U.S.A.; Institute of Radio Engineering and Electronics, Russian Academy of Sciences, Moskau, Russland.

MICA – Mirror Coronagraph for Argentina.- R. Schwenn in Zusammenarbeit mit Instituto de Astronomia y Fisica del Espacio (IAFE) in Buenos Aires, Observatorio Astronomico Felix Aguilar (OAFA) der Universität in Juan, Argentinien, MPE in Garching.

Microflares and the solar emission distribution.- S.K. Solanki in Zusammenarbeit mit A. Pauluhn, ISSI, Bern, Schweiz.

Microscope on Beagle 2.- High spatial resolution imaging of the surface of Mars from the lander, Beagle 2, to fly with ESA's Mars Express – Beagle 2 Lead scientist, C.T. Pillinger, Open University; MPAE Participants: N. Thomas (PI), H.U. Keller, W.J. Markiewicz, S.F. Hviid, D.T. Titov.

MIRO (Mirowave Instrument for the ROSETTA-Orbiter).- P. Hartogh, W. Ip und I. Mann in Zusammenarbeit mit S. Gulkis, M. Allen, M. Frerking, M. Hofstadter, M. Janssen, T. Spilker (JPL, Pasadena), D. Muhleman (Caltech, Pasadena), G. Beaudin, D. Bockelee-Morvan, J. Crovisier, P. Encrenaz, T. Encrenaz, E. Lellouch (Observatoire de Paris-Meudon), D. Despois (Observatoire de Bordeaux), H. Rauer (DLR, Berlin), P. Schloerb (University of Massachusetts, Amherst).

Mirror Coronagraph for Argentina (MICA).- R. Schwenn in Zusammenarbeit mit G. Haerendel, O. Bauer, E. Rieger und A. Valenzuela (Max-Planck-Institut für Extraterrestrische Physik, Garching), R.G. Hutton, J.A. Lopez, C. Lopez (Observatorio Astronomico Felix Aguilar, San Juan, Argentinien), H.S. Ghielmetti, M. Rovira (Instituto de Astronomica y Fisica del Espacio, Buenos Aires, Argentinien).

Molecular Zeeman effect.- S.K. Solanki in Zusammenarbeit mit S. Berdyugina und C. Frutiger, ETH Zürich, Schweiz.

Moving magnetic features.- S.K. Solanki in Zusammenarbeit mit J. Wang und J. Zhang, National Astronomical Observatories, Beijing, VR China.

NASA STEREO-Mission – IMPACT.- Bau der Flugzeit-Elektronik für das SIT-Instrument. V. Bothmer und A. Korth in Zusammenarbeit mit J. Luhmann (PI), UC Berkeley Space Sciences Laboratory, USA; NASA Goddard Space Center, USA; California Institute of Technology, USA; University of Maryland, USA; Universität Kiel; Centre d'Etude Spatiale des Rayonnements, Frankreich; Los Alamos National Laboratory, USA; Jet Propulsion Laboratory, USA; ESA/ESTEC – European Space and Technology Center, Niederlande; CNRS Observatoire Midi-Pyrenees and Observatoire de Paris, Frankreich; University of California, Los Angeles, USA; SAIC, Science Applications, USA; International Corporation, USA; NOAA Space Environment Center, USA; University of Michigan, USA; KFKI, Hungarian Institute for Particle and Nuclear Physics, Ungarn.

NASA STEREO-Mission – SECCHI.- V. Bothmer und R. Schwenn in Hardware-Kollaboration: Naval Research Laboratory, Washington, USA; NASA Goddard Space Flight Center, USA; Universität Kiel; University of Birmingham, UK; Lockheed Martin Advanced Technology Center, USA; Swales Aerospace, USA, Hytec Incorporated, USA; Praxis Incorporated, USA, Rutherford Appleton Laboratory, UK sowie: Mullard Space Science Laboratory, UK; Centre de Spatial Liege, Belgien; Centre d'Astrophysique Spatiale, Frankreich; Institut d'Optique, Frankreich; USAF Space Test Program, USA; The Hammers Company, USA; Boston College, USA; Smithsonian Astrophysical Observatory, USA; Royal Observatory of Belgium, Belgien; Observatoire de Paris, Frankreich; Laboratoire d'Astronomie Spatiale, Frankreich; NASA Jet Propulsion Laboratory, USA; Science Applications International Corporation, USA; Stanford University, USA; University of Michigan, USA; Southwest Research Institute, USA.

OSIRIS – Optical, Spectroscopic, and Infrared Remote Imaging System.- An instrument for the imaging system on board the orbiter of the International Rosetta Mission. Principle Investigator: H.U. Keller, MPAE; Lead Scientists: C. Barbieri, University of Padova; P. Lamy, LAS Marseille; H. Rickman, Astronomical Observatory Uppsala, R. Rodrigo, IAA Granada; K.–P. Wenzel, ESTEC, Noordwijk.

Projekt Interball (Mehrfachsatelliten-wissenschaftliche Auswertung).- J. Büchner in Zusammenarbeit mit dem IKI Moskau.

Projekt Mars-DFG/Simulator.- H.U. Keller, D. Titov, B. Grieger, K. Frädrich, R. Greve in Zusammenarbeit mit der Universität Hamburg und der Technischen Universität Darmstadt durchgeführt.

Projekt MITREMA.- (Mehrfachsatelliten-wissenschaftliche Vorbereitung) J. Büchner in Zusammenarbeit mit dem CNRS Toulouse / CNES Frankreich.

Projekt MMS.- (Mehrfachsatelliten-wissenschaftliche Vorbereitung) J. Büchner in Zusammenarbeit mit der NASA, mit dem Southwest Research Institute und dem Goddard Space Flight Center (beide USA).

Projekt Roy.- (Mehrfachsatelliten-wissenschaftliche Vorbereitung) J. Büchner in Zusammenarbeit mit dem IKI Moskau.

Projekt THEMIS.- (Mehrfachsatelliten-wissenschaftliche Vorbereitung) J. Büchner in Zusammenarbeit mit der NASA, mit der University of California at Berkeley und dem Jet Propulsion Laboratory Pasadena, USA.

Quiet Sun magnetism.- A. Lagg und S.K. Solanki in Zusammenarbeit mit E.V. Khomenko, Main Astronomical Observatory, Kiev, Ukraine; M. Collados, J. Trujillo Bueno, Instituto de Astrofisica de Canarias, Teneriffa, Spanien.

Ramanspektrospkopie.- M. Hilchenbach in Zusammenarbeit mit J. Popp, Universität Würzburg, und T. Stuffler, Kayser-Threde, München.

RAPID auf Cluster II.- Das Teilchen-Spektrometer RAPID (Principle Investigator: P.W. Daly; Co-Investigators: U. Mall, J. Büchner, A. Korth, J. Woch, Sir Ian Axford und V.M. Vasyliūnas in Zusammenarbeit mit J.B. Blake, J.F. Fennell (AC, Los Angeles); Z.Y. Pu (Beijing University, Beijing); T.A. Fritz, Q.-G. Zong (BU, Boston); F. Gliem (IDA, Braunschweig); I. Sandahl (IRF, Kiruna); H. Borg (Univ. Umea); K. Kecskemety (KFKI, Budapest); R.D. Belian, G.D. Reeves (LANL, Los Alamos); D.N. Baker (LASP, Boulder); M. Grande, M. Carter, C.H. Perry, J. Davies, M. Dunlop (RAL, Chilton); S. McKenna-Lawlor (SPC, Maynooth); F. Søraas, K. Aarsnes, K. Oksavik (Univ. Bergen); K. Mursula, P. Tanskanen (Univ. Oulu); E.T. Sarris (Univ. Thrace, Greece); M. Schulz (Lockheed Res. Lab., Palo Alto); M. Scholer (MPE, Garching)).

Raumsonde Ulysses.- *KEP (EPAC) Energetic Particle Composition Experiment:* E. Keppler, N. Krupp und J. Woch in Zusammenarbeit bei der Auswertung und Verarbeitung der anfallenden wissenschaftlichen Daten mit M. Yamauchi (Kiruna, Schweden), J.B. Blake (Los Angeles, CA, USA), J.J. Quenby (London, England) und M. Fränz (London, England), B. Tsurutani (JPL, Pasadena, USA), C. Claßen (Astrophysikalisches Institut, Potsdam), F.B. McDonald (University of Maryland, College Park, MD, USA).

Raumsonde Ulysses.- *KEP (GAS):* Interstellar Neutral GAS Experiment. H. Rosenbauer, M. Witte, N. Krupp, J. Woch und E. Keppler zusammen mit H. Fahr, Universität Bonn und M. Banaszkiewicz, SRC, Warschau, Polen.

Raumsonde Ulysses.- *SWICS: Solar Wind Ion Composition Spectrometer*. Datenauswertung. J. Woch in Zusammenarbeit mit Universität Bern, Schweiz und University of Maryland, USA.

Secular evolution of the Sun's magnetic field.- M. Schüssler, und S.K. Solanki in Zusammenarbeit mit I. Usoskin und K. Mursula, University Oulu, Finnland.

SIR – SMART-1 Near IR Spectrometer.- Technical Investigator: H.U. Keller, W.J. Markiewicz, A. Nathues und U. Mall in Zusammenarbeit mit P. Huber, Tec5, Steinbach (Taunus).

SOFIA-GREAT (SOFIA – German Receiver for Astronomy at Thz frequencies).- P. Hartogh in Zusammenarbeit mit R. Guesten, K. Menten, P. v. d. Wal (MPI für Radioastronomie, Bonn), R. Schieder, J. Stutzki (Universität Köln), H.W. Hübers (DLR-Berlin), H.P. Rösner (Institut für Raumfahrtsysteme, Universität Stuttgart).

Solar and Heliospheric Observatory (SOHO).- *Solar Ultraviolet Measurements of Emitted Radiation (SUMER)* W. Curdt, D.E. Innes, E. Marsch, U. Schühle, S.K. Solanki, T. Wang und L. Teriaca in Zusammenarbeit besonders mit P. Lemaire, A.H. Gabriel, J.-C. Vial (IAS, Orsay, Frankreich); A.I. Poland (GSFC, Greenbelt, USA); M.C.E. Huber (Schweiz); J. Hollandt (PTB, Berlin); O. Siegmund (SSL, Berkeley, CA, USA); D. Hassler (SWRI, Boulder, USA); G.A. Doschek, U. Feldman, J.T. Mariska (NRL, Washington, USA); P.G. Judge (HAO, Boulder, USA); N. Brynildsen, M. Carlsson, P. Maltby, O. Kjeldseth-Moe (ITA, Oslo, Norwegen); P. Brekke (ESA/GSFC, Greenbelt, USA); H.P. Warren (HSCA, Cambridge, USA); B.N. Dwivedi (DAP, Varanasi, Indien); C.-Y. Tu (DG, Peking, China); H. Peter (KIS, Freiburg); J.G. Doyle (Armagh Observatory, Irland); P. Heinzel (Czech Academy); A. Pauluhn (ISSI Bern, Schweiz).

Solar coronal MHD simulation.- J. Büchner in collaboration with the University of Alaska, Fairbanks, Institute for Geophysics, Prof. A. Otto.

Solar infrared spectropolarimetry.- N. Krupp, A. Lagg, S.K. Solanki und J. Woch in Zusammenarbeit mit M. Collados, Instituto de Astrofisica de Canarias, Teneriffa, Spanien.

Solar irradiance variations.- S.K. Solanki und N. Krivova in Zusammenarbeit mit Y. Unruh, Imperial College, London, und T. Wenzler, ETH Zürich, Schweiz.

Solar kinetic plasma simulation.- J. Büchner in collaboration with the University of Alberta, Edmonton, Canada, Prof. R. Sydora.

Solar radius variations.- S.K. Solanki in Zusammenarbeit mit J.H.M.J. Bruls, Kiepenheuer-Institut für Sonnenphysik, Freiburg.

Spurengase in der Atmosphäre –- Erstellung einer Datenbank über Messungen mit Kryosammlern zwischen 1977 und 1999.- R. Borchers in Zusammenarbeit mit P. Fabian, Technische Universität München.

Starspots.- A. Semenova und S.K. Solanki in Zusammenarbeit mit Y.C. Unruh, Imperial College, London; S. Berdyugina, ETH Zürich, Schweiz; E. Günther und A. Hatzes, Landessternwarte Tautenburg.

Structure of sunspot penumbrae.- J.M. Borrero, A. Lagg, S.K. Mathew und S.K. Solanki in Zusammenarbeit mit L. Bellot Rubio und R. Schlichenmaier, Kiepenheuer-Institut für Sonnenphysik, Freiburg; M. Collados, Instituto de Astrofisica de Canarias, Teneriffa, Spanien; I. Rüedi, PMOD/WRC, Davos, Schweiz.

Structure of the solar chromosphere.- S.K. Solanki in Zusammenarbeit mit M. Loukitcheva, University St. Petersburg, Ukraine; S. White, University of Maryland, Greenbelt, USA, und M. Carlssson, University Oslo, Norwegen.

Sunrise: Ballongetragenes 1-m-Sonnenteleskop für hochauflösende spektro-polarimetrische Beobachtungen der Sonnenatmosphäre.- S.K. Solanki, W. Curdt, A. Gandorfer und M. Schüssler in Zusammenarbeit mit dem Kiepenheuer-Institut für Sonnenphysik, Freiburg, Instituto de Astrofisica de Canarias, Teneriffa, Spanien, High Altitude Observatory, NCAR, Boulder, USA, Lockheed Martin Solar and Astrophysical Lab, Palo Alto, USA.

SWAP - Sun Watcher using APS detector on-board PROBA II.- A new EUV imager for solar monitoring on board ESA mission PROBA II. U. Schühle in Zusammenarbeit mit J.M. Defise, P. Rochus, E. Mazi, T. Thibert, (Centre Spatiale de Liège) D. Berghmans, J.F. Hochedez (Royal Observatory of Belgium, Brussels), P. Nicolosi, M.G. Pelizzo (University of Padova):

TIP (Tenerife Infrared Polarimeter).- A. Lagg, S.K. Solanki, N. Krupp, J. Woch, J.M. Borrero, S. Mathew, R. Aznar und N. Raouafi in Zusammenarbeit mit dem Instituto de Astrofisica de Canarias mit Manolo Collados Vera.

Untersuchung von kinetischen Plasmaprozessen in der Chromosphäre und unteren Korona der Sonne mittels der Daten des SUMER-Instruments an Bord der Raumsonde SOHO.- E. Marsch und K. Wilhelm in Zusammenarbeit mit G. Mann und C. Vocks (Astrophysikalisches Institut Potsdam).

Venus-Express Experiment ASPERA-4.- (Analyzer of Space Plasmas and EneRgetic Atoms) Entwicklung und Bau des Experimentes. J. Woch und N. Krupp in Zusammenarbeit mit dem IRF Kiruna, Schweden (federführend) und weiteren europäischen und amerikanischen Institutionen.

Vertrag über gemeinsame Nutzung des Zweikanal-Fokalreduktors des MPAE am 2m RCC-Zeiss-Teleskop des Internationalen Zentrums für Astronomische und Medizinisch-Ökologische Forschung (Goloseevo bei Kiew) vom 1. Januar 1998 bis 31. Dezember 2002.- Im Rahmen dieses Vertrages werden auch wissenschaftliche Projekte gemeinsam mit ukrainischen Astronomien durchgeführt, z.B. Astrometrie und Photometrie ausgewählter Satelliten von Jupiter und Saturn. K. Jockers gemeinsam mit I. Kulyk, Hauptobservatorium der nationalen Akad. Wiss.

WASPAM.- P. Hartogh, C. Jarchow und L. Song in Zusammenarbeit mit G. Hansen (NILU, Tromsö), U.P. Hoppe (FFI, Kjeller), Michael Gauser (ALOMAR, Andenes), U. v. Zahn, F.J. Lübken, U. Berger, G. Sonnemann (IAP Kühlungsborn), Gerald Nedoluha, M. Stevens (NRL, Washington), D. Marsh (NOAA, Boulder).

Projektförderungen durch das Bundesministerium für Bildung und Forschung (BMBF) und ESA/Project grants provided by BMBF and ESA

DLR: ULYSSES, ASPERA-3, CASSINI-DAT., COSAC, Datenausw. CIS, DAWN, Entwicklung tragbarer Gaschromatograph, HIFI WBS, IDS, LASCO, Mars Express, MARSIS, MECA, MIMI, MIMI-LEMMS, MIRO, NIXT, OSIRIS, RAPID, RELICT-2, ROLAND, Rosetta Lander, R-TOF, SCHWARM, Stereo Corona, Stereo IMPACT, Stereo SECCHI, Subsystem für den Rosetta Lander, SUMER-LASCO, Sumer-Op., Sunrise, ULYGAL.

ESA: ESA Cluster CIS, ESA MIRO, ESA SIR.

Lehrtätigkeiten/Teaching

Von Mitgliedern des MPAE wurden an mehreren, inländischen und ausländischen Universitäten verschiedene Vorlesungen gehalten:/
MPAE scientists have lectured at a number of German and foreign universities:

Georg-August-Universität zu Göttingen

Dr. J. Büchner
WS 2003/2004: Introduction into astrophysical plasmas and particles

Dr. J. Büchner und Dr. J.-P. Kuska
WS 2001/2002: Numerische Methoden

SS 2002: Simulation von Astro-Plasmen und Teilchen; 1. Grundlagen

WS 2002/2003: Simulation von Astro-Plasmen und Teilchen: 2. Visualisierung

SS 2003: Simulation von Astro-Plasmen und Teilchen 3. Praktikum

Prof. Dr. U. Christensen
WS 2002/2003: Physik der Planeten
WS 2003/2004: Planetary Interior and Surfaces

Prof. Dr. K. Jockers
SS 2002: Entstehung von Sonnensystemen
WS 2002/2003: Lichtstreuung an Staubteilchen und Regolith
3. – 7. März 2003: Small bodies of the solar system, für (International Max Planck Research School on Physical Processes in the Solar System and Beyond)
SS 2003: Molekül-Astrophysik
WS 2003/2004: Lichtstreuung an Staubteilchen und Regolith

Prof. Dr. E. Marsch
Lectures an der IMPRS
28. Oktober – 1. November 2002: “Solar Corona and Heliosphere”
23. Juni – 27. Juni 2003: “Space Plasma Physics”

Prof. Dr. K. Schlegel
WS 2001/2002: Elektrodynamik der Erdatmosphäre

Prof. Dr. R. Schwenn
WS 2001/2002: „Physik der Heliosphäre I”
WS 2003/2004: „Explosive Prozesse im Sonnensystem: Flares, Massenauswürfe, interplanetare Stoßwellen”

Universität Potsdam und Humboldt-Universität zu Berlin

Dr. C.-V. Meister
Vorlesungstätigkeit im SS02, WS02/03 und SS03.

Department of Physics and Astronomy, University of Western Ontario, London, Canada

Prof. Dr. K. Schlegel
1. August –- 31. Oktober 2003: Atmospheric Optics, Atmospheric Trace Gases and Air Pollution

“Escuela Mexicana de Astrofísica 2002”, Guanajuato, Mexico

Prof. Dr. R. Schwenn
Juli/August 2002 “Physics of the Heliosphere: an introduction”

Eidgenössische Technische Hochschule Zürich, Schweiz

Prof. Dr. S.K. Solanki
SS 2003:
Sternatmosphären (zusammen mit Dr. W. Schmutz)

IMPRS Vorlesungen/IMPRS lectures

Introductory Course, 18 – 22 February 2002 (Christensen, Glassmeier, Jockers, Kneer, Marsch, Motschmann, Schmitt, Schüssler, Schwenn, Solanki, Tilgner, Thomas, Wilhelm)

“Transients on the Sun and solar-terrestrial relations”, February 2002 (Schwenn)

Inverse Problems in Space Physics, May 2002 (Inhester)

Planetary Atmospheres, 24 – 28 June 2002 (Basilevsky, Rodin, Titov)

Plasma Physics, 24 – 28 June 2002 (Schmitt, Schüssler)

Vorlesungsreihe “Plasma Physics I”, 1 – 5 July 2002 (Schmitt/Schüssler)

“Physics of the Heliosphere: an introduction”, October 2002 (Schwenn)

Solar Corona and Heliosphere, 28 October – 1 November 2002 (Marsch, Schwenn)

Stellar Physics, 28 October – 1 November 2002 (Glatzel)

Small Bodies of the Solar System, 3 – 7 March 2003 (Jockers)

Dynamo Theory, 3 – 7 March 2003 (Christensen, Rädler, Schmitt, Schüssler, Tilgner)

Space Plasma Physics, 23 – 27 June 2003 (Marsch)

Space Instrumentation, 23 – 27 June 2003 (Schwenn, Curdt, Gandorfer, Hilchenbach, Hoekzema, Pardowitz, I. Richter, Schühle)

Planetary Surfaces and Interiors, 17 – 21 November 2003 (Christensen, Grieger, Küppers, Mall, Markiewicz, Nathues)

Stellar Atmospheres and Radiative Transfer, 17 – 21 November 2003 (Dreizler)

Solar System Seminar, 22 seminar days with 62 talks by students and 20 tutorial talks by guests (Schmitt)

Weitere Lehrtätigkeiten oder Kurse/ Other lectures or courses

XLAB (Göttinger Experimentallabor für Junge Leute e.V.)

Dr. D. Schmitt:
Klimaveränderung – Treibhauseffekt oder Sonnenaktivität? XLAB Göttingen, 18. März 2003.

Dr. D. Schmitt/Prof. Dr. R. Schwenn/Prof. Dr. M. Schüssler:
„Die Sonne – der unruhige Stern nebenan", Kurs am XLAB Göttingen (jeweils mehrere Kurse in 2002 und 2003).

Prof. Dr. R. Schwenn:
Magnetische Stürme toben durch's Sonnensystem: Wie funktioniert das Weltraumwetter? XLAB-Kurs, Göttingen, 27. Mai und 2. Juni 2003; Magnetic storms are roaring through the solar system – how to predict Space Weather? A course at the XLAB Science Camp, Göttingen, Germany, 22 and 24 July 2003.

Prof. Dr. R. Schwenn:
Einige Veranstaltungen im XLAB Göttingen.

EISCAT Incoherent Scatter Radar School, SRI International, Menlo Park, CA/U.S.A.

Prof. Dr. T. Hagfors:
Basic physics of incoherent scatter, 22. – 24. August 2003.

Mitgliedschaften in wissenschaftlichen Gremien/Memberships in scientific councils

Bothmer V.: Member of Scientific Advisory Board of ESPERE (Environmental Science Published for Everybody Round the Earth) – Subject Sun, Earth and Solar Cycle (www.espere.net); Selected Member of NASA's Solar Probe Science & Technology Definition Team (December 2003); Secretary for Solar Physics, European Geophysical Union (formerly EGS); Team Member of the ESA Space Weather EURO News Group; Member of the Advisory Committee of Planetarium Hamburg.

Büchner J.: Chairman of AEF (Arbeitsgemeinschaft Extraterrestrische Forschung) Commission 1 (Near Earth's Space); Member of the International Scientific Committee of the World Institute for Space Environmental Research (WISER); Member of the International Scientific Committee of the International Conferences on Space Plasma simulation (ISSS); Member of the Scientific Committee of the International School for Plasma-Astrophysics Varenna-Abastumani; Member of COSPAR Commission D (Space Plasmas in the Solar System); Member of IAU Commission 10 (Solar Activity); Member of the International Living With A Star Task Group "magnetospheres".

Christensen U.: Advisory board / Center of Dynamics of Complex Systems, Universität Potsdam; American Geophysical Union; Deutsche Akademie der Naturforscher Leopoldina; Deutscher Vertreter im Standing Committee for Life and Environmental Sciences der European Science Foundation (ESF); Ehrenmitglied der European Union of Geosciences; Executive Committee der International Association of Seismology and Physics of the Earth's Interior (IASPEI); Göttinger Akademie der Wissenschaften; Kommission für Geowissenschaftliche Hochdruckforschung der Bayerischen Akademie der Wissenschaften.

Curdt W.: JOSO (Joint Organisation of Solar Observatories); IAU (International Astronomical Union).

Daly P.W.: Cluster Science Data System, Implementation Working Group.

Hagfors T.: Alomar Proposal Review Committee.

Hartogh P.: Alomar Scientific Advisory Committee.

Jockers K.: Mitglied im "Scientific Organizing Committee“ der Konferenz "5 YEARS AFTER HALE-BOPP: PROGRESS IN COMETARY SCIENCE“, Santa Cruz, Tenerife, 21.–25. Januar 2002; Member of Commission 15 (IAU International Astronomical Union); European Geophysical Society (EGS).

Kutzner C.: American Geophysical Union.

Lagg A.: Telescope Allocation Committee (TAC) für Vakuum-Turm Teleskop auf Teneriffa.

Marsch E.: Mitglied im Solar Physics Section Board der European Physical Society (2002); Mitglied im Gutachterausschuss Extraterrestrik des DLR (ab 2001); Mitglied in der Solar System Working Group (SSWG) der ESA (ab 2001).

Rietveld M.T.: URSI-Kommission G; American Geophysical Union (AGU); European Geophysical Society (EGS); Royal Astronomical Society (RAS).

Schlegel K.: President of the International Union of Radio Sciences (URSI), August 2002 – 2005; Mitglied der URSI Kommission G in Deutschland; ständiger Gastprofessor der Wuhan Universität, China.

Schühle U.: Member of ESA's "Solar Orbiter Payload Working Group".

Schüssler M.: Advisory Committee, High Altitude Observatory, NCAR, Boulder, Colorado/USA.

Schwenn R.: Mitglied in der Solar Physics Planning Group der ESA.

Solanki S.K.: Präsident IAU Commission 12 (Solar Radiation and Structure); "Solar Physics" Editorial Board; Mitglied des wissenschaftlichen Beirats des High Altitude Observatory in Boulder, Colorado/USA, des Istituto Ricerche Solari Locarno (IRSOL) und der Gesellschaft für Wissenschaftliche Datenverarbeitung Göttingen; Mitglied des Senatsausschusses des DLR; Mitglied des Programmausschusses Extraterrestrik des DLR; Mitglied des MOWG des Living With a Star Programms der NASA.

Wicht J.: American Geophysical Union; Deutsche Geophysikalische Gesellschaft; European Geophysical Society.

Gutachtertätigkeiten/Review reports

Gutachtertätigkeiten für wissenschaftliche Zeitschriften/Reviews for scientific journals
(Die folgende Aufstellung soll nur eine kurze Übersicht über die Gutachtertätigkeiten von Wissenschaftlern des MPAE für wissenschaftliche Zeitschriften geben. Angeführt sind die Namen der Gutachter (alphabetisch), die Zeitschriften sowie die Anzahl der in den Jahren 2002 und 2003 dafür gegebenen Gutachten./*In the following the names of the reviewers and the journals together with the total number of reviews per journal are listed.*)

Gutachter/Reviewers: V. Bothmer, J. Büchner, U. Christensen, W. Curdt, P.W. Daly, T. Hagfors, P. Hartogh, D. Innes, K. Jockers, M. Küppers, E. Marsch, C.-V. Meister, M.T. Rietveld, K. Schlegel, M. Schüssler, R. Schwenn, S.K. Solanki, V.M. Vasyliūnas, J. Wicht. J. Woch.

Zeitschriften/Journals: Advances in Space Research (7), AGU Monograph Series (2), Annales Geophysicae (13), Astronomy and Astrophysics (11), Astrophysical Journal (8), Comets II book (Kluwer, Michel Festou, Uwe Keller, and Hal Weaver eds.) (2), COSPAR (2), Earth & Planetary Science Letters (1), Earth, Moon and Planets (2), Geofisica International (1), Geophysical & Astrophysical Fluid Dynamics (1), Geophysical Research Letters (19), Icarus (2), IEEE Transactions on Plasma Science (4), Journal of Atmospheric and Solar-Terrestrial Physics (5), Journal of Atmospheric and Terrestrial Physics (3), Journal of Geophysical Research (18), Nature (2), Optics and Laser in Engineering (1), Nonlinear Processes in Geophysics (1), Physics of Plasmas (3), Physics of the Earth and Planetary Deep Interiors (3), Physical Review Letters (1), Planetary and Space Science (7), Radio Science (2), Science (3), Solar Physics (7), SW 10 (2), URSI Radio Science Bulletin (1).

Gutachtertätigkeiten anderer Art/Other types of reviews:

Büchner J.: Peer reviewer for: NASA (USA), NSF (USA), PPARC (UK).

Christensen U.: Fachgutachter der DFG für Physik des Erdkörpers; Begutachtung von Projektanträgen beim DLR, Helmholtzgesellschaft, NSF, NERC; Berufungskommission Geophysik ETH Zürich.

Hagfors T.: PhD Examination "Préparation de la mission Rosetta: simulation de la propagation d'ondes radio à travers des modèles de noyaux cométaires" von Alexandre Piot, l'Univers de Grenoble, Frankreich, 18. Februar 2002; Mitglied: PPARC Research Grant Application: Research in Solar System Plasmas and Atmospheric Physics at the University of Leicester 2002-2006; Mitglied: International Expert Pool, Research Council for Natural Sciences, Academy of Finland, 2002-2004; 7 Personen-Reviews für: Boston University/U.S.A., Dalhousie University/Kanada, Lancaster University/U.K., NAIC/U.S.A., NTNU/Norwegen, STEL/Japan, University of Western Ontario/Kanada.

Jockers K.: Personengutachten (2).

Küppers M.: Referee für "Monthly Notices of the Royal Astronomical Society".

Marsch E.: 1 Gutachten für Research proposal, University of Leuven, Belgium, 2002; 1 Gutachten für National Science Foundation, USA, 2003; 1

Gutachten für GSFC, NASA, Personal Promotion, USA, 2003.

Meister, C.-V.: Gutachter Physik/Astrophysik für Marie-Curie Fellowships der Europäischen Gemeinschaft.

Schlegel K.: Gutachter für University of Saskatchewan, Saskatoon, Canada; Gutachter für University of Western Ontario, London, Canada.

Schüssler M.: Fachgutachter der DFG für Astronomie/Astrophysik; Gutachter für PPARC, Großbritannien; Gutachter für NSF, USA.

Schwenn R.: Gutachten für den Schweizerischen Nationalfonds zur Förderung der wissenschaftlichen Forschung über ein Forschungsvorhaben; Gutachter im Peer Review Panel der NASA über MIDEX Projekte (2002).

Solanki S.K.: Gutachten für National Science Foundation, USA (2); für die Deutsche Forschungsgemeinschaft (1); für Berufungskommissionen der Universität Göttingen und der Universität Jena sowie etliche Personengutachten.

Vasyliūnas V.M.: ein Gutachten für National Science Foundation Proposal (2002).

Wicht J.: Gutachten für die University of Sydney.

Woch J.: Gutachten für NASA Research Proposals.

Tätigkeiten als Convener bei wissenschaftlichen Tagungen/Converenships during scientific meetings

Bothmer V.: Chair for session 6B "3-D Reconstruction Techniques for Chromospheric and Coronal Observations" of the 1st STEREO Workshop, Paris, 2002. Co-Convener of session ST19 "Open session on Solar and Heliospheric Physics", EGS 27th General Assembly, Nice, France, 21 – 26 April 2002. Co-Convener of session ST2 "Space Weather", EGS 27th General Assembly, Nice, France, 21 – 26 April 2002. Convener of session ST21 "Stereoscopic observations of the Sun and the inner Heliosphere", EGS 27th General Assembly, Nice, France, 21 – 26 April 2002. Co-Convener of session ST 4 "Open session on solar and heliospheric physics", 1st joint EGS, AGU, EGU Assembly, Nice, France, April 2003. Co-Convener of session ST 23.04 "Sources of Space Weather: Aspects from Solar & Heliospheric Missions", 1st joint EGS, AGU, EGU Assembly, Nice, France, April 2003. Session on CME Initiation, International Solar Cycle Studies Symposium 2003: 'Solar Variability as an input to the Earth's Environment', Tatranska Lomnica, Slovak Republic, 23 – 28 June 2003. Chairman: International Efforts in Space Weather Research, Effects of Space Weather on Technology Infrastructure ESPRIT), hyperlink "http://www.nato.int/science/" NATO Advanced Research Workshop, Rhodes, Greece, 25 – 29 March 2003. Co-Chair, Working group G: Inner Heliosphere, CME workshop, Elmau, Germany, 6 – 12 February 2003.

Büchner J.: 34th COSPAR General Assembly – World Space Congress, Houston, Texas, USA, 10 – 18 October 2002, Convener of symposium "Magnetic Helicity at sun and in magnetospheres" (co-convener: A. Pevtsov). EGS, XXVII General Assembly, Nice, France, 21 – 26 April 2002, Convener of session "Theory and simulation of solar system plasmas". EGS-AGU-EUG, Joint Assembly, Nice, France, 6 – 11 April 2003, Convener of session "Theory and simulation of solar system plasmas". 2003 NATO workshop on "Multiscale processes in the Earth's magnetosphere: from Interball to Cluster", Prague, 9 – 12 September 2003, Co-convener.

Christensen U.: Co-Convener, EGS-AGU-EUG Joint Assembly, Nice, France, 6 — 11 April 2003, Session GD1 The geodynamo, core-mantle interactions and the evolution of the Earth.

Curdt W.: Convener of session 5: "Transition region Dynamics: Transients, Jets" in SOHO 13: "Waves, oscillations and small scale events in the Solar Atmosphere. A joint view from SOHO and TRACE", 29 September – 3 October 2003, Palma de Mallorca, Spain.

Daly P.W.: Co-convener, European Geophysical Society XXVII General Assembly, Nice, France, 22 – 26 April 2002, Session GO3.02: Space instrumentation: Time-of-flight instrumentations for space plasmas (in memoriam of Berend Wilken).

Hartogh P.: International Scientific Conference of the Astronomische Gesellschaft "The Sun and Planetary Systems – Paradigms for the Universe", Splinter-Meeting "Observation and Modelling of Planetary Atmospheres", Freiburg, Germany, 15 – 20 September 2003.

Krupp N.: EGS-AGU-EUG Joint Assembly of the European Geophysical Society, Nice, France, 22 – 26 April 2002, Session: PS11, Plasma Physics. EGS-AGU-EUG Joint Assembly of the European Geophysical Society, Nice, France, 6 – 11 April 2003, Session: PS5.03, Outer Planets: Plasma Physics.

Marsch E.: 10th European Solar Physics Meeting, Session: Solar Wind and its Frontiers, EPS, Praha, Czechia, 9 – 14 September, 2002.

Meister C.-V.: Organisator (zusammen mit Dr. P. Hartogh) of the Splinter-Meeting “Observation and Modelling of Planetary Atmospheres” during the International Scientific Conference of the “Astronomische Gesellschaft” “The Sun and Planetary Systems – Paradigms for the Universe”, 15 – 20 September 2003.

Rietveld M.T.: Convener, Ionospheric modification session bei dem 11th biennial EISCAT Workshop, Menlo Park, USA, 25 – 29 August 2003.

Schühle U.: Annual Meeting of the SPIE – The International Society for Optical Engineering, Conference AM124: Telescopes and Instrumentation for Solar Astrophysics, San Diego, 2 -– 8 August 2003, convener and chair of the session “Detectors for Solar Space Missions”.

Schüssler M.: Convener of Minisymposium “Magneto-Hydrodynamics”, GAMM Meeting 2002, Augsburg, April 2002.

Solanki S.K.: SOC-Member of 1st Potsdam Thinkshop on Sunspots and Starspots, Potsdam, 6 – 10 May 2002. SOC-Member of Euroconference and IAU Colloquium 188 “Magnetic Coupling of the Solar Atmosphere”, Santorini, Greece, 11 – 15 June 2002. SOC-Member of IAU Symposium 210 “Modelling of Stellar Atmospheres”, Uppsala, Sweden, 17 – 21 June 2002. SOC-Member of 3rd International Workshop on “Solar Polarization”, Puerto de la Cruz, Tenerife, Spain, 30 September – 4 October 2002. SOC-Member of COSPAR Workshop “Solar Variability and Climate Change”, 34th COSPAR Scientific Assembly in Houston, TX, USA, 10 – 19 October 2002. SOC-Member of Workshop “Planetenbildung: Das Sonnensystem und extrasolare Planeten”, Weimar, 19 – 21 February 2003.

Organisation von Workshops/ Workshop organisation

Bothmer V.: First STEREO Workshop, Paris, France, 2002.

Büchner J.: AEF (Working group for extraterrestrial research) Jörg Büchner: organisator of the workshops on the near Earth space: Leipzig 2002 and Jena, 23 – 28 February 2003.

Christensen U.: Mercury Workshop, MPAe, Katlenburg-Lindau, 5. und 12. Mai 2003; Informal Workshop Geodynamo, MPAe, Katlenburg-Lindau, 26. – 27. Mai 2003.

Röttger R., M. Rietveld and K. Schlegel: Workshop über die Zukunft von EISCAT-bezogener Forschung in Deutschland, MPAe, Katlenburg-Lindau, 14. – 15. März 2002.

Schühle U.: Organizer and Co-Chair (with G. Tsiropoula) of the Euroconference and IAU Colloquium 188 “Magnetic Coupling of the Solar Atmosphere, SOLMAG 2002” on Santorini, Greece, 11 – 15 June 2002.

Öffentlichkeitsarbeit/Public relations

Dr. N. Krupp (Pressesprecher des MPAe seit 1. Juni 2002), Prof. Dr. K. Schlegel (Pressesprecher des MPAe bis 31. Mai 2002), Dr. B. Wöbke, Dr. P. Czechowsky.

Dr. N. Krupp:
Organisation Pressekonferenz Rosetta im Deutschen Museum München (5. Dezember 2002).

Pressenotizen/Press releases

Im Berichtszeitraum wurden die folgenden Pressenotizen herausgegeben:

- Gibt es Leben auf anderen Welten? Zwanzigster Vortrag der Erich-Regener-Vortragsreihe. 28. Januar 2002.
- Sonnenuhren – Dokumente der Zeitmesskunst. 21. Vortrag der Erich-Regener-Vortragsreihe. 22. Februar 2002.
- Der Ursprung der Sternbilder. 22. Vortrag der Erich-Regener-Vortragsreihe. 3. Mai 2002.
- Niedersachsens Ministerpräsident Gabriel besucht Ausstellung des Max-Planck-Instituts für Aeronomie (MPAe) in Northeim. 4. Juni 2002.
- Die musikalische Sonne. Materiebögen schwingen wie Gitarrensaiten. 27. Juni 2002.
- Direkt zum Mars. 23. Vortrag der Erich-Regener-Vortragsreihe. 22. Juli 2002.
- Bedeutendes Amt für einen Wissenschaftler des MPAe. Prof. Dr. Kristian Schlegel wird Präsident der URSI. 27. August 2002.
- Politiker besuchen das Max-Planck-Institut für Aeronomie. Wolfgang Jüttner und Erika Mann besuchen MPAe. 13. September 2002.
- Lässt sich Grundlagenforschung vermarkten? 24. Vortrag der Erich-Regener-Vortragsreihe. 28. Oktober 2002.
- Weiche Landung auf einem kosmischen Vagabunden. Europa startet aufregende Weltraummission „Rosetta“ zum Kometen

„Wirtanen“. Drei Max-Planck-Institute beteiligt. 20. November 2002.

- Astronaut Ewald spricht über die ISS. 25. Vortrag der Erich-Regener-Vortragsreihe. 9. Dezember 2002.
- Rosetta-Start verschoben. 14. Januar 2003.
- Rosetta-Start auf unbestimmte Zeit verschoben. 16. Januar 2003.
- Astronomische Uhren. 26. Vortrag der Erich-Regener-Vortragsreihe. 6. Februar 2003.
- Erforschung der Asteroiden. 27. Vortrag der Erich-Regener-Vortragsreihe. 28. März 2003.
- Christensen neuer MPAe-Direktor.
  Prof. Dr. Ulrich Christensen wird offiziell neuer Direktor am Max-Planck-Institut für Aeronomie, Geschäftsführer Dr. Peter Czechowsky wird verabschiedet. 8. Mai 2003.
- ESA-Mission „Mars Express“ vor dem Start. 19. Mai 2003.
- Impakte von Asteroiden. 28. Vortrag der Erich-Regener-Vortragsreihe. 6. Juni 2003.
- Abgase der Space Shuttles können Nachtleuchtende Wolken erzeugen. 16. Juli 2003.
- „Smarte“ Mondforschung beginnt Anfang September. 15. August 2003.
- MPAe an Mission Phoenix beteiligt. 22. August 2003.
- ARIANE, Europas Weg in den Weltraum. 29. Vortrag der Erich-Regener-Vortragsreihe. 1. September 2003.
- Abwehr von Kometen und Asteroiden. 30. Vortrag der Erich-Regener-Vortragsreihe. 24. September 2003.
- Heizregion der Sonnenkorona erstmals direkt beobachtet. Forscherteam am Max-Planck-Institut für Aeronomie entdeckt einen „Ofen“ für die Heizung der Sonnenkorona auf mehr als eine Million Grad. 15. Oktober 2003.
- Sonne seit 1940 aktiver denn je. Seit 1940 ist die Sonne ungewöhnlich aktiv, belegt eine neue Studie des Max-Planck-Instituts für Aeronomie zur Sonnenfleckenaktivität von 850 bis heute. 30. Oktober 2003.
- Die Sternfreunde Braunschweig-Hondelage e.V. – Amateure greifen nach den Sternen. 31. Vortrag der Erich-Regener-Vortragsreihe. 21. November 2003
- ESA-Mission „Mars Express“ vor dem Ziel. „Mars Express“ soll Oberfläche und Atmosphäre des Mars und die Wechselwirkung des interplanetaren Mediums mit der Marsatmosphäre erkunden. 17. Dezember 2003.

Ausstellungsstände/Exhibition stands

Der mobile Ausstellungsstand, mit dessen Hilfe die wissenschaftliche Arbeit am Institut der Öffentlichkeit in verständlicher Form vorgestellt wird, wurde bei folgenden Anlässen ausgestellt:

- Informationsmarkt zur Berufsfindung, Berufsbildende Schulen II, Northeim, 28. – 29. Mai 2002.
- Northeim (Heimatmuseum), 2. – 30. Juni 2002.
- Burg Hardenberg in Nörten-Hardenberg, 17. – 18. August 2002.
- Göttingen (DLR), Tag der Raumfahrt, 6. September 2002.
- München (Deutsches Museum), Rosetta-Pressekonferenz, 5. Dezember 2002.
- Duderstadt (Heimatmuseum), 4. April – 4. Mai 2003.
- Informationsmarkt zur Berufsfindung, Berufsbildende Schulen II, Northeim, 13. – 14. Mai 2003.
- Göttingen (3 Standorte), „Ab in die Mitte“ 19. – 20. September 2003.
- Braunschweig (DLR), Tag der Raumfahrt, 19. – 20. September 2003.
- Buxtehude (Halepaghen-Schule), Astrobux 2003, 20. – 23. Oktober 2003.

Bei den Ausstellungen in Northeim und Duderstadt wurden jeweils mehrere gut besuchte Ausstellungs-Führungen durchgeführt, bei der Ausstellung in Duderstadt auch vier Abendvorträge:

8. April 2003
Prof. Dr. Manfred Schüssler: *„Steuert die Sonne das Erdklima?“*
15. April 2003
Prof. Dr. Kristian Schlegel: *„Polarlicht“*.
23. April 2003
Dr. Björn Grieger: *„Titan – die verschleierte Welt“*.
29. April 2003
Dr. Urs Mall: *„SMART 1: Das Eichsfeld geht zum Mond“*.

Institutsführungen und Anfragen/Institute tours and information

Im Jahr 2002 fanden 29 Führungen mit 466 Personen, im Jahr 2003 fanden 14 Führungen mit 209 Personen statt.

Erich-Regener-Vortragsreihe/
Erich-Regener lecture series

Vorträge dieser Reihe wenden sich an in der Region wohnende Laien.

4. Februar 2002
Prof. Dr. Ronald Weinberger (Institut für Astrophysik der Leopold-Franzens-Universität Innsbruck): Gibt es Leben auf anderen Welten?

6. März 2002
Arnold Zenkert (Potsdam): Sonnenuhren -– Dokumente der Zeitmesskunst.

15. Mai 2002
Kai Helge Wirth (Frankfurt a. M.): Der Ursprung der Sternbilder.

8. August 2002
Dr. Björn Grieger (Max-Planck-Institut für Aeronomie, Katlenburg-Lindau): Direkt zum Mars -– Die Vision der Mars Society von der Besiedelung des roten Planeten.

7. November 2002
Dr. Bernhard Hertel (Garching Innovation GmbH, München): Vom Labor an die Börse — Lässt sich Grundlagenforschung vermarkten?

16. Dezember 2002
Dr. Reinhold Ewald (Astronaut der ESA): Die Europäische Beteiligung an der Internationalen Raumstation ISS -– aus der Perspektive eines Astronauten.

20. Februar 2003
Prof. Dr. Manfred Schukowski (Rostock): Astronomische Uhren.

7. April 2003
Dr. Andreas Nathues (Max-Planck-Institut für Aeronomie, Katlenburg-Lindau): Die Erforschung der Welt der Asteroiden (Asteroiden I).

16. Juni 2003
Prof. Dr. Dieter Stöffler (Humboldt-Universität Berlin): Impakte von Asteroiden und Kometen in der Erdgeschichte (Asteroiden II).

11. September 2003
Horst Holsten (Astrium Raumfahrt-Infrastruktur): ARIANE, Europas Weg in den Weltraum.

9. Oktober 2003
Dr.-Ing. Christian Gritzner (TU Dresden): Abwehr von Kometen und Asteroiden (Asteroiden III).

27. November 2003
Hans Zimmermann (Braunschweig): Die Sternfreunde Braunschweig-Hondelage e.V. — Amateure greifen nach den Sternen.

Öffentliche Vorträge/Public presentations

Büchner J.: Popular Lecture "Killerelektronen" at URANIA Berlin.

Schüssler M.: Öffentliche Vorträge an/bei Hölty-Gymnasium, Wunstorf; 5. Göttinger Woche: Wissenschaft und Jugend 2002: Hainberg-Gymnasium, Göttingen, Georg-Christoph-Lichtenberg-Gesamtschule, Göttingen, Valentin-Traut-Schule, Groß-Almerode,; Museum Duderstadt,; 6. Göttinger Woche: Wissenschaft und Jugend 2003: Hainberg-Gymnasium, Göttingen, Otto-Hahn-Gymnasium, Göttingen, Valentin-Traut-Schule, Groß-Almerode, Jacob-Grimm-Gymnasium, Kassel.

Schwenn R.: Mehrere öffentliche Vorträge an Planetarien, Volkshochschulen, Gymnasien etc. Mitgestaltung der „Weltraumwetterwoche“ in Berlin im November 2002, Beiträge zur CD-ROM „Weltraumwetter“ der ESA.

Solanki S.K.: Die Sonne, ein Motor für globale Klimaänderungen? Annual Scientific Meeting of the Astronomische Gesellschaft, "The Sun and Planetary Systems – Paradigms for the Universe", Freiburg, 15. – 20. September 2003.

Werner S.: Die Cassini-Mission – Eine Reise zum Saturn. Vortrag zum Tag der Raumfahrt, DLR Göttingen, 6. September 2002.

Verschiedenes/Miscellaneous

Dr. V. Bothmer:
- Organisation of international Sun-Earth Day in collaboration with ESA, NASA X-LAB, and University Göttingen, March 18, 2003.
- Vorführung der 3D Visualisierung von Sonnenbeobachtungen der ESA/NASA Weltraumsonde und Erläuterung der geplanten Zusammenarbeit des Planetariums Hamburg an aktuellen ESA, NASA Weltraummissionen mit MPAe, Galaabend des Planetariums Hamburg, 11. August 2003,
- Sonne und Erde - eine stürmische Beziehung, eingeladener Vortrag, Heinrich-Nordhoff-Gesamtschule Wolfsburg, 8. Juli, 2003,
- Kontinuierliche Zusammenarbeit mit dem Magazin

Focus, Thematik: Physik der Sonne und des Sonne-Erde-Systems, Weltraumwetter
- Eingeladener Vortrag, Astrobux 2003, Arbeitskreis Astronomie der MNU, 20. – 23. Oktober, 2003.
- Betreuung des MPAE Beitrags zum Thema Sonne für die Göttinger AllTage in 2003, Thematik: SOHO und Darstellung des deutschen Beitrags zur NASA STEREO Mission.

Dr. P.W. Daly: Betreuung der Online-Veröffentlichungsliste.

Dr. N. Krupp: Erstellung einer neuen Ausstellung im Foyer des Instituts.

Dr. C.-V. Meister: Ehrenamtliche Leitung des Projektes „Kosmische Plasmaphysik" im Hochschul- und Wissenschaftsprogramm 2001-2003/Land Brandenburg.

Ernennungen/Appointments

Prof. Dr. T. Hagfors
Ehrenmitglied der EISCAT Scientific Association auf Lebenszeit, Verleihung der EISCAT Beynon Medaille, EISCAT Scientific Association, 4. Februar 2002; Verleihung der Ehrendoktorwürde der Faculty of Science, University of Oulu, Finnland, 25. Mai 2002; Verleihung der Ehrendoktorwürde der University of Tromsø, Norwegen, 28. März 2003.

Prof. Dr. S.K. Solanki
Harold Jeffreys Lecturer 2002 der Royal Astronomical Society; Verleihung einer Honorarprofessur an der Technischen Universität Braunschweig (2003).

Prof. Dr. V.M. Vasyliūnas wurde vom Council der Royal Astronomical Society London zum "Associate of the Society" ernannt (2003).

Auszeichnungen/Awards

Christian Vocks
wurde die Otto-Hahn-Medaille der MPG verliehen (2002).

Matthias Rempel
wurde die Otto-Hahn-Medaille der MPG verliehen (2003).

Christoph Keller
wurde der Friedrich-Wilhelm-Bessel-Preis der Alexander-von-Humboldt-Stiftung verliehen. Herr C. Keller hat unser Institut für seinen mit dem Preis verbunden Forschungsaufenthalt ausgewählt (September 2003 – April 2004).

Herausgebertätigkeiten/Editorships

Büchner J.: Editor (since 1999) of the EGU-AGU Journal "Nonlinear Processes in Geophysics"; Co-editor (J. Büchner and G. Belmont) of "Theory and simulation waves and chaos in space plasmas", EGU., 173 pp, 2002 .ISSN 1023-5809; Co-editor (J. Büchner, C. Dum and M. Scholer) of the Proceedings of the "Sixth International School/Symposium on Space Plasma Simulation", Lange, Berlin, 413 pp., 2002. ISBN 3-9804862-8-1; Editor of "Comparative Reconnection studies at sun and in magnetospheres", Elsevier Science, Oxford, New York, Tokyo, 113 pp, 2002, ISSN 0277-1173; Co-editor (E. Mjolhus, B. Tsuruani, J. Büchner) of "Nonlinear waves and chaos in space plasmas", EGU., 182 pp, 2003. ISSN 1023-5809; Co-editor (J. Büchner, C. Dum and M. Scholer) of Springer Lecture Notes in Physics on "Space Plasma Simulation", Springer Berlin, Heidelberg, New York, 351 pp, 2003. ISBN 3-540-00698-2; Co-editor (J. Büchner and A.A. Pevtsov) of "Magnetic Helicity at the sun, in solar wind and magnetospheres", Elsevier Science, Oxford, New York, Tokyo, 187 pp, 2003. ISSN 0277-1173.

Hartogh, P.: Atmospheric Chemistry and Physics (Subject: Gases, Aerosols, Clouds and Precipitation, Isotopes, Radiation, Dynamics) (Activity: Remote Sensing).

Marsch, E.: Mitherausgeber der Zeitschrift: "Living Reviews in Solar Physics" since 2003.

Meister, C.-V.: Mitherausgeber von „Wissenschaftler und Verantwortung" (seit April 2003).

Direktionsbeirat des MPAE/
„Direktionsbeirat" at MPAE

Gewählte Mitglieder des Direktionsbeirates für die Amtszeit 2002 waren:
Dr. Iancu Pardowitz, Prof. Dr. Manfred Schüssler, Dipl.-Ing. Eckhard Steinmetz als Ersatzmitglied *Dr. Andreas Lagg.*

Gewählte Mitglieder des Direktionsbeirates für die Amtszeit 2003 waren:
Dr. Paul Hartogh (Planeten), als Ersatzmitglied *Dr. Urs Mall, Prof. Dr. Eckart Marsch (Sonne),* als Ersatzmitglied *Dr. Andreas Lagg, Dipl.-Ing. Reinhard Meller (Zentrale Dienste),* als Ersatzmitglieder *Michael Bruns, Helmut Zapf.*

40 Jahre in der MPG/40 years at MPG

- Helmut Schild (16. Juli 2002)
- Peter Fahlbusch (1. Oktober 2002)

- Wolfgang Neumann (1. Oktober 2002)
- Norbert Meyer (1. April 2003)
- Ulrich Strohmeyer (1. April 2003)

25 Jahre in der MPG/25 years at MPG

- Marianne Krause (1. März 2003)

VIII. Berichte, Vorträge und Veröffentlichungen/ Reports, Talks and Publications

Interne MPAE-Berichte/ Internal MPAE reports

(W wissenschaftlicher, T technischer Bericht; M Handbuch (Manual); V Vorschlag für ein Experiment; L Manuskript für eine Vorlesung/Seminar)

(W scientific, T technical report; M manual; V experiment proposal; L lecture paper/seminar)

MPAE-L-853-02-01
G. K. Hartmann
Komplementarität im Abendland und Nicht-Abendland
Dr. Klaus Wilhelm zum 65. Geburtstag

MPAE-W-848-02-02
J. Büchner und B. Nikutowski
Datenvalidierung und -auswertung
Equator-S
- Schlußbericht -

MPAE-L-853-02-03
G. K. Hartmann
Wenn Selbstverständliches fragwürdig wird.

MPAE-W-852-02-04
K. J. Kossacki and W. J. Markiewicz
Martian seasonal CO_2 ice in polygonal troughs in southern polar region: role of the distribution of subsurface H_2O ice.

MPAE-L-853-02-05
G. K. Hartmann
Space research and the problems of data validation: quality versus quantity.

MPAE-W-100-02-06
P. Hartogh, C. V. Meister and G. Villanueva
Hydrodynamics model of the Mars atmosphere between near-surface layers and an altitude of about 130 km.

MPAE-W-100-02-07
C. V. Meister
Coherent nonlinear wave interaction in the auroral ionosphere.

MPAE-W-485-02-08
Jing-Song Wang and Erling Nielsen
Faraday rotation and absorption in the Martian crustal strong magnetic field region.

MPAE-W-485-03-01
Jing-Song Wang and Erling Nielsen
Preliminary numerical simulation on hydrodynamic waves in Mars´ topside ionosphere.

MPAE-W-472-03-02
J. R. Kramm, H. Sierks, P. Barthol, R. Müller, G. Tomasch and D. Germerott
Benefit from annealing proton irradiation defects on the OSIRIS CCDs.

MPAE-W-100-03-03
A. V. Volosevich and C. V. Meister
Ion-acoustic and electron-acoustic nonlinear waves in multi-component.

MPAE-T-100-03-04
C. V. Meister
The numerical programme MART-ACC by A. Ebel and U. Berger: Programme description and hints at further programme development.

Experimentvorschläge/Proposals

AIS/SDO: Atmospheric Imaging Spectrograph for the Solar Dynamics Observatory. (PI: Donald M. Hassler, SWRI, Boulder, USA), (U. Schühle, W. Curdt, E. Marsch, D. Innes, MPAE). Proposal submitted in response to NASA AO 02-OSS-01 (not selected).

ASCE: Advanced Spectrographic and Coronagraphic Explorer. (PI: John Kohl, CfA Harvard, USA), (U. Schühle, E. Marsch, D. Innes, V. Bothmer, S. Solanki, MPAE). Proposal for a NASA MIDEX mission (not selected).

BOLD: Beyond Optical Light Detectors. (Coordinator: U. Schühle and U. Mall, A. Gandorfer, M. Hilchenbach, MPAE). Proposal for an Integrated Project to the European Commission in the 6th Framework Programme.

MAMBO: Mars Atmospheric Microwave Brightness Observer. (Co-I: P. Hartogh, MPAE). Proposal to CNES, nicht genehmigt, 2002.

MARVEL: Mars Volcanic Emission and Life. (Co-I: P. Hartogh, MPAE). Proposal to NASA, erfolgreiche Phase A, Endausscheidung nicht genehmigt, 2002.

NEXUS: Normal Incidence Extreme Ultraviolet Spectrograph. (PI: Joseph Davila, GSFC, Greenbelt, USA), (U. Schühle, W. Curdt, E. Marsch, D. Innes, MPAE). Proposal submitted to NASA in response to AO 03-OSS-02.

NEXUS/SDO: Normal Incidence Extreme Ultraviolet Imaging Spectrometer. (K.P. Dere et al., NRL), (V. Bothmer, S. Solanki, W. Curdt, MPAE). Proposal für die NASA SDO Mission (AO 02-OSS-01) (Apr. 2002).

SHARPP/SDO: The solar atmospheric imaging assembly (AIA) aboard the Solar Dynamics Observatory. (PI: Russ Howard, Naval Research Lab., Washington DC, USA), (U. Schühle, V. Bothmer, R. Schwenn, S. Solanki, MPAE). Proposal in response to NASA AO 02-OSS-01. (cancelled)

Technical assistance in the development of optically blind detectors. (Coordinator: Chr. Van Hoof IMEC, Leuven Belgium), (U. Schühle, MPAE). Proposal to ESA as a technology development for the Solar Orbiter mission.

Dissertationen/Dissertations

Volkmar Holzwarth: Dynamik magnetischer Flussröhren in Riesensternen und engen Doppelsternen (summa cum laude). Universität Göttingen, 10. Juli 2002.

Katja Janßen: Struktur und Dynamik kleinskaliger Magnetfelder der Sonnenatmosphäre. Universitäts-Sternwarte, Universität Göttingen, 2003.

Michael Jordan: JI-3D Eine neue Methode zur hochauflösenden regionalen seismischen Tomographie: Theorie und Anwendungen. Universität Göttingen, 27. März 2003.

Carsten Kutzner: Untersuchung von Feldumkehrungen an einem numerischen Modell des Geodynamos. Universität Göttingen, 27. März 2003.

Oliver Preuß: Astronomical tests of the Einstein Equivalence Principle. Universität Bielefeld, 28. November 2002.

Santo Valentin Salinas Cortijo: Multi-dimensional Polarized Radiative Transfer Modeling of Titan's Atmosphere. Universität Göttingen, 2003.

Alexander Vögler: Three-dimensional simulations of magneto-convection in the solar photosphere (summa cum laude). Universität Göttingen, 11. Juli 2003.

Peter Vollmöller: Untersuchung der Wechselwirkung von Magnetfeldkonzentrationen und konvektiven Strömungen mit dem Strahlungsfeld in der Photosphäre der Sonne. Universität Göttingen, 8. Februar 2002.

Maren Wunnenberg: Untersuchung kurzperiodischer akustischer Wellen in der Sonnenatmosphäre mit Hilfe der Wavelet-Transformation. Universitäts-Sternwarte, Universität Göttingen, 2003.

Lidong Xia: Equatorial Coronal HOles and Their Relation to the High-Speed Solar Wind Streams. Universität Göttingen, 2003.

Tee-Seminare/Tea Seminars

Leitung/Organizers: Dr. P.W. Daly, Dr. B. Inhester und Dr. J. Woch

In den Seminaren wird von Wissenschaftlern des MPAE, aber auch von Gästen in unregelmäßigen Zeitabständen über laufende Arbeiten vorgetragen.

MPAE scientists, as well as guests to the Institute, report on their current work in the informal seminars.

Dr. R. Garmier, Observatoire Midi-Pyrénées: Modeling of the gravity field of asteriod 433 Eros by an ellipsoidal harmonic expansion in the frame of the NEAR mission. 4. Januar 2002.

Dr. D. Stankevich and Dr. V. Kaydash, Astronomical Observatory of Kharkov University, Ukraine: Modeling optical properties of regolithlike media and cosmic dust particles in the geometrics optics approximation and Structure anomalies of the lunar regolith from Clementine/Smart-1 data. 18. Januar 2002.

Monique Pick and Nicole Vilmer, Observatoire de Paris, Meudon, Frankreich: What can be learnt from multiwavelength observations on accelerated particles in flares and coronal mass ejections? 23. Januar 2002.

Dr. Hans-Günter Ludwig, Lund Observatory: Hydrodynamic simulations of stellar convection: status and perspectives. 1. Februar 2002.

Dr. Luca Teriaca, Osservatorio Astrofisico di Arcetri, Firenze, Italia: UV explosive events: do they play a role in coronal heating? 5. Februar 2002.

Prof. F. Menk, University of Newcastle,Callaghan, Australia: Mapping the plamasphere and the plasmapause using geomagnetic field line resonances. 11. Februar 2002.

Krishan Khurana, UCLA, USA: Liquid water and its exploration on the jovian moon Europa. 12. Februar 2002.

Dr. Reiner Friedel, Los Alamos National Lab., USA: Relativistic Electron Dynamics in the Inner Magnetosphere - a Review. 15. Februar 2002.

Prof. A. Zippelius, Institut für Theoretische Physik, Universität Göttingen: Kinetic Theory of Granular Gases. 8. März 2002.

Dr. I. Usoskin, Sodankyla Geophysical Observatory: A New Standpoint on the Long-term Solar Activity. 19. März 2002.

Rudolf von Steiger, ISSI, Bern: The 3-D Structure of the Heliosphere. 21. März 2002.

Dr. A.R. Choudhuri, Indian Institute of Science, Bangalore, India: The origin of the solar cycle. 3. Mai 2002.

Dr. S.P. Rajaguru, Blackett Laboratory, Imperial College, London, UK: Active region seismology from ring diagram analysis. 13. Mai 2002.

Dr. R. Beck, MPI für Radioastronomie, Bonn: Magnetic fields in spiral galaxies. 13. Mai 2002.

Dr. Klaus Scherer, Dathex, Lindau: Dynamics of the heliospheric structure due to solar cycle variations. 15. Mai 2002.

Prof. Larry Esposito, University of Colorado - LASP, Boulder, USA: Cassini UVIS and Saturn's wandering shepherds. 16. Mai 2002.

Prof. Tadashi Mukai, Graduate School of Science and Technology, Kobe University, Japan: MUSES-C - Sample return mission to the asteroid. 17. Mai 2002.

Paul Hanlon, Imperial College, London, UK: Cassini observations of solar wind events upstream of Jupiter. 22. Mai 2002.

Nicolas André, Observatoire Midi-Pyrénées, Toulouse, France and Imperial College, London, UK: Low-frequency waves and instabilities in gyrotropic plasmas: Application to the centrifugal and mirror instabilities in the jovian environment. 22. Mai 2002.

Dr. Alexander Rodin, IKI, Moscow: A moment-based model of stochastic coagulation: implications for Titan's aerosols. 23. Mai 2002.

Prof. Dr. Artie P. Hatzes, Thüringer Landessternwarte, Tautenburg: The Thüringer Landessternwarte Extra-solar Planet Search Program. 28. Mai 2002.

Dr. A.R. Choudhuri, Department of Physics, Indian Institute of Science, Bangalore, India: The evolution of magnetic fields in neutron stars. 20. Juni 2002.

Dr. R. Neuhäuser, Max-Planck-Institut für Extraterrestrische Physik: Direct imaging of sub-stellar companions around young nearby stars. 19. Juli 2002.

Dr. R. Cameron, Science University of Tokyo, Japan: Compressible axisymmetric magnetoconvection and quiet Sun magnetic fields. 31. Juli 2002.

Dr. E. Schnepp, Institut für Geophysik, Universität Göttingen: Retrieving secular variations of the Earth's magnetic field by archeomagnetic investigantions. 23. August 2002.

Dr. M. Guedel, Institut für Astronomie, ETH Zürich, Schweiz: A new look at stellar X-rays with XMM-Newton and Chandra. 28. August 2002.

Dr. G. Vekstein, University of Manchester, UK: Signatures of the Nanoflare Heated Solar Corona. 6. November 2002.

Dr. Hertel, Garching Innovations, München: Die Garching Innovation GmbH – Technologietransfer in der Max-Planck-Gesellschaft. 8. November 2002.

Dr. M. Küppers, Physikalisches Institut, Bern, Schweiz: The evolution of regolith and surface properties of 433/Eros and other asteroids. 8. November 2002.

Prof. Z. Kaymaz, Istanbul Technical University: A Review on the IMF Control of the Earth's Magnetosheat Geometry. 15. November 2002.

Dr. Vasundhara Raju, Indian Institute of Astrophysics: Cometary studies at the Indian Institute of Astrophysics. 18. November 2002.

Dr. R. Szczerba, N. Copernicus Astronomical Centre, Torun, Polen: The Herschel Space Observatory mission - the project, instruments and a scientific overview. 18. November 2002.

Dr. C. Vocks, Astrophysikalisches Institut, Potsdam: Kinetics of Electrons in the Solar Corona and Solar Wind. 21. November 2002.

Dr. S. Dreizler, Universität Tübingen: From pulsating stars to extrasolar planets. 21. Januar 2003.

Dr. J. Kissel, MPE Garching: COSIMA - Staubmassenspektrometer auf Rosetta: Voraussetzungen und Möglichkeiten. 30. Januar 2003.

Dr. T. Imamura, Institute of Space and Astronautical Science, Japan: Strategy of meteorological observations of Venus in the Japanese Planet-C mission. 6. Februar 2003.

Dr. N. Nakamura, Institute of Space and Astronautical Science, Japan: Planet-C: scenario of the Japanese orbiter mission to Venus. 6. Februar 2003.

Dr. G. Siscoe, Boston University, USA: The unknown magnetosphere: the magnetosphere under extreme conditions. 14. Februar 2003.

Dr. E. Wiehr, Universitätssternwarte Göttingen: Spectroscopic observations of prominences with SUMER, TRACE and telecopes on the Canary Islands. 17. März 2003.

K. Berndt, Jena Optronic GmbH: Instrumentenentwicklung für die zukünftige Weltraumforschung bei Jena Optronic. 27. März 2003.

Prof. Pierre Kaufmann, INPE, Sao Paulo, Brasilien: The launch of solar coronal mass ejections and submillimeter pulse bursts. 15. April 2003.

Dr. H. Hiesinger, Brown University, Rhode Island, USA: Lunar Science – an Introduction and Overview. 16. April 2003.

Dr. W. Kalkofen, Centre for Astrophysics, Harvard University, USA: The violent solar chromosphere. 5. Mai 2003.

Dr. R. Schwenn, MPAE: What is left in heliospheric research for the IHY? 14. Mai 2003.

Dr. W. Rammacher, Institut für theoretische Astrophysik, Universität Heidelberg: Zeitabhängige Ionisationsprozesse in der Chromosphäre – numerische Simulation und erste Vergleiche mit Beobachtungen. 21. Mai 2003.

Dr. J. Beer, EAWAG, Dübendorf, Schweiz: Cosmogenic isotopes: A versatile tool in solar-terrestrial sciences. 21. Mai 2003.

Dr. B. Kromer, Institut für Umweltphysik, Universität Heidelberg und Heidelberger Akademie der Wissenschaften: 14C from tree-rings - a proxy of solar and oceanic variability. 23. Mai 2003.

Dr. Peter Hoyng, SRON Lab. for Space Research, Utrecht, The Netherlands: Geomagnetic Reversals: a Nonthermal Exit Problem. 26. Mai 2003.

Dr. Jean-Pierre Barriot, Observatoire Midi-Pyrénées, Toulouse, France: Research in Radio Sciences at the Observatoire Midi-Pyrénées in Toulouse, France. 12. Juni 2003.

Dr. A. Basilevky, Vernadsky Institute of Goechemistry and Analytical Chemistry, Moscow: Venus Geology: What we know about it and which problems can be resolved through the analysis of the VEX Venus Monitoring Camera data. 13. Juni 2003.

Dr. Jon Rotvig, University of Exeter, England, UK: Dynamos and convection: mean flow generation. 24. Juni 2003.

Dr. Hermann Böhnhardt, MPI für Astronomie, Heidelberg: Split Comets. 25. Juni 2003.

Dr. Harald Krüger, MPI für Kernphysik, Heidelberg: Jupiter's Dust Disk: An Astrophysical Laboratory. 25. Juni 2003.

Dr. Johannes Benkhoff, DLR Institut für Planetenerkundung, Berlin-Adlershof: Gas flux modelling – A tool to study planetary surfaces. 26. Juni 2003.

Priv. Doz. Dr. Martin Pätzold, Institut für Geophysik und Meteorologie, Universität Köln: Radio Science experiments on interplanetary spacecraft: Contributions to Planetary Geophysics. 26. Juni 2003.

Dr. Joachim Saur, APL/JHU, Laurel, USA: Jupiter: Satellite interaction and magnetospheric turbulence. 27. Juni 2003.

Dr. S. Jordan, Universität Tübingen: Magnetic white dwarfs: observations in cosmic laboratories. 1. Juli 2003.

Dr. J. Veizer, Institut für Geologie, Mineralogie und Geophysik, Bochum: What drives the climate? A perspective from 4 billion years of carbon cycle. 4. Juli 2003.

Dr. D. Banerjee, Center for Astrophysics, University of Leuven: Dynamics of the transition region as seen by CDS. 25. August 2003.

Dr. C.T. Russell, University of California, Los Angeles, USA: The Dawn Mission – a Journey to the Beginning of the Solar System. 12. September 2003.

Dr. B.C. Low, High Altitude Laboratory, Boulder, USA: The Hydromagnetic Nature of Solar Coronal Mass Ejections. 25. September 2003.

Prof. A. Nishida, Japan Society for Promotion of Science, Tokyo, Japan: The Magnetosphere of Jupiter - Recirculation Model of Trapped Particles Revisited. 8. Oktober 2003.

Dr. Ignatiev, Space Research Institute of the Russian Academy of Sciences: Near infrared radiation in the Venus atmosphere: implications for the Venus Monitoring Camera (VMC). 24. Oktober 2003.

Thorsten Knetter, Universität Köln: Solar wind discontinuity observations using simultaneously magnetic field and plasma data from 4 Cluster S/C. 29. Oktober 2003.

Prof. Sydora, University of Alberta, Edmonton, Canada: Nonlocal transport for solar physics applications - Theory and simulation. 6. November 2003.

Dr. B. Kliem, Astrophysikalisches Institut Potsdam: Imaging and spectral observation of erupting core flux in the 2002 April 21 X flare. 12. November 2003.

Dr. Stefan Muehlbachler, Space Research Institute, Graz, Austria: Dayside Magnetic Erosion. 18. November 2003.

Jon Nichols, University of Leicester, England, UK: Magnetosphere - Ionosphere Coupling Currents in Jupiter's Middle Magnetosphere. 27. November 2003.

Prof. Dzhalilov, IZMIRAN: Eigenoscillations of the differentially rotating Sun. 1. Dezember 2003.

Dr. C.-V. Meister, MPAE: Nonideal effects on the electron partial pressure in the solar interior up to density order 5/2. 1. Dezember 2003.

Dr. D. Galloway, University of Sydney, Australia: Current state of fast dynamo theory. 8. Dezember 2003.

IMPRS Solar System Seminars S^3/IMPRS Solar System Seminars S^3

The S^3 takes place every second Wednesday afternoon from 13:00 to 16:30. It consists of up to three talks by students on their PhD projects (each 20 min talk plus 10 min discussion), an extended coffee break for further discussion and a tutorial talk (60 min).

Tra-Mi Ho:
Data analysis and modelling of the dust emission of comet 19P/Borrelly.
Anja Neuhaus:
A parametric model of the paleomagnetosphere.
Ilya Silin:
Theory and simulation of kinetic plasma instabilities.
Bernd Inhester:
Inverse problems in space physics - Part 1: Examples.
2. Mai 2002.

Santo Salinas:
Simulating the internal, polarized radiation field of Titan as seen from Huygens/DISR with a new spherical model.
Alexander Vögler:
Simulations of solar magnetoconvection.
Thorsten Bagdonat:
Simulation of the solar wind - comet interaction.
Bernd Inhester:
Inverse problems in space physics - Part 2: Direct methods.
16. Mai 2002.

Oliver Preuß:
Astronomical tests of the Einstein equivalence principle - status and prospects.
Katja Janßen:
Speckle spectro-polarimetry of solar faculae.
Michael Rost:
ADAM/Hotzenplotz two microgravity experiments on preplanetary dust aggregation.
Bernd Inhester:
Inverse problems in space physics - Part 3: Iterative methods.
30. Mai 2002.

Maren Wunnenberg:
Short-period acoustic waves in the solar atmosphere.
Oleg Okunev:
Study of polar faculae by means of high resolution observations and numerical calculations.
Dieter Schmitt:
Why does the magnetic field of the Earth reverse?
13. Juni 2002.

Jens Stadelmann:
Diffusion of secular variation through the Earth mantle.
Sergey Shelyag:
Spectral analysis of magnetoconvection models.
Juan Manuel Borrero:
Inversion of Stokes profiles.
Lidong Xia:
Equatorial coronal holes and their relation to high-speed streams.
11. Juli 2002.

Ana Tomas:
Changes of the energetic particles characteristics in the inner part of the Jovian magnetosphere and the relation to the auroral features.
Dragos Constantinescu:
Magnetic mirror modelling.
Denise Tortorella:
Numerical simulation of zonal winds on the major planets.
Volkmar Holzwarth:
Dynamics of magnetic flux tubes in giant stars and close binaries.
17. Oktober 2002.

Geronimo Villanueva:
The high-resolution spectrometer for SOFIA.
Itahiza Dominguez:
Quiet Sun magnetic fields.
Michael Heuer:
Kinetic dispersion (stability) analysis of Helios plasma data.

Olena Podladchikova:
Quiet sun coronal heating - observations and statistical models.
14. November 2002.

Carsten Köllein:
Numerical simulations of the structure of cometary nuclei.
Aveek Sarkar:
Fluid flow simulation using Lattice Boltzmann.
Hebe Cremades:
Magnetic field configurations in coronal mass ejections.
Natalie Krivova:
Solar variability and global warming.
28. November 2002.

Martin Schrinner:
Mean-field coefficients for geodynamo models.
Andrey Seleznyov:
Solar variability and extrasolar planets.
Ganna Portyankina:
On the stability of undersurface water ice on Mars.
Matthias Rempel: (Boulder, Colorado, USA):
Overshoot at the base of the solar convection zone - What can we learn from numerical simulations.
12. Dezember 2002.

Yasuhito Narita:
Polarization and dispersion analysis of ULF waves using Cluster data.
Fedor Kolesnikov:
The Kelvin-Helmholtz instability of flows rotating around magnetic tubes.
Ingo Baumann:
Magnetic flux transport on the Sun.
Norbert Krupp:
Planetary magnetospheres.
9. Januar 2003.

Aleksandra Andjic:
Preliminary analysis of short period acoustic waves in solar atmosphere.
Yevgen Grynko:
Intensity, color and polarization of the comet 96P/Machholz 1 at large phase angles - The look of a planetary scientist on the LASCO C3 images.
Marilena Mierla:
The wavelet equalization technique: Applications on LASCO images.
Willi Deinzer (Göttingen):
Red giants - Why?
23. Januar 2003.

Jean-Mathias Grießmeier:
Magnetospheres of extrasolar planets.
Maxim Kramar:
Vector tomography for the coronal magnetic field.
Rupali Mahajan:
Dynamic simulation of north polar ice cap of Mars.
Jörg Büchner:
Space weather and plasma simulations.
6. Februar 2003.

Luciano Rodriguez:
Characterization of interplanetary coronal mass ejections seen by Ulysses.
Durgesh Tripathi:
Properties of post-eruptive arcades in solar cycle 23.
Mark Cheung:
Supernova remnants and the interstellar medium.
Karl Heinz Glassmeier:
The magnetosphere of planet Mercury.
8. Mai 2003.

Sabine Preusse, J. Büchner, U. Motschmann:
“Superflares” and extra-solar planets.
Ilya Silin:
Theory and kinetic simulations of magnetic reconnection.
Juan Manuel Borrero:
Magnetic field and velocity vectors in the penumbra of sunspots.
22. Mai 2003.

Ana Tomas:
The Jovian aurorae: new insights from Galileo particle and field measurements.
Monika Buske:
Three-dimensional evolution models of convection in the Martian mantle.
Vasily Zakharov:
Phase diversity: technique of high-resolution solar observations.
Andreas Pack (Köln):
Introduction into cosmochemistry - what the meteorites can tell us.
5. Juni 2003.

Sergey Shelyag:
Comparison between radiative MHD simulations and solar observations in the G-band.
Oleg Okunev:
Numerical modeling and observations of spatially unresolved magnetic structures in solar photosphere.
Denise Tortorella:
Zonal wind generation by thermal convection in giant planets’ atmospheres. Anelastic vs. Boussinesq approximation theory.
Sami Solanki:
“A passage through India.”
3. Juli 2003.

Nazaret Bello Gonzalez:
Sunspot penumbra: Evershed effect and preliminary results.

Santo Salinas:
A spherical model for computing polarized radiation in Titan's atmosphere.
Martin Gander:
Singular Value Decomposition and applications.
(17 July 2003 in the University Observatory Göttingen, 14:00-18:00).

Boon Chye Low (HAO/NCAR):
Self-similarity in classical fluids and MHD.
8. Oktober 2003.

Geronimo Villanueva:
High-resolution spectroscopy: Instrumentation, modeling and observation.
Markus Sailer:
Simulation of KAOS (Kiepenheuer Adaptive Optics System).
Dragos Constantinescu:
Particles distribution inside magnetic mirrors.
Mark Cheung:
A trip through western China: a multimedia presentation.
22. Oktober 2003.

Anja Stadelmann:
Energetic particles in a model paleomagnetosphere.
Elena Kronberg:
Signatures of magnetic reconnection in the Jovian magnetosphere - Substorms at Jupiter?
Hebe Cremades:
3D magnetic field configuration of coronal mass ejections.
Andreas Burkert (München):
The formation of stars and stellar clusters in turbulent molecular clouds.
5. November 2003.

Katerina Radioti:
Plasma composition of the Jovian magnetosphere.
Aleksandra Andjic:
Short-period acoustic waves at different heights in the solar atmosphere.
Itahiza Dominguez:
Mesogranulation detected in polarization.
Julien Aubert:
Planetary magnetic fields.
3. Dezember 2003.

Michael Heuer:
Does Helios plasma data provide evidence for pitch angle scattering of solar wind protons?
Martin Schrinner:
Comparison of mean-field and 3D models of the geodynamo.
Ganna Portyankina:
Spider patterns in the cryptic region of the Martian south polar cap.
Alexander Vögler:
Three-dimensional simulations of magneto-convection in the solar photosphere.
17. Dezember 2003.

Instituts-Seminare/Institute seminars

Leitung: Das Kollegium

In den Institutsseminaren wird hauptsächlich über die Fortführung laufender und die Aufnahme neuer Projekte berichtet, einschließlich der finanziellen und personellen Belange.

The Institute seminars report on the status of current projects as well as presentations of future projects, including questions of financing and personnel.

P. Hartogh: MAMBO - Mars Atmosphere Microwave Brightness Observer.
J. Woch: Bericht aus der Sektion. 8. Januar 2002.

W. Curdt, U. Schühle: Beteiligung des MPAE am Solar Dynamics Explorer (SDO). 16. April 2002.

P. Hartogh: MARVEL: Mars vulcanic emission and life. 6. Juni 2002.

U. Schühle: Möglichkeiten einer MPAE Beteiligung an den NASA-Missionen ASCE und SDO. 22. Oktober 2002.

U. Christensen, H.U. Keller: DAWN - ein Besuch bei den Kleinplaneten. Kameras für die Discovery Mission. 13. Juni 2003.

MPAE-Kolloquien/MPAE Colloquia

Leitung: Prof. Konrad Sauer

Zu diesen Kolloquien werden meistens nur auswärtige Wissenschaftler eingeladen, um möglichst allgemein über ihr Arbeitsgebiet zu berichten.

Colloquia are usually given by external scientists invited to the Institute to report fairly broadly on their field of research.

Prof. Harry Nussbaumer, ETH Zürich, Schweiz: Symbiotic stars: A final phase for binary star systems. 17. Januar 2002.

Dr. Stefan Schönert, Max-Planck-Institut für Kernphysik, Heidelberg: Experiment with Solar and Atmospheric Neutrinos: Evidence for Neutrino Masses and Lepton Mixing. 22. April 2002.

Prof. Bernard F. Schutz, MPI für Gravitationsphysik (Albert-Einstein-Institut), Golm: Gravitational Wave Astronomy. 24. Mai 2002.

Dr. Ir.W.A. Baan, Westerbork Radio Observatory: LOFAR, the Low Frequency Array – A new window to the Universe. 13. September 2002.

Prof. Hans-Walter Rix, Max-Planck-Institut für Astronomie, Heidelberg: Destruction in the Milky Way: Tidal tail tales from the sloan digital sky survey. 23. Oktober 2002.

Prof. L. Lanzerotti, AT&T Bell Labs, New Jersey, USA: 1) Influence of solar radio bursts on wireless communications. 2) The recommended future of solar and space physics in the U.S. 14. November 2002.

Prof. Gerd Fussmann, Max-Planck-Institut für Plasmaphysik, Bereich Plasmadiagnostik, Berlin: Flow of magnetized plasmas. 3. April 2003.

Prof. Dr. Peter Ulmschneider, Institut für theoretische Astrophysik, Universität Heidelberg: The generation of waves in the sun and late-type stars and their role in the heating of the outer stellar layers. 13. Mai 2003.

Dr. H. Thomas, Centre for Interdisciplinary Plasma Science, MPI für extraterrestrische Physik, Garching: Complex Plasmas - New Discoveries in the Laboratory and in Space. 27. Mai 2003.

Prof. G. Hensler, Institut für Theoretische Physik und Astrophysik, Universität Kiel: The realm of Galaxies. 17. Juni 2003.

Prof. G. Chanteur, CETP, Velizy, France: Hybrid code simulation of solar wind - Mars interaction. 26. August 2003.

Prof. Egidio Landi, Arcetri, Firenze, Italy: On the interpretation of the second solar spectrum. 24. September 2003.

Prof. Glatzmaier, UC Santa Cruz: Modeling the Earth's Dynamo. 30. September 2003.

Prof. A. Burkert, Universität München: The formation of stars and stellar clusters in turbulent molecular clouds. 5. November 2003.

Prof. N. Cramer, University of Sidney: Dust in the Universe. 11. November 2003.

Prof. H. Fahr, Universität Bonn: The dynamical heliosphere reflected in particles of different energies. 28. November 2003.

Vorträge 2002/Talks 2002

*Wenn über das Ergebnis einer Arbeit, an der mehrere Wissenschaftler beteiligt waren, berichtet worden ist, dann sind alle diese Wissenschaftler genannt. Der Name des Vortragenden ist stets hervorgehoben. Eingeladene Vorträge sind mit einem * gekennzeichnet.*

*When several scientists contributed to the presentation of a work, then all names appear. The name of the person making the presentation always appears in boldface. Invited talks are marked with *.*

Armand N.A., V.M. Smirnov and T. Hagfors: MARSIS signal distortion by the Martian ionosphere, correction base on group delay. MARSIS Team Meeting, Rome, Italy, 18 - 19 April 2002.

Axford W.I.: Origin of galactic cosmic rays. Conference on Particle Transport and Acceleration in Cosmic Plasmas, University of California at Riverside and UCLA Conference Center, Lake Arrowhead, CA, USA, 10 - 13 February 2002.

— Origin of galactic cosmic rays. Lecture, Institute of Geophysics and Planetary Physics, University of California at Riverside, CA, USA, 18 February 2002.

— The origin of cosmic rays. Seminar, Institute for Geophysics and Planetary Physics, University of California at Riverside, CA, USA, 14 March 2002.

— The origin of cosmic rays. Seminar, California Institute of Technology, Dept. of Physics, Pasadena, CA, USA, 4 April 2002.

— Conference summary. Symposium on Galactic Clusters, National Central University, Chung-Li, Taiwan, April 2002.

— Origin of the solar wind. Seminar, National Central University, Chung-Li, Taiwan, May 2002.

— The theory of stellar winds. Seminar, National Central University, Chung-Li, Taiwan, May 2002.

— Origin of the solar wind. Seminar, National Tsing Hua University, Hsinchu, Taiwan, 14 May 2002.

Axford W.I. and D. Winterhalter: The solar wind interaction with Mars - a review. 2002 Western Pacific Geophysics Meeting, Wellington, New Zealand, 9 - 12 July 2002.

Baker D., J. Blake, J. Burch, P. Daly, M. Dunlop, R. Ergun, R. Friedel, and T. Fritz: Cluster observations of magnetospheric substorm behavior in the near- and mid-tail regions. EGS XXVII General Assembly, Nice, France, 21 - 26 April 2002.

Baker D.N., W. Peterson, R. Ergun, S. Eriksson, J. Blake, J. Burch, P. Daly, E. Donovan, M. Dunlop, H. Frey, R. Friedel, T. Fritz, A. Korth, S. Mende, J. Roeder, and H. Singer: Cluster observations of geomagnetic storms and of magnetospheric substorm behavior in the near- and mid-tail regions. 34th COSPAR Scientific Assembly - World Space Congress, Houston, TX, USA, 10 - 19 October 2002.

Balmaceda L., A. Dal Lago, G. Stenborg, C. Francile, W.D. Gonzalez and R. Schwenn: Continuous tracking of CMEs using MICA and LASCO-C2 and -C3 coronagraphs 34th COSPAR Scientific Assembly - World Space Congress, Houston, TX, USA, 10 - 19 October 2002.

Bamert K., R.F. Wimmer-Schweingruber, R. Kallenbach, M. Hilchenbach, and B. Klecker: Charge-to-mass fractionation during injection and acceleration of suprathermal particles associated with the bastille day event: SOHO/CELIAS/HSTOF data. Conference Solar Wind 10, Pisa, Italy, 16 - 21 June 2002.

Barrow C.H., R.J. MacDowall, and A. Lecacheux: On the two demiensional model for jovian HOM radio emission. EGS XXVII General Assembly, Nice, France, 21 - 26 April 2002.

Belova E., P. Chilson, S. Kirkwood, and M. Rietveld: Response of polar mesosphere summer echoes to ionospheric heating. EGS XXVII General Assembly, Nice, France, 21 - 26 April 2002.

— A time constant of response of PMSE to ionospheric heating. 27th URSI General Assembly, Maastricht, The Netherlands, 17 - 24 August 2002.

Belova E., S. Kirkwood, M. Rietveld, and I. Häggström: Study of polar mesosphere winter echoes during solar proton events with the EISCAT VHF radar. 34th COSPAR Scientific Assembly - World Space Congress, Houston, TX, USA, 10 - 19 October 2002.

Berdichevsky D.B., C. Farrugia, R. Lepping, A. Galvin, R. Schwenn, D. Reames, I. Richardson, and K. Oglivie: March 23 – April 26, 2001: Solar-heliospheric-magnetospheric observations. Conference Solar Wind 10, Pisa, Italy, 16 - 21 June 2002.

Berger U., P. Hartogh, **C.-V. Meister**, and G. Villanueva: Hydrodynamic model of the Martian atmosphere between near-surface layers and an altitude of about 130 km. Internationale Jahrestagung der Astronomischen Gesellschaft

2002 “The Cosmic Circuit of Matter”, Berlin, Germany, 24 - 28 September 2002.

Berkey F.T., C.S. Fish, G.O.L. Jones, W.K. Hocking, C.E. Meek, A.H. Manson, and M.T. Rietveld: MF radar measurements with the NOAA dynasonde. Western Pacific Geophysical Meeting, Wellington, New Zealand, 9 - 12 July 2002.

Bertucci C., C. Mazelle, D. Crider, D. Mitchell, K. Sauer, M. Acuna, J. Connerney, H. Reme, R. Lin, P. Cloutier, N. Ness, and D. Winterhalter: Compressive low frequency waves at the Martian magnetic pile-up boundary: MGS observations. EGS XXVII General Assembly, Nice, France, 21 - 26 April 2002.

Bertucci C., C. Mazelle, D. Crider, D. Vignes, M. Acuna, K. Sauer, J. Connerney, H. Reme, D. Mitchell, R. Lin, P. Cloutier, N. Ness, and D. Winterhalter: Magnetic field line draping enhancement across the Martian magnetic pileup boundary. EGS XXVII General Assembly, Nice, France, 21 - 26 April 2002.

Biccari D., D. Gurnett, R. Jordan, R. Huff, L. Marinangeli, E. Nielsen, G.G. Ori, G. Picardi, J. Plaut, F. Provedi, R. Seu, and E. Zampolini: Vensis: Venus advanced radar for subsurface and ionosphere sounding. EGS XXVII General Assembly, Nice, France, 21 - 26 April 2002.

Blake J.B., J.F. Fennell, J.L. Roeder, R.S. Selesnick, D.N. Baker, M. Carter, P. Daly, T.A. Fritz, M. Grande, and C. Perry: Joint Cluster and Polar study of energetic particle bursts in the magnetotail. EGS XXVII General Assembly, Nice, France, 21 - 26 April 2002.

Blake J.B., J.L. Roeder, R.J. Selesnick, D.N. Baker, P. Daly, M. Grande, and M. Carter: Cluster-Polar simultaneous observations of energetic particles in the plasma sheet - evidence for radiation belt leakage? AGU 2002 Fall Meeting, San Francisco, CA, USA, 6 - 10 December 2002.

Bogdanova Y.V., B. Klecker, G. Paschmann, E. Georgescu, M.I. Kubyshkina, L.M. Kistler, C. Mouikis, E. Moebius, H. Rème, J.M. Bosqued, I. Dandouras, J.A. Sauvaud, A. Korth, M.B. Bavassano-Cattaneo, T. Phan, C. Carlson, G. Parks, J.P. McFadden, M. McCarthy, and R. Lundin: Investigation of the source region of ionospheric oxygen outflow in the cusp using multi-spacecraft observations by CIS onboard Cluster. 34th COSPAR Scientific Assembly - World Space Congress, Houston, TX, USA, 10 - 19 October 2002.

Bogdanova Y.V., B. Klecker, G. Paschmann, T. Phan, L.M. Kistler, E. Moebius, M.A. Popecki, H. Rème, J.M. Bosqued, I. Dandouras, J.A. Sauvaud, A. Korth, V. Formisano, M.B. Bavassano-Cattaeno, A.M. DiLellis, C. Carlson, J.P. McFadden, G.K. Parks, M. McCarthy, H. Balsiger, R. Lundin, and M.V. Kubyshkina: Oxygen beams in the polar cap and cusp regions: Multispacecraft observations by CIS Cluster. EGS XXVII General Assembly, Nice, France, 21 - 26 April 2002.

Bonev T. and K. Jockers: Spatial distribution of the dust color in comet C/LINEAR (2000 WM1). Internationale Konferenz, ACM 2002 - Asteroids, Comets, Meteors, Berlin, Germany, 29 July - 2 August 2002.

Borrero J.M., A. Lagg, and S.K. Solanki: Evidence for cooling tubes in a sunspot penumbra. Workshop “From the Gregory-Coudé Telescope to GREGOR: A Development from Past to Future”, Göttingen, Germany, 24 - 26 July 2002.

Bothmer V.: Post-eruptive arcades and magnetic flux ropes. SOHO-11-Symposium “From Solar Min to Max: Half a Solar Cycle with SOHO”, a Symposium dedicated to Roger M. Bonnet, Congress Centre, Davos, Switzerland, 11 - 15 March 2002.

— Physical constraints on 3D CME structures derived from image reconstructions. First STEREO Workshop: The 3-D Sun and Inner Heliosphere - The STEREO View, Carré des Sciences, Paris, France, 18 - 20 March 2002.

— The prime science objectives during different phases of the STEREO mission. EGS XXVII General Assembly, Nice, France, 21 - 26 April 2002.

— The solar sources of magnetic helicity in interplanetary space.* 34th COSPAR Scientific Assembly - World Space Congress, Houston, TX, USA, 10 - 19 October 2002.

Bothmer V., P. Cargill, A.V. Dmitriev, K.G. Ivanov, A.F. Kharshiladze, O.A. Panasenco, E.P. Romashets, E.P. Veselovsky, and A.N. Zhukov: Processes on the Sun and in the heliosphere responsible for geomagnetic perturbations during the rising phase and maximum of 23-rd solar cycle. EGS XXVII General Assembly, Nice, France, 21 - 26 April 2002.

Bothmer V., H. Cremades, and D. Tripathi: Large-scale coupling of the solar photospheric field. Euroconference and IAU Colloquium 188 “Magnetic Coupling of the Solar Atmosphere”, Santorini, Greece, 11 - 15 June 2002.

Büchner J.: Thin current sheets and kinetic reconnection: Interball and Cluster observations.* COSPAR-Symposium "Interball and beyond", Sofia, Bulgaria, 7 February 2002.

— Current understanding of the particle physics of reconnection - simulations and Cluster observations.* Sixth International Conference on Substorms, University of Washington, Seattle, WA, USA, 25 - 29 March 2002.

— Mission oriented simulation of reconnection - predictions and comparison with Cluster observations.* AGU Western Pacific Geophysics Meeting, Wellington, Australia, 11 July 2002.

— Magnetic reconnection in space - multi-spacecraft observations.* Lecture, 11th International Congress on Plasma Physics, Sydney, Australia, 16 July 2002.

— Current results of the investigation of thin current sheets by simulation and Cluster observations.* Lecture, World Space Environment Forum 2002, Adelaide, Australia, 24 July 2002.

— Kinetic simulation of collision less space plasmas by different numerical simulation codes.* Tutorial Lecture, WISER workshop on High Performance Computing, Adelaide, Australia, 30 July 2002.

— Is magnetic helicity still a good invariant in collisionless reconnection?* 34th COSPAR Scientific Assembly - World Space Congress, Houston, TX, USA, 10 - 19 October 2002.

— Comparative view at computer simulation of space plasmas: Present and Future.* Solicited, 34th COSPAR Scientific Assembly - World Space Congress, Houston, TX, USA, 10 - 19 October 2002.

Büchner J. and the Cluster-team: Properties, kinetic simulation and Cluster observation of thin current sheets. MPAe Helioseminar, Katlenburg-Lindau, Germany, January 2002.

Büchner J. and B. Nikutowski: A spacecraft-Schwarm for the in situ observation of turbulence and microscale reconnection in space plasmas. Workshop on future multispacecraft experiments, APL, Laurel, MD, USA, 16 February 2002.

Büchner J., B. Nikutowski, P. Daly, **U. Mall**, A. Balogh, K. Glassmeier, K. Fornaçon, A. Korth, J. Sauvaud, and H. Rème: Cluster multipoint observations of magnetotail current instabilities reveal signatures predicted by simulation. AGU 2002 Spring Meeting, Washington, DC, USA, 28 - 31 May 2002.

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— The formation of sunspots and starspots. 1st Potsdam Thinkshop on Sunspots & Starspots, Potsdam, Germany, 6 - 10 May 2002.

— Magnetic field dynamics in giants, binaries, and the Sun. Colloquium High Altitude Observatory, NCAR, Boulder, CO, USA, 13 August 2002.

— MHD simulations - what's next? 3rd International Workshop on Solar Polarization, Puerto de la Cruz, Tenerife, Spain, 30 September - 4 October 2002.

— MHD simulations in solar physics. MHD Days 2002, Dresden, Germany, 25 - 26 November 2002.

— Wie gut verstehen wir die Sonne? Physikalisches Kolloquium, Universität Kiel, Kiel, Germany, 5 November 2002.

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— SOHO und das neue Bild der Sonne. Greifswalder Physikalisches Kolloquium, Ernst-Moritz-Arndt-Universität, Greifswald, Germany, 27 June 2002.

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— The Sun as the driver of space weather: Recent developments based on observations from SOHO. Seminar at the UNAM Istituto de Geofisica, Mexico City, Mexico, 31 July 2002.

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Segschneider J.: Das Klima auf dem Mars – Beobachtungen und Modelle. Tag der Raumfahrt, DLR, Göttingen, Germany, 6 September 2002.

Segschneider J., H.U. Keller, D. Titov, B. Grieger, K. Fraedrich, and R. Greve: From the "Portable University Model of the Atmosphere (PUMA)" to the "Mars Climate Simulator". Kolloquium der Deutsche Forschungsgemeinschaft zum Schwerpunktprogramm "Mars und die terrestrischen Planeten", Westfälische Wilhelms-Universität Münster, Germany, 8 -9 April 2002.

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Silin I., J. Büchner, and L. Zelenyi: Analytical investigation and numerical simulations of instabilities of thin current sheets. Frühjahrstagung der AEF, Leipzig, Germany, 18 - 22 March 2002.

— Analytical investigation and numerical simulations of instabilities of thin current sheets. Session ST18, EGS XXVII General Assembly, Nice, France, 21 - 26 April 2002.

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— Solar variations and climate change: is there a link?* Royal Astronomical Society Harold Jeffeys Lecture, London, UK, 11 January 2002.

— Was hat das Magnetfeld der Sonne mit Einstein und dem Erdklima zu tun?* Kolloquiumsvortrag, Universität Erlangen, Germany, 28 January 2002.

— The solar system within astrophysics. Introductory Course "International Max Planck Research School on Physical Processes in the Solar System and Beyond", Germerode, Germany, 18 - 22 February 2002.

— Introduction to solar physics. Introductory Course "International Max Planck Research School on Physical Processes in the Solar System and Beyond", Germerode, Germany, 18 - 22 February 2002.

— How does the magnetic cycle change radiance and irradiance of the Sun?* SOHO-11 "From Solar Min to Max: Half a Solar Cycle with SOHO", Davos, Switzerland, 11 - 15 March 2002.

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Solanki S.K. and L. Gizon: Achieve more accurate masses of extrasolar planets using asteroseismology.* Workshop "Planetenbildung: Das Sonnensystem und extrasolare Planeten", Berlin-Adlershof, Germany, 18 - 20 February 2002.

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Stenborg G., P. Cobelli, M. Mierla, R. Schwenn, B. Podlipnik, and B. Inhester: A wavelet packets equalization technique to reveal the multiple spatial-scale nature of coronal structures. LASCO/EIT Consortium, Birmingham, UK, 16 - 18 September 2002.

— Towards a better determination of the onset-time and time development of coronal transients: Looking for the right tool. LASCO/EIT Consortium, Birmingham, UK, 16 - 18 September 2002.

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Taylor M.G., R.H. Friedel, G.D. Reeves, M.F. Thomsen, M.G. Henderson, M.W. Dunlop, T.A. Fritz, P.W. Daly, and A. Balogh: Cluster - RAPID measurements of high energy electron gradients in the Earth's magnetotail. AGU 2002 Fall Meeting, San Francisco, CA, USA, 6 - 10 December 2002.

Tomas A., J. Woch, N. Krupp, A. Lagg, K.H. Glassmeier, and K.K. Khurana: Changes of the energetic particles characteristics in the inner part of the Jovian magnetosphere and the relation to auroral features. Jupiter after Galileo and Cassini, A Euroconference about the Giant Planets, Lisbon, Portugal, 17 - 21 June 2002.

Tomasz F., J. Rybak, A. Kucera, W. Curdt, and H. Woehl: Transition region blinker - spatial and temporal behaviour. VIth Astrophysical Hvar Colloquium: Explosive Phenomena in the Solar Atmosphere, Hvar, Croatia, 6 - 10 October 2002.

Trattner K.J., T. Yeoman, S.A. Fuselier, A. Korth, M. Fränz, F. Frutos, C. Mouikis, H. Kucharek, L.M. Kistler, H. Rème, I. Dandouras, J.A. Sauvaud, J.M. Bosqued, B. Klecker, C. Carlson, T. Phan, J.P. McFadden, M.B. Bavassano-Cattaneo, and L. Eliasson: Combining ground observations with Cluster observations in the cusp. 34th COSPAR Scientific Assembly - World Space Congress, Houston, TX, USA, 10 - 19 October 2002.

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— Physical meaning of the geomagnetic indices Dst and AE.* Egeland Symposium on Auroral and Atmospheric Research, Oslo, Norway, 19 April 2002.

— Ring current decay time. Workshop on Substorms in the Recovery Phase of Magnetic Storms/HILDCAAs. Henningsvaer, Norway, 17 - 21 June 2002.

— Lessons for Earth: A Summary.* Comparative Magnetospheres. 34th COSPAR Scientific Assembly - World Space Congress, Houston, TX, USA, 10 - 19 October 2002.

— Meaning and time evolution of the Dst index. Seminar, Physics and Astronomy Department, Rice University, Houston, TX, USA, 21 October 2002.

— The unreasonable success of magnetosphere-ionosphere coupling theory.* AGU Meeting, San Francisco, CA, USA, 6 - 10 December 2002.

Villanueva G. and P. Hartogh: Draft of the GREAT-CTS FCC Certification. Max-Planck-Institut für Radioastronomie, Bonn, Germany, 15 November 2002.

Vilmer N., M. Pick, and R. Schwenn: On the solar origin of interplanetary disturbances observed in the vicinity of the Earth. LASCO/EIT Consortium, Birmingham, UK, 16 - 18 September 2002.

Vocks E. and G. Mann: Kinetics of electrons in the Solar corona and wind. Conference Solar Wind 10, Pisa, Italy, 16 - 21 June 2002.

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von Steiger R., T.H. Zurbuchen, J. Geiss, G. Gloeckler, D.J. McComas, S.K. Solanki, J. Woch, and J. Zhang: Fast solar wind streams around the solar cycle - are they all the same? Conference Solar Wind 10, Pisa, Italy, 16 - 21 June 2002.

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— Determining the hydrogen distribution in the geocorona using UVIS/HDAC Lyman-alpha observations during Cassini’s Earth swingby. 34th COSPAR Scientific Assembly - World Space Congress, Houston, TX, USA, 10 - 19 October 2002.

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— Observations of the solar chromosphere with SUMER on SOHO. 200th Meeting of the American Astronomical Society, Albuquerque, NM, USA, 2 - 6 June 2002.

Witte M., M. Banaszkiewicz, and H. Rosenbauer: On the kinetic parameters of interstellar neutral Helium: An update from ULYSSES/GAS results. EGS XXVII General Assembly, Nice, France, 21 - 26 April 2002.

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— Stability study of equatorial dipole configuration in dynamo models. Workshop of the DFG-Priority Programme, GeoForschungsZentrum, Potsdam, Germany, 1 - 2 October 2003.

Axford W.I.: Origin of cosmic rays. UCR IGPP Symposium, Palm Springs, CA, USA, February 2003.

Axford W.I., V. Florinski, and G.P. Zank: The solar system in a dense interstellar cloud. Carbon 14 Conference, Wellington, New Zealand, September 2003.

Barrow C.H.: Jupiter's aurora, the hectometric radio emission and the solar wind. EGS-AGU-EUG Joint Assembly, Nice, France, 6 - 11 April 2003.

— Radio astronomy: Another window on Jupiter. Institut für Geophysik, Astrophysik und Meteorologie, Karl-Franzens-Universität, Graz, Austria, 4 June 2003.

Belova E., P.B. Chilson, M. Rietveld, and S. Kirkwood: Polar mesosphere summer echoes ionospheric heating experiment with high time resolution using the EISCAT VHF radar and the heating facility. IUGG XXIII General Assembly, Sapporo, Japan, 30 June - 11 July 2003.

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Bothmer V.: Magnetichelicity of coronal mass ejections at the Sun and in interplanetary space. NASA STEREO-Mission, Jet Propulsion Laboratory, Pasadena, CA, USA, 3 - 14 March 2003.

— Sonne und Erde - eine stürmische Beziehung. Internationaler "Sonne-Erde-Tag" (veranstaltet von ESA und NASA mit dem Max-Planck-Institut für Aeronomie) am XLAB - Göttinger Experimentallabor für junge Leute e.V., Göttingen, Germany, 18 March 2003.

— The solar and interplanetary causes of space storms in solar cycle 23.* NATO Advanced Research Workshop on Effects of Space Weather on Technology Infrastructure (ESPRIT), Rhodos, Greece, 25 - 29 March 2003.

— Future Missions.* International DPG Spring School: Space Weather Science - The Physics behind a Slogan, Bad Honnef, Germany, 30 March - 4 April 2003.

— Solar sources and IP aspects of storms in the cycle (also forecasting of SEOs). STEREO/SECCHI-Meeting, Königliche Sternwarte von Belgien, Brussels, Belgium, 14 - 15 April 2003.

— Contribution to SHARPP and SDO. SDO/SHARPP-Meeting, Königliche Sternwarte von Belgien, Brussels, Belgium, 16 - 17 April 2003.

— Weltraumwetter aus Sicht der Wissenschaft. Astrium, Space Weather Science, Friedrichshafen, Germany, 29 April 2003.

— Sources of magnetic helicity over the solar cycle.* International Solar Cycle Studies Symposium 2003: Solar Variability as an Input to the Earth's Environment, Tatranska Lomnica, Slovak Republic, 23 - 28 June 2003.

— Sonne und Erde - eine stürmische Beziehung* Heinrich-Nordhoff-Gesamtschule, Wolfsburg, Germany, 8 July 2003.

— Zusammenarbeit des Planetarium Hamburg an aktuellen Weltraummissionen mit MPAe, ESA, NASA. Galaabend des Planetariums, Hamburg, Germany, 11 August 2003.

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— Space Weather and plasma simulation. IMPRS, Katlenburg-Lindau, Germany, 6 February 2003.

— Nonlinear reconnection instability.* Fifth International Workshop on Nonlinear Waves and Chaos in Space Plasmas, Mumbai, India, 2 - 7 March 2003.

— Nonlocal instabilities of collisionless current sheets.* EGS-AGU-EUG Joint Assembly, Session ST12, Nice, France, 6 - 11 April 2003.

— Erdmagnetfeld und Weltraumwetter: Stand und Perspektiven der Forschung.* Weltraumwetter-Kolloquium des Geoforschungszentrums Potsdam, Potsdam, Germany, 14 - 15 May 2003.

— Coupling complexity in the course of reconnection.* IUGG XXIII General Assembly, Sapporo, Japan, 30 June - 11 July 2003.

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— Nonlinear dynamics and self-organisation in magnetospheric plasmas.* Lecture, The Abdus Salam International Centre for Theoretical Physics Autumn College, Trieste, Italy, 13 - 18 October 2003.

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Büchner J., B. Nikutowski, and A. Otto: Transition region energization due to shear flow reconnection. EGS-AGU-EUG Joint Assembly, Session ST18, Nice, France, 6 - 11 April 2003.

— Could shear flow reconnection cause EUV bright point heating? Magnetic Reconnection and the Dynamic Sun, University of St Andrews, Scotland, UK, 8 - 10 September 2003.

— Shear flow reconnection causing bright point heating. AGU Fall Meeting, Session SH00, San Francisco, CA, USA, 8 - 12 December 2003.

Büchner J. and I. Silin: Coupling of waves and reconnection in thin, collisionless current sheets. AGU Fall Meeting, Session SM00, San Francisco, CA, USA, 8 - 12 December 2003.

Buske M. and U.R. Christensen: Dreidimensionale Evolutionsmodelle der Konvektion im Marsmantel. 63rd Annual Meeting of the Deutschen Physikalischen Gesellschaft and Spring Meeting of the Arbeitsgemeinschaft Extraterrestrische Physik, Jena, Germany, 23 - 28 February 2003.

Buske M. and U.R. Christensen: Three-dimensional evolution models of convection in the martian mantle. EGS-AGU-EUG Joint Assembly, Nice, France, 6 - 11 April 2003.

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