

# Max-Planck-Institut für Aeronomie



## TÄTIGKEITSBERICHT

**2000 und 2001**



**Katlenburg-Lindau**



## MPAE • Tätigkeitsbericht für 2000 und 2001

### Zu den Bildern auf dem Umschlag

#### Vorderseite:

Luftbild des Max-Planck-Instituts für Aeronomie.

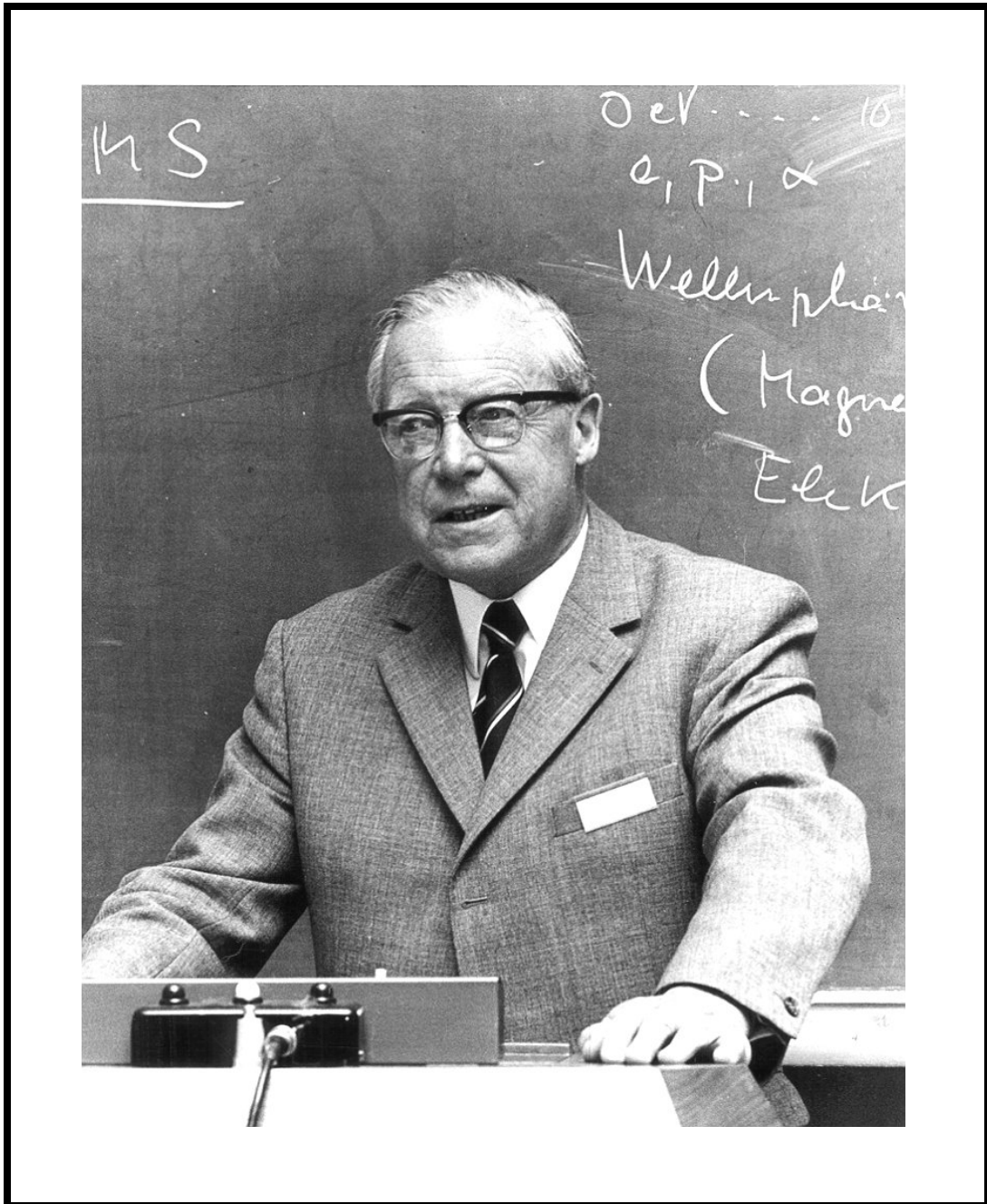
(Foto: W. Boogaerts, Bearbeitung: P. Fahlbusch)

#### Rückseite:

Die Abbildung zeigt in einer künstlerischen Darstellung die vier Cluster-Satelliten in ihrer Umlaufbahn um die Erde, um die solar-terrestrischen Wechselwirkungen auf das Weltraumplasma zu untersuchen (s. Artikel auf Seite 91). An der rechten Seite sind Spektrogramme und Pitchwinkelverteilungen von den 2 Cluster-Instrumenten mit Beteiligung des MPAE eingefügt: CIS (oben rechts) deckt Ionen im Energiebereich 30 eV bis 40 keV ab und RAPID (unten rechts) misst Elektronen und Ionen ab 30 keV. Gezeigt sind Daten während einer Stunde am 22. August 2001, als die Satelliten die Mitte des geomagnetischen Schweifs an der Nachtseite der Erde durchquerten. Die beiden Instrumente ergänzen sich: Wenn die energiereichen Ionen den Energiebereich von CIS verlassen, erscheinen sie im niedrigen Messbereich des RAPID-Experimentes.

*The illustration shows an artist's concept of the four Cluster spacecraft in their orbit about the Earth, to study the solar-terrestrial interactions of space plasma (see article on page 96). The insets at the right are spectrograms and pitch angle distributions from the 2 Cluster instruments with MPAE participation: CIS (upper right) covering lower energy ions from 30 eV to 40 keV, and RAPID (lower right) measuring electrons and ions from 30 keV. The plots are taken from a 1-hour interval on August 22, 2001, as the spacecraft crossed the center of the geomagnetic tail on the nightside of the Earth. The two instruments complement each other: as the energised ions move out the CIS energy range, they appear in the lower ranges of the RAPID experiment.*

(P.W. Daly, U. Mall, A. Korth)



**Prof. Dr. Walter Dieminger**

07.07.1907 – 29.09.2000

Gründer und langjähriger Direktor des Max-Planck-Instituts für Aeronomie

*Founder and for many years Director of the Max-Planck-Institute for Aeronomy*

MAX-PLANCK-INSTITUT FÜR AERONOMIE

KATLENBURG-LINDAU

**Tätigkeitsbericht**  
**für die Jahre 2000 und 2001**

*Herausgegeben von der Institutsleitung:*

*Dr. Helmut Rosenbauer*

*Prof. Dr. Sami K. Solanki*

*Prof. Dr. Vytenis Vasyliūnas*

*Redaktion:*

*Dr. Reinhard Borchers*

*Dr. Patrick W. Daly*

*Karin Peschke*

*Koordinatoren des wissenschaftlichen Teils:*

*Dr. Patrick W. Daly*

*Dr. Norbert Krupp*

*Prof. Dr. Eckart Marsch*

*Prof. Dr. Kristian Schlegel*

*Prof. Dr. Sami K. Solanki*

*Dr. Nicolas Thomas*

Einen guten, allgemeinverständlichen Überblick über Geschichte und Arbeitsgebiete des Instituts bietet eine Institutsbroschüre, die im März 1998 neu erschienen ist. Außerdem kann ein Videofilm vom Institut bezogen werden.

Alle Rechte vorbehalten.- Copyright 2002 MPAE, 37191 Katlenburg-Lindau.  
Erschienen im September 2002.

**Anschrift:**

Max-Planck-Institut für Aeronomie  
Max-Planck-Straße 2  
37191 Katlenburg-Lindau  
Deutschland  
Tel.: 05556-979-0  
Fax: 05556-979-240  
<http://www.linmpi.mpg.de>

# Inhalt/Contents

## I Allgemeines zum Institut/Institute Overview

Gegenstand und Methoden der Forschung/Subject and Methods of Research . . . . .	1
Struktur und Leitung des Instituts/Structure and Management of the Institute . . . . .	2
Personelle Entwicklung/Personnel Development . . . . .	2
Das Kuratorium des Instituts/Board of Trustees of the Institute . . . . .	3
Der Fachbeirat des Instituts/Scientific Advisory Board of the Institute . . . . .	4
Für das Institut aufgewendete Mittel/Institute Resources . . . . .	4

## II Wissenschaftliche Arbeiten/Scientific Projects

### 1 *Sonne und Heliosphäre/Sun and Heliosphere*

Schwerpunktthema: Das Magnetfeld der Sonne – Quelle des Weltraumwetters und möglicher Klimafaktor . . . . .	9
Highlight: The solar magnetic field: cause of space weather and suspected driver for terrestrial climate change . . . . .	15
Solar interior . . . . .	22
Intensification of magnetic field by conversion of potential energy . . . . .	22
Storage of magnetic flux at the bottom of the solar convection zone . . . . .	22
Heating of magnetic flux tubes . . . . .	23
Secular evolution of the Sun's magnetic field . . . . .	23
Helio- and asteroseismology, with applications to extrasolar planets . . . . .	23
Photosphere and chromosphere . . . . .	24
Development of MHD codes with radiative transfer . . . . .	24
Non-grey radiative transfer in photospheric MHD simulations . . . . .	24
Local dynamo action in the solar photosphere . . . . .	25
Total magnetic flux of the Sun . . . . .	25
The 1.3-year and 158-day periodicities in sunspot data . . . . .	26
Molecular Zeeman effect . . . . .	26
Infrared polarimetry with TIP . . . . .	26
Structure of the solar chromosphere . . . . .	26
Continuum contrast and thermal structure of faculae . . . . .	27
A relationship between solar cycle strength and length . . . . .	27
Solar variability and global warming . . . . .	27
Solar transition region and corona . . . . .	28
Solar Ultraviolet Measurements of Emitted Radiation – SUMER . . . . .	28

---

Hot loop oscillations observed by SUMER . . . . .	28
SUMER – The SUMER spectral atlas of solar disk features . . . . .	29
Hydrogen temperature gradient in the transition region of a solar coronal hole . . . . .	29
Structure and dynamics of magnetic loops in an active region on the Sun . . . . .	31
Short-term EUV variations in the quiet Sun . . . . .	31
Unresolved fine structures. The morphology of the solar upper atmosphere during the sunspot minimum and the interface with the chromosphere . . . . .	32
Observations of solar transition region structures and dynamics – statistics of quiet-sun extreme ultraviolet radiances . . . . .	32
Solar radiance variability measured with SUMER and inter-calibration with SOHO instruments	33
Coronal holes . . . . .	33
Polarisation of the solar F-corona . . . . .	35
A kinetic model for ions in the corona . . . . .	35
On cyclotron wave heating of solar wind ions in the solar corona . . . . .	36
Wave dissipation by ion cyclotron resonance in the solar corona . . . . .	36
Large-scale coronal field structure and source-region features for a halo CME . . . . .	37
LASCO (Large Angle and Spectrometric COronagraph on SOHO) . . . . .	37
A tool for improved space weather predictions: the CME expansion speed . . . . .	38
MICA (Mirror Coronagraph for Argentina) . . . . .	38
Solar wind and heliosphere . . . . .	39
Solar energetic particle events observed by SOHO/CELIAS/STOF . . . . .	39
Regulation of the proton thermal anisotropy in the solar wind . . . . .	39
Pitch-angle diffusion of solar wind protons in resonance with cyclotron waves . . . . .	39
Long-term variations of the flow direction and angular momentum of the solar wind observed by Helios . . . . .	41
Deriving ACR shock spectrum from observations of the energetic neutral atoms . . . . .	41
Velocity, temperature and density of interstellar He-atoms: recent Ulysses-GAS results . . . . .	41
Resonant interactions of ions with plasma waves in quasi-linear theory . . . . .	43
Status of ongoing and future solar missions . . . . .	44
SUNRISE: a balloon-borne solar telescope . . . . .	44
Tunable X-ray Imager (TXI) . . . . .	45
Participation in the NASA STEREO Mission . . . . .	45
Sun Earth Connection Coronal and Heliospheric Investigation (SECCHI) for STEREO – SCIP	46
Stereoscopy and Tomography for SECCHI on STEREO . . . . .	46
Solar Orbiter, a high-resolution mission to the Sun and inner heliosphere . . . . .	47
Stars and solar-stellar connection . . . . .	48
Surface distribution of erupting magnetic flux tubes in close binaries . . . . .	48
Dynamics of magnetic flux tubes in evolved stars . . . . .	49

A stream of particles from the $\beta$ Pictoris disc . . . . .	49
Size distribution of dust in circumstellar discs . . . . .	50
Fluffy dust aggregates in the shells of Herbig Ae/Be stars . . . . .	50
Tests of the Einstein equivalence principle . . . . .	50
<b>2 Planeten, ihre natürlichen Satelliten und Kometen/</b> <i>Planets, their moons and comets</i>	
Schwerpunktthema: Die Galileo Mission, neue Erkenntnisse über planetare Magnetosphären . . . . .	51
Highlight: The Galileo Mission, new insights about planetary magnetospheres . . . . .	58
Mars research . . . . .	66
Martian aerosols and their influence on the spectrophotometry of the surface . . . . .	66
Martian seasonal CO <sub>2</sub> ice in polygonal troughs: Role of the subsurface H <sub>2</sub> O ice . . . . .	66
Mars plasma research – an ISSI activity . . . . .	67
Jupiter research . . . . .	68
Global flows of energetic ions in Jupiter’s magnetosphere . . . . .	68
Particle bursts in the Jovian magnetosphere: Evidence for a near-Jupiter neutral line . . . . .	69
Particle leakage in Jupiter’s dusk magnetosphere . . . . .	69
Polarisation and beaming of the jovian bKOM and HOM observed at 5 AU from Jupiter . . . . .	69
Resistive MHD simulations of Ganymede’s magnetosphere . . . . .	70
Magnetic induction effects at Europa . . . . .	70
Observations of the Io torus on Pik Terskol with the Two-Channel Focal Reducer . . . . .	71
Observations of the inner Jovian satellites Methis, Amalthea and Thebe on Pik Terskol with the Two-Channel Focal Reducer . . . . .	71
Saturn research . . . . .	71
A new spherical model for computing the internal radiation field of Titan . . . . .	71
Inverse radiation modelling of Titan’s atmosphere to assimilate Solar Aureole Imager data from Huygens/DISR . . . . .	72
D/H ratio determination . . . . .	73
General planetary studies . . . . .	73
On the problem of light scattering by planetary regolith . . . . .	73
Cometary research . . . . .	75
Observations of comets on Pik Terskol with the MPAE Two-Channel Focal Reducer . . . . .	75
Scattering properties of aggregate particles and their relation to cometary dust and to regolith on atmosphereless solar system bodies . . . . .	76
Comet Borrelly encountered by Deep Space 1 . . . . .	76
The temperature and bulk flow speed of a gas effusing or evaporating from a surface into a void after reestablishment of collisional equilibrium . . . . .	77
Cometary theoretical work . . . . .	78
The Earth’s moon . . . . .	79

On the creation of electric fields around the moon – applications to remote sensing of electric conductivities . . . . .	79
Future projects in planetary and cometary science . . . . .	80
BEPICOLOMBO: Mission to Mercury . . . . .	80
VENUS EXPRESS: A proposed European mission to Venus in 2005 . . . . .	80
MARS EXPRESS: The first European mission to Mars . . . . .	81
Mars advanced radar for subsurface and ionospheric sounding, MARSIS . . . . .	83
Analyser of space plasmas and energetic atoms (ASPERA-3) for Mars Express . . . . .	83
MAMBO: Mars Atmosphere Microwave Brightness Observer . . . . .	84
MAOAM: The Martian Atmosphere: Observation and Modelling . . . . .	84
MARVEL: Mars Volcanic Emission and Life . . . . .	85
SOFIA: Stratospheric Observatory for Infrared Astronomy . . . . .	85
GREAT: German Receiver for THz Astronomy . . . . .	86
HERSCHEL Space Observatory (former Far Infrared Space Telescope – FIRST) . . . . .	86
HIFI . . . . .	87
ROSETTA: Mission to comet 46P/Wirtanen . . . . .	87
CONSERT: Cometary Nucleus Sounding Experiment by Radiowave Transmission . . . . .	87
ROSINA: Rosetta Orbiter Spectrometer for Ion and Neutral Analysis . . . . .	88
MIRO: Microwave instrument for the ROSETTA-Orbiter . . . . .	88
OSIRIS: Camera system on ROSETTA . . . . .	88
Impact on a comet: Rosetta Lander simulations . . . . .	89
SMART-1 (Small Missions for Advanced Research in Technology) . . . . .	90
SIR . . . . .	90
Concluding remarks . . . . .	90

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

Schwerpunktthema der Magnetosphärenforschung: Die Cluster-Mission . . . . .	91
Highlight of magnetospheric research: The Cluster mission . . . . .	96
Research projects in the neutral atmosphere . . . . .	102
Structure and dynamics of the atmosphere – SOUSY . . . . .	102
Thunderstorms, lightning and solar activity – middle Europe – . . . . .	103
Value added validation and more efficient use of remote sensing data from the Earth atmosphere	104
The WASPAM experiment . . . . .	105
Trace gases in the atmosphere . . . . .	105
Ionospheric research: EISCAT and STARE . . . . .	106
Diurnal harmonics in Schumann resonance parameters observed on both hemispheres . . . . .	106
A D-region conductivity model from EISCAT VHF measurements . . . . .	107

---

Auroral E-region electron density gradients measured with EISCAT . . . . .	107
Conductivity gradients in field-aligned current measurements . . . . .	108
A self-consistent estimate of $O^+ + N_2^-$ -rate coefficient and total EUV solar flux with $\lambda < 1050 \text{ \AA}$ using EISCAT observations . . . . .	108
Equinoctial transitions in the ionosphere and thermosphere . . . . .	109
The high latitude thermospheric ion-drag time constant . . . . .	109
EISCAT observation of a high-latitude ionisation trough associated with a reversed westward plasma flow in the pre-noon sector during southward IMF . . . . .	110
Diurnal, seasonal, and geomagnetic variations of large field-aligned ion upflows in the high- latitude ionospheric $F$ region . . . . .	111
Positive storm effects in the dayside polar ionospheric F-region observed by EISCAT and ESR during the magnetic storm of May 15, 1997 . . . . .	111
Combined ESR and EISCAT observations of the dayside polar cap and auroral oval during the May 15, 1997 storm . . . . .	112
Penetration of auroral electric fields to the equator during a substorm . . . . .	112
Scandinavian Twin Auroral Radar Experiment (STARE) . . . . .	113
Ionospheric modification . . . . .	113
DASI observations of artificial airglow from heating . . . . .	113
New EISCAT VHF radar observations of PMSE echoes . . . . .	114
ULF wave excitation observed on FAST satellite . . . . .	114
EISCAT measurements of powerful HF pump-induced electron temperature enhancements and radio-induced airglow . . . . .	114
Directional SEE and artificial ionospheric irregularity measurements . . . . .	115
EISCAT measurements of plasma and ion lines from powerful HF pumping of the E-region and from coherent echoes associated with an auroral arc . . . . .	115
Ionospheric modification experiments with the Russian SURA facility . . . . .	115
Magnetosphere . . . . .	116
RAPID experiment on Cluster . . . . .	116
High-latitude dayside flux transfer event . . . . .	117
Cluster magnetopause observations . . . . .	118
CIS experiment on Cluster . . . . .	118
Magnetic storm ions . . . . .	119
Magnetic depressions in the solar wind . . . . .	119
Scalar and vector field gradients from CIS . . . . .	120
Cluster observations of thin current sheet dynamics . . . . .	121
Reconnection in surface waves: EQUATOR-S . . . . .	121
INTERBALL observations of magnetic bubbles . . . . .	122
ATIC balloon experiment for high energy cosmic ray research . . . . .	122
Energetic particles and CASSINI Earth swing-by . . . . .	123

Suprathermal plasma instrument package SMS on WIND . . . . .	123
Multiple plasmoids in the magnetotail . . . . .	124
Evolution of magnetic helicity . . . . .	124
Instability of collisionless current sheets . . . . .	125
3D kinetic reconnection — simulation and visualisation . . . . .	125
Oscillitons applied to “Lion Roars” . . . . .	126
A SCHWARM of small satellites . . . . .	127
From RELIKT-2 to INTERBALL-3 . . . . .	127
Storm-substorm relationships in the inner magnetosphere measured with the CRRES S/C. O <sup>+</sup> transport into the ring current . . . . .	128

### III Abteilung Rosenbauer/Department Rosenbauer

Einleitung . . . . .	131
Zusammenfassung . . . . .	131
Projekte . . . . .	131
Wissenschaftliche Arbeiten und Datenauswertung . . . . .	132
Laborergebnisse . . . . .	133
Das Landegestell (LG) als Gerät zur Unterstützung der Kometenforschung . . . . .	134
Weitere Projekte . . . . .	137
Laufende: . . . . .	137
Zukünftige: . . . . .	138
Introduction . . . . .	138
Executive summary . . . . .	138
Projects . . . . .	138
Scientific activities and data evaluation . . . . .	138
Laboratory results . . . . .	139
The Landing Gear (LG) as a science support device . . . . .	140
Further projects . . . . .	143
Ongoing: . . . . .	143
Future: . . . . .	144
Anhang . . . . .	145
Appendix . . . . .	146

### IV Rechenzentrum, Elektroniklabor und Werkstätten/ Computer Centre, Electronic Laboratory and Workshops

Rechenzentrum/Computer Centre . . . . .	147
Elektroniklabor/Electronic Laboratory . . . . .	150

Mechanische Werkstätten, Haustechnik, Ausbildung/Engineering workshops, physical plant, training . . . . .	152
--	-----

**V Personelle Gliederung/Personnel**

Kollegium, wissenschaftliche Mitglieder/Board of directors, scientific members . . . . .	155
Wissenschaftliche und wissenschaftlich-technische Mitarbeiter/Scientific staff . . . . .	155
Doktoranden/Ph.D. students . . . . .	158

**VI Wissenschaftliche Zusammenarbeit/  
Scientific Collaboration**

Wissenschaftler, die als Gäste längere Zeit am MPAE tätig waren/Scientific guests with long-term visits to MPAE . . . . .	161
Wissenschaftler, die als Gäste nur kurzzeitig am MPAE tätig waren/Scientific guests with short-term visits to MPAE . . . . .	164
Wissenschaftler, die als Gäste am MPAE vom Deutschen Akademischen Austauschdienst (DAAD) gefördert worden sind/Scientific guests at MPAE sponsored by the DAAD . . . . .	165
Längere Aufenthalte von Wissenschaftlern des MPAE an anderen Instituten/Long-term visits of MPAE scientists to other institutes . . . . .	165
Projekte in Zusammenarbeit mit anderen Institutionen/Projects in collaboration with other institutions . . . . .	166
Projektförderungen durch das Bundesministerium für Bildung und Forschung (BMBF)/Project grants by BMBF . . . . .	171
Lehrtätigkeiten/Teaching . . . . .	171
Weitere Lehrtätigkeiten oder Kurse/Other lectures or courses . . . . .	172
Mitgliedschaften in wissenschaftlichen Gremien/Membership in scientific councils . . . . .	172
Gutachtertätigkeiten/Review reports . . . . .	174
Tätigkeiten als Convener/Convenerships during scientific meetings . . . . .	175
Organisation von Workshops/Workshop organisation . . . . .	176
Öffentlichkeitsarbeit/Public relations . . . . .	176
Pressemitteilungen/Press releases . . . . .	176
Ausstellungsstand/Exhibition stand . . . . .	177
Institutsführungen und Anfragen/Institute tours and information . . . . .	177
Erich-Regener-Vortragsreihe/Erich-Regener lecture series . . . . .	177
Öffentliche Vorträge/Public presentations . . . . .	178
Verschiedenes/Miscellaneous . . . . .	178
Ernennung/Appointment . . . . .	178
Herausgebertätigkeit/Editorships . . . . .	179
Direktionsbeirat des MPAE/„Direktionsbeirat“ at MPAE . . . . .	179
25 Jahre in der MPG/25 years at MPG . . . . .	179

**VII Berichte, Vorträge und Veröffentlichungen/  
Reports, Talks and Publications**

Interne MPAAE-Berichte/Internal MPAAE reports . . . . .	181
Experimentvorschläge/Proposals . . . . .	181
Dissertationen/Dissertations . . . . .	182
Tee-Seminare/Tea seminars . . . . .	182
Mitarbeiter-Seminar Heliosphäre/Staff seminar of the Heliosphere . . . . .	185
Instituts-Seminare/Institute seminars . . . . .	187
MPAAE-Kolloquien/MPAAE-Colloquia . . . . .	187
Vorträge 2000/Talks 2000 . . . . .	189
Vorträge 2001/Talks 2001 . . . . .	206
Veröffentlichungen 2000/Publications 2000 . . . . .	227
Veröffentlichungen 2001/Publications 2001 . . . . .	240

# 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, 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 (insbesondere Mars) und deren Monde analysiert. Bei der überwiegend experimentell ausgerichteten Arbeitsweise des Instituts stehen Ent-

wicklung 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.

---

*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 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, accompanied 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. Sir Ian Axford (2001 emeritiert), Dr.-Ing. H. Rosenbauer, Prof. Dr. S.K. Solanki und Prof. Dr. V.M. Vasyliūnas gemeinschaftlich geleitet (Gesamtkollegium).

Die Geschäftsführung hatte im Jahr 2000 Prof. Dr. V.M. Vasyliūnas. 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 aufgliedert: Abteilung Rosenbauer, 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 Geschäftsführer (Dr. P. Czechowsky) 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 Konstruktions- und Zeichenabteilung, Werkstätten für Mechanik, ein Entwicklungslabor für Elektronik, ein Rechenzentrum und eine spezielle Bibliothek.

---

*The institute was managed jointly by the directors Prof. Sir Ian Axford (emeritus since 2001), Dr.-Ing. H. Rosenbauer, Prof. S. K. Solanki, and Prof. V. M. Vasyliunas (general board of directors)*

*In 2000 the managing director was Prof. V. M. Vasyliunas. 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 Rosenbauer department, 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 manager (Dr. P. Czechowsky) 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 research plan a project 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 design and drawing department, mechanical workshops, an electronic development laboratory, a computing centre and a library.*

### **Personelle Entwicklung/Personnel Development**

In den Jahren 2000 und 2001 hat sich die Zahl der Mitarbeiterinnen und Mitarbeiter des Instituts entsprechend dem Sozialplan verändert.

Die Zahl der Planstellen verringerte sich bis Ende Dezember 2001 auf 135,5. Davon waren 40 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 2001 etwa 98.

Mitarbeiter, die nach dem Sozialplan ausgeschieden sind:

Heinz-Jürgen Baur, Klaus-Dieter Eulig, Klaus Fischer, Bernhard Gräve, Heiner Grünwaldt, Ingeborg Güttler, Wolfgang Güttler, Monika Hale, Marianne Hartmann, Dr. Gerd Hartmann, Helga Haupt, Inge Kurtoglu, Hans Lauche, Herbert Lindner, Maria Ott, Dr. Klaus Richter, Walter Schmidt, Werner Tappert.

In den Ruhestand traten:

Klaus-Dieter Hagen, Rita Pfeiff, Dr. Rüdiger Rüster, Dr. Gerhard Schmidt, Manuela Schmidt.

---

During the years 2000 and 2001 the number of institute staff was reduced according to the social plan.

The number of permanent positions decreased to 135.5 by the end of December 2001. Of these 40 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 98 on 31st December 2001.

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

Heinz-Jürgen Baur, Klaus-Dieter Eulig, Klaus Fischer, Bernhard Gräve, Heiner Grünwaldt, Ingeborg Güttler, Wolfgang Güttler, Monika Hale, Marianne Hartmann, Dr. Gerd Hartmann, Helga Haupt, Inge Kurtoglu, Hans Lauche, Herbert Lindner, Maria Ott, Dr. Klaus Richter, Walter Schmidt, Werner Tappert.

The following have retired:

Klaus-Dieter Hagen, Rita Pfeiff, Dr. Rüdiger Rüster, Dr. Gerhard Schmidt, Manuela Schmidt.

### Das Kuratorium des Instituts/Board of Trustees of the Institute

Dem Kuratorium des Instituts gehörten in den Jahren 2000 und 2001 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 des Landkreises Northeim;

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

Prof. Dr. Karl-Heinz Glaßmeier, Institut für Geophysik und Meteorologie der Technischen Universität, Braunschweig;

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

Dr. Hubert Hofmann, Dornier GmbH, Friedrichs- hafen;

Prof. Dr. Martin C.E. Huber, ESTEC/SSD, Noordwijk, Niederlande;

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

Frau Erika Mann, Mitglied des Europäischen Par- laments, Hannover;

Dr. Fritz Merkle, Carl Zeiss GmbH, Oberkochen;

Dr. Uwe Reinhardt, Staatssekretär im Nie- dersächsischen Ministerium für Wissenschaft und Kultur, Hannover;

Prof. Dr. H. Thomann, Siemens AG, München.

Das Kuratorium tagte am 3. Februar 2000 in Lin- dau.

---

The following were members of the board of trust- ees of the institute in the years 2000 and 2001:

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

Mr. Axel Endlein, president of the German coun- ties legislative assembly, member of the Lower Sa- xony state legislative assembly, district adminis- trator of Northeim county;

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

Prof. Dr. Karl-Heinz Glaßmeier, Institute for Geo- physics and Meteorology of the Technical Univer- sity, Braunschweig;

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

Dr. Hubert Hofmann, Dornier GmbH, Friedrichs- hafen;

Prof. Dr. Martin C.E. Huber, ESTEC/SSD, Noordwijk, The Netherlands;

Prof. Dr. Oskar von der Lüche, Kiepenheuer Insti- tute for Solar Physics, Freiburg;

Frau Erika Mann, member of the European Par- liament, Hannover;

Dr. Fritz Merkle, Carl Zeiss GmbH, Oberkochen;

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

Prof. Dr. H. Thomann, Siemens AG, Munich.

The board of trustees met on 3rd February, 2000 in Lindau.

## Der Fachbeirat des Instituts/ Scientific Advisory Board of the Institute

Im Juni 1996 wurde vom Präsidenten der Max-Planck-Gesellschaft ein neuer Fachbeirat für das Institut berufen. In den Jahren 1996–2001 gehören dem Fachbeirat die folgenden Mitglieder an:

Prof. Dr. S.W.H. Cowley, Leicester, England;  
Prof. Dr. R. Genzel, Garching, Deutschland;  
Dr. T. Holzer, Boulder, CO, USA;  
Dr. L.J. Lanzerotti, Murray Hill, NJ, USA;  
Dr. P. Lemaire, Orsay, Frankreich;  
Prof. Dr. K. Mauersberger, Heidelberg, Deutschland;  
Prof. Dr. N.F. Ness, Newark, DE, USA;  
Prof. Dr. F.M. Neubauer, Köln, Deutschland;  
Prof. Dr. D.J. Southwood, Paris, Frankreich.

Im Berichtszeitraum fand die Zusammenkunft des Fachbeirats vom 31. Januar – 2. Februar 2000 im MPAE in Lindau statt.

---

*In June 1996 a new advisory board for the institute was appointed by the President of the Max Planck Society. During the years 1996-2001 the following were members of the scientific advisory board:*

*Prof. Dr. S.W.H. Cowley, Leicester, UK;  
Prof. Dr. R. Genzel, Garching, Germany;  
Dr. T. Holzer, Boulder, CO, USA;  
Dr. L.J. Lanzerotti, Murray Hill, NJ, USA;  
Dr. P. Lemaire, Orsay, France;  
Prof. Dr. K. Mauersberger, Heidelberg, Germany;  
Prof. Dr. N.F. Ness, Newark, DE, USA;  
Prof. Dr. F.M. Neubauer, Köln, Germany;  
Prof. Dr. D.J. Southwood, Paris, France.*

*During the period of this report the advisory board met in Lindau from 31st January to 2nd February 2000.*

## 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 2000 17,6 Mio. DM für Personal und 5,1 Mio. DM für Sachen. An Investitionsmitteln (Geräte mit Preisen über 10.000 DM) wurden 0,6 Mio. DM bewilligt. Für das Jahr 2001 lauten diese Zahlen: 17,6 Mio. DM für Personal, 5,0 Mio.

DM für Sachausgaben und 1,4 Mio. DM für Investitionen.

Besondere Forschungsvorhaben sind durch das BMBF (Bundesministerium für Bildung, Wissenschaft, Forschung und Technologie) und die ESA (European Space Agency) gefördert worden. Vom BMBF (DLR) erhielt das Institut 2000 insgesamt 9,9 Mio. DM und 2001 16,3 Mio. DM. Die entsprechenden Beträge der ESA waren 0,8 Mio. DM und 2,3 Mio. DM.

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 17.6 million DM for personnel and 5.1 million DM for materials in 2000. Capital investment funds (equipment over 10000 DM) of 0.6 million DM were approved. For 2001 the figures are: 17.6 million DM for personnel, 5.0 million DM for materials, and 1.4 million DM 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 9.9 million DM in 2000 and 16.3 million DM in 2001. The corresponding sums from ESA were 0.8 million DM and 2.3 million DM.*

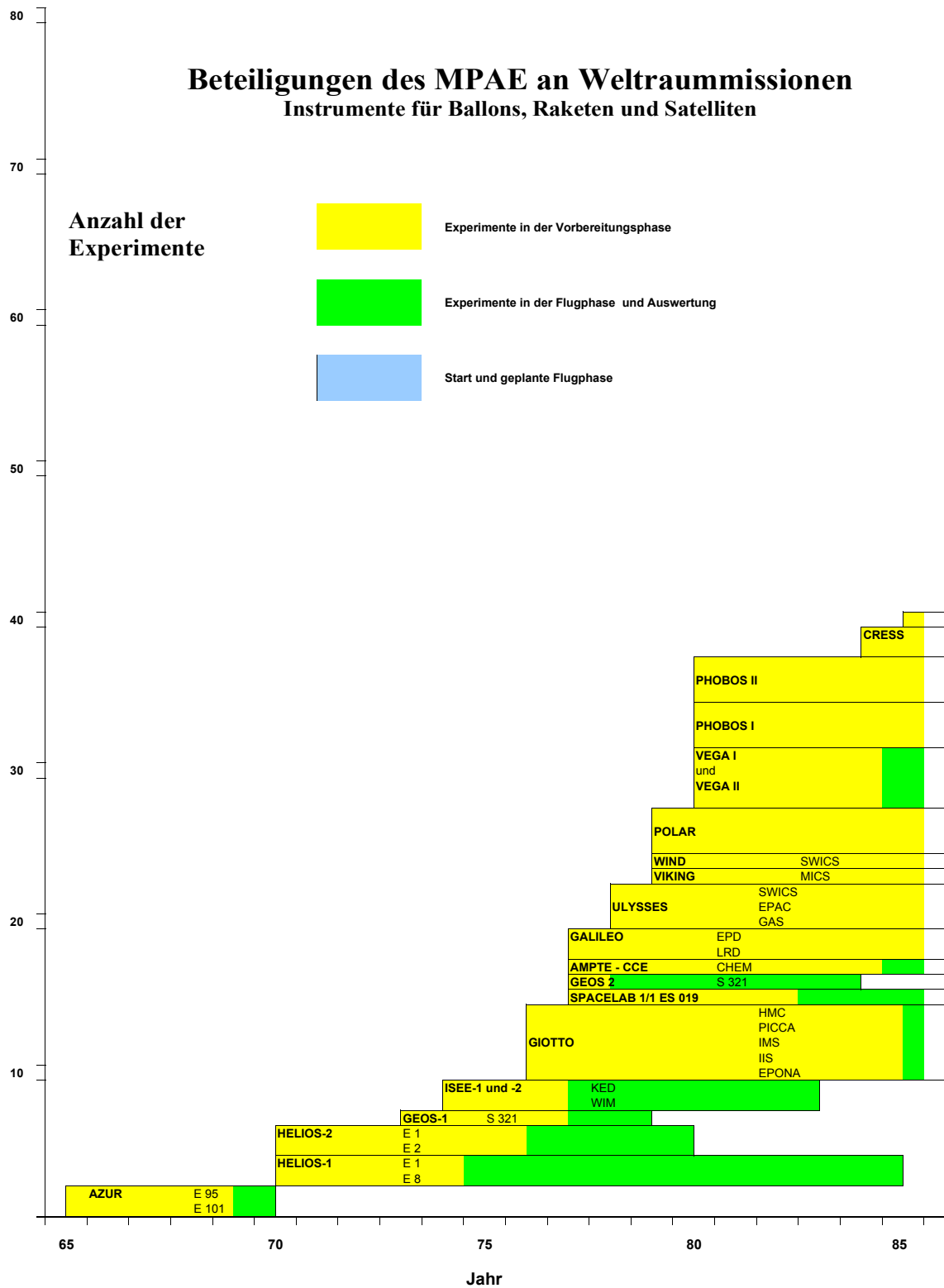
*For this financial assistance, without which many experimental research programmes would not be possible, we wish to express our gratitude.*

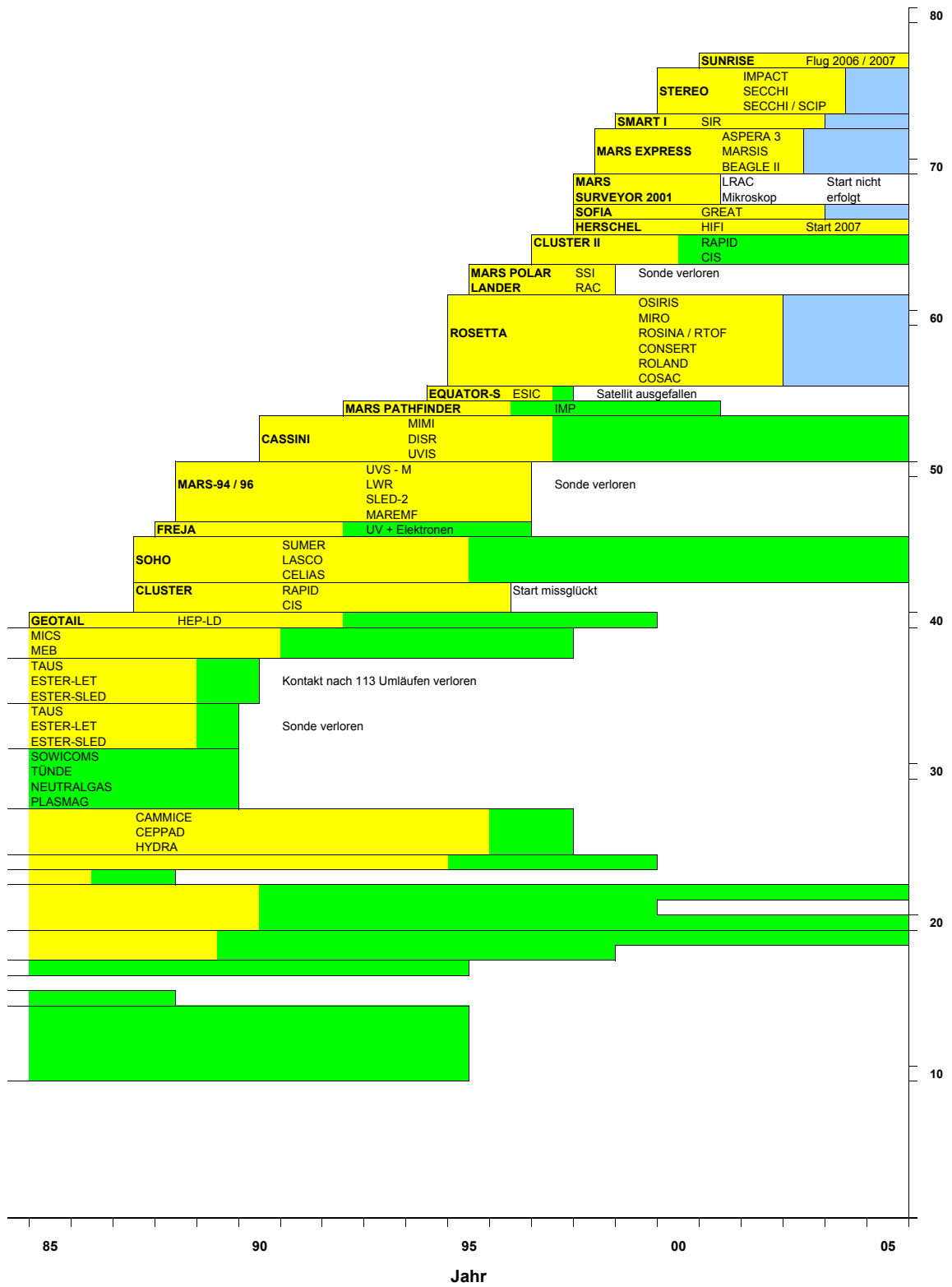
**Folgende Seiten:**

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.







## II. Wissenschaftliche Arbeiten/Scientific Projects

### 1. Sonne und Heliosphäre/Sun and Heliosphere

#### **Schwerpunktthema:**

#### **Das Magnetfeld der Sonne – Quelle des Weltraumwetters und möglicher Klimafaktor**

(English version see page 15)

Seit George Ellery Hale im Jahre 1908 mittels des wenige Jahre zuvor gefundenen Zeeman-Effekts entdeckte, dass Sonnenflecken starke Magnetfelder (einige tausend mal stärker als das Erdfeld) besitzen, wissen wir, dass die Sonne ein „magnetischer Stern“ ist. Die Existenz von Sonnenflecken (siehe Abb. 1) war in Europa seit dem Beginn des

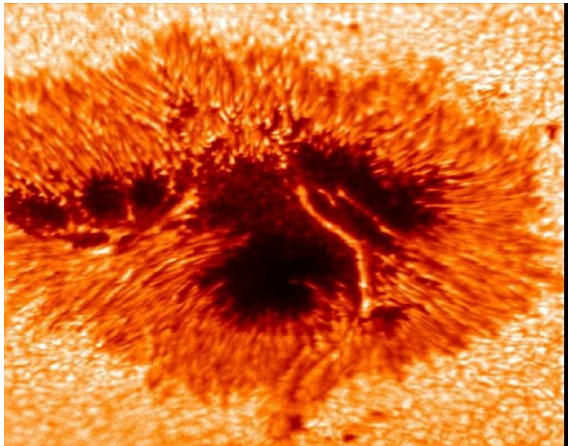


Abb. 1: Großer Sonnenfleck, der Anfang September 1998 auf der Südhälfte der Sonne zu sehen war. Das Bildfeld umfasst ca. 65 000 km × 65 000 km auf der Sonne – dies entspricht etwa der 8-fachen Größe der Erdoberfläche. Sonnenflecken erscheinen dunkel, weil das in ihnen durch die Sonnenoberfläche tretende starke Magnetfeld den konvektiven Energietransport behindert. (Quelle: Kiepenheuer-Institut für Sonnenphysik)

17. Jahrhunderts bekannt (in China schon lange vorher), ihre physikalische Natur blieb aber lange rätselhaft. Heute wissen wir, dass in Sonnenflecken magnetischer Fluss aus dem Sonneninneren austritt und dass sie gegen die gleißend helle Sonnenoberfläche dunkel erscheinen, weil das starke Magnetfeld von etwa 3000 Gauß den Energie-

transport durch Gasströmungen (Konvektion) zur Oberfläche unterdrückt.

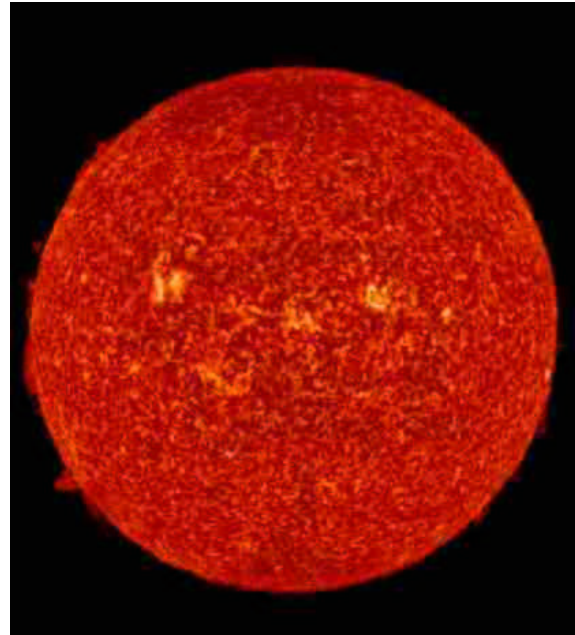


Abb. 2: Die Sonne im Licht der Emissionslinie von Helium bei einer Wellenlänge von 584 Å, aufgenommen mit dem am MPAE gebauten Spektrographen SUMER auf dem weltraumgestützten Sonnenobservatorium SOHO (Solar and Heliospheric Observatory, ESA/NASA). Diese Spektrallinie wird in der Chromosphäre der Sonne bei einer Temperatur von etwa 20000 K gebildet. Die Intensität ist in magnetischen Gebieten verstärkt.

Das Magnetfeld der Sonne ist aber nicht auf die Sonnenflecken beschränkt, denn magnetischer Fluss tritt in mehr oder weniger konzentrierter Form (im sogenannten magnetischen Netzwerk gezeigt in Abb. 2) fast überall durch die Sonnenoberfläche. Ein Teil davon reicht weit (siehe z.B. die Magnetfeldschleifen in Abb. 3) in die heiße Umgebung der Sonne, die Korona, und in den interplanetaren Raum heraus (siehe weiter unten die Abb. 5). Die mannigfaltigen Erscheinungen der „Sonnenaktivität“, welche die Sonne zu solch einem spektakulären Objekt astrophysikalischer Forschung machen, gehen alle direkt oder

indirekt auf das Magnetfeld und seine Veränderungen zurück.

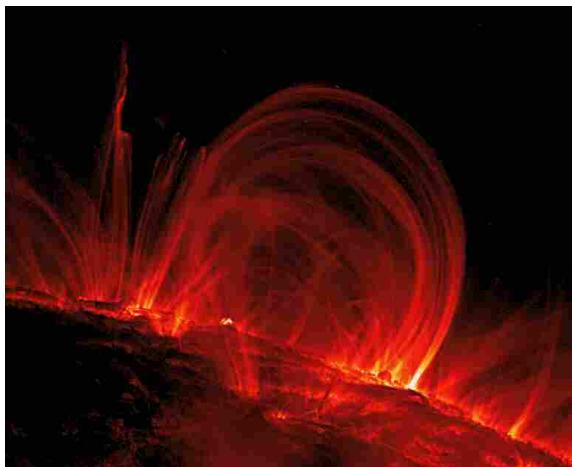


Abb. 3: In hohen Bögen reicht das solare Magnetfeld bis in die Sonnenkorona und in den interplanetaren Raum hinaus. Diese Aufnahme im kurzwelligeren ultravioletten Licht stammt vom NASA-Satelliten TRACE (Transition Region and Coronal Explorer). Sie zeigt heißes Gas, das sich entlang der magnetischen Kraftlinien in der Sonnenkorona angesammelt hat.

Im Jahre 1843 fand Samuel Heinrich Schwabe heraus, dass die Häufigkeit von Sonnenflecken rhythmisch in einem etwa 11-jährigen Zyklus schwankt (siehe Abb. 4). Da die Sonnenfleckenanzahl ein Maß für den an der Oberfläche der Sonne auftauchenden magnetischen Fluss ist, verwundert es nicht, dass auch alle anderen durch die magnetische Aktivität der Sonne hervorgerufenen Erscheinungen im gleichen Rhythmus variieren, so dass man vom „Aktivitätszyklus“ der Sonne spricht. Allerdings ist der 11-jährige Rhythmus einigen Schwankungen unterworfen, was die Länge und die Stärke der einzelnen Aktivitätszyklen angeht.

Eine besondere Anomalie in der Abfolge der Zyklen stellt der Zeitraum zwischen 1640 und 1710 dar, denn während dieser Zeit verschwanden die Sonnenflecken weitgehend; das gelegentliche Auftauchen eines Sonnenflecks wurde zum wissenschaftlichen Ereignis. Diese Zeit wird nach Edward Walter Maunder, der als einer der ersten um 1900 auf diese fleckenarme Periode der Sonne hinwies, „Maunder-Minimum“ genannt. Einen weniger ausgeprägten Rückgang der Fleckenaktivität gab es zu Beginn des 19. Jahrhunderts. Darüber wie Sonnenaktivität und Erdklima möglicherweise zusammenhängen könnten, wurde schon bald nach der Entdeckung der Sonnenflecken spekuliert, insbesondere aber nachdem der 11-jähri-

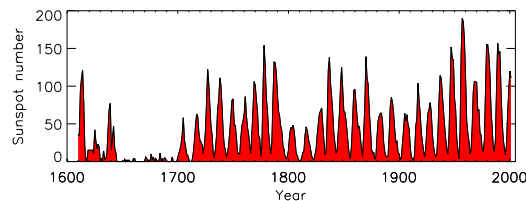


Abb. 4: Sonnenfleckenrelativzahl, ein Maß für die Sonnenaktivität, vom Jahr 1600 bis zur Gegenwart. Der 11-jährige Aktivitätszyklus und seine langfristige Modulation ist deutlich sichtbar. Im „Maunder-Minimum“ zwischen 1640 und 1710 kam die Fleckenaktivität fast vollständig zum Erliegen.

ge Aktivitätszyklus gefunden worden war. Manche Korrelationen zwischen der Sonnenfleckenanzahl und Temperaturaufzeichnungen oder anderen Klimaindikatoren erwiesen sich als zeitlich oder räumlich variabel und ließen keine eindeutigen Aussagen über einen kausalen Zusammenhang zu. Seit etwa 20 Jahren wird jedoch, vor allem wegen der globalen Erwärmung des Erdklimas seit Beginn des 20. Jahrhunderts, wieder zunehmend ein möglicher solarer Einfluss auf die langfristige Klimavariabilität diskutiert. So berichteten die dänischen Forscher Eigil Friis-Christensen und Knut Lassen im Jahre 1991 über eine bemerkenswert gute Korrelation zwischen der Länge der Sonnenzyklen und der mittleren Landtemperatur auf der Nordhalbkugel.

Die Sonnenaktivität und das mit dem Sonnenwind auch in den erdnahen Weltraum getragene Magnetfeld der Sonne (siehe z.B. in der Abb. 5 den Massenauswurf mit schleifenförmigem Magnetfeld in der Sonnenkorona, der angetrieben wird durch die Freisetzung von magnetischer Energie) wirken tatsächlich in vielfältiger Art und Weise auf die Magnetosphäre und Atmosphäre der Erde ein. Das reicht von „magnetischen Stürmen“ im Erdmagnetfeld über durch energiereiche Teilchen hervorgerufene Polarlichter bis zur Ausdehnung der oberen Atmosphäre durch verstärkte UV-Strahlung, welche 1979 den (unkontrollierten!) Absturz des US-Weltraumlabor „Skylab“ verursachte. Teilchenschauer nach großen Explosionen (sog. Flares) auf der Sonne können den Funkverkehr auf der Erde stören. Die durch Sonnenaktivität ausgelösten geomagnetischen Stürme können durch elektromagnetische Induktion Stromnetze lahmlegen, die Elektronik von Satelliten schädigen und nicht zuletzt Astronauten gefährden. Je mehr wir uns auf weltraumgestützte Systeme für Telekommunikation, Navigation und Datenübertragung verlassen, um so größer wird auch die öko-

nomische Bedeutung dieses von der Sonne verursachten „Weltraumwetters“.

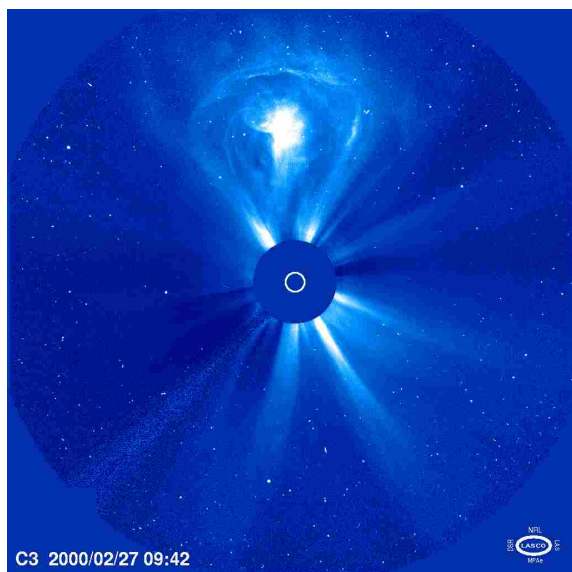


Abb. 5: Massenauswurf in der Sonnenkorona, angetrieben durch die Freisetzung magnetischer Energie. Die Aufnahme stammt vom teilweise am MPAE gebauten Koronagraphen LASCO, einem Instrument des weltraumgestützten Sonnenobservatoriums SOHO (Solar and Heliospheric Observatory, ESA/NASA). Die Sonne selbst und ihre nähere Umgebung ist durch eine Blende (im Bildzentrum) abgedeckt. Solche Eruptionen können das „Weltraumwetter“ in der Umgebung der Erde stark beeinflussen.

Das Magnetfeld der Sonne schickt nicht nur energiereiche Teilchen zur Erde, sondern hält solche auch von der Erde ab. Die hochenergetischen Teilchen der vorwiegend aus Protonen bestehenden kosmischen Strahlung, deren Ursprung außerhalb des Sonnensystems liegt, werden vom Magnetfeld der Sonne und seinen Fluktuationen im interplanetaren Raum gestreut, so dass im solaren Aktivitätsmaximum (stärkeres Magnetfeld) deutlich weniger kosmische Strahlung die Erde erreicht als im Aktivitätsminimum (schwächeres Magnetfeld).

Je nach ihrer Energie können Teilchen der kosmischen Strahlung verschieden tief in die Erdatmosphäre eindringen, wo sie mit Stickstoff- und Sauerstoffatomen wechselwirken. Dabei entstehen einerseits Neutronen, die am Erdboden seit Mitte des 20. Jahrhunderts mittels Neutronenmonitoren nachgewiesen werden können, andererseits aber radioaktive Isotope wie  $^{14}\text{C}$  und  $^{10}\text{Be}$ , deren Häufigkeit somit ein Maß für die Stärke der kosmischen Strahlung zum Zeitpunkt ihrer Bildung darstellt. Durch die Bestimmung der  $^{14}\text{C}$ -Häufigkeit

in Holz, dessen Alter aus Baumringen bestimmt werden kann, bzw. von  $^{10}\text{Be}$  in Eisbohrkernen im grönländischen Inlandeis ist es somit möglich, die Intensität der kosmischen Strahlung in die Vergangenheit bis weit vor den Beginn der direkten Messungen zurück zu verfolgen.

Wegen des gegenläufigen Zusammenhangs zwischen Sonnenaktivität und kosmischer Strahlung ist folglich die Produktionsrate der „kosmogenen“ Isotope  $^{14}\text{C}$  und  $^{10}\text{Be}$  auch ein Maß für die Aktivität und das Magnetfeld der Sonne in der Vergangenheit. Verfolgt man beispielsweise die entsprechenden Zeitreihe für  $^{10}\text{Be}$  zurück, so fällt auf, dass es neben dem 11-jährigen Zyklus auch längerfristige, nichtzyklische Trends darin gibt (vergleiche Abb. 6). Demnach hat in den letzten hundert Jahren die Intensität der kosmischen Strahlung deutlich abgenommen. Da die kosmische Strahlung selbst aus vielen unabhängigen Quellen stammt, deutet dies darauf hin, dass das Magnetfeld der Sonne in diesem Zeitraum zugenommen hat. Diese These wurde durch Mike Lockwood und Mitarbeiter in Großbritannien eindrucksvoll bestätigt. Sie konnten an Hand des aa-Index, der die Störungen des Erdmagnetfeldes quantifiziert und seit 1868 aufgezeichnet wird, die Stärke des interplanetaren Magnetfeldes zurückverfolgen. Dabei zeigte sich, dass sich dieses (und folglich auch das zugrundeliegende „offene“ Quellfeld der Sonne) im letzten Jahrhundert tatsächlich mehr als verdoppelt hat.

Während es einige Ansätze dafür gibt, den zyklischen Teil der magnetischen Variabilität der Sonne als selbsterregten Dynamoprozess im Sonneninneren zu beschreiben, gab es bis vor kurzem keine Erklärung für die von Lockwood gefundene längerfristige Änderung des offenen Magnetfelds. Ein erster Ansatz dafür wurde kürzlich am Max-Planck-Institut für Aeronomie in Zusammenarbeit mit Kollegen in Zürich entwickelt (Solanki, Schüssler and Fligge, Nature 408, 445, 2000). Wesentlich dabei ist, dass der aus ausgedehnten magnetisch unipolaren Gebieten auf der Sonne stammende magnetische Fluss, welcher in den interplanetaren Raum hinausragt, eine Verweilzeit an der Sonnenoberfläche von einigen Jahren hat. Neuer magnetischer Fluss erscheint überwiegend um das Maximum des Aktivitätszyklus herum, wobei man eine Beziehung zwischen der beobachteten Zahl der Sonnenflecken und der neu erscheinenden Flussmenge herstellen kann.

Da die Sonnenfleckenanzahl seit etwa 1700 recht gut bekannt ist, kann man somit den neu auftauchenden magnetischen Fluss abschätzen. Der

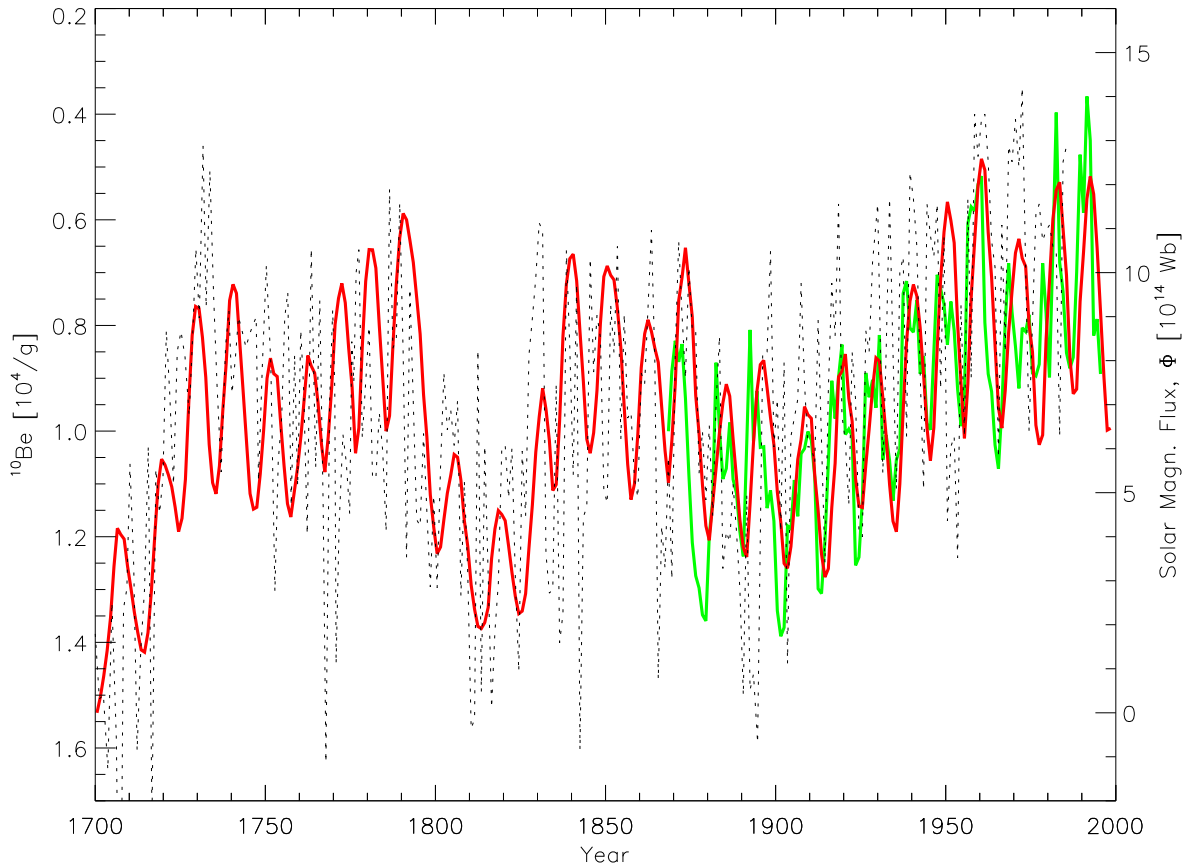


Abb. 6: Rekonstruierte Zeitentwicklung des offenen solaren Quellfeldes (rot) seit 1700 bis zur Gegenwart im Vergleich mit dem interplanetaren Magnetfeld (grün, aus dem aa-Index nach Lockwood) und der  $^{10}\text{Be}$ -Konzentration (gestrichelt, linke invertierte Skala).

Großteil dieses Flusses verschwindet innerhalb eines Zeitraums von Tagen bis Wochen. Es bleibt aber ein Rest, der mehrere Jahre auf der Sonnenoberfläche verbleiben kann, so dass magnetischer Fluss aus dem vorangehenden Aktivitätszyklus noch vorhanden ist, wenn der nächste Zyklus beginnt. So können sich die Flüsse überlagern und zu einem nicht-zyklischen „Untergrund“ beitragen. Die Höhe des nicht-zyklischen Anteils hängt sowohl von der Menge des neu erscheinenden Flusses (d.h. der Stärke des Sonnenzyklus) wie auch von der Zykluslänge ab. Ist ein Zyklus kurz, so bleibt mehr vom langlebigen Anteil des Flusses erhalten, zu dem sich magnetischer Fluss vom nächsten Zyklus addieren kann.

Mit einem solch einfachen Modell kann die Zeitentwicklung des interplanetaren Magnetfelds überraschend genau rekonstruiert werden. In Abb. 6 ist das für den Zeitraum seit 1700 errechnete Magnetfeld rot dargestellt, während das aus dem geomagnetischen aa-Index rekonstruierte Feld mit grün gekennzeichnet ist. Beide Kurven beziehen sich auf die rechte Skala. Zusätzlich ist in

Abb. 6 die gemessene Konzentration des neu entstandenen  $^{10}\text{Be}$  (invertierte linke Skala) durch die gepunktete Linie dargestellt. Die gute Übereinstimmung zeigt auch, dass die  $^{10}\text{Be}$ -Konzentration tatsächlich als quantitatives Maß für die langfristige Entwicklung der Sonnenaktivität in der Vergangenheit verwendet werden kann.

Die Modulation der in die Erdatmosphäre eindringenden kosmischen Strahlung durch das veränderliche Magnetfeld der Sonne ist einer der Mechanismen, welche für einen möglichen Einfluss der Sonne auf das Erdklima diskutiert werden. So haben Svensmark und Friis-Christensen vorgeschlagen, dass die Variation der kosmischen Strahlung zu einer leichten Schwankung der globalen Wolkenbedeckung im Rhythmus des Sonnenzyklus führt, da die Luftionisation durch die kosmische Strahlung über komplizierte Prozesse die Bildung von Kondensationskeimen begünstigen könnte. Tatsächlich fanden Marsh und Svensmark für den Zeitraum nach 1983, für den globale Daten vorliegen, eine gute Korrelation zwischen dem Bedeckungsgrad tiefliegender Wolken und der Son-

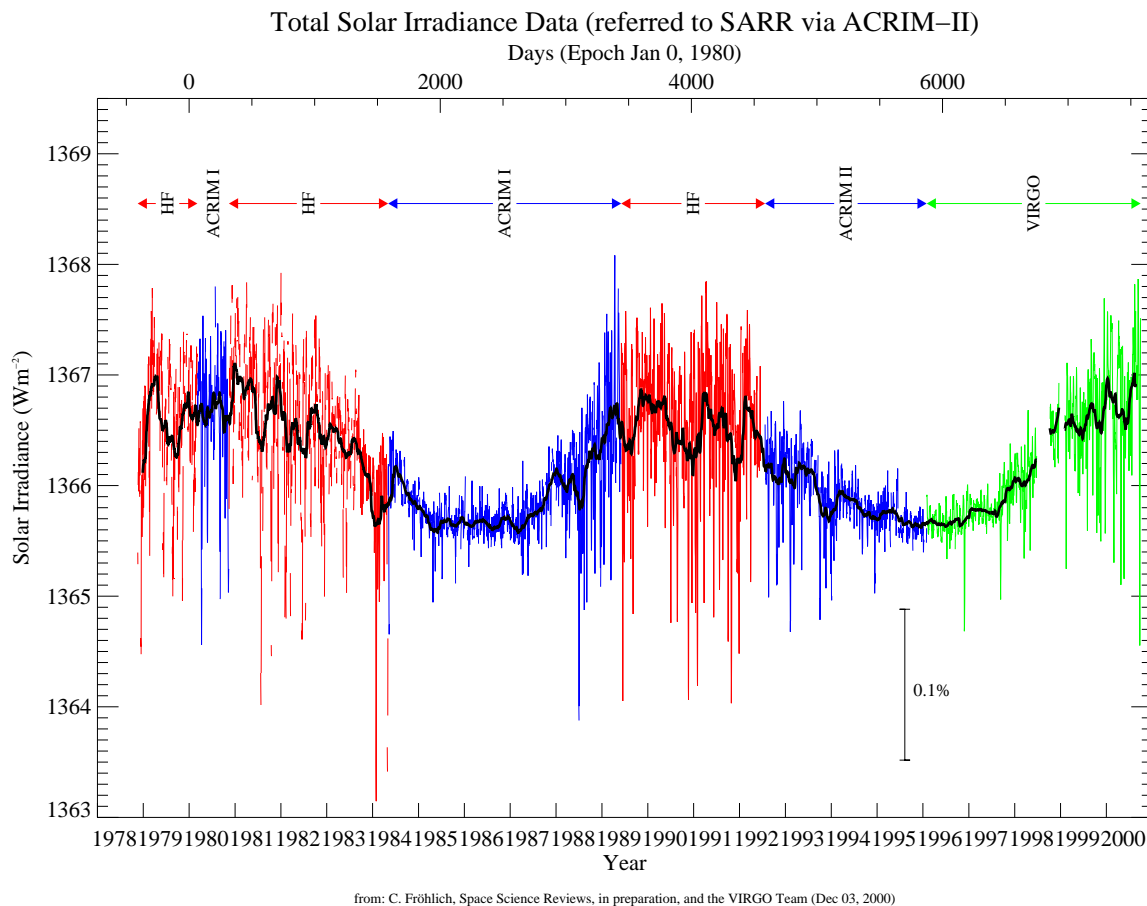


Abb. 7: Variation der Gesamtstrahlung der Sonne seit 1979. Die Datensätze verschiedener Instrumente sind farbig gekennzeichnet. Der oberhalb der Erdatmosphäre einfallende solare Energiefluss schwankt im Gleichtakt zum Sonnenzyklus um etwa 0.1% (entsprechend ca.  $1.4 \text{ W/m}^2$ ).

nenaktivität. Da tiefliegende Wolken wegen der erhöhten Albedo eine kühlende Wirkung haben, würde dies zu einer positiven Korrelation zwischen Sonnenaktivität und Erdtemperatur führen.

Grundsätzlich könnte also ein Teil der weltweiten Erwärmung in den letzten hundert Jahren auf die erhöhte Sonnenaktivität zurückzuführen sein; allerdings sind die Prozesse der Wolkenbildung gegenwärtig bei weitem noch nicht ausreichend verstanden, um diese Wirkung verlässlich quantifizieren zu können. Immerhin waren in der Vergangenheit Zeiten geringer Sonnenaktivität tatsächlich meist mit niedrigen Temperaturen verbunden. So fällt das Maunder-Minimum im 17. Jahrhundert mit dem Höhepunkt der sogenannten „kleinen Eiszeit“ zusammen, als Europa unterdurchschnittliche Temperaturen und vor allem sehr kalte Winter erlebte.

Ein direkterer Weg, auf welchem die Sonne die Erdatmosphäre und insbesondere das Erdklima beeinflusst, ist durch ihre Strahlung. Dies betrifft

sowohl die Gesamtstrahlung (die sogenannte „Solarkonstante“) als auch ihre Emission in einzelnen Wellenlängenbereichen. So schwankt die kurzwellige UV-Strahlung der Sonne um einen Faktor 2 im Verlaufe des Sonnenzyklus, was zu einer periodischen Ausdehnung der äußersten Schichten der Erdatmosphäre führt. Die schwankende UV-Strahlung kann aber auch über photochemische Prozesse Temperaturänderungen in der Stratosphäre bewirken, welche ihrerseits großräumige Luftströmungen in der Troposphäre beeinflussen können, so dass eine globale Klimawirkung nicht auszuschließen ist.

Auch relativ geringe Schwankungen der Gesamtstrahlung der Sonne können einen Einfluss auf das Klima haben, wenn sie ausreichend lange andauern. Solche Schwankungen werden wiederum durch das Magnetfeld der Sonne bewirkt. Dieses ist auf der Sonnenoberfläche nicht nur auf die dunklen Sonnenflecken beschränkt, sondern bildet auch helle Gebiete, die als Fackeln bezeichnet

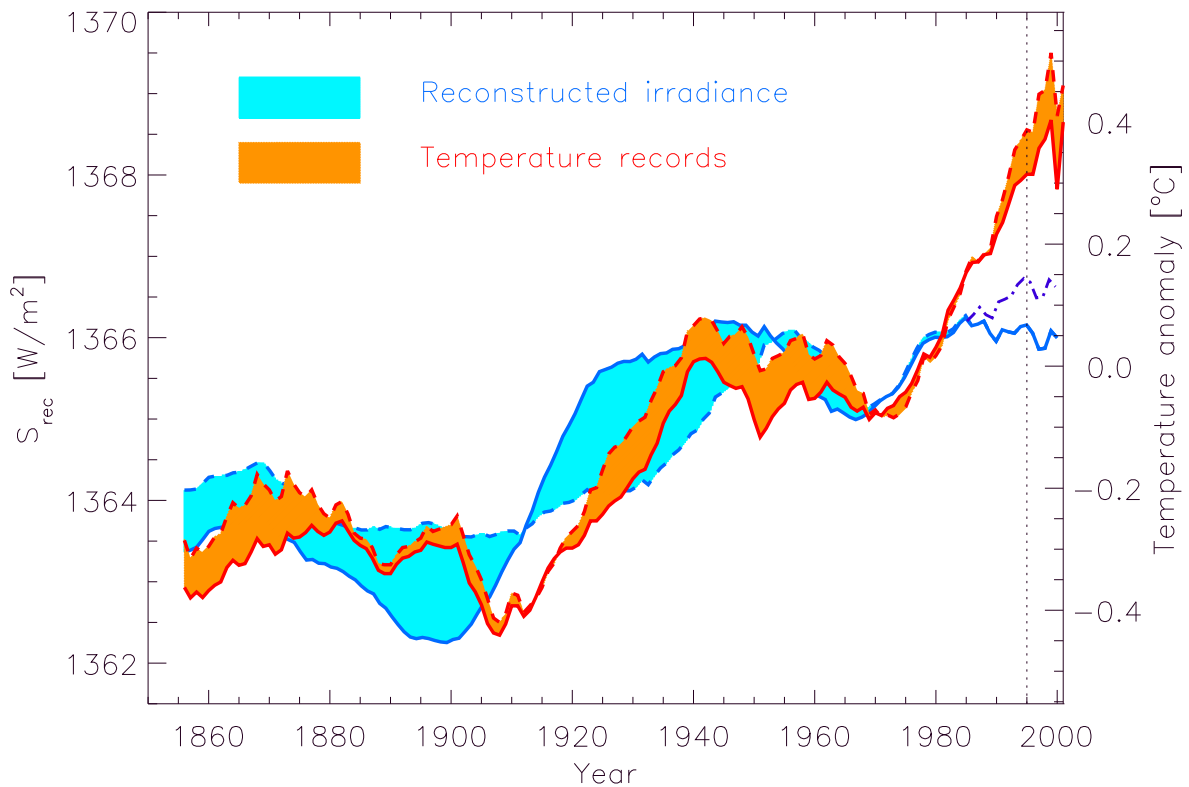


Abb. 8: Verlauf des rekonstruierten langfristigen Trends der solaren Gesamtstrahlung (blau, linke Skala) im Vergleich mit der (zeitlich gemittelten) Entwicklung der globalen Erdtemperatur (orange, rechte Skala). Die Breite der farbigen Bänder deutet die jeweilige Unsicherheit der Daten und der Rekonstruktion an. Die gute Übereinstimmung im Verlauf beider Kurven vor ca. 1980 weist auf einen möglichen Einfluss der Sonne auf das Erdklima hin. Nach 1980 bleibt jedoch die Strahlung der Sonne im Mittel gleich, während die globale Temperatur weiterhin deutlich ansteigt.

werden. Zuverlässige Messungen von Helligkeitsschwankungen der Sonne gibt es erst seit 1978, d.h. bis jetzt über fast genau zwei volle Sonnenzyklen. Die Messreihe ist in Abb. 7 dargestellt.

Sie zeigt einerseits scharfe Einsenkungen, wenn dunkle Sonnenflecken über die sichtbare Hemisphäre der rotierenden Sonne wandern. Andererseits wird aber deutlich, dass die Sonnenhelligkeit im Gleichtakt mit dem Aktivitätszyklus schwankt. Da die Sonne im Aktivitätsmaximum (wenn es mehr dunkle Flecken auf ihrer Oberfläche gibt) heller ist, folgt, dass die Zahl der hellen Fackeln vom Aktivitätsminimum zum -maximum stärker als die Zahl der Sonnenflecken wächst und so deren Wirkung überkompensiert. Modelle, die am Max-Planck-Institut für Aeronomie in Zusammenarbeit mit der Eidgenössischen Technischen Hochschule Zürich entwickelt worden sind, reproduzieren die Helligkeitsmessungen mit großer Genauigkeit. Wichtig ist dabei, dass möglichst der gesamte magnetische Fluss an der Sonnenoberfläche berücksichtigt wird.

Um abschätzen zu können, wie groß der Einfluss solarer Helligkeitsänderungen auf das Erdklima ist, muss der Helligkeitsverlauf über einen Zeitraum rekonstruiert werden, der weit länger ist als die Periode nach 1978, für die direkte Messungen existieren. Dazu muss man Modelle konstruieren, welche einen Zusammenhang zwischen den vorhandenen Messdaten und der gesuchten Helligkeit herstellen. Insbesondere ist eine Rekonstruktion der Zeitentwicklung des gesamten magnetischen Flusses auf der Sonnenoberfläche notwendig.

Bis 1700 zurückgehendes Datenmaterial ist aber auf Beobachtungen von Sonnenflecken, welche nur einen kleinen Teil des Gesamtflusses tragen, beschränkt. Bisherige Ansätze, dieses Problem zu lösen, gehen von einem festen (indirekten) Zusammenhang zwischen dem gesamten Feld und der Fleckenzahl aus. Dabei werden Beobachtungen von sonnenähnlichen Sternen herangezogen, welche darauf hindeuten, dass beim Ausbleiben von Sonnenflecken (wie während des Maunder-Minimums) auch der sonstige magnetische Fluss praktisch verschwindet.

Darüber, wie die genaue zeitliche Entwicklung des gesamten Feldes aussieht, erhält man auf diese Art und Weise allerdings keine genaue Antwort. Nach Einführung weiterer Annahmen ergibt sich jedoch eine gute Korrelation zwischen dem so erhaltenen Helligkeitsverlauf und dem Erdklima, zumindest für die Zeit vor 1980. Seither setzt die Erdtemperatur allerdings ihren Anstieg ungebrochen fort, während die Sonnenhelligkeit (bis auf zyklische Variationen) konstant geblieben ist. Ein neuer Ansatz für die Rekonstruktion des Gesamtflusses aus Sonnenfleckendaten wurde in jüngster Zeit am MPAE entwickelt. In Erweiterung des Modells für die Rekonstruktion des interplanetaren Feldes wird dabei neben dem magnetischen Fluss in Sonnenfleckengruppen nunmehr auch das Auftauchen von Fluss in kleinen Aktivitätsgebieten (sog. „ephemeral active regions“) berücksichtigt. In diesen tritt einerseits sehr viel mehr Fluss zutage als in den großen Fleckregionen, andererseits zeigen sie erheblich längere Aktivitätszyklen von etwa 15 Jahren, die sich jeweils um ca. 4 Jahre überlappen, so dass sie mit dem eigentlichen 11-jährigen Sonnenfleckenzyklus synchronisiert bleiben.

Unter der Annahme, dass diese Verhältnisse in der Vergangenheit ähnlich waren wie in dem Zeitraum, über den direkte Beobachtungen von „ephemeral active regions“ vorliegen, wird es so möglich, den Gesamtfluss der Sonne bis zurück zum Ende des Maunder-Minimums zu rekonstruieren (Fig. 8). Es zeigt sich, dass sich nicht nur der Quellfluss des interplanetaren Feldes, sondern auch der Gesamtfluss der Sonne in den letzten hundert Jahren verdoppelt hat. Die Berechnung der daraus resultierenden Helligkeitsvariation der Sonne wird gegenwärtig durchgeführt. Bei allen Hinweisen auf einen signifikanten, vielleicht sogar dominierenden Einfluss der Sonne auf die Klimavariabilität in der Vergangenheit bleibt festzuhalten, dass spätestens seit 1980 andere Faktoren für die ungebrochene Aufheizung der Erde verantwortlich gewesen sind, allen voran die anthropogenen Treibhausgase. Eine genaue Quantifizierung der direkten und indirekten Wirkungen der veränderlichen Sonne auf das Erdklima steht noch aus. Dies ist neben der großen Komplexität der beteiligten Prozesse nicht zuletzt auch durch die Unsicherheiten bei der Rekonstruktion der wesentlichen solaren Parameter, des magnetischen Flusses und der (spektralen und gesamten) Helligkeit, bedingt. Um hier Fortschritte zu erzielen, ist ein besseres Verständnis der zugrundeliegenden physikalischen Prozesse auf der Sonne selbst erforderlich.

(S.K. Solanki, N. Krivova, E. Marsch, M. Schüssler, R. Schwenn, K. Wilhelm)

### **Highlight:**

#### **The solar magnetic field: cause of space weather and suspected driver for terrestrial climate change**

Ever since George Ellery Hale in 1908, employing the Zeeman effect found about a decade earlier, discovered that sunspots harbour strong magnetic fields (a few thousand times stronger than the magnetic field at the surface of the Earth), we know that the Sun is a “magnetic star”. The existence of sunspots (Fig. 1) was known in Europe

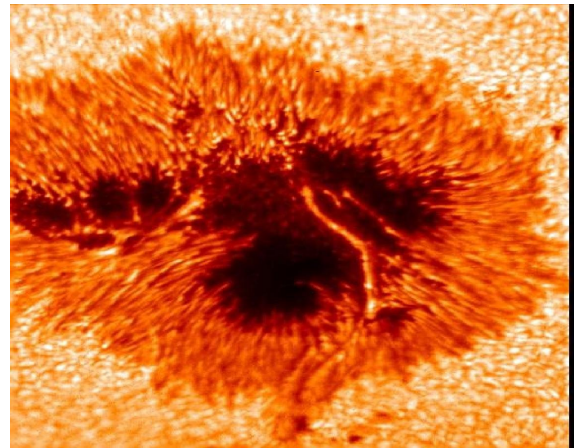


Fig. 1: Big sunspot, which appeared in the beginning of September 1998 on the southern hemisphere of the Sun. The image comprises an area of about  $65\,000\text{ km} \times 65\,000\text{ km}$  on the Sun, corresponding to about 8 times the surface area of the Earth. Sunspots appear dark because their strong magnetic field suppresses the convective energy transport (image courtesy of Kiepenheuer-Institut für Sonnenphysik, Freiburg).

already since the beginning of the 17th century (much earlier so in China), but their physical nature remained enigmatic. Today we understand that in sunspots magnetic flux emerges from the solar interior; they appear dark in comparison to the brighter surrounding regions of the solar surface because the strong magnetic field of about 3000 Gauß largely suppresses the transport of energy to the surface by way of gas motions (convection).

The solar magnetic field is not restricted to sunspots: magnetic flux in more or less concentrated form can be found nearly every-

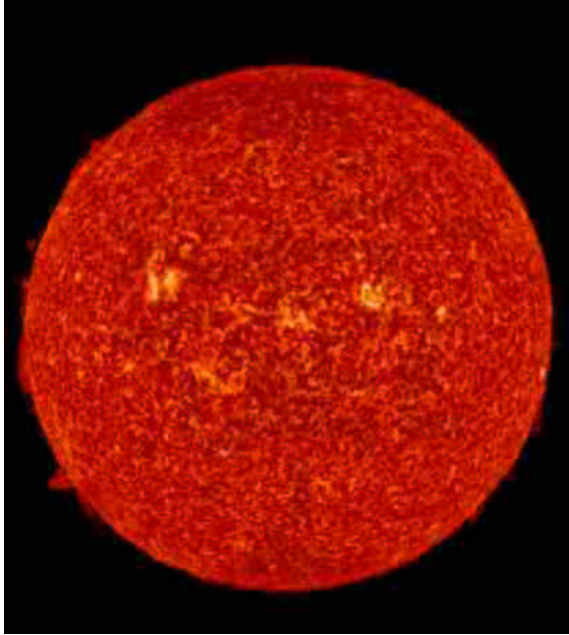


Fig. 2: The Sun in the light of the spectral emission line of neutral Helium at a wavelength of 58.4 nm. The line is formed in the chromosphere at a temperature of about 20,000 K. The raster image has been taken with the spectrograph SUMER (built at MPAAE) on SOHO (Solar and Heliospheric Observer, ESA/NASA).

where on the solar surface (Fig. 2). Part of this flux extends deep into the hot envelope of the Sun (Fig. 3), the corona, and into inter-planetary space (see Fig. 5). The many phenomena of “solar activity”, which make the Sun such a spectacular object of astrophysical research, are all, directly or indirectly, caused by the magnetic field and its variations.

Samuel Heinrich Schwabe found in 1843 that the number of sunspots varies regularly in a cycle with a period of about 11 years (Fig. 4). Since the abundance of sunspots is a measure of the magnetic flux appearing at the solar surface, it is not surprising that all other phenomena of solar activity vary in the same rhythm, the “activity cycle” of the Sun. However, the cycle is not fully regular: there are variations of the strength and also the length of the individual activity cycles.

The interval between 1640 and 1710 represents a particular anomaly in the sequence of solar cycles. During this time, sunspots almost completely disappeared; the occasional sighting of a sunspot became a scientific event. This period of low solar activity has been named “Maunder minimum” after Edward Walter Maunder, who first noted the lack of sunspots during this period. A less pro-

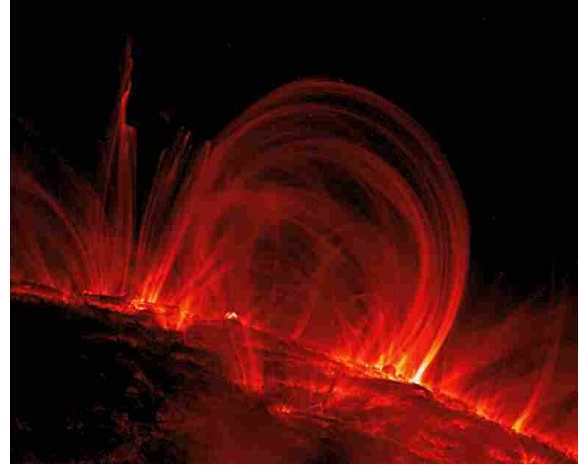


Fig. 3: Large coronal loops illustrate the extension of the solar magnetic field into the corona. This image, taken in ultraviolet light, shows hot plasma that has accumulated along magnetic field lines in the solar corona. It has been provided by the NASA mission TRACE (Transition Region and Coronal Explorer).

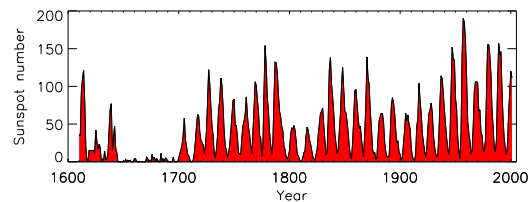


Fig. 4: The time series of the relative sunspot number, a measure for the magnetic activity of the Sun, from 1600 until the present. The 11-year solar cycle and its long-term modulation are clearly visible. During the “Maunder minimum” between 1630 and 1710, almost no sunspots were present on the solar surface.

nounced decrease of sunspot activity with relatively weak 11-year cycles took place around the turn of the 18th century.

Soon after the discovery of the sunspot cycle, the possible relationship between sunspot activity and terrestrial climate became subject of heated discussion and speculations. Various correlations between sunspot number and local temperature records or other climate indicators were found, but most of them proved to be spatially or temporarily variable and hardly significant in the long run; a causal relation could not be established. In connection with the global warming of the terrestrial climate since the beginning of the 20th century, the question of possible solar influences on long-term climate variability found new interest. As an

example, Eigil Friis-Christensen and Knut Lassen reported in 1991 about a remarkably tight correlation between the length of the individual sunspot cycles and the record of the average land temperature on the Northern hemisphere.

Solar activity and the solar magnetic field, which the solar wind transports into the space environment of the Earth (Fig. 5), affect the terrestrial magnetosphere and atmosphere in various ways. These include “magnetic storms”, aurorae caused by energetic particles, and the expansion of the outer atmosphere by enhanced solar UV radiation, which led to the (unforeseen!) re-entry of the orbiting laboratory “Skylab” in 1979. Parti-

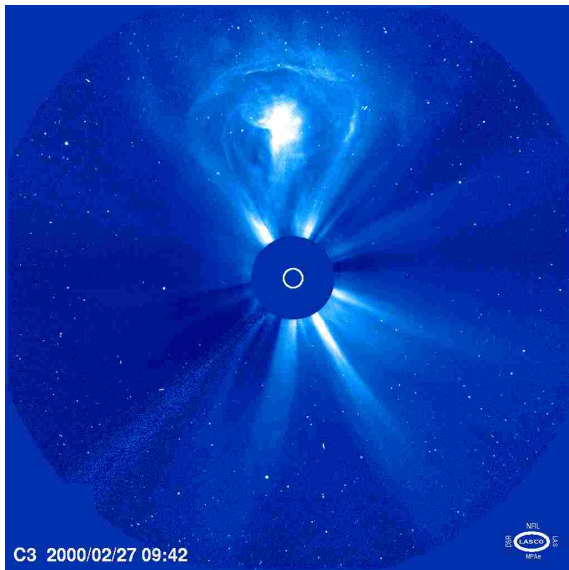


Fig. 5: Coronal mass ejection, driven by the release of magnetic energy in the corona. Such eruptions can affect the “space weather” in the vicinity of the Earth. The image has been taken with the (partly MPAE-built) coronagraph LASCO onboard SOHO. An occulting disk covers the solar disk and its immediate environment.

cle showers after large eruptions (flares and coronal mass ejections) on the Sun can disturb radio communication, disrupt electrical power networks, destroy electronic components of satellites, and may create hazards for astronauts. The more our civilisation depends on space-based systems for telecommunication, navigation, Earth observation, and data transfer, the larger becomes the economical importance of such “space weather” caused by the magnetic activity of the Sun.

While the solar magnetic field sends energetic particles into interplanetary space, at the same time it partly shields the Earth from another type of corpuscular radiation. High-energy cosmic rays,

mainly protons originating from outside the solar system, are scattered by the solar magnetic field and its fluctuations in the heliosphere, so that the cosmic ray flux incident to the Earth atmosphere becomes significantly weaker during activity maximum (stronger magnetic field) than during times of low solar activity (weaker magnetic field). Depending on their energy, the cosmic ray particles can penetrate to more or less deep into the terrestrial atmosphere, where they interact with the nuclei of oxygen and nitrogen atoms. This leads to the production of free neutrons, which are regularly detected by neutron monitors on the surface since the middle of the 20th century, and also of the so-called cosmogenic isotopes  $^{14}\text{C}$  and  $^{10}\text{Be}$ , whose abundance can be used to determine the particle flux of cosmic rays at the time of their production in the atmosphere. By measuring the  $^{14}\text{C}$  abundance in wood, whose age can be determined through tree rings, or by detecting  $^{10}\text{Be}$  in yearly layered ice cores taken from Greenland’s ice shield, one can reconstruct the cosmic ray intensity back into the past, far beyond the beginning of the direct measurements. Because of the anticorrelation between solar activity and cosmic rays, the production rate of the cosmogenic isotopes becomes a measure for the magnetic field and the magnetic activity of the Sun in the past.

Inspection of the corresponding time sequences for  $^{10}\text{Be}$  reveals besides the 11-year sunspot cycle also other, non-periodic trends (see Fig. 6). These data show that the cosmic ray intensity has clearly decreased during the last 100 years. Since the cosmic rays originate from a large number of independent sources in the galaxy, this indicates that the magnetic field of the Sun has secularly increased during the same interval of time. This was impressively confirmed by results found by Mike Lockwood and his co-workers. Using the aa-index, a measure for the geomagnetic disturbances, for which a record exists back to 1868, they were able to show that the strength of the interplanetary magnetic field (and, therefore also the amount of the underlying “open” magnetic flux of the Sun) has indeed doubled during the last century.

While there exist various theoretical approaches to describe the cyclic part of solar magnetic variability in terms of a self-excited hydromagnetic dynamo in the solar interior, until recently there existed no explanation for the long-term trend found by Lockwood. Recently, a first model has been developed at MPAE in collaboration with a colleague from the ETH Zürich [Solanki, Schüssler and Fligge, *Nature* 408, 445 (2000)]. The key

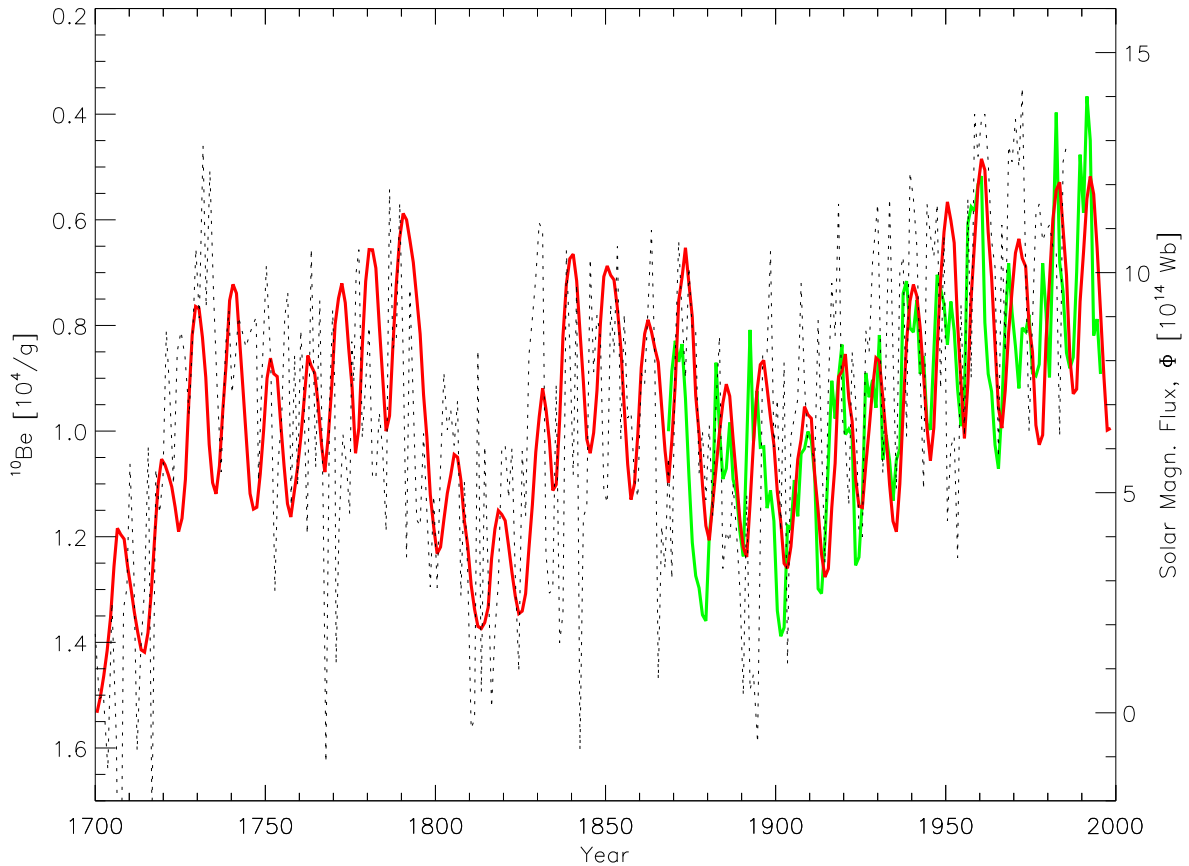


Fig. 6: Top: reconstructed time evolution of the open solar magnetic flux (red) from 1700 up to the present, compared with the interplanetary magnetic field (green, after Lockwood) and the  $^{10}\text{Be}$  concentration (dashed, left inverted scale).

point in the model is the hypothesis that the open magnetic flux from large unipolar regions, which is the source of the interplanetary magnetic field, has a rather long decay time, so that it resides at the solar surface for a time of a few years. New magnetic flux emerges mainly around activity maximum and there is an empirical relationship between the observed sunspot number and the rate of flux emergence. While most of the flux decays within days or weeks, a small fraction of typically a few percent becomes organised in large-scale patterns and can remain on the solar surface for a much longer time. As a consequence, flux from the previous cycle still is present when a new cycle begins, so that a non-cyclic background flux is built up. The amount of the background flux depends on the flux emergence rate (i.e., the strength of a given cycle) as well as on the cycle length: if a cycle is shorter, more of the long-lived component of the flux remains to which the flux of the new cycle adds.

On the basis of the historical data series of sunspot numbers, which covers the time from 1700 until

the present, this simple model leads to a surprisingly precise reconstruction of the temporal evolution of the solar open magnetic flux and thus of the interplanetary magnetic field. Fig. 6 shows the reconstructed magnetic field (red curve) together with the interplanetary magnetic field as determined from the geomagnetic aa index (green curve). Both curves refer to the scale to the left. In addition, the dotted line shows the  $^{10}\text{Be}$  concentration in an ice core from Greenland (inverted scale to the right). The very good agreement shows that  $^{10}\text{Be}$  can indeed be used as a quantitative measure for the long-term variation of solar activity in the past.

In addition to the large bipolar magnetic regions containing sunspots, there is a much larger rate of flux emergence in small bipolar magnetic regions (so-called ephemeral regions), which do not form sunspots. The activity cycles of the ephemeral regions are longer than the corresponding sunspot cycles and overlap for about 4 years, so that they stay synchronised with the sunspot cycle. Extending the model for the open solar flux to include

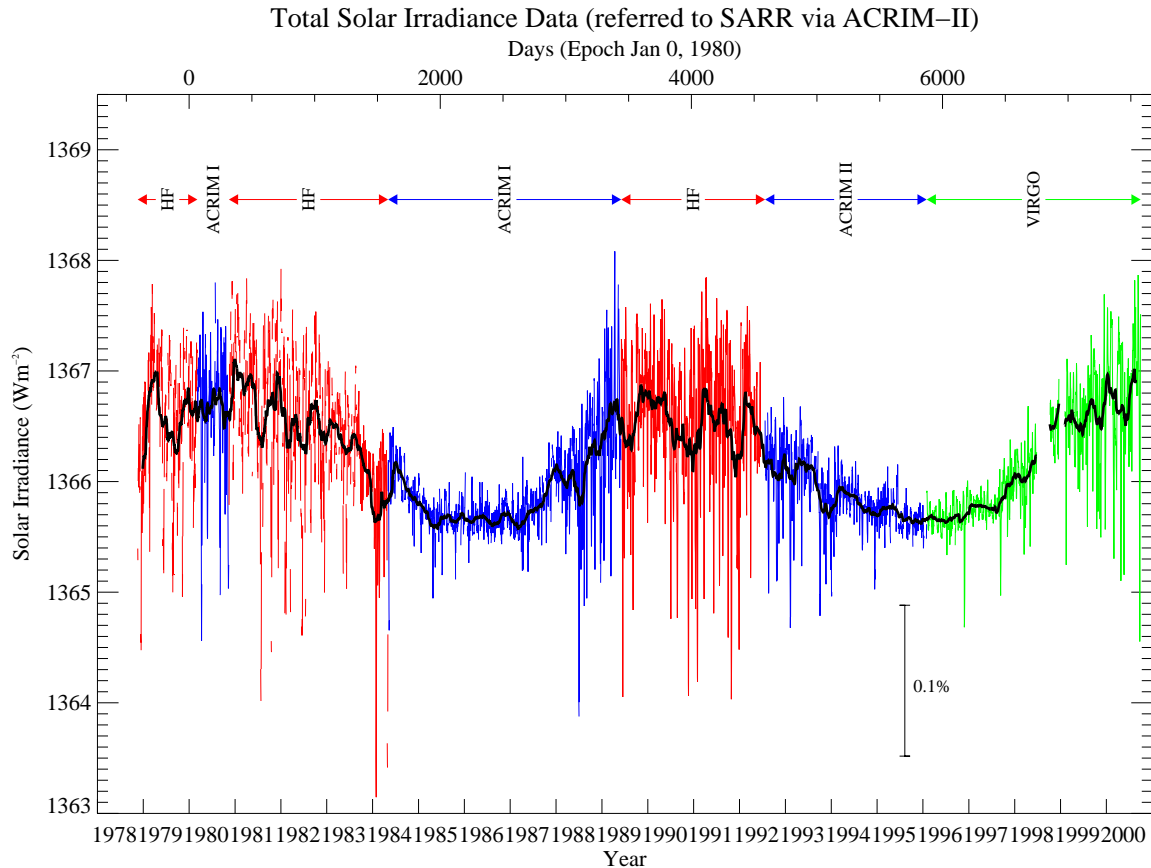


Fig. 7: Total solar irradiance since 1979. The irradiance varies in phase with the solar cycle by an amount of about  $1.4 \text{ Wm}^{-2}$  (corresponding to roughly 0.1%). The colours indicate data sets taken with different instruments.

the effect of flux emergence in ephemeral regions, it was found that the overlap of the ephemeral region cycles strengthens the build-up of the open background flux. Again the effect depends on the cycle length since the overlap of the ephemeral region cycles is stronger for short cycles. Assuming that the relationship between sunspot activity and ephemeral regions has not changed, it is thus possible to reconstruct both the open (heliospheric) magnetic flux and the total magnetic flux on the solar surface. The results indicate that not only the open flux has secularly doubled during the last hundred years but also its total magnetic surface flux. This may have important consequences for the long-term variation of solar irradiance as a possible driver for terrestrial climate changes (see below).

The modulation of the cosmic ray flux penetrating the Earth's atmosphere due to the variable magnetic field of the Sun is one of the mechanisms by which the Sun could possibly influence the terrestrial climate. Svensmark und Friis-Christensen

have suggested that the variation of the cosmic ray flux leads to an associated modulation of the global cloud cover over the solar cycle, because the cosmic rays may affect the ionisation of the air and thus influence the complicated processes leading to the production of condensation nuclei. In fact, Marsch and Svensmark found during the period since 1983, for which global cloud data are available, a good correlation between the coverage with low clouds and solar activity. Since low clouds enhance the albedo of the Earth and thus have a cooling effect, this would support a positive correlation between solar activity and temperature. This means that, at least in principle, part of the global warming trend during the 20th century could have been caused by the secularly rising solar activity and the related doubling of the heliospheric magnetic field. However, the complex mechanisms for cloud formation are not sufficiently understood to determine a reliable quantitative relationship between the cloud coverage on the one hand and heliospheric magnetic field

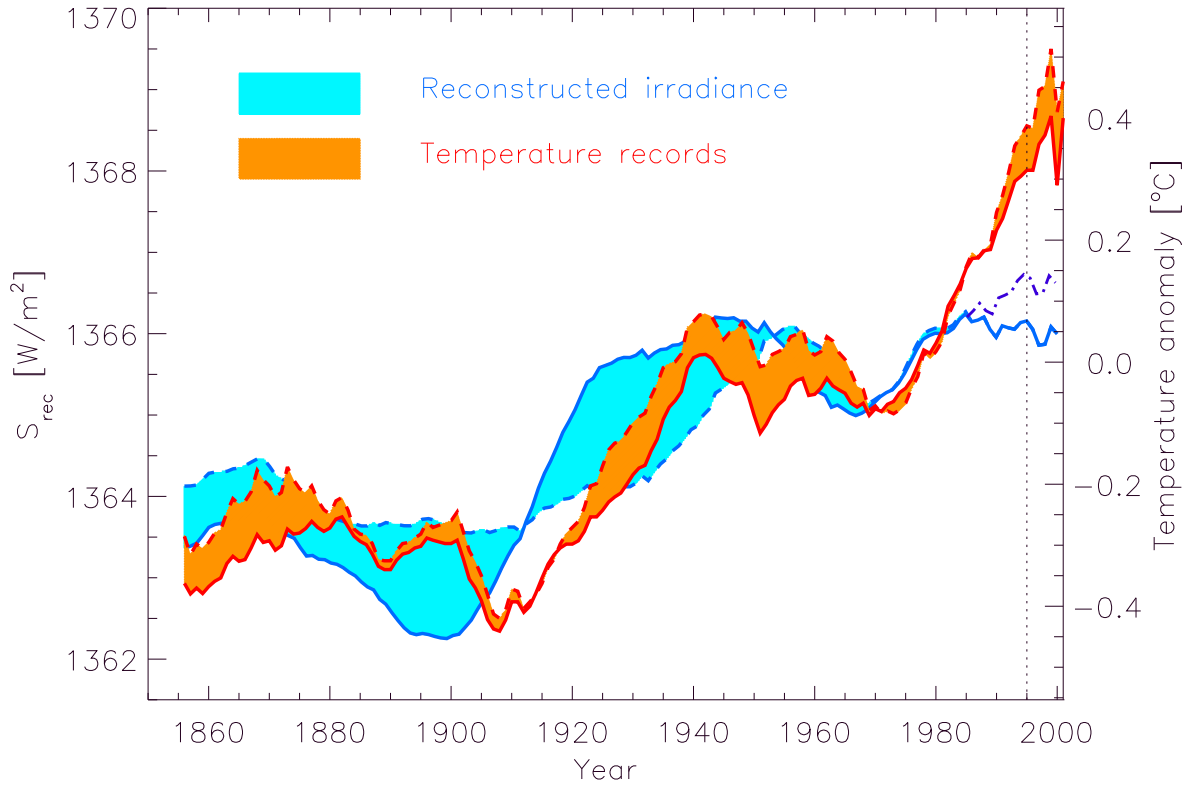


Fig. 8: Temporal evolution of the reconstructed long-term trend of solar irradiance in comparison with the (smoothed) terrestrial temperature record. The width of the bands roughly indicates the uncertainty of the data and reconstructions. There is rather good agreement between the two sets of curves for the time before 1980, indicating a possible solar influence on the climate. Thereafter, however, the solar irradiance has remained constant on average while the global temperature continues to grow.

and cosmic rays on the other. Circumstantial evidence for such a link, however, is provided by the observation that periods of low solar activity often coincide with cool periods on Earth. For instance, the Maunder minimum in the 17th century corresponds to the culmination of the “little ice age”, during which Europe suffered from low average temperatures and, in particular, from very cold winters.

A more direct connection between the Sun and the terrestrial atmosphere and climate is its radiative output. This concerns both the total energy flux density arriving above the terrestrial atmosphere (traditionally called the “solar constant”, when it was believed not to vary in time, now better called total irradiance) as well as the spectral irradiance measured in specific wavelength bands. For instance, the short-wavelength solar UV irradiance varies by a factor 2 during the solar activity cycle, which leads to a periodic expansion of the outer layers of the terrestrial atmosphere. By way of photochemical processes involving ozone and other molecules, the variable UV radiation affects

the temperature structure of the stratosphere, so that an influence on global climate cannot be excluded.

Small modulations of the total solar irradiance can affect the climate if they persist for a sufficiently long time. Such variations are also caused by the solar magnetic field, which is not restricted to the dark sunspots but also resides in bright regions called faculae. Reliable measurements of solar irradiance from space exist only since 1978, i.e., now over more than two activity cycles. This data set is shown in Fig. 7. On the one hand, sharp depressions indicate sunspots wandering over the visible hemisphere of the Sun owing to its rotation. Apart from this, however, the measured solar irradiance varies in phase with the activity cycle, so that the Sun is brightest during activity maximum when the number of dark sunspots is largest. This means that the area of bright faculae increases even stronger toward activity maximum and more than compensates the effect of the dark sunspots. Models of solar irradiance on the basis of the observed distribution of sunspots and facu-

lae have been developed at MPAE in cooperation with colleagues from the ETH Zürich; they reproduce the measured irradiance variations remarkably well. It is crucial for such models, that all of the magnetic flux on the solar surface is taken into account.

In order to estimate the effect of solar irradiance variations on the long-term terrestrial climate change, the irradiance has to be reconstructed into the past, for which no direct measurements exist. This requires the construction of models that provide a connection between available data sets and irradiance. In particular, a reconstruction of the total solar magnetic flux is needed. The only existing data set reaching back as far as 1700 is the record of sunspots, which carry only a small fraction of the total flux. Existing approaches to solve this problem assume a fixed (indirect) relationship between the total magnetic flux and the sunspot number. This is supported by observations of solar-like stars, which indicate that the vanishing of sunspots (like during the Maunder minimum) entails the disappearance of most of the total flux as well. The detailed temporal evolution of the total magnetic flux, however, is probably not well covered by this approach. Nev-

ertheless, as shown in Fig. 8, such reconstructions indicate a good correlation between solar irradiance and the terrestrial temperature record, at least up to about 1980. Since then, the growth of the global temperature has continued while the solar irradiance (apart from its cyclical variation) has remained constant.

Consequently, in spite of the tantalising indications of a solar effect on terrestrial climate variability, it is clear that other factors dominate the rapid warming of the global climate since 1980, presumably the effect of the anthropogenic greenhouse gases. A reliable quantitative evaluation of the direct and indirect influences of the variable Sun on the Earth's climate does not yet exist. The reason for this unsatisfactory state of affairs is the large complexity of the solar, interplanetary, and terrestrial processes, but also the considerable uncertainty in the reconstruction of the relevant solar parameters, the magnetic flux and the (spectral and total) irradiance. To make progress here, a better understanding of the physical processes connected with the solar magnetic field is required.

(S.K. Solanki, N. Krivova, M. Schüssler, R. Schwenn, K. Wilhelm)

## Wissenschaftliche Einzelberichte/ Individual scientific reports

(only in English)

### Solar interior

#### Intensification of magnetic field by conversion of potential energy

Simulations of rising magnetic flux tubes in the solar convection zone indicate, the observed properties of sunspot groups require the existence of a toroidal flux system with a strength of about 10 T ( $10^5$  G) at the base of the convection zone. Both, the convective motions and the differential rotation of the sun are not capable of producing such a strong field, unless there is a very efficient mechanism to restore the differential rotation in the latter case. We have studied an alternative amplification process that is based upon the ‘explosion’ of magnetic flux tubes, a sudden loss of pressure equilibrium at the summit of a flux loop rising through the superadiabatically stratified convection zone (Fig. 9). With the help of a

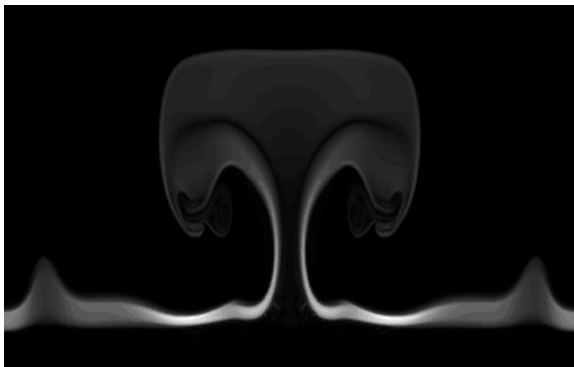


Fig. 9: Magnetic field strength during the explosion of a magnetic sheet. Whereas the field strength near the summit of the loop drops drastically, the field is amplified in the lower part by a buoyant outflow out of the exploded loop.

2D MHD simulation addressing the main features of this process we showed that the explosion of magnetic flux tubes provides a very efficient intensification mechanism: the flow of high-entropy material out of the exploded loop leads to a significant intensification of the magnetic field in the underlying flux sheet at the bottom of the convection zone. In contrast to the amplification by differential rotation, this process converts potential energy of the superadiabatic stratification of the convection zone into magnetic energy and is not dynamically limited by the back-reaction on

the flow field via the Lorentz force. The magnetic field strength that can be reached by this process is determined by the superadiabaticity of the convection zone. Given the values of a typical convection zone model, an amplification up to 10 T ( $10^5$  G) within six months is possible.

(M. Rempel, M. Schüssler)

#### Storage of magnetic flux at the bottom of the solar convection zone

In order to avoid rapid flux loss by magnetic buoyancy, the storage of toroidal magnetic field is crucial for the operation of the solar dynamo. Since the structure of the magnetic field at the base of the solar convection zone is unclear (an ensemble of isolated magnetic flux tubes or a more homogeneous magnetic layer) we have extended our previous studies of flux tube equilibria and analysed the more general equilibrium properties of a magnetic layer in spherical geometry. As sketched in Fig. 10, the equilibrium of a magnetic layer is determined by four forces: gravity (buoy-

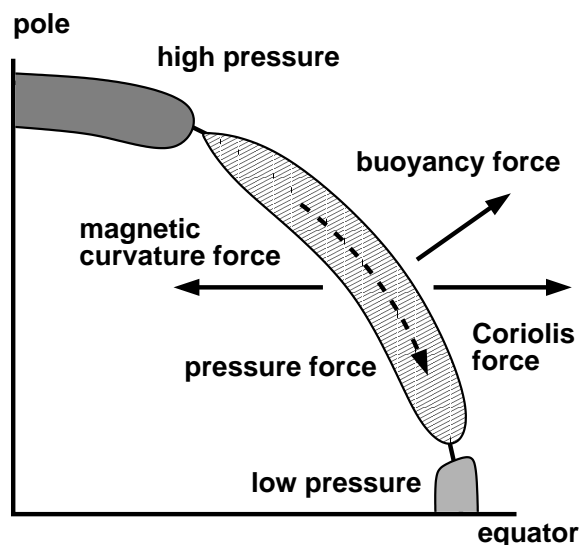


Fig. 10: Schematic illustration of the mechanical equilibrium of an magnetic layer.

ancy), magnetic curvature force, Coriolis force due to a field-aligned toroidal flow in a rotating system, and pressure force. This combination of four forces leads in general to no unique solution, so that the dynamical evolution towards an equilibrium determines the final equilibrium properties.

Numerical simulations describing the evolution towards an equilibrium show that the superadiabaticity of the stratification mainly determines the force balance. Whereas in a strongly subadiabatic

stratification (radiation zone) the magnetic buoyancy and curvature force is balanced by a latitudinal pressure force, in a weakly subadiabatic stratification (overshoot region) the Coriolis force balances the magnetic forces. The latter case is similar to the equilibria of single magnetic flux tubes stored in the overshoot region.

(M. Rempel, M. Schüssler)

### Heating of magnetic flux tubes

Storage of magnetic flux tubes at the base of the solar convection zone requires neutral buoyancy and, therefore, a temperature deficit of the internal plasma with respect to the external medium. The mechanical equilibrium is disturbed by radiative heating arising from the non-vanishing divergence of the radiative heat flow in the overshoot region and deep solar convection zone.

We have considered the heat flow and temperature structure within and in the surroundings of a magnetic flux tube. The stationary thermal equilibrium state is determined through the analytical solution of a two-dimensional heat diffusion problem for an infinitely long cylinder with different thermal conductivities inside and outside the cylinder, both spatially variable. In the exterior of the cylinder, convective heat transport is approximated in terms of a linear diffusive process, while in its interior convection is assumed to be suppressed and only the much smaller radiative conductivity remains. The results show that, under the conditions prevailing near the bottom of the solar convection zone and in the limit of small cylinder radius, the temperature disturbance (thermal shadow) in the exterior of the insulating cylinder is almost negligible due to the large efficiency of convective energy transport. The spatial dependence of the conductivities and the curvature of the external temperature profile lead to a *temperature excess* in the interior with respect to the undisturbed temperature profile far away from the cylinder. We show that, within the framework of the thin magnetic flux tube approximation, this temperature excess is due to a heating term equal to the negative divergence of the undisturbed radiative heat flow.

Radiative heating leads to buoyancy of the flux tubes and causes an upward motion leading to a flux loss within a few months. Only for a sufficiently subadiabatic stratification, i.e.  $\delta = \nabla - \nabla_{\text{ad}} < 10^{-4}$ , storage times of a few years are possible. A significant influence of an external equatorward flow (meridional circulation) exists

only for flux tubes with small magnetic flux (less than 1% of the flux of a large sunspot). Radiative heating affects also the equilibrium of magnetic flux stored in form of a magnetic layer. In contrast to single flux tubes the quenching of convective motions within the magnetic layer can stabilise the stratification and thus improve the conditions for flux storage.

(M. Rempel, M. Schüssler, in cooperation with F. Moreno Insertis, University of La Laguna, Tenerife, Spain)

### Secular evolution of the Sun's magnetic field

A surprising recent discovery was that in addition to the well-known cyclic behaviour, with a period of roughly 11 years, the Sun's open magnetic flux exhibits a secular variation. Lockwood et al. (1999, Nature 399, 437) showed from historical geomagnetic data that the Sun's open flux has doubled in the course of a century.

We have constructed a simple model of the evolution of the Sun's magnetic field since the Maunder minimum in the 17th century. The model for the first time predicts secular changes of the Sun's open flux. It reproduces the results of Lockwood. We later extended this model to describe the secular evolution of the Sun's total magnetic flux, for which no previous model existed either. It is found that the Sun's magnetic field had practically disappeared by the end of the Maunder minimum. Recently, the modelled open magnetic flux has been employed to reconstruct the cosmic ray flux reaching Earth. This is found to be consistent with the concentration of  $^{10}\text{Be}$  in Greenland ice cores.

(M. Schüssler, S.K. Solanki, in collaboration with M. Fligge, ETH Zürich, Switzerland, and I. Usoskin, University of Oulu, Finland)

### Helio- and asteroseismology, with applications to extrasolar planets

Helioseismology is the main means of studying the interior of the Sun. The accuracy of the obtained results depends sensitively on the parameters of the individual modes (frequencies, shifts, splittings, widths). These are in turn strongly affected by the stochastic nature of the excitation of these modes (excitation noise, which follows  $\chi^2$  statistics). Fitting procedures (e.g. maximum likelihood techniques) have been developed to obtain the relevant parameters in spite of the noisy

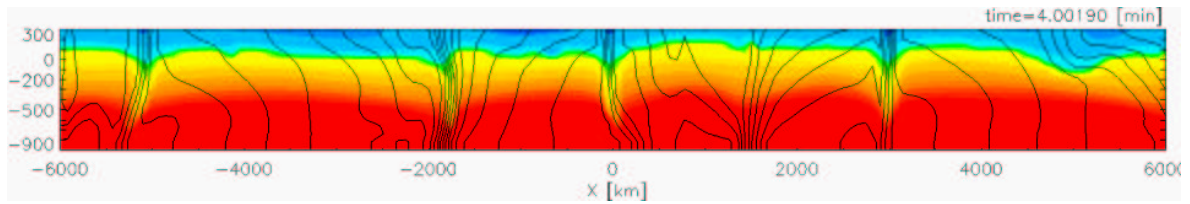


Fig. 11: Simulated formation of magnetic flux concentrations in convective downflow regions. An initially homogeneous vertical magnetic field has been preferentially carried to the downdrafts by the horizontal flow. Cooling by radiation enhances the downflow along the field lines. The resulting partial evacuation and lateral pressure balance lead to field strengths in the kG range. Snapshot from a time sequence of near-surface magneto-convection: black lines are field lines; colour-coding indicates temperature between 14,000 K (red) and 4,000 K (blue); the visible solar surface is located near the transition between yellow and blue.

data. To test the reliability of these values we have applied a noise reduction procedure based on wavelet packets to  $p$ -mode power spectra. After the smoothing, least squares fits to the data could be made, since the smoothing changes the noise statistics, making it nearly Gaussian. A comparison between the parameters obtained through these two independent techniques confirms that there are no significant biases.

We are developing asteroseismology as a tool for determining  $i$ , the angle between the line-of-sight and the stellar rotation axis. This is not just of interest for a number of applications in stellar physics, but also for obtaining more reliable masses of extrasolar planets. Note that the generally employed radial velocity technique for detecting extrasolar planets only gives  $m_p \sin i$ . With a knowledge of  $i$  obtained from asteroseismology (and the assumption that the orbital plane corresponds to the stellar equatorial plane) the planet's mass,  $m_p$ , can be determined unambiguously.

(S.K. Solanki, in collaboration with M. Fligge, ETH Zürich, Switzerland, L. Gizon, Stanford University, USA, and C. Regulo, IAC, Tenerife, Spain)

## Photosphere and chromosphere

### Development of MHD codes with radiative transfer

Codes for the numerical simulation of time-dependent magnetohydrodynamic (MHD) processes in 2 and 3 spatial dimensions have been developed. The codes are based upon unstructured (triangular in 2D, tetrahedral in 3D) adaptive grids with domain decomposition and dynamical load balancing. The latter is important in parallel computing environments in order to main-

tain approximately equal loads for each processor. The codes employ finite volume schemes with approximate MHD Riemann solvers for an adequate description of shocks and low numerical diffusivity.

The codes are used for simulations of magneto-convection in the near-surface and photospheric layers of the Sun and for simulations of the dynamics of magnetic structures in the deep convection zone. The first kind of applications requires the inclusion of partial ionisation and a proper treatment of the radiative energy transport. A new hybrid scheme for the radiative transfer has been developed, which combines the advantages of short-characteristic and discontinuous Galerkin methods. Under the conditions prevailing in the solar (sub)photosphere (e.g., very strong temperature dependence of the opacity), the new scheme provides high accuracy at lower computational cost in comparison to previously used methods.

The 2D version of the code with partial ionisation and radiative transport has been applied to study the interaction of convective flows and magnetic field in the solar (sub-)photosphere. Fig. 11 gives a snapshot from a simulated time evolution, showing the formation of intense magnetic flux concentrations. The 3D version has been used to simulate the dynamics of magnetic flux tubes in the deep layers of the solar convection zone.

(P. Vollmöller, M. Schüssler, in cooperation with A. Dedner, M. Wesenberg, C. Rohde and D. Kröner, Institute of Applied Mathematics (IAM), University of Freiburg, Germany)

### Non-grey radiative transfer in photospheric MHD simulations

MHD simulations of the solar photosphere require a detailed treatment of frequency dependent ra-

diative transfer in order to obtain sufficiently accurate energy exchange rates in the optically thin upper layers. For later use in simulations, we implemented and tested a method for radiative transfer that uses a statistical description of the strong frequency dependence of opacities (spectral lines). In the *opacity binning* approach, continuum opacities and lines of comparable strength form separate (usually non-contiguous) frequency bands, which are represented by a mean opacities, reducing the computational effort by a factor of  $10^6$  in comparison with the exact treatment. In order to assess the accuracy of the opacity-binning approximation, we conducted a series of comparative studies in 1D- and more realistic non plane-parallel 2D-atmospheres that included different sorting and averaging schemes, using the exact frequency dependent solutions as a reference. We found that a moderate number of 4 – 6 frequency bands is sufficient to produce radiative heating rates that are far superior to the results of grey (frequency-averaged) radiative transfer. The advantage over the grey case becomes most apparent in 2D situations with strong directional heating and cooling where the inaccurate optical depth scales of the grey approach result in a qualitatively wrong spatial dependence of the radiative heating rate. The timescales on which the errors due to the opacity binning approximation manifest themselves in the photospheric temperature structure were found to be large compared with typical dynamical timescales of the photosphere, underlining the good performance and applicability of this method.

(A. Vögler, M. Schüssler, in collaboration with J. Bruls, Kiepenheuer-Institut, Freiburg, Germany)

### Local dynamo action in the solar photosphere

Recent magnetic field measurements on the sun suggest that the quiet photosphere is permeated by randomly oriented magnetic structures with sizes at the limit of current resolution and field strength of the order of several 100 G. One possible explanation for the generation of these granular fields is given by fast dynamo theory, which predicts that any highly conducting turbulent fluid acts as a dynamo, the relevant property being the chaotic nature of the three-dimensional flow. Earlier numerical studies of magnetoconvection in the quasi-incompressible Boussinesq approximation have indicated that a substantial part of the granular field might be the result of such local dynamo action. In the context of photospheric

convection, however, compressibility plays an important role since it breaks the symmetry between up- and downflowing motions, thereby affecting the flow topology on which local dynamo action

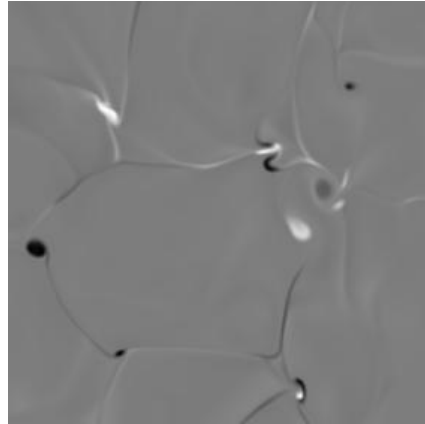


Fig. 12: Magnetic field at the top of the computational domain (black/white: strong field, grey: weak field).

crucially depends (Fig. 12). We have conducted 3D simulations of fully compressible, thermally-driven magnetoconvection in a stratified layer. It turns out that weak magnetic seed becomes amplified with a typical growth time of the order of the convective turnover timescale. The magnetic energy reaches a saturation level of roughly 10% of the kinetic energy, thus asserting the relevance of fast dynamo action in the case of compressible convection. The magnetic field at the top of the computational domain is concentrated into highly time-dependent thin structures located at the cellular boundaries and corners, a structure that closely resembles observed field configurations in the quiet photosphere.

(A. Vögler, M. Schüssler, in collaboration with T. Emonet and F. Cattaneo, University of Chicago, USA)

### Total magnetic flux of the Sun

Variations in the radiative output of the Sun are directly allied to changes in the amount and distribution of solar surface magnetic field. Variations at time-scales of a solar cycle and secular variations are produced by changes of the quiet-Sun magnetic flux. The relative amounts of the magnetic flux in active regions and in the quiet Sun as well as their cyclic evolution have been previously studied on the basis of the NSO/Kitt Peak (KP) synoptic maps. Since a single pixel of such a map is much bigger than individual small-scale

magnetic elements and opposite polarities may be present within the same pixel, some magnetic flux went uncounted.

We use MDI full-disc and high-resolution magnetograms to estimate the total magnetic flux of the Sun. Our results suggest that in the quiet Sun the true flux is a factor of 1.4–2.2 times higher than deduced from KP synoptic charts, while for active regions this factor is close to 1.

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

### The 1.3-year and 158-day periodicities in sunspot data

Helioseismic data have revealed a pronounced 1.3-year periodicity in the solar rotation rate near the bottom of the solar convection zone. In order to test whether these rotation rate variations have a significant impact on the solar dynamo, we search for such a periodicity in tracers of relatively freshly emerged flux at the solar surface, namely sunspots. Sunspot areas and sunspot numbers time series are studied with the help of the wavelet transform.

Significant power at this period (1.28 years) is indeed found, but is observed to vary strongly with time. The power at the 158-day Rieger period of solar flares is seen to vary approximately in phase with the 1.28-year period. Based on this we propose that the Rieger period is the third harmonic ( $3 \times 156 \text{ days} = 1.28 \text{ years}$ ) of the 1.3-year period and that the enhanced flaring with this period is finally driven by the 1.3 year periodicity of the solar rotation rate.

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

### Molecular Zeeman effect

The Zeeman effect is the primary technique employed to measure solar and stellar magnetic fields. Consequently, the physics of the atomic Zeeman effect has been worked out in great detail. Less well studied is the molecular Zeeman effect, for which only analytical solutions for special cases (e.g. doublet terms of diatomic molecules for certain Hund's cases) are known.

We have developed a code capable of calculating the Zeeman splittings of arbitrary terms and the Zeeman patterns of arbitrary transitions of diatomic molecules for the astrophysically relevant Hund's cases a and b as well as the mixed a-b case. First applications to Stokes spectra of TiO

and OH molecules observed in sunspots exhibit an excellent agreement. In particular, the previously unexplained presence of Stokes V profiles of opposite sign in the infrared spectrum of OH could be reproduced.

(S.K. Solanki, in collaboration with S. Berdyugina, University of Oulu, Finland, and C. Frutiger, ETH Zürich, Switzerland)

### Infrared polarimetry with TIP

Infrared lines are an ideal tool for studying the magnetic field of the solar photosphere: the large Zeeman splitting increases the sensitivity to small magnetic field strengths, and the near-infrared spectral region is relatively free of telluric blends. The analysis of the polarisation signals of spectral lines in this region reveals physical parameters of the solar atmosphere like magnetic field vector, temperature or velocity fields with a high accuracy.

Observations performed with the Tenerife Infrared Polarimeter (TIP) at the Vacuum Tower Telescope (VTT) on the Canary Islands are analysed using a sophisticated inversion technique. The results are three dimensional maps of the solar atmosphere showing signatures of unresolved fine-scale structures such as small magnetic flux tubes in the penumbrae of sunspots.

An interesting dataset of infrared lines formed in the solar photosphere and upper chromosphere clearly shows emerging flux in an active region of the Sun. New magnetic flux tubes penetrate the solar photosphere and rise to chromospheric heights with velocities of a few km/s. This up-flow region is surrounded by areas of moderately slow downflows with a few to less than 10 km/s, forming an arch system of filaments connecting the opposite polarity fields on either side of the neutral line. Following the field lines near a forming pore, downflow velocities well in excess of the sound speed are inferred.

(N. Krupp, A. Lagg, S.K. Mathew, S.K. Solanki, J. Woch, in collaboration with M. Collados, IAC, Tenerife, Spain)

### Structure of the solar chromosphere

There is an ongoing debate on the structure of the solar, and by proxy also stellar, chromosphere(s). The two major alternatives are (1) static models having chromospheric plateaus and (2) dynamic models with strong, hot shocks separated by cool

gas. Both types of models have been shown to reproduce observations in the visible part of the solar spectrum, in particular the chromospheric Ca II H and K lines.

We use mm-wave radiation to test both types of models. Mm-waves have different diagnostic capabilities compared with atomic lines in the visible, due to the former's much weaker temperature sensitivity. Hence shocks are not expected to play such a strong role in the production of mm-wave radiation. Preliminary results suggest that in spite of this both models reproduce the data. The main reason is that enhancement of the electron pressure in the shocks drives the mm-wave intensity.

(S.K. Solanki, in collaboration with M. Loukitcheva, University of St. Petersburg, Russia, and M. Carlsson, ITA, University of Oslo, Norway)

### Continuum contrast and thermal structure of faculae

The continuum contrast of faculae is a diagnostic not only for the structure of magnetic flux tubes, but is also an important input for reconstructions of solar irradiance. We have used the Michelson Doppler Interferometer (MDI) on SOHO to determine the continuum contrast as a function of position on the solar disk and magnetogram signal. Compared to previous determinations, which used ground-based data obtained under conditions of variable seeing, the major advantage of this investigation is the constant spatial resolution, which is the same for magnetograms and continuum images. It is found that the centre-to-limb variation of the contrast depends strongly on the amount of magnetic flux in the pixel. This is also true for the contrast per magnetic flux, with magnetic elements having a lower flux being brighter. This is expected to have consequences for the magnitude of the secular trend in solar irradiance. From fits to the data we deduce simple relationships describing the behaviour of the contrast.

These are currently being employed to construct simple models of facular and network atmospheres. In a first step we have shown that by appropriately combining the contrasts from the two models it is possible to reproduce the complete set of contrast measurements.

(S.K. Solanki, in collaboration with M. Fligge, T. Wenzler, ETH Zürich, Switzerland, and A. Ortiz, University of Barcelona, Spain)

### 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, Switzerland)

### Solar variability and global warming

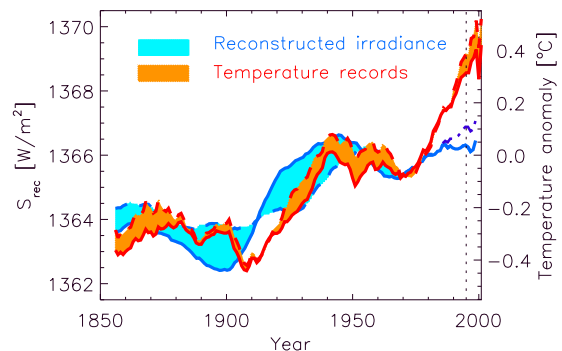


Fig. 13: Total solar irradiance and terrestrial temperature vs. time. The blue curves enclosing the light-blue hatched area prior to 1979 represent irradiance reconstructions (one being cycle-length based, the other cycle-amplitude based). From 1979 onwards they represent total irradiance measurements (solid: composite of Fröhlich and Lean 1998, GRL 25, 4377; dot-dashed: composite following Willson 1997, Science 277, 1963). The red curves enclosing the orange hatched region represent northern hemisphere and global temperatures. All curves have been smoothed by an 11-year running mean. After the epoch marked by the vertical dotted line the averaging period has been successively reduced.

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. Given the complexity of the climate system, however, such modelling is perforce based on simplifying assumptions, which leaves it open to criticism.

We take a complementary 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 significant (Fig. 13).

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

## Solar transition region and corona

### Solar Ultraviolet Measurements of Emitted Radiation – SUMER

SUMER is a high-resolution vacuum-ultraviolet telescope and spectroscope on the Solar and Heliospheric Observatory (SOHO) of ESA and NASA. Details of the instrument, the investigation and the mission in general have been communicated in annual reports since 1995 and are not repeated here.

SUMER has obtained high-resolution spectra of the Sun from solar minimum around 1996 to the peak of the solar cycle around 2000. Since the lifetime of the instrument is limited by the accumulated photon load seen by the detectors, measures have been taken to extend the operating life for several more years to be able to participate in the Solar Cycle Mission (the NASA/ESA-approved extension of the SOHO mission to the next solar minimum around 2007). Since 2000, SUMER is operated in a campaign-type mode and observes preferably off-disk. During solar maximum, the corona is frequently shaken by chromospheric eruptions (flares), and spectacular results have been obtained (cf., Fig. 14).

In 2000, campaigns have taken place from March 10 to 15, from May 2 to 23, from June 13 to July 12, from September 13 to November 13, and from December 1 to 18. During 2001, campaign were run from February 26 to April 6, from April 14 to

30, from August 20 to 31, and from October 15 to November 29.

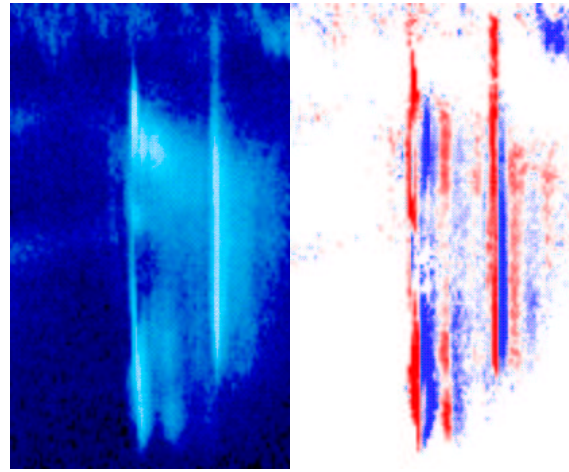


Fig. 14: Time series in the light of Fe XIX (1118 Å) recorded on September 29, 1999, 50 arcsec above the solar limb. Left panel displays brightness, right panel displays the Doppler-flow of the emitting source. The abscissa is scaled to 240 minutes and the ordinate shows half of the SUMER slit (110 000 km): rapid injections of energy repeatedly lead to flashes of extremely hot emission and strongly damped oscillations.

The data analysis continues with high productivity, which is the basis for the enormous scientific return visible in more than 500 published articles. Since May 2001, the entire set of SUMER data is accessible via internet and open to the solar community.

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

### Hot loop oscillations observed by SUMER

Oscillations in coronal loops may provide insight into the process of coronal heating. An investigation of observations made by SUMER spectrometer on SOHO led to the discovery of Doppler shift oscillations in hot flare lines (e.g. Kliem et al. 2002). We determine physical parameters of the Doppler oscillations, explore the relationship between Doppler oscillations and the loop properties using Yohkoh/SXT, SOHO/EIT, and TRACE EUV images, and discuss possible excitation mechanisms.

We find that only hot flare lines formed at higher than about  $4 \times 10^6$  K show the oscillations, with

lines formed below  $2 \times 10^6$  K recording no signature. The oscillations are always associated with a brightening of the flare lines. There is a large shift pulse of up to  $190 \text{ km s}^{-1}$  during the rising phase of the flux which is followed by two or three periods of strongly damped alternating red and blue shift oscillations with periods in the range 12–31 min. Slow mode standing waves match the observed period, although there is no sign that the waves are compressive. However, the initial large Doppler shift pulse suggests that the waves are impulsively generated. Unlike the oscillating loops seen in the TRACE images, these Doppler shift oscillations are sometimes seen without an associated flare.

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

### SUMER – The SUMER spectral atlas of solar disk features

A far-ultraviolet and extreme ultraviolet spectral atlas of the SUN between  $670 \text{ \AA}$  and  $1609 \text{ \AA}$  in first order of diffraction has been derived from SUMER observations. The atlas contains radiometrically calibrated spectra of the average quiet Sun, a coronal hole and a sunspot on disk. We also show the quiet-Sun network contrast (ratio of the spectral radiance in bright network and cell interior). With a few exceptions, all major lines ( $> 1100$ ) are given with their identifications and solar wavelengths. Lines that appear in second order are superimposed on the first order spectra. These lines are clearly marked in the atlas. The spectra include emissions from atoms and ions in the temperature range  $6 \times 10^3 \text{ K}$  to  $2 \times 10^6 \text{ K}$ , i.e., continua and emission lines emitted from the lower chromosphere to the corona.

The spatially resolved solar EUV/FUV spectra studied in this atlas provide a wealth of information on plasma parameters of structures in the solar atmosphere. This information has, therefore, a tremendous diagnostic value for the emitting source. Together with the high spatial resolution of the SUMER spectrograph, compared to other solar EUV spectrometers flown during the last decades, physical processes of small solar features can be investigated. The atlas also provides an excellent reference for astrophysical applications (cf., Fig. 15).

The spectra are also valuable input to irradiance models, which use detailed radiance spectra of solar features to compose the solar irradiance spectrum.

The SUMER spectrograph combines better spectral and spatial resolutions as well as coverage than any previous observations in the same wavelength range, and permits the extensive use of spectroscopic techniques in determining temperatures, pressures, densities and velocities in the upper solar atmosphere. In particular, the wavelength range below  $1100 \text{ \AA}$  as observed by SUMER represents a significant improvement over the spectra produced in the past. The atlas also presents a powerful tool for the planning of future observations, i.e., to determine adequate integration times, to identify possible blends, and to select proper data extraction windows in upcoming solar studies.

(W. Curdt, B.N. Dwivedi, U. Schühle, K. Wilhelm, in collaboration with P. Brekke, ITA, University of Oslo, Norway, U. Feldman, NRL, Washington, USA, and P. Lemaire, IAS, Paris, France)

### Hydrogen temperature gradient in the transition region of a solar coronal hole

The Lyman series of hydrogen was observed by SUMER on SOHO on the north polar limb of the Sun. The data analysis corroborates earlier findings on the Lyman lines but also yields phenomena which cannot be fully understood at the present time. Firstly, the line width of the Lyman lines increases with decreasing series or quantum number. Secondly, the hydrogen temperature gradient in the height range from  $12000 \text{ km}$  to  $18000 \text{ km}$  is unexpectedly small and does not reveal a steep jump as might be expected from modelling of the transition region.

We have used six emission lines of the H I Lyman series which were observed in a northern polar coronal hole with a long exposure time of more than ten hours. The H I Ly5, Ly6, Ly7, Ly9, Ly10 and Ly11 lines attain a Gaussian shape at different locations within a small height range, i.e., between about  $12''$  and  $23''$  ( $1'' \approx 715 \text{ km}$ ), a range which is determined by the fact that opacity effects terminate the analysis at lower heights and scattered light contributions at greater heights. The line width is explained as being caused by Doppler broadening transforming into an effective temperature of the hydrogen gas, in which wave turbulence and ion-kinetic or thermal components are usually included.

The observations were made to corroborate earlier findings and to establish new empirical values of the hydrogen (proton) temperature low in the solar atmosphere, to be used as reference points

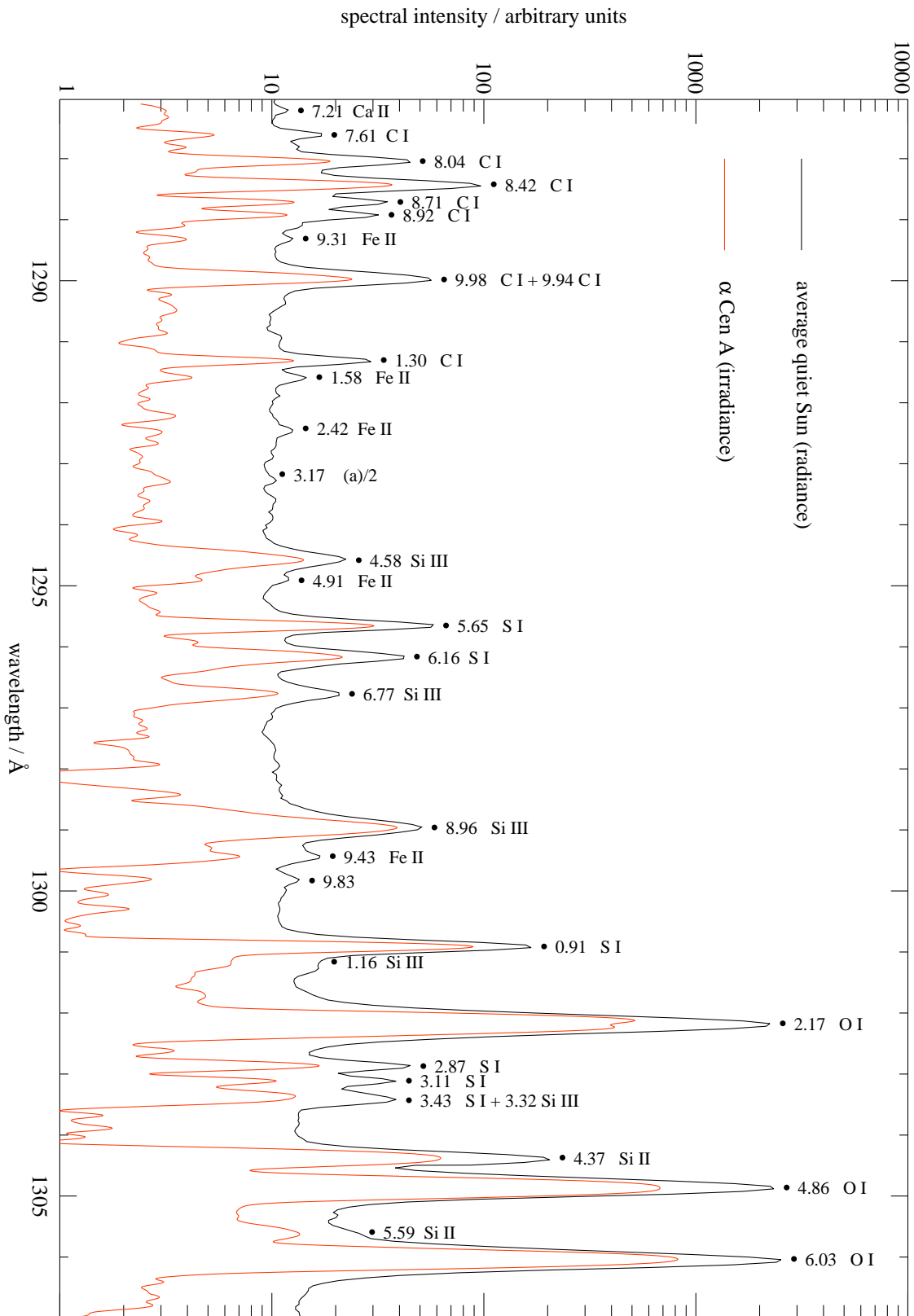


Fig. 15: Comparison of the FUV irradiance spectrum of  $\alpha$ -Cen A and of the quiet Sun radiance spectrum at disk centre in the range from 1287 Å to 1307 Å. The stellar spectrum (courtesy: HST-STIS consortium) has been degraded to the SUMER resolution by a convolution with a Gaussian of standard deviation  $\sigma = 60$  mÅ.

for solar wind models. The average height profiles are shown in Fig. 16. The dashed line refers

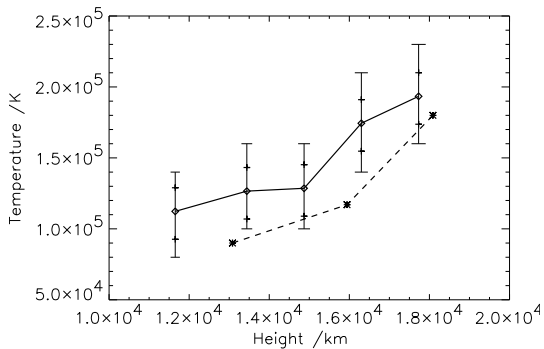


Fig. 16: Hydrogen temperature variation with height in the lower solar atmosphere. The diamonds and the asterisks represent results obtained from two different data sets. Both sets of points are derived from the measurements, assuming a wave turbulence amplitude of  $\xi = 30 \text{ km s}^{-1}$ .

to data obtained in a polar hole albeit in an earlier phase of the solar cycle closer to minimum. We see that the temperatures derived from the two data sets show a similar gradient, although slightly displaced. From  $1.2 \times 10^4 \text{ km}$  to  $1.8 \times 10^4 \text{ km}$ , the temperature increases from  $1 \times 10^5 \text{ K}$  to about  $2 \times 10^5 \text{ K}$ . This temperature profile is comparatively flat when compared with the conventional empirical and physical transition region models. If extrapolated into the open corona, however, this profile would yield the canonical  $1 \times 10^6 \text{ K}$  temperature slightly above the photosphere at about  $1.1 R_{\odot}$  (here  $R_{\odot}$  means the solar radius) and much higher values beyond. The extended gradient is too steep, though. It is neither consistent with the SOHO UVCS (Ultraviolet Coronagraph Spectrometer) measurements of the hydrogen Lyman  $\alpha$  line nor recent theoretical model results for a coronal funnel, which yield about  $2 \times 10^6 \text{ K}$  near  $2 R_{\odot}$ .

(E. Marsch, C.Y. Tu, K. Wilhelm)

### Structure and dynamics of magnetic loops in an active region on the Sun

The structure and dynamics of an active-region system of magnetic loops, observed by SUMER on SOHO on the 26th of July 1996 close to the central meridian on the solar disc, was investigated and described in detail. To this purpose the spectra were reduced and the intensities, widths and shifts of various extreme ultraviolet emission lines were analysed in all the spatially resolved elements of the observed area on the Sun. By a comparison

of the line characteristics with maps of the photospheric magnetic field, several loops have clearly been identified, some of which are visible simultaneously over a broad range of temperatures, while others appear only in a limited temperature domain.

The data analysis has shown that few loops exhibit the velocity fields typical of syphon-type flows, whereby the lines emitted in the compact loops seem to indicate higher Doppler velocities. Two compact loops shining in transition-region lines reveal asymmetric flow patterns and show large nonthermal broadenings at the footpoint where upflow occurs. Yet, strong nonthermal line widths are sometimes also observed in the downflows of a large loop. Besides such loops, other bright features in transition region lines were observed, whose morphology remains unclear but does not resemble arch-like structures. They have no coronal counterpart, exhibit red shifts (with respect to the median-centroid line position) indicating down flows and have strong non-thermal velocities.

(E. Marsch, in collaboration with D. Spadaro, Osservatorio Astrofisico, Catania, Italy)

### Short-term EUV variations in the quiet Sun

Short-term (minutes-hours) variability of the EUV radiation emitted by the quiet Sun has been studied employing the Coronal Diagnostics Spectrometer (CDS) and SUMER (both on SOHO). This is of interest, since such variability may carry information on heating events in the transition region and corona. An exhaustive study of blinkers, strong brightenings that are particularly prominent in transition region lines, has been carried out and their statistical properties have been determined. The small correlation between brightenings seen in chromospheric, transition region and coronal lines argues strongly against a direct connection between these different temperature regimes and supports models of the solar atmosphere in which gas of different temperatures is isolated within, e.g., separate magnetic loops.

A comparison between brightness variations seen in simultaneously and cospatially recorded CDS and SUMER time series reveals that the latter instrument detects a three times higher variability due to its higher spatial resolution. An extremely tight correlation between the variability seen in a given EUV spectral line and the average

wavelength shift of that line is also found. Models aimed at understanding this relationship are currently being developed.

(S.K. Solanki, in collaboration with A. Brkovic, H. Peter, Kiepenheuer Institut für Sonnenphysik, Freiburg, Germany, and I. Rüedi, PMOD-WRC, Davos, Switzerland)

### Unresolved fine structures. The morphology of the solar upper atmosphere during the sunspot minimum and the interface with the chromosphere

An important objective of the solar physics community is the unambiguous determination of the morphology of the fine structures of the solar upper atmosphere in quiet-Sun and coronal hole regions and the relationship of the cold chromosphere to the hot corona. The solar upper atmosphere is defined as the volume above the photosphere filled with plasmas with electron temperatures above  $\sim 20\,000$  K. Until the Skylab era, only little was known about the morphology of the solar upper atmosphere, while the quality of the spectroscopic observations was continually improving. A spherically symmetric atmosphere was assumed at that time, in which the temperature increased with height. With advances in the observational techniques, it became apparent that the morphology of the solar upper atmosphere was very complex even during the minimum of the magnetic cycle. In particular, spectroscopic measurements with high spectral and spatial resolution, which were made in the light of ultraviolet emission lines representing a variety of temperatures, led to the conclusion that most of the radiation from the solar transition region could not be explained by assuming a continuous chromosphere-corona interface, but rather by a region of unresolved fine structures.

Recently, SUMER succeeded in obtaining observations that can be used to study the spatial relationship between previously unresolved fine structures and the chromospheric emissions that underlie them. The main result is that looplike structures seen in transition region lines with length scales of  $10'' - 20''$  (see Fig. 17) straddle the chromospheric network and have no chromospheric counterpart near their apparent footpoints.

(I.E. Dammasch, K. Wilhelm, in collaboration with U. Feldman, NRL, Washington, USA)

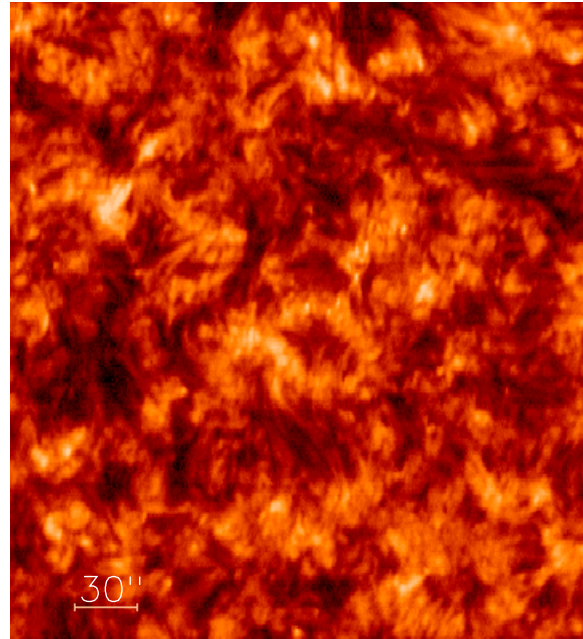


Fig. 17: A quiet-Sun region near disk centre in the light of the O VI 1032 resonance line obtained by SUMER on January 30, 1996, with a step width of  $0.75''$  and an exposure time of 3 s. The area displayed has dimensions of  $\sim 190\,000$  km  $\times$   $210\,000$  km ( $271'' \times 300''$ ) and was scanned in 18 min.

### Observations of solar transition region structures and dynamics – statistics of quiet-sun extreme ultraviolet radiances

Raster scans of SUMER in quiet-Sun areas were used to build up a good statistical base to study the region between the chromosphere and the corona, i.e. the transition region with a temperature range between  $\sim 30\,000$  K and  $400\,000$  K. The aim was to calculate probability distributions of line radiances and shifts, and to study the relationship between radiances and shifts. These signatures were determined for emission lines with various formation temperatures across the transition region. Results show that radiance contrasts as well as Doppler shifts depend on the formation temperature and peak around  $100\,000$  K, which is also the region with the strongest relation between line radiances and shifts.

The logarithm of the radiances can generally be fitted quite well by a Gaussian probability distribution. The widths of these log-normal probability distributions start with their narrowest values in the chromosphere, peak at twice this width in the transition region around  $100\,000$  K, and almost return to their initial values in the corona

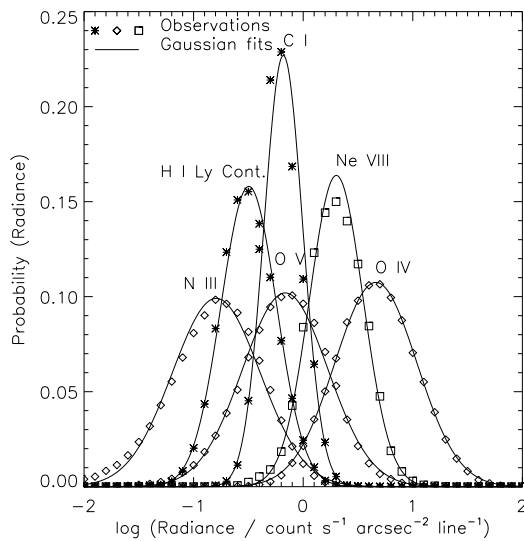


Fig. 18: Probabilities of logarithms of radiance fitted to normal distributions. Most examples are taken from a SUMER study in June 1998, C I is from February 1999. All observations are taken in quiet-Sun areas.

(see Fig. 18). The continua observed in our spectral range behave like lines being formed around 10 000 K. The widths of the line shift probability distributions also start with low values in the chromosphere and reach their highest values in the transition region just above 100 000 K. The relationship between average line shift and radiance can best be observed for short exposure times. On the average, upper-chromospheric and transition region lines show red shifts for high radiance; the dependence again peaks around 100 000 K.

(I.E. Dammasch, E. Landi, I. Rüedi, U. Schühle, S.K. Solanki, K. Wilhelm, in collaboration with A. Pauluhn, ISSI, Bern, Switzerland)

### Solar radiance variability measured with SUMER and inter-calibration with SOHO instruments

For the measurement of solar irradiance in the extreme ultraviolet the SUMER instrument has been calibrated before the mission with a radiometric transfer standard source traceable to the primary source standard, the electron storage ring BESSY I at the Physikalisch Technische Bundesanstalt. The variability of solar irradiance in this spectral range is of major importance for the upper atmosphere of the Earth. To understand the variability of solar irradiance on short and long time scales, SUMER can measure the radiance of

detailed areas of the solar disk and determine their contributions to the irradiance. However, to measure long term variations occurring during a solar cycle, the instrument calibration must be maintained and any changes in the sensitivity must be recorded. For this purpose the radiance of selected quiet-Sun areas on the solar disk has been measured regularly at several wavelengths over the entire time period of the SOHO mission. It has been found by these measurements that the calibration of the SUMER instrument was stable during the mission and the radiance of the quiet-Sun areas increased between 45% and 100% during the rising part of the solar activity cycle between 1996 and 2000 (Fig. 19).

When inferring such long-term trends, the inter-calibration of SUMER with other instruments on SOHO in the same wavelength range is of highest importance to insure that the trends observed are not instrumental artefacts. Therefore it was arranged that all instruments on SOHO with common wavelength ranges participated in many of the measurements, so that results can be compared. In an effort to put the radiometric calibration of SOHO remote sensing instruments on a common footing, a SOHO Inter-calibration Workshop was held at the International Space Science Institute (ISSI) in Bern, where all calibration results have been compared among instruments at their common wavelengths. This led to a refinement of many of the spectral responsivity curves to be published in a book of the ISSI monograph series.

(U. Schühle, K. Wilhelm, S.K. Solanki in collaboration with J. Hollandt, PTB, Berlin, M.C.E. Huber, A. Pauluhn, ISSI, Bern, Switzerland, and P. Lemaire, IAS, Paris, France)

### Coronal holes

We study an equatorial coronal hole (ECH) observed by SUMER on November 5, 1999. The spectral window used by SUMER ranges from 1530 Å to 1552 Å, including lines emitted from the chromosphere, transition region and the base of the corona, respectively. We deduce radiance, line-of-sight Doppler-shifts and line widths, and compare with the underlying photospheric magnetic field observed by MDI/SOHO.

Fig. 20 shows that this hole was occupied predominantly by photospheric fields with a single polarity, while small flux tubes with the opposite polarity were also present. We find that the Ne VIII line has an average blue shift of about 8 km s<sup>-1</sup>.

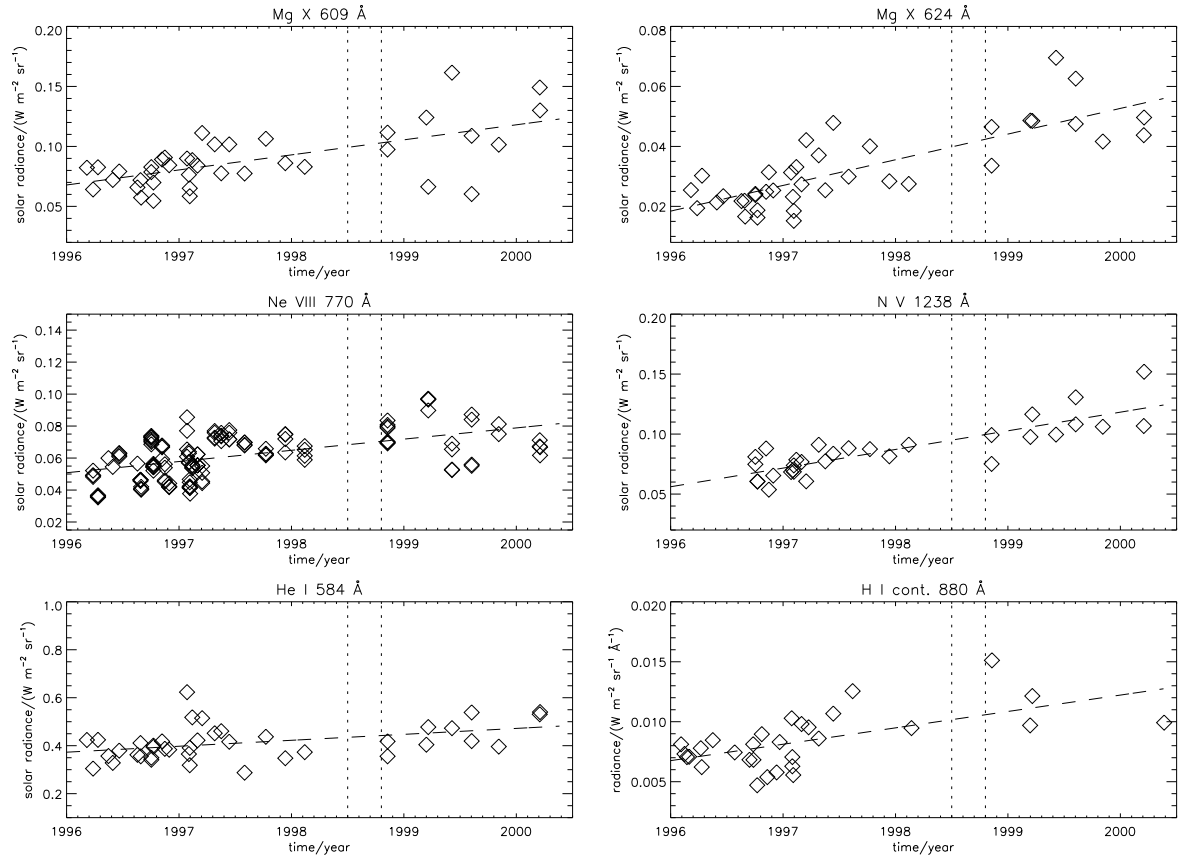


Fig. 19: The radiance of quiet Sun areas measured with SUMER at six wavelengths in the EUV during the rising phase of the solar activity cycle between 1996 and 2000. The wavelength is indicated above each panel. The large scatter of the data is due to short-term variability of the Sun. The dashed line represents a linear fit to the data.

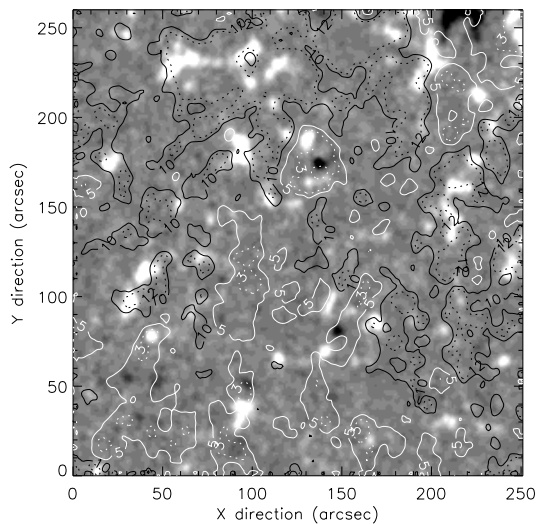


Fig. 20: Magnetoheliogram (white: positive polarity; black: negative polarity) with overlaid contour plots of Doppler-shifts ( $\text{km s}^{-1}$ , with cool lines C I and Si II as reference lines) of the Ne VIII line (black dotted: 12, black solid: 10, white solid: 5, and white dotted: 3  $\text{km s}^{-1}$ ). Note a small active region at the right-upper corner, which is outside of the coronal hole.

In agreement with the model prediction that the fast solar wind is initially accelerated in the coronal funnel, contour plots show that larger blue

shifts with speeds above  $10 \text{ km s}^{-1}$  come mainly from those regions of the magnetic network without large bipolar features nearby, while smaller

ones with speeds below  $5 \text{ km s}^{-1}$  come mainly from bright points (BPs). Such BPs can be well defined in images of radiances, and are spatially associated with regions where bipolar magnetic features are present. Line widths measured in BPs are only 3% different from those in darker areas. Moreover, the mass flux contributed by BPs to the total outflow within the measured hole area is estimated to be about 15%. This indicates that BPs may not be the main source of the fast solar wind.

Coronal holes on the solar disk are investigated using SUMER and CDS spectra. Spectral lines covering as large a temperature range as possible are used. For lines with formation temperatures above  $7 \times 10^5 \text{ K}$  the intensity contrast between coronal hole and quiet Sun areas increases very rapidly. The spectral lines are also found to be increasingly blueshifted with increasing temperature. Finally, the qualitative correlation between wavelength shift of Ne VIII 770 Å and brightness of the network found by Hassler et al. (1999, Science 283, 810) is put on a quantitative footing and extended to a broad temperature range. It is found that this relationship is different for chromospheric, transition-region and coronal spectral lines.

(E. Marsch, U. Schühle, S.K. Solanki, L. Xia, in collaboration with K. Stucki, ETH Zürich, Switzerland)

### Polarisation of the solar F-corona

While the Zodiacal light brightness seems to be continued smoothly into the solar F-corona, the polarisation drops drastically as the elongation of the line-of-sight decreases from about 15 degrees (inner Zodiacal Cloud) to 2 degrees (F-corona). We have calculated the polarisation within 1 AU using a semi-empirical approach to describe the dust grains. The observed huge fall in the polarisation level can only be explained, if particles near the Sun that contribute to the brightness are much smaller than brightness-dominating particles at 1 AU. In addition, a change of the dust chemical composition towards more transparent materials decreases the polarisation.

(N.A. Krivova, I. Mann)

### A kinetic model for ions in the corona

A kinetic model for the plasma dynamics of ions in the solar corona has been developed. This numerical model includes wave-particle interactions

within the framework of quasilinear theory and Coulomb collisions calculated by using the Landau collision integral. The integration of the ion velocity distribution functions (VDFs) over the velocity components perpendicular to the background magnetic field yields so-called “reduced VDFs”. Coupled Vlasov/Boltzmann equations for these reduced VDFs are derived. Since they depend only on the height coordinate  $s$ , speed  $v_{\parallel}$  and time  $t$ , they can be solved numerically with reasonable effort. The model equations guarantee conservation of energy between waves and particles and are numerically solved using a temporal relaxation scheme. Several tests of the numerical method concerning the conservation of momentum and energy, relaxation into thermal equilibrium, and reproduction of the known shape of a VDF in the case of a coronal temperature gradient have successfully been performed.

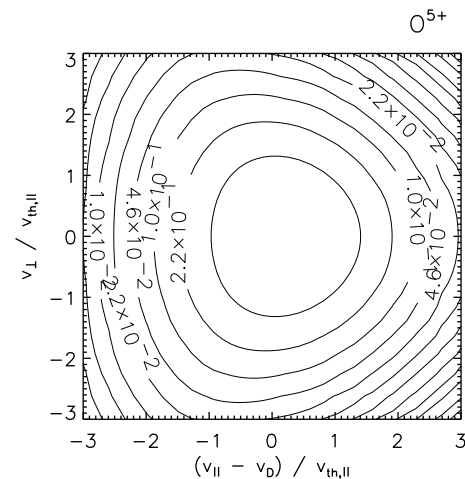


Fig. 21: Reconstructed two-dimensional gyrotropic velocity distribution function of the heavy coronal ion  $\text{O}^{5+}$ . Note the perpendicular temperature anisotropy and skewness along the magnetic field.

Various kinetic models for the corona have been constructed. In particular, results were obtained for heavy ions in a coronal funnel. They show in good agreement with SOHO (Solar and Heliospheric Observatory) observations a preferential heating of the heavy ions and strong deviations of their reduced VDFs from a Maxwellian distribution function. This finding is illustrated in Fig. 21. It is also found that heavy ions are heated preferentially with respect to the protons, and that sizable temperature anisotropies and heat fluxes form. The reduced VDFs of the heavy ions de-

velop pronounced deviations from a Maxwellian, which tend to increase with height due to the decreasing efficiency of Coulomb collisions. Calculations of the wave damping/growth rate  $\gamma$  show that the VDFs can reach the limit of marginal stability over a wide range of resonance speeds, where the wave absorption ceases. The consequences for the spectral evolution of the waves and their absorption, causing ion heating in the corona, have extensively been discussed in several publications. Furthermore, how the heavy ion mass and charge influence the kinetic model results has in detail been studied.

(E. Marsch, C. Vocks)

### On cyclotron wave heating of solar wind ions in the solar corona

The preferential heating and acceleration of  $O^{+5}$  ions, as observed by Ultraviolet Coronagraph Spectrometer (UVCS) on Solar and Heliospheric Observatory (SOHO) in the solar coronal holes have been interpreted and modelled by invoking wave-particle cyclotron resonance. However, in these models the assumption of a rigid slope of the wave spectrum was made in calculating the wave energy absorption by the different ion species. We have shown that a self-consistent treatment of the wave damping and absorption is necessary and leads to substantially different results. On the basis of quasi-linear theory, the interaction between the ions and the ion-cyclotron waves is studied. The total energy conservation equation, including the kinetic energy of the resonant particles and the wave energy, is derived and discussed in detail.

The spectral evolution equation for cyclotron waves, when being controlled by the wave growth/damping rate and WKB effects, is solved self-consistently together with the full set of anisotropic multifluid equations for the ions including the cyclotron-resonance wave heating and acceleration rates.

From the numerical results we reach the following conclusions: (1) It is physically questionable to use a spectrum with a fixed spectral slope near the cyclotron resonance when one calculates the partition of wave energy among the different ionic species and the kinetic degrees of freedom parallel and perpendicular to the magnetic field. This assumption neglects the important effects of wave absorption and the concurrent reshaping of the wave spectrum, and thus leads in the dissipation domain to extremely low amplitudes of the waves and to difficulties in supplying enough energy to

balance the wave absorption at the cyclotron resonances. (2) If the spectrum is allowed to evolve self-consistently and concurrently with the particles' heating and acceleration through wave absorption, such a high perpendicular temperature and corresponding large temperature anisotropy as observed by UVCS do not occur or cannot be maintained.

We conclude that, although the UVCS observations of EUV line broadenings are often interpreted as signatures of cyclotron wave heating, the modelling efforts have not come to convincing conclusions that this process is indeed responsible for the heating. The observations have in our mind not yet been explained satisfactorily, neither by the theory of cyclotron wave resonance nor by other theories. Both theoretical work and data analysis or further observations are needed to understand better the ion heating and acceleration mechanism in the corona.

(E. Marsch, C.Y. Tu)

### Wave dissipation by ion cyclotron resonance in the solar corona

It has recently been suggested that small-scale magnetic reconnection occurring in the chromospheric network creates high-frequency Alfvén waves, which may represent a main energy source for the heating of the solar corona and generation of the solar wind. Given these waves exist, they will be absorbed first and preferentially by the minor heavy ions having low gyrofrequencies. Thus it is unclear whether there remains enough wave energy for heating of the major solar wind ions, protons and alpha particles. We have studied this problem with a multi-fluid model, including the self-consistent treatment of the damping of the waves as well as heating of the ions. If the wave power density, with an assumed spectral index of  $-2$ , is sufficiently large, say about  $1000 \text{ nT}^2\text{Hz}^{-1}$  at  $160 \text{ Hz}$  and  $2.5 R_{\odot}$ , then the wave absorption by a minor ion such as  $O^{+5}$  is small. Most of the wave energy is then left for absorption by protons, because the minor ions are quickly (within several gyroperiods) accelerated and partially surfing the waves. However, if the wave power is too low, say lower than  $10 \text{ nT}^2\text{Hz}^{-1}$  at  $160 \text{ Hz}$  and  $2.5 R_{\odot}$ , then the damping of the wave power by the  $O^{+5}$  ions is severe, and little wave energy is finally left for the protons.

Fig. 22 shows the spatial and spectral evolution of the normalised spectrum under the influence of wave damping. Here the spectrum density at

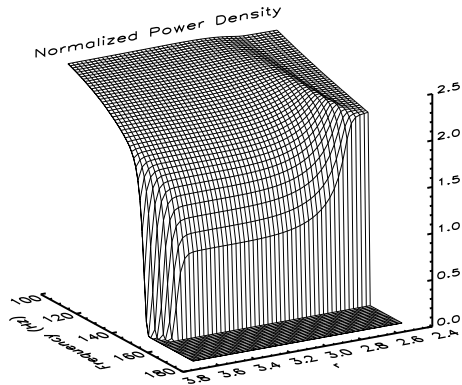


Fig. 22: Radial evolution of the wave power spectrum normalised to the WKB value. The z-axis shows  $\log_{10}(P(r, f)/[\text{nT}^2\text{Hz}^{-1}\text{WKB}] + 1)$ , the x-axis the radial distance from  $2.5 R_{\odot}$  to  $3.7 R_{\odot}$ , and the y-axis the frequencies from 100 Hz to 180 Hz.

$r = 2.5 R_{\odot}$  is about  $100 \text{ nT}^2\text{Hz}^{-1}$  at 160 Hz. The numerical results indicate that how much wave energy is resonantly absorbed by the heavy ions, depends strongly on the amount of power that is initially available at the lower boundary.

(E. Marsch, C.Y. Tu)

### Large-scale coronal field structure and source-region features for a halo CME

Coronal Mass Ejections (CMEs) are one of the most extensively studied solar objects, because they produce a direct impact on the geomagnetic environment of the Earth. The origin of CMEs is still unclear. The source regions of halo CMEs, being near solar disk center, are particularly open to study, including the associated magnetic structure.

The halo CME of the 2 May 1998 is a good example, which was associated with a X-class flare near disk centre. Using the boundary element method (BEM) on a global potential model, we reconstruct the large-scale coronal field structure from an observed boundary. The extrapolated large field lines outline a transequatorial interconnecting loop (TIL) seen in soft X-rays (SXR) between two active regions. The loop disappeared after the CME. The spatial relationships between EIT dimmings, the SXR TIL, and the computed coronal magnetic structure suggest that the investigated CME was caused by a global restructuring of multipolar magnetic systems due to flare disturbances. Mass, magnetic energy and flux of the

ejected material estimated from the dimming regions are comparable to the output of large CMEs.

At the CME source region, Huairou vector magnetograms show a rapidly developing emerging flux region (EFR) with strong shear. Magnetic field extrapolations reveal the presence of a “bald patch” (defined as the location where the magnetic field is tangent to the photosphere) at the edge of the EFR. The EUV loop brightenings and SXR jets appearing at the bald patch in the pre-flare phase suggest a slow reconnection between the TIL and EFR field systems. A fast expanding motion of loops above a bright core seen in SXT just before the hard X-ray onset, may be a precursor for the eruption of the sheared EFR flux to produce the flare. We propose a scenario, similar to the “breakout model”, that can interpret many observed features.

(T.J. Wang, in collaboration with Y. Yan, J.L. Wang, National Astronomical Observatories of China, and H. Kurokawa, K. Shibata, Kwasan and Hida Observatories, Kyoto University, Japan)

### LASCO (Large Angle and Spectrometric CORonagraph on SOHO)

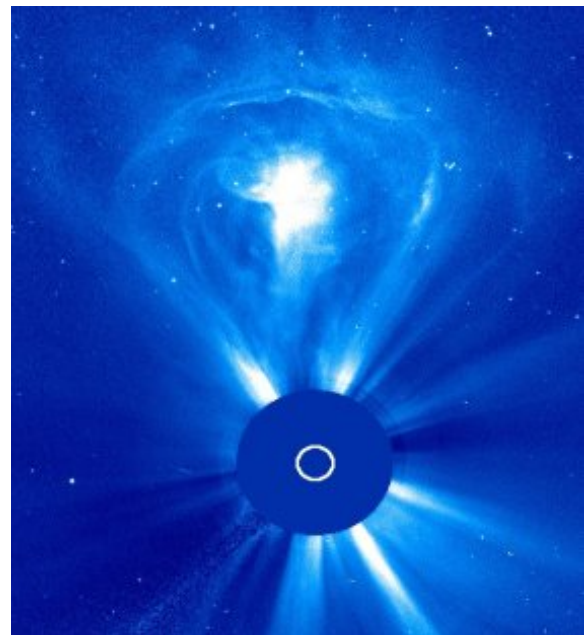


Fig. 23: The “light bulb” coronal mass ejection (CME) of December 28, 1999, as observed by the LASCO-C3 coronagraph on SOHO. Near the maximum of solar activity the variety of CME shapes and directions has increased dramatically.

The remaining telescopes C2 and C3 of the LASCO instrument on SOHO worked flawlessly

throughout the past two years, without any unscheduled interruption. The data coverage is almost perfectly continuous and at a reasonable cadence. Degradation of the optical systems and the CCDs is surprisingly slow. Not even the big flare events in the recent solar activity maximum phase caused any remaining damage. We have all reasons to believe that LASCO can well survive until the presently planned mission end in 2007 (Fig. 23).

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

### A tool for improved space weather predictions: the CME expansion speed

For limb CMEs, there is usually a good correlation between the apparent radial speed  $v_{rad}$  and the lateral expansion speed  $v_{exp}$  of CME clouds. In case of halo CMEs,  $v_{rad}$  is inaccessible because of the geometry, but  $v_{exp}$  can always be determined. Thus, the halos'  $v_{rad}$  can be inferred and their travel time to Earth be estimated. We studied this connection using solar and interplanetary data for a period from January 1997 to April 2001. The data were provided by the LASCO coronagraphs on SOHO, plus additional information from EIT. Solar wind data from SOHO, ACE, and Wind were used to identify the arrivals of ejecta clouds at 1 AU.

Out of 280 cases of full and partial halo CMEs we found 102 cases uniquely correlated with ejecta signatures. For 94 of them, both  $v_{exp}$  and the travel time  $T_{tr}$  could be determined. Assuming that acceleration or deceleration of ejecta is proportional to the speed difference to the ambient solar wind we derived the empirical function

$$T_{tr} = 220.8 - 22.75 \ln(v_{exp})$$

that fits the data best. This function can be considered a practical tool for predictions, with a 95% certainty that the prediction will not be off by more than 24 hours. The remaining uncertainty is due to processes occurring during the “trip” of the ejecta from the Sun to 1 AU (see Fig. 24).

It is important to note that 4 out of 81 (6%) full front side halo CMEs never reached the Earth and would have caused false alarms. On the other hand, 12 out of 148 (8%) shocks at 1 AU were not related to any CME. 1 out of 30 intense geomagnetic storms and 4 out of 78 moderate storms were not related to any CME, i.e. 6% of moderate/intense storms were not at all predicted. All very intense storms ( $D_{st} \leq 200$  nT) were related to halo CMEs. These remarks illustrate that

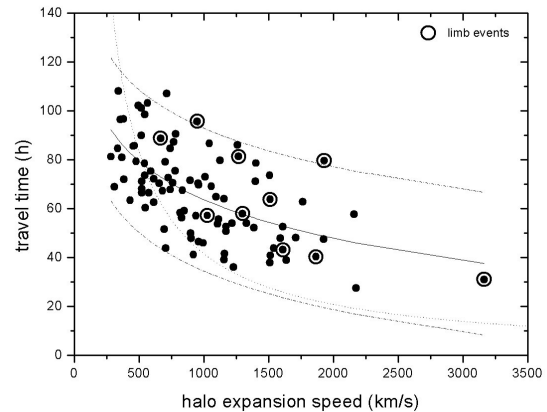


Fig. 24: Correlation between CME (full and partial halos) expansion speed and measured travel time to 1 AU of associated ejecta of 94 unique cases. For the fit curve (solid line) it is assumed that acceleration or deceleration of the ejecta is proportional to the speed difference with respect to the ambient solar wind.

much more work is needed to improve our abilities of space weather prediction.

(R. Schwenn, in collaboration with Alisson Dalgado, INPE, Brazil, and Emilia Huttunen, FMI, Finland)

### MICA (Mirror Coronagraph for Argentina)



Fig. 25: The domes of the MICA and HASTA telescopes, located in El Leoncito (province of San Juan, Argentina) in 2400 m altitude, in front of the Andes main chain. The instruments were built in a cooperative effort between MPAE Lindau, MPE Garching, the University of San Juan, and IAFE in Buenos Aires.

The MICA telescope as part of the German-Argentinean Solar Observatory in El Leoncito is a nearly exact copy of the LASCO-C1 instrument

on SOHO that could not be revived after the accident in June 1998. MICA, together with the H-alpha telescope HASTA has been in regular operation throughout 2000 and 2001. On almost 50% of the days the sky conditions allowed taking useful images. They complement the SOHO observations in an ideal way. For several events, the combined data analysis lead already to interesting results, others are being worked on (Fig. 25).

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

## Solar wind and heliosphere

### Solar energetic particle events observed by SOHO/CELIAS/STOF

Since the launch of the Solar and Heliospheric Observatory (SOHO), the Suprathermal Time-Of-Flight (STOF) energetic particle sensor has observed gradual and impulsive solar particle events from solar activity cycle minimum to maximum. The instrument CELIAS/STOF has the capability of detecting energetic ions between 35 and 630 keV/q and can determine the mass, energy and charge of each particle. We determined from the detected energetic particle events in the interval from 1996 to 2000 the daily averages of the He/Pr and Fe/O elemental ratios as well as the He charge states. For selected events we analysed the velocity dispersion of the suprathermal ions and estimated the onset of the solar event and set limits on the propagation length along the connecting magnetic field line (example shown in Fig. 26).

(M. Hilchenbach, H. Sierks, in collaboration with B. Klecker, Max-Planck-Institut für extraterrestrische Physik, Garching, K. Bamert, Physikalisches Institut der Universität Bern, Switzerland, and R. Kallenbach, International Space Science Institute, Bern, Switzerland)

### Regulation of the proton thermal anisotropy in the solar wind

The velocity distribution functions (VDFs) of protons measured by Helios in fast solar wind have been analysed anew in the framework of quasilinear theory (QLT). Evidence is found that the regulation of the temperature anisotropy,  $A = T_{\perp}/T_{\parallel} - 1$ , of the core part of the VDFs can be

explained by wave-induced plateau formation according to QLT. The plateau is formed by protons in resonance with cyclotron waves.

A comparison of data and theoretical results is given in Fig. 27. The crosses show the proton data taken from various data sets obtained in high-speed streams, whereas the solid lines show the anisotropies as determined by the proton pitch-angle-diffusion plateau, calculated by means of the cold plasma dispersion relation (top line). When considering thermal effects in the dispersion relation, an even better agreement between theory and observations is obtained (line in the middle). The lowest thin line with full dots shows an instability threshold from a numerical simulation, yielding  $A = 0.6\beta^{0.40}$  as a function of the core-proton plasma beta,  $\beta$ .

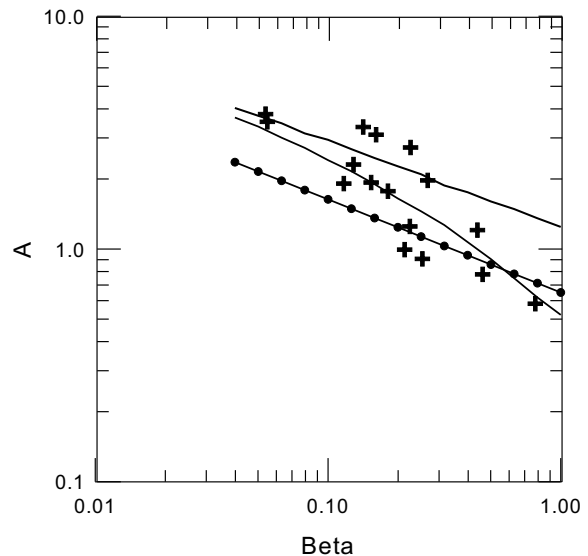


Fig. 27: Proton core-temperature anisotropy as a function of the core plasma beta.

For non-dispersive waves, a simple analytical relation between the ion thermal speed parallel to the magnetic field and the ion temperature anisotropy can be derived, which is shown to be also consistent with the anisotropy of the heavy coronal ion  $O^{+5}$  as observed on SOHO (Solar and Heliospheric Observatory), as well as with the anisotropy as predicted numerically by a hybrid simulation of the ion-temperature regulation by waves.

(E. Marsch and C.Y. Tu)

### Pitch-angle diffusion of solar wind protons in resonance with cyclotron waves

Quasilinear theory predicts that ions in resonance with transverse ion-cyclotron waves suffer merely

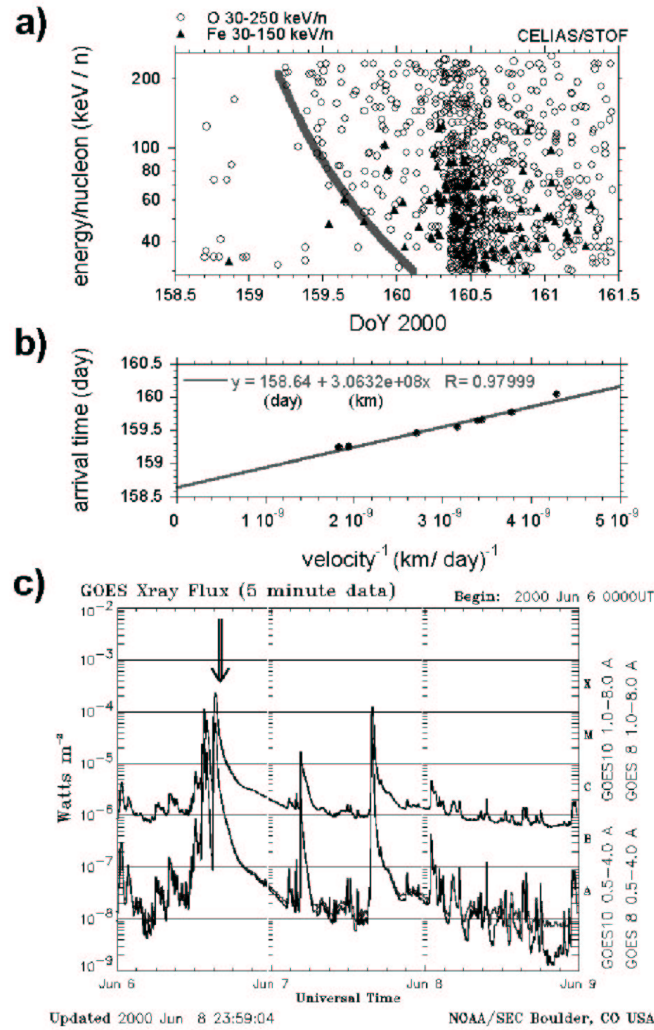


Fig. 26: a) Velocity dispersion of O and Fe ions on June 8, 2000. b) Linear fit to calculate the event onset (DoY 158.64) and the ion path along the interplanetary magnetic field  $L$  divided by the cosine of the pitch angle  $u$  ( $L/u$  about 2 AU). c) Solar X-ray data from GEOS Satellite Data. The arrow indicates the calculated event onset (June 6, 2000, 15:30 UT).

pitch-angle diffusion while conserving their total kinetic energy in a frame moving with the wave phase speed. For the first time, observational evidence from Helios plasma data is obtained for the occurrence of this pitch-angle diffusion of solar wind protons.

The proton velocity distribution shows a plateau which is defined by vanishing pitch-angle gradients implying marginal plasma stability. Parts of the isodensity contours in velocity space shown in Fig. 28 are well outlined by a sequence of segments of circles centred at the phase speed  $V_{ph}$  (dots indicate its location), which is assumed to vary slightly and to be due to dispersion smaller than the local Alfvén speed. For the contours between

0.2 and 0.4 of the maximum density, the plateau can be as wide as 70 degrees in pitch angle calculated in the wave frame of reference. However, in the core part of the distribution, the plateau extent is found generally to be narrower in pitch angle.

The appearance of a plateau provides direct evidence for the cyclotron resonance process being at work in the high-speed solar wind. The evolution of the proton distribution, at least of its sunward core part, is controlled or highly influenced by pitch-angle diffusion in the wave frame of left-handed Alfvén and/or ion-cyclotron waves propagating away from the Sun.

(E. Marsch, C.Y. Tu)

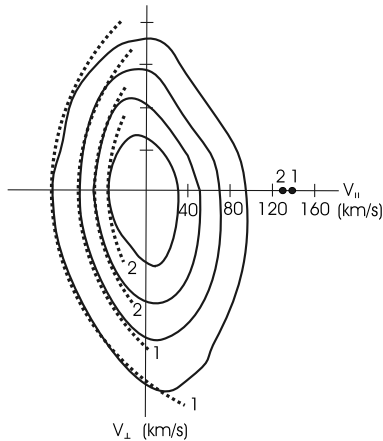


Fig. 28: Comparison of a proton velocity distribution with the quasilinear plateau. The horizontal axis gives  $v_{\parallel}$  and the vertical  $v_{\perp}$ . The four measured contours correspond to fractions of 0.8, 0.6, 0.4, 0.2 of the maximum. The thick dotted theoretical lines (circular arcs) are delineating the diffusion plateau.

#### Long-term variations of the flow direction and angular momentum of the solar wind observed by Helios

The flow directions of solar wind protons were measured in situ by the Helios spacecraft. A long-term average of the velocity shows a systematic drift in the latitudinal flow angle of about  $-1^{\circ}$  south and in the longitudinal flow angle of about  $+1^{\circ}$  north over a period of almost 10 years for Helios 1 and 6 years for Helios 2. This systematic shift with time of the plasma flow direction may be caused by solar-cycle variations of the orientation of the Sun's magnetic field which partially corotates with the Sun inside the Alfvénic surface (varying in distance between  $10 R_{\odot}$  over the poles and  $30 R_{\odot}$  near the equator). These variations must have been imprinted on the solar wind flow when it detached from corotation with the Sun near the Alfvén point. The angular momentum of the wind is intimately connected with the flow and field directions. The gain of total angular momentum of the wind, which is carried away by the plasma and the frozen-in field, equals the loss of mechanical angular momentum of the Sun, which is caused by the torque exerted through the coronal magnetic field on the rotating Sun. The implications of these observations for models of the magnetic fields of the Sun as well as the solar wind are extensively discussed.

(K. Scherer, E. Marsch, R. Schwenn, H. Rosenbauer)

#### Deriving ACR shock spectrum from observations of the energetic neutral atoms

One of the sources of the energetic neutral atoms (ENA) in the heliosphere are the low-energy (up to few 100 keV) anomalous cosmic ray (ACR) ions in the outer heliosphere, close to and beyond the solar wind termination shock. The ENAs can penetrate into the inner solar system, and, if observed, provide the information about the ACR distribution in the source region. Using the results of numerical simulations of the ACR spatial and energy distributions in the heliosphere, we derive approximate relations between the ENA energy spectrum as observed at the orbit of the Earth and the ACR spectrum near the solar wind termination shock. With some assumptions about the parameters of the heliosphere, these relations allow one to obtain the ACR shock spectrum from the observed ENA spectrum. We applied this method to the data from CELIAS/HSTOF and set limits on the ACR energy spectra parameter (Fig. 29).

(M. Hilchenbach, in collaboration with A. Czechowski, Space Research Centre, Polish Academy of Sciences, Warsaw, Poland, and K.C. Hsieh, University of Arizona, Tucson, USA)

#### Velocity, temperature and density of interstellar He-atoms: recent Ulysses-GAS results

Neutral particles, like He-atoms, can penetrate into the inner solar system and are accessible there to direct measurements. The determination of their kinetic parameters (velocity vector, density, and temperature) provides immediately clues about the physical state of the local interstellar medium, surrounding the solar system. In addition, the velocity vector of the He-particles in turn gives the velocity and direction, with which the solar system moves through the ambient environment. For astronomers, e.g., this is important basic information, because much of their knowledge is based on dopplershifts of spectral lines in the light of stars, which need to be corrected for by the appropriate components of the proper motion of the solar system.

The GAS-instrument aboard the Ulysses mission is dedicated to measure the local distribution of the interstellar He-particles in the inner solar system (within  $\sim 2$  AU distance from the sun). This has been possible during three mission phases: in 1990/1991 after launch, around perihelion in

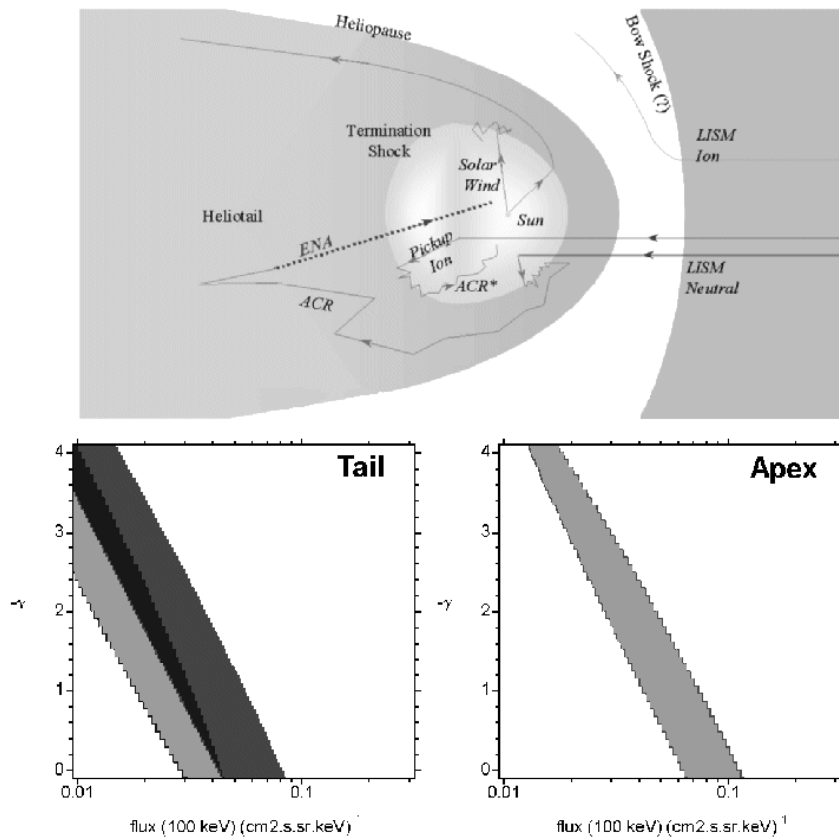


Fig. 29: The upper panel is the schematic view of the heliosphere with a typical history of an ACR ENA particle. The lower panels show the results of the fits to the ENA data, assuming that the ACR flux at the shock is given by a simple power law. The x axis shows the ACR flux intensity value at 100 keV, the y axis the exponent of the energy-spectra power law as derived from chi-square fits to the observed energetic neutral hydrogen data of SOHO/CELIAS/HSTOF.

1994/1996, and recently in 2000/2002. It is noteworthy, that these observations cover a complete solar activity cycle.

Because of the scientific importance of the kinetic parameters, continued effort has been spent to the refinement of the determination procedure. Significant improvements could be obtained in several fields:

1. About 200 new distributions could be observed in 2000/2002 from positions along the Ulysses orbit at solar latitudes between  $-80^\circ \dots +80^\circ$  and were added to the data base.
2. By using the measurements of more than 200 star positions it was possible to verify the absolute, over-all precision in the determination of the direction of the optical axis of the instrument. Given the width of the intrinsic field-of-view of the detectors of  $\sim 2.4^\circ$  resp.  $4.7^\circ$  (FWHM), a systematic offset in the pointing of about only

0.5 degrees could be found by applying special techniques (oversampling) and statistical methods. Because the kinetic parameters of the He must solely be derived from the observed angular distribution the correction of the seemingly small error in the arrival direction determination results in a sizeable correction of the velocity components (see Table 1).

3. From the observed local densities the interstellar density of He can be inferred only with sufficient knowledge about the losses the particles experience on their way to the observer. In case of He, the predominant loss process is photoionisation by solar UV-light. Sufficiently precise, time-resolved measurements of the integral solar irradiances of the He I and He II lines have become available now from the SEM instrument on SOHO (McMullin, et al., private communication, ISSI-Workshop, 2001), which allowed us for the first time to apply actual ionisation rates

Table 1: Local interstellar medium parameters derived from the Ulysses neutral gas experiment

		Witte et al. 1996 <sup>1)</sup>	1994/1996	2000/2001
Velocity	$V_{\infty}$ (km/s)	$25.0 \pm 0.6$	$26.3 \pm 0.4$	$26.15 \pm 0.5$
Ecl. Longitude	$L_{\infty}$ (°)	$74.4 \pm 0.9$	$74.7 \pm 0.5$	$74.7 \pm 0.5$
Ecl. Latitude	$B_{\infty}$ (°)	$-5.1 \pm 0.5$	$-5.2 \pm 0.2$	$-5.2 \pm 0.2$
Temperature	$T_{\infty}$ (K)	$6600 \pm 600$	$6285 \pm 270$	$6410 \pm 300$
Density	$n_{\infty}$ ( $10^{-2} \text{cm}^{-3}$ )	1.4 - 1.7	1.5	1.4
@ Photoionisat.	$\beta_{\text{Ion}}$ ( $10^{-7} \text{s}^{-1}$ )	0.6 - 1.1	2)	2)
No. of observations			85	121

<sup>1)</sup> Witte et al., Space Sci. Rev., 78, 289, 1996, <sup>2)</sup> ionisation rates derived from SEM/SOHO measurements.

Interstellar He-Parameter: Summary 2002

to the observed He distributions. However, the resulting values for the interstellar He densities showed a significant variation with the solar latitude of the Ulysses position, which presently is explained by a latitudinal variation of the solar irradiance, resulting in too high average density values ( $n_{\text{He}} \approx 1.6 \times 10^{-2} \text{cm}^{-3}$ ).

By applying a simple model it can be shown that the latitudinal variation can be compensated and that an average density of  $n_{\text{He}} \approx 1.4 \times 10^{-2} \text{cm}^{-3}$  should be more appropriate. Presently, a program is initiated to get latitudinal resolved irradiances with the help of EIT-data from SOHO, which will enable us to replace the simple model assumption with more realistic ionisation rates.

(M. Witte, M. Banaszkiewicz)

### Resonant interactions of ions with plasma waves in quasi-linear theory

On the basis of the quasilinear theory for wave-particle interactions, involving diffusion of particles by pitch-angle scattering in the broad-band and random-phase wave fields, the resonant interactions between ions and waves in an anisotropic plasma are analysed and discussed. In particular, the general situation for electromagnetic Alfvén and ion-cyclotron waves propagating along or obliquely to the background magnetic field has been considered.

By taking moments of the quasi-linear diffusion operator, the parallel and perpendicular wave heating and acceleration rates for gyrotropic particle velocity distribution functions (VDFs) are derived. These rates can be used in anisotropic multi-component fluid equations, in order to describe the wave-particle interactions of ions with, for examples, kinetic Alfvén and electro-

magnetic or electrostatic ion-cyclotron, or fast-magnetosonic waves near the ion gyrofrequency.

High-frequency plasma waves of coronal origin, which are propagating along globally open field lines (as they exist in coronal holes) away from the Sun into the interplanetary medium, can resonantly heat the ions in the solar corona and solar wind ions, and in particular accelerate minor ions preferentially with respect to the protons. These processes are often invoked to explain and understand the measured characteristics of ion VDFs in the solar wind and coronal holes, and to interpret recent spectroscopic evidence obtained from EUV emission line measurements made by the Solar and Heliospheric Observatory (SOHO) spacecraft. These observations indicate considerable line broadenings and Doppler shifts, which are presumably related with or caused by ion-wave interactions.

Furthermore, a closed set of reduced (with respect to the perpendicular velocity component) quasilinear diffusion equations has been derived, which involve reduced one-dimensional velocity distributions, as they occur typically in wave dispersion relations. These semi-kinetic diffusion equations for the reduced VDFs are still adequate to describe prominent nonthermal features observed in solar wind VDFs. A two-dimensional kinetic model VDF can even be reconstructed by making use of the so-called Gaussian approximation. The wave-particle heating and acceleration rates, based on the reduced diffusion operator, are also calculated. They attain mathematical forms resembling the ones known from the Coulomb-collision rates for friction and temperature-anisotropy relaxation, but involve the wave spectrum as a crucial ingredient.

(E. Marsch)

## Status of ongoing and future solar missions

### SUNRISE: a balloon-borne solar telescope

SUNRISE is a light-weight solar telescope with 1 m aperture and instrumentation for spectropolarimetric observations of the solar atmosphere on the intrinsic spatial scale of its magnetic structure. Initially, the telescope will be operated during a series of long-duration balloon flights in order to obtain diffraction-limited image quality and to study the UV spectral region down to  $\simeq 200$  nm, which is not accessible from the ground. Later, it is planned to make the telescope shell the core instrument of a space-borne solar observatory. The light-weight mirror technology developed in the course of this project is a major step towards affordable large telescopes in space for astronomical and Earth-observation purposes (Fig. 30).

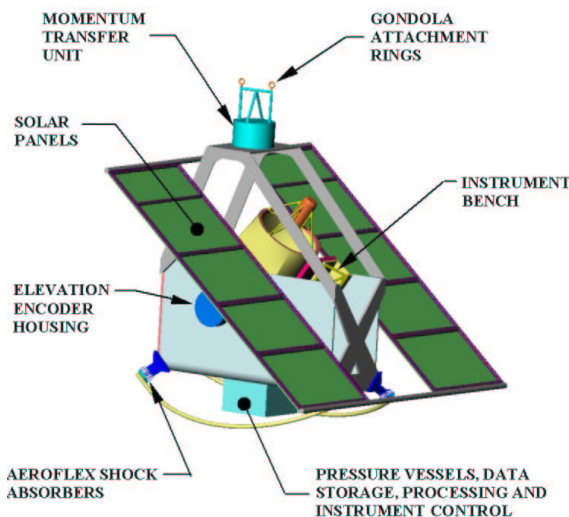


Fig. 30: Sunrise telescope assembled in the balloon gondola: operation mode. During ascent, descent, and landing the telescope is stowed horizontally. The shock absorbers allow for large deflections and high energy dissipation during landing.

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 energy 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 instrumentation of SUNRISE consists of a 1-m Gregorian telescope with silicon carbide lightweight primary mirror, which will provide diffraction-limited spatial resolution down to 0.05 arcsec at 200 nm, corresponding to  $\simeq 35$  km on the Sun. 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. A 10-cm telescope with a  $4k \times 4k$  pixel CCD provides full-disk images and will be used for local helioseismology with high-degree acoustic oscillations. The 1-m main telescope feeds a focal-plane package consisting of a spectrograph-polarimeter for high-precision spectral line measurements of the four Stokes parameters, a filtergraph for high-resolution images in the visible and the UV, and a magnetograph providing two-dimensional maps of the complete 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 the Instituto de Astrofísica de Canarias (IAC), Tenerife. MPAE is responsible for the main telescope (to be built by industry, phase A was completed in 2001, phase B is to be carried out in 2002), the auxiliary telescope, the spectrograph/filtergraph, and the the central computer and data storage unit. After a test flight over continental USA in 2005, a first long-duration balloon flight of about 2 weeks from Antarctica is planned for the (northern) winter 2006/2007.

(S.K. Solanki, W. Curdt, M. Schüssler and MPAE engineering team, in cooperation with teams led by W. Schmidt, KIS, Germany, B.W. Lites, HAO, Boulder, USA, A.M. Title, LMSAL, Palo Alto, USA, and V. Martínez Pillet, IAC, Tenerife, Spain)

### Tunable X-ray Imager (TXI)

The EUV and X-ray telescope TXI is a rocket instrument payload built for observations of the solar corona by the SAO and funded by NASA. The MPAE's contribution to the experiment is the provision of an EUV imaging detector. The incident EUV radiation passes through a double mirror, multilayer coated monochromator that allows narrow wavelength bands around lines between 171 nm and 211 nm (emitted by coronal regions around temperatures of one to two million degrees) to be selected. A spherical mirror then forms an image on the detector's front surface. There EUV photons are converted to visible light in a phosphor layer; thereafter this image is amplified by an image intensifier like in night vision devices, and is finally read out by a CCD with 2048 x 2072 pixels. One pixel corresponds to about one arc second in angular width.

The instrument is designed as a rocket payload for instrument development as well as for scientific research. For EUV observations the rocket has to reach altitudes of well above 100 km; a typical flight provides about 5 min clear EUV observation time. A rocket flight in September 2000 from White Sands Missile Range in New Mexico, USA, showed the whole instrument to be working well, but failed to produce images of the sun due to a failure of the pointing system which caused the telescope to aim several degrees off the solar direction. The payload landed on a parachute with only minor damage on impact. It was refurbished and flown a second time on 21 June 2001, several hours after the total solar eclipse (during the eclipse the sun over America had not yet risen). This time it provided images of the solar

corona. Unfortunately the parachute for descent did not deploy properly so that the payload was totally destroyed on impact on the ground, but the images (although slightly out of focus for an unknown reason) were telemetered to the ground in real time so that no loss of data occurred.

One of the first surprises with the data obtained was that the EUV flux was about a factor 20 higher than expected from the calibration data of the SOHO/EIT camera. We expect that a careful calibration of the TXI images will yield more precise estimates of the solar EUV flux.

The MPAE contribution was funded by the DLR under award No. PSAero456

(A. Dannenberg, B. Inhester, D. Innes, W.K.H. Schmidt, as part of a collaboration led by L. Golub of the Harvard-Smithsonian Astrophysical Observatory, Cambridge, USA)

### Participation in the NASA STEREO Mission

Two suitably equipped spacecraft are being developed for NASA's STEREO (Solar TERrestrial RElations Observatory) mission to provide a totally new perspective on the 3-dimensional structure of the Sun's corona and on solar eruptions, especially coronal mass ejections (CMEs), and their consequences for Earth. The launch date for STEREO A, leading the Earth in its orbit, and STEREO B, lagging the Earth in its orbit, is end of 2005 to early 2006. The prime phase of the mission is two years, the extended phase covers three more years.

The two spacecraft which drift away from the Sun-Earth-line at a rate of 22 degrees per year (Fig. 31), 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 of STEREO. SECCHI (Sun-Earth Connection Coronal and Heliospheric Investigation) encompasses four optical

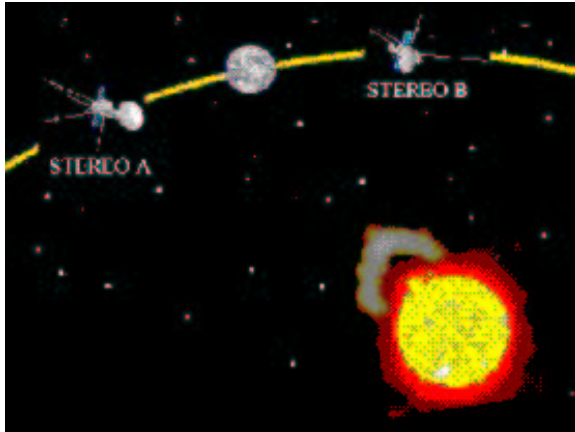


Fig. 31: Position of the two STEREO spacecraft after about two years.

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.

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

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

The Max-Planck-Institut für Aeronomie participates in the development of the SECCHI instrumentation, one of the key science payload packages of the NASA STEREO mission. SECCHI, named after the Italian astronomer Pietro Angelo Secchi (1818-1878) who pioneered stellar spectroscopy and solar eclipse observations, is a combined suite of optical telescopes, including EUV wavelengths, to advance our understanding of the three-dimensional nature of the solar corona and inner heliosphere and of coronal mass ejections (CMEs). CMEs are the most powerful solar eruptions that have been detected so far. 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. Amongst other space weather hazards, CMEs and their associated effects at geospace have led to losses of tele-

communication satellites or power outages (space weather effects).

To accomplish the science objectives, both STEREO spacecraft will carry identical Sun Centred Imaging Packages (SCIP) consisting of the following telescopes (Fig. 32):

- internally occulted Lyot coronagraph (COR1),
- Externally occulted Lyot coronagraph (COR2),
- EUV narrow-bandpass Cassegrain telescope (EUVI).

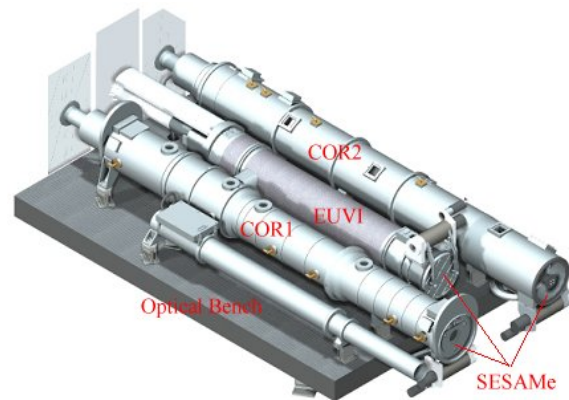


Fig. 32: The SECCHI/SCIP telescopes.

The Institute is leading the development and fabrication (in collaboration with the University of Kiel) of the Secchi Experiment Sun Aperture Mechanisms (SESAME, Fig. 32) for the SCIP telescopes. It is further involved in the development of stereoscopic analysis techniques in order to explore the origin, 3D magnetic field structure and heliospheric evolution of CMEs through collaborations within the international SECCHI consortium.

(V. Bothmer, as part of a collaboration led by R. Howard, NRL, Washington, USA)

### 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 birth, acceleration and interplanetary propagation of coronal mass ejections. Both the initial conditions on the Sun's surface and the later evolution are strongly determined by magnetic fields and their three-dimensional shape. The two STEREO spacecraft

will enable for the first time continuous and simultaneous observations of this phenomenon from two different vantage points in space and will thus allow to reconstruct its three-dimensional structure. As part of the contribution to this project, the institute is preparing software tools for the three-dimensional analysis of the SECCHI data which is based on stereoscopic and tomographic algorithms.

As far as stereoscopy is concerned, we have finished an image rectification tool which prepares the images from the two STEREO spacecraft, so that they are immediately comparable, and a final line-tying reconstruction program. The big challenge here is the step in between which matches the various structures visible in the stereo image pair automatically.

For tomography a larger set of images is necessary. Use is made of the Sun's rotation to obtain projections from different directions, in addition to the different view points of the STEREO spacecraft. The tilt of the Sun's axis with respect to the plane of the ecliptic requires a fully three-dimensional reconstruction approach unless the desired resolution is low. The tomography tool which we are developing for SECCHI is a fully three-dimensional finite element code with special regularisation features built in which help to improve the resolution close to the Sun's surface.

A third part of the analysis tools for SECCHI will be a force-free magnetic field modelling program which we are designing in collaboration with Dr. T. Wiegmann, University of St. Andrews, Scotland).

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

### **Solar Orbiter, a high-resolution mission to the Sun and inner heliosphere**

The Solar Orbiter mission was conceived and proposed by a team of European scientists, lead 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 (2011-2012).

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 in-situ the properties and dynamics of plasma, fields and particles in the near-Sun heliosphere,
- to investigate the fine-scale structure and dynamics of the Sun's magnetised atmosphere, using close-up, high-resolution remote sensing,
- to identify the links between activity on the Sun's surface and the resulting evolution of the corona and inner heliosphere, using solar co-rotation passes,
- to observe and fully characterise the Sun's polar regions and equatorial corona from high latitudes.

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 innermost regions of our solar system,
- study the Sun from close-up (at 45 solar radii, or 0.21 AU, a 35 km pixel size is equivalent to 0.05 arcsec from Earth),
- 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 polar regions from heliographic latitudes up to 38°.

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. 33. 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.

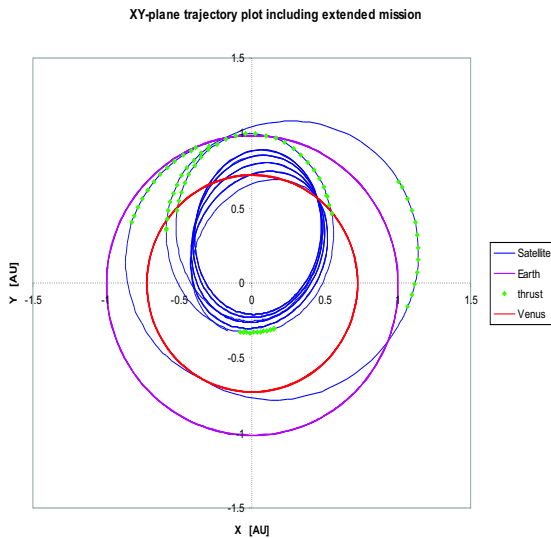


Fig. 33: Orbit design of Solar Orbiter: Ecliptic projection of the spacecraft trajectory.

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 assessment study and viable solutions have been identified.

The Solar Orbiter will achieve its wide-ranging aims with a suite of sophisticated instruments, optimised to meet the solar and heliospheric science objectives: *Heliospheric in-situ instruments*: solar wind analyser, radio and plasma wave analyser, magnetometer, energetic particle

detectors, interplanetary dust detector, neutral particle detector, solar neutron detector. *Solar remote-sensing instruments*: Extreme ultraviolet (EUV) full-Sun and high resolution imager, high-resolution EUV spectrometer, high-resolution visible-light telescope and magnetograph, EUV and visible-light coronagraph, radiometer. The payload mass is 130 kg.

MPAE has been a major player in the design of this mission and its objectives, and intends to participate in it with key instrumentation. Technology studies have been started at the institute and critical instrument components are presently being developed.

(E. Marsch, R. Schwenn)

## Stars and solar-stellar connection

### Surface distribution of erupting magnetic flux tubes in close binaries

Observations of close binaries employing indirect surface imaging techniques indicate the existence of preferred longitudes in the azimuthal distribution of starspots. Since the dependence on system period suggests that this non-uniformity is caused by the proximity of the companion star, we have explored whether tidal effects are capable to modify the instability and dynamics of rising magnetic flux loops, which give rise to starspots upon emergence at the stellar surface. We consider both the tidal forces and the deformation of the active star in lowest-order perturbation theory.

The linear stability of toroidal flux tubes in mechanical equilibrium has been studied analytically while the nonlinear evolution of unstable, rising loops has been investigated by numerical simulations. We find that, in the case of fast-rotating binaries with periods of a few days, magnetic flux tubes erupting at mid latitudes show a considerably inhomogeneous longitudinal distribution; the degree of azimuthal non-uniformity increases with decreasing rotation period and, therefore, binary separation. Our results thus substantiate the concept that the appearance of starspots at preferred longitudes of an active component is due to the influence of the companion star (Fig. 34).

(V. Holzwarth, M. Schüssler)

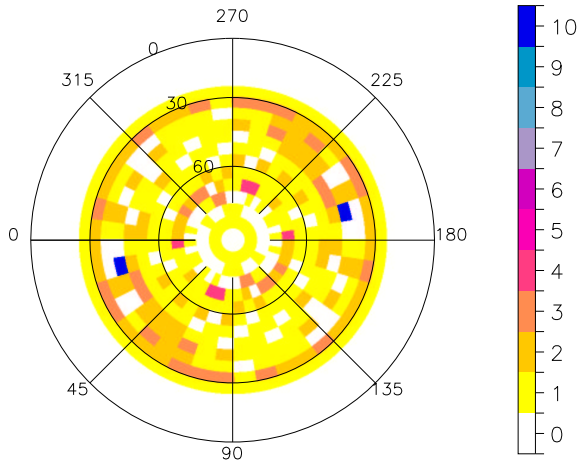


Fig. 34: Polar projection of a surface distribution of erupting magnetic flux tubes on a close binary, indicated by colour-coding (dark: many spots). The direction towards the companion star ( $\phi = 0$ ) and its anti-direction are clearly preferred spot longitudes.

### Dynamics of magnetic flux tubes in evolved stars

We have applied the concepts for storage, instability and emergence of magnetic flux, which have been successfully used for understanding the origin of sunspots, to evolved stars. Magnetic flux is stored and amplified by a dynamo process near

ical field strength is exceeded, instabilities lead to rising flux loops which, upon emergence at the stellar surface, form bipolar magnetic regions and large-scale coronal loops (Fig. 35).

By considering the stability, dynamics, and rise of magnetic flux tubes along evolutionary sequences of stellar models we find that flux loops become trapped in the stellar interior when the depth of the convective envelope exceeds about 80% of the stellar radius in the course of the star's evolution toward the red giant branch. This trapping is caused by an increase of field line curvature at the loop summit, so that eventually the magnetic tension force dominates over the buoyancy force. The magnetic loops then find a stable equilibrium configuration within the convection zone. The transition from emerging to trapped flux tubes is close to the 'coronal dividing line' in the Hertzsprung-Russell, across which a strong decline of stellar coronal X-ray emission is observed. In the absence of large magnetically active regions at the stellar surface there are no extended X-ray-emitting coronal loops. We suggest that flux tube trapping is the cause for existence of the 'coronal dividing line'.

(V. Holzwarth, M. Schüssler)

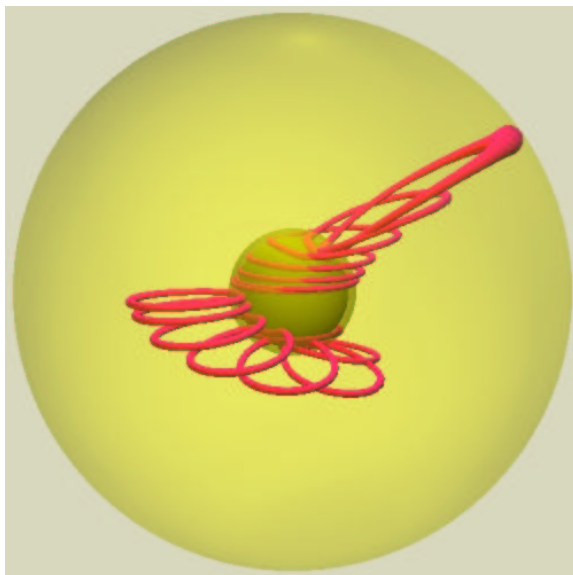


Fig. 35: Snapshots of an emerging flux tube (right side) and a trapped flux tube (left side) in a giant star.

the interface between the convection zone and the underlying radiative core of the star. Once a crit-

### A stream of particles from the $\beta$ Pictoris disc

Recently, a stream of particles originating from the direction of  $\beta$  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.

The theory of Solar System formation suggests that up to  $300 M_{\oplus}$  were ejected completely out of the Solar System by nascent giant planets. The same mechanism was also responsible for populating the Oort Cloud of comets. We show that scattering by a Jupiter-mass proto-planet hidden in the disc of  $\beta$  Pictoris gives excellent agreement with the observed properties of the stream. 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, S.K. Solanki)

### Size distribution of dust in circumstellar discs

Understanding size or mass distribution of dust particles in dust environments – from cometary tails or dusty planetary rings to circumstellar debris discs – is a key to essential physical processes operating in a particular system. Size distribution is not easy to retrieve, however. Derivation of it is usually only possible by combining various types of observational data with theoretical modeling that gives guidelines towards which type of size distribution to expect in one or another particular system.

Circumstellar debris discs represent a good example. We derive the size distribution in circumstellar debris discs, exemplified by the disc of  $\beta$  Pictoris, by modelling the collisional and dynamical evolution of the circumstellar dust. We also model the linear polarisation of the radiation of  $\beta$  Pictoris scattered by dust particles in the disc and show that the dynamically-justified size distribution explains the observed polarisation and colours of the disc much better than commonly assumed single power-law distributions. Although particular calculations were made for the  $\beta$  Pic disc, our basic qualitative conclusions directly apply to the debris discs in other Vega-type systems with similar optical depths.

(A.V. Krivov, N.A. Krivova, I. Mann)

### Fluffy dust aggregates in the shells of Herbig Ae/Be stars

Herbig Ae/Be (HAeBe) stars are young, pre-main-sequence stars of moderate mass ( $2 - 8 M_{\odot}$ ), representing early evolutionary stages of Vega-type systems. The objects of both kinds are surrounded by dust discs/shells and received widespread attention when recent observations provided evidence of planet formation in these discs. Circumstellar dust particles are thought to form by a coagulation of submicron-sized grains and are therefore expected to be fluffy aggregates of such subgrains. This brings up the question of how the grain porosity affects observational manifestations of the dust shells.

Monte Carlo simulations of polarised radiation transfer in the shells of Herbig Ae/Be stars are used to model various manifestations of dust. Effective Medium Theory and the Discrete Dipole

Approximation are utilised to describe the optical properties of circumstellar dust aggregates. Whereas porous particles provide generally a better explanation of available data, highly porous grains are unlikely to be abundant in the shells as they produce too low linear polarisation to account for the observations of the HAeBe stars.

(N.A. Krivova, H. Kimura, I. Mann, in collaboration with V.B. Il'in, University of St. Petersburg, Russia)

### Tests of the Einstein equivalence principle

Based on the assumption of the Einstein equivalence principle and the principle of general covariance general relativity describes the gravitational field successfully as a purely geometrical property of the four dimensional spacetime on Riemannian manifolds.

However, despite the so far remarkable accuracy in its experimental verification, general relativity remains a classical theory. So the necessity of finding a quantum mechanical description of the gravitational field implies the need to embed or to modify the above principles in a more general framework, which is one of the major challenges in modern theoretical physics.

In our project we investigate specific predictions of such a class of more general theories, the so called nonmetric theories of gravity. Within this framework theories based on e.g., a metric-affine geometry of spacetime predict that in a gravitational field a pair of orthogonal linear polarisation states of light propagates with different phase velocities. This gravity-induced birefringence could in principle be measured in local test experiments and, hence, violates the Einstein equivalence principle.

Therefore we have used polarisation measurements in solar spectral lines and of white dwarfs to constrain the essential coupling constants for this effect predicted by metric-affine gravity and other prototypes of nonmetric theories. With improved modelling techniques our results yielded a  $10^4$  times sharper limit than previous works, which possibly helped to rule out a candidate theory of this class.

(O. Preuss, S.K. Solanki, in collaboration with M. P. Haugan, Purdue University, West Lafayette, USA)

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

### Schwerpunktthema:

### Die Galileo Mission, neue Erkenntnisse über planetare Magnetosphären

(English version see page 58)

#### Einleitung

Mit der Mission Galileo hat ein neues Zeitalter in der Erforschung der äußeren Planeten unseres Sonnensystems begonnen. Erstmals in der Geschichte der Weltraumfahrt wurde eine von Menschenhand gebaute Raumsonde (Abb. 36) in die Umlaufbahn eines der Gasriesen in unserem Planetensystem eingeschossen.

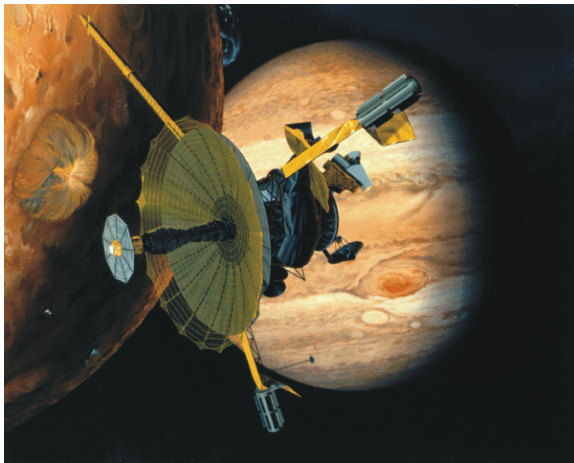


Abb. 36: Die Raumsonde Galileo erreicht Jupiter nach mehr als 6 Jahren Flug durch das Sonnensystem.

Seit Dezember 1995 umkreist Galileo Jupiter, den größten Planeten in unserem Sonnensystem, und übermittelt faszinierende Daten, und das, obwohl die Mission nicht vom Glück verfolgt war. Das Projekt Galileo wurde Ende der siebziger Jahre von der amerikanischen Weltraumorganisation NASA mit starker Beteiligung der deutschen Weltraumagentur DLR offiziell vorgeschlagen. Der ursprüngliche Starttermin war für 1982 vorgesehen. Nach mehreren Verzögerungen des technisch sehr anspruchsvollen Projekts sollte der Start 1986 erfolgen. Durch das Unglück der Raumfähre Challenger musste auch dieser Starttermin fallengelassen werden und erfolgte erst im Oktober 1989. Galileo konnte nun aber Ju-

piter nicht mehr direkt anfliegen, sondern musste mithilfe mehrfacher Vorbeiflüge an Venus und Erde Schwung holen (sog. *gravitational assists* durchführen). Erst im Dezember 1995 schwenkte Galileo in eine Umlaufbahn um Jupiter ein. Einen weiteren Rückschlag erlebte die Mission, als sich die für die Datenübertragung vorgesehene Hauptantenne der Raumsonde nicht öffnete. Jedoch konnten über eine Rekonfiguration der wissenschaftlichen Experimente und durch den Einsatz komplexer Datenkompressionsalgorithmen die wissenschaftlichen Zielsetzungen fast vollständig erreicht werden.

Galileo setzt sich aus der eigentlichen Raumsonde, dem sog. Galileo Orbiter und aus einer kleinen Atmosphärenkapsel, der Galileo Probe zusammen. Während der Orbiter seine elliptischen Umlaufbahnen um Jupiter zieht, wurde die Galileo Probe im Dezember 1995 in die Jupiteratmosphäre abgeworfen. Die wissenschaftliche Zielsetzung war die Untersuchung der äußeren Gasschichten des Planeten, deren chemischer Zusammensetzung und Dynamik. Zur wissenschaftlichen Instrumentierung der Probe gehörte auch ein Experiment zur Messung von Blitzen in der Jupiteratmosphäre, an dem das Max-Planck-Institut für Aeronomie (MPAE) maßgeblich beteiligt war. Die Mission des Orbiters wurde aufgrund der hervorragenden Qualität der von ihr gelieferten wissenschaftlichen Daten inzwischen mehrfach verlängert. Obwohl die Sonde im Jupitersystem einer extrem hohen Strahlungsbelastung ausgesetzt ist, arbeiten sie und ihre wissenschaftlichen Experimente nach wie vor hervorragend (Stand 07/2002).

Die wissenschaftliche Nutzlast des Galileo Orbiters umfasst Experimente zur planetaren Erkundung des Jupiters und der Galileischen Monde. Dies sind i.w. in unterschiedlichen Wellenlängenbereichen arbeitende Kameras, teilweise mit spektroskopischen und interferometrischen Modulen (Abb. 37). Neben den klassischen planetaren Aufgabenstellungen ist ein Hauptziel des Galileo Orbiters aber auch die Erkundung der Magnetosphäre des Jupiters und die Wechselwirkung der magnetosphärischen Teilchenpopulation mit den in der Magnetosphäre umlaufenden Monden. Hierzu befinden sich an Bord des Orbiters eine Vielzahl von Experimenten zur Messung der elektromagnetischen Felder und Wellen sowie der ionisierten Materie. Einer der komplexen Senso-

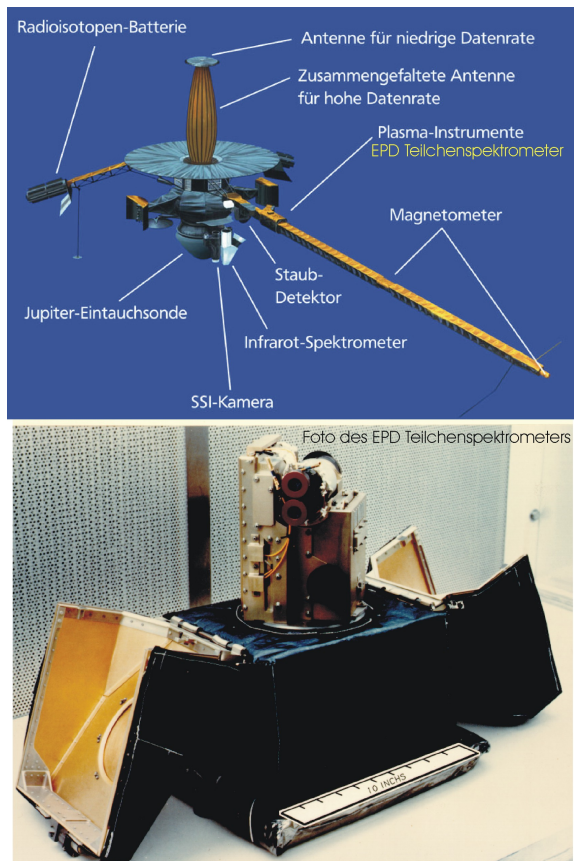


Abb. 37: Die wissenschaftlichen Instrumente auf der Raumsonde Galileo und ein Foto des Teilchenspektrometers EPD.

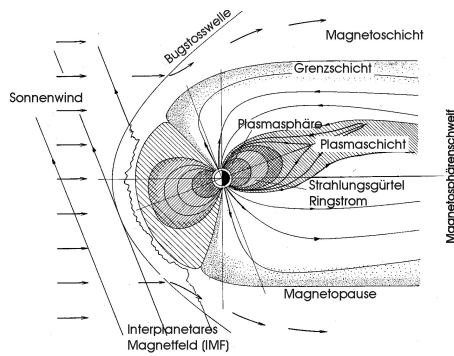
ren zur Messung der Verteilung von geladenen Teilchen wurde vom MPAE als Teil des EPD (Energetic Particles Detector) beigestellt. Neben dem MPAE, als einzigem europäischen Co-I-Institut, sind am EPD einige herausragende US-amerikanische Institutionen beteiligt. EPD misst die energiereiche Elektronen- und Ionenkomponente der Jupitermagnetosphäre, Teilchen mit Energien von einigen 10 Kiloelektronenvolt (keV) bis zu einigen Megaelektronenvolt (MeV), die den Hauptteil der Energiedichte der Magnetosphäre tragen und damit wesentlich für die in ihr ablaufenden dynamischen Prozesse sind. Die Ionen in diesem Energiebereich haben Geschwindigkeiten von einigen tausend bis einigen zehntausend Kilometer pro Sekunde, die Elektronen erreichen bereits einen wesentlichen Bruchteil der Lichtgeschwindigkeit. Der Nachweis dieser schnellen Teilchen im Weltraum stellt messtechnisch höchste Anforderungen an die Experimente, besonders dann, wenn man, wie beim vom MPAE gebauten Experiment, nicht nur die Energie, sondern auch die Masse der Ionen bestimmen will. Gerade diese Bestimmung der Ionenart erlaubt es aber, die

unterschiedlichen Teilchenquellen und deren Ergebigkeit zu charakterisieren. Da EPD zudem die Teilchenverteilung in allen Raumrichtungen misst, d.h. auch die Flugrichtung der Teilchen ermittelt werden kann, bietet das Instrument erstmalig die Möglichkeit, die wesentlichen Teilchentransport- und Beschleunigungsprozesse in der Jupitermagnetosphäre zu untersuchen.

## Die Magnetosphäre

Die Planeten unseres Sonnensystems sind in einem von der expandierenden Sonnenkorona herrührenden Plasmastrom eingebettet. Dieser sogenannte Sonnenwind trägt auch einen Teil des Sonnenmagnetfeldes in den interplanetaren Raum. Bei Planeten mit internem Magnetfeld, wie etwa Erde, Merkur, Jupiter, Saturn, Uranus und Neptun führen komplexe Wechselwirkungen mit dem anströmenden magnetisierten Sonnenwindplasma zur Induktion großräumiger Ströme, die das planetare Magnetfeld auf den planetnahen Raum begrenzen. Die sich ausbildende magnetische Struktur wird Magnetosphäre genannt. Mit den ersten Satellitenstarts Ende der fünfziger Jahre konnte die Existenz der Erdmagnetosphäre experimentell nachgewiesen werden. Nach vielen Jahren Beobachtungen sind die wesentlichen Elemente der Erdmagnetosphäre recht gut verstanden. Die Magnetopause als äußere Grenzschicht trennt das planetare Feld, zumindest teilweise, vom Sonnenwind und dem interplanetaren Magnetfeld (IMF, *interplanetary magnetic field*). Die der Sonne zugewandte Seite der Magnetosphäre wird vom Sonnenwind komprimiert. Der momentane Abstand der Magnetopause von der Erde ist vom Druck des Sonnenwindes abhängig und damit stark variabel; im Durchschnitt beträgt er etwa 10 Erdradien  $R_E$  ( $1 R_E = 6371 \text{ km}$ ), wie in Abb. 38 angedeutet. Zur anderen Seite wird das planetare Magnetfeld als so genannter Magnetosphärenschweif in den interplanetaren Raum hinausgezogen. Im Zentrum des Schweifes bildet sich eine Stromschicht aus, die entgegengesetzt gerichtete Magnetfeldlinien voneinander trennt. Hier lagert sich auch eine Schicht energiereicher Teilchen, die Plasmaschicht, an. Die weiter andauernde intensive Erforschung der Erdmagnetosphäre (z.B. mit den noch in diesem Jahr startenden 4 Clustersatelliten) soll zu einem detaillierteren Verständnis der in der Magnetosphäre ablaufenden Prozesse führen. Die Frage, wie Energie, Masse und Impuls aus dem Sonnenwind in die Magnetosphäre überführt werden und unter welchen Bedingungen dies besonders effektiv geschieht,

### Modell der Erdmagnetosphäre



### Modell der Jupitermagnetosphäre

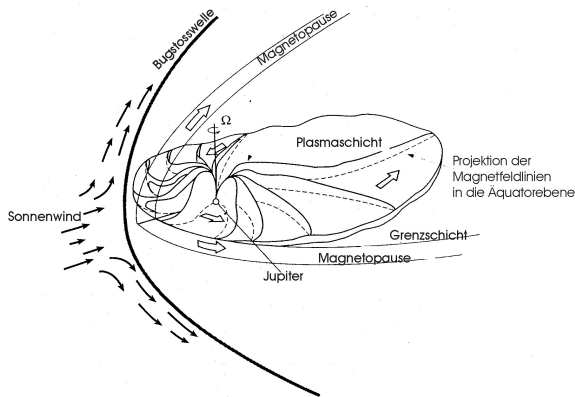


Abb. 38: Schematische Darstellungen von Erd- und Jupitermagnetosphäre.

steht dabei im Vordergrund. Weiterhin werden im sog. Weltraumwetterprogramm die Auswirkungen von transienten in der Sonnenkorona ablaufenden Störungen auf die Erdmagnetosphäre untersucht. Diese können zu sogenannten geomagnetischen Teilstürmen führen, d.h. zu impulsartiger Freisetzung von im Schweif gespeicherter Energie. Eine Verstärkung von Polarlichtern, aber auch erhebliche Störungen in Navigationssystemen oder in der Stromversorgung können die Folgen sein. Ein wesentlicher Bestandteil des neu ins Leben gerufenen NASA-Programms "Living with a Star" wird der Erforschung dieser komplexen Vorgänge gewidmet sein und der Magnetosphärenforschung neue Impulse geben.

Darüber hinaus ist die Untersuchung der Physik der Erdmagnetosphäre durchaus von allgemeinem astrophysikalischen Interesse. Magnetosphären umgeben nicht nur unseren Planeten. Die magnetischen Strukturen von anderen Himmelskörpern, wie die der Heliosphäre selbst, aber auch die von Pulsaren oder Radiogalaxien sind of-

fenbar verblüffend ähnlich. Bisher war aber nur die Magnetosphäre der Erde einer direkten, detaillierten Beobachtung vor Ort zugänglich. Damit basieren unsere Kenntnisse auf einem einzigen Spezialfall. Die wenigen Vorbeiflüge an anderen Planeten konnten nur sehr begrenzte Momentaufnahmen von deren Magnetosphären liefern.

Die Raumsonde Galileo eröffnet nun zum ersten Mal die Möglichkeit, unsere Vorstellungen in einer anderen Magnetosphäre mittels detaillierter Langzeitbeobachtungen zu testen und zwar in einer überaus interessanten und im Vergleich zur Erdmagnetosphäre in vieler Hinsicht völlig andersartigen Umgebung.

### Magnetosphären im Vergleich

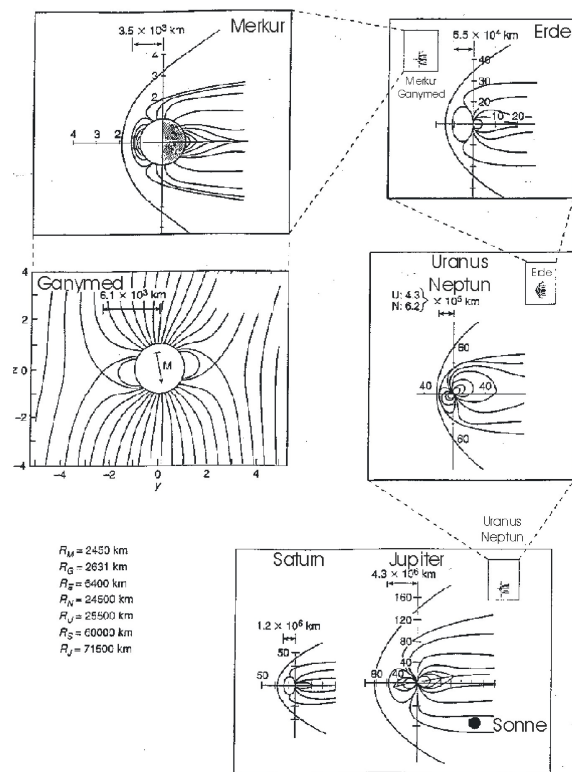


Abb. 39: Alle bekannten Magnetosphären unseres Sonnensystems im Größenvergleich.

Die Jupitermagnetosphäre, deren Existenz zunächst indirekt aus erdgebundenen Beobachtungen geschlossen wurde, ist die größte Magnetosphäre in unserem Sonnensystem (Abb. 39). Könnte man sie mit dem bloßen Auge sehen, würde sie einem Beobachter auf der Erde 4 Mal größer erscheinen als die Sonnenscheibe oder der Vollmond. Auf der sonnenzugewandten Seite erreicht sie eine Ausdehnung von zeitweilig mehr als 100 Jupiterradien  $R_J$  ( $1 R_J = 71400$  km). Zudem ist Jupiter ein vergleichsweise schnell

rotierender Planet. So dauert ein Jupitertag nur ca. 10 Stunden. Die Teilchenpopulation in der Erdmagnetosphäre wird vorwiegend durch den Sonnenwind, in geringerem Umfang durch die Atmosphäre gespeist. In der Jupitermagnetosphäre hingegen ist der innerste Galileische Mond Io eine gigantische vulkanische Teilchenquelle, die etwa 1 Tonne Material pro Sekunde, vor allem  $\text{SO}_2$ , ausstößt. Dieses Material wird in der Magnetosphäre dissoziiert, ionisiert und beschleunigt. Sowohl die schnelle Rotation als auch die internen Plasmaquellen haben weitreichende Auswirkungen auf die Struktur und Topologie der Jupitermagnetosphäre.

Bereits aus den ersten Vorbeifügen von Raumsonden Anfang der siebziger Jahre gab es Anhaltspunkte, dass das magnetosphärische Plasma und die energiereicheren geladenen Teilchen durch die enorme Zentrifugalkraft weit nach draußen gezogen werden und sich in der Äquatorebene des Planeten konzentrieren. Es bildet sich eine mit Jupiter mitrotierende pfannkuchenartige Plasmaschicht aus. Da die Rotationsachse von Jupiter mit seiner magnetischen Achse einen Winkel von  $9,6^\circ$  bildet, bewegt sich diese Plasmaschicht für einen raumfesten Beobachter auf und ab. Eine detailliertere Untersuchung dieser topologischen Struktur und der darin ablaufenden plasmaphysikalischen Prozesse wurde jedoch erst jetzt mit der Galileo-Mission möglich.

### Globale Bewegung energiereicher Teilchen in der Äquatorebene des Planeten

Im Dezember 1995 durchquerte Galileo die Magnetopause der Jupitermagnetosphäre. Seitdem hat die Raumsonde Jupiter 32 Mal umrundet und dabei vor allem Jupiters Magnetosphärenschweif erkundet. Die dabei durchgeführten Beobachtungen bilden eine Datenbasis von enormem Ausmaß.

Eine der vor Galileo ungeklärten fundamentalen Probleme zum Verständnis der Jupitermagnetosphäre ist die Frage nach der globalen Teilchenbewegung, dem sog. *global flow pattern*. Vor Galileo hatte man lediglich bruchstückhaft Teilchengeschwindigkeiten entlang der Bahn einer Raumsonde messen können, die in wenigen Tagen die Planetenumgebung wieder verlassen hat. Nun bietet sich erstmals die Möglichkeit, diese Geschwindigkeitsfelder über einen langen Zeitraum genauer zu bestimmen. Basis für die Berechnungen ist die Analyse der richtungsaufgelösten EPD-Daten mittels Kugelflächenfunktionen. Dabei wird der gerichtete differentielle Teilchenfluss

$j(E, \theta, \varphi)$  durch normierte Legendre-Polynome  $P_{nm}$  beschrieben. Die resultierenden Richtungsanisotropien  $A_{nm}$  energiereicher Teilchen charakterisieren die Teilchenbewegung. Die Anisotropie erster Ordnung  $A_{1m}$  beschreibt eine monodirektionale Bewegung, also einen Fluss von Teilchen aus einer bestimmten Richtung. Die Stärke ist durch die Amplitude  $A_1$  bestimmt. Diese Anisotropie erster Ordnung lässt sich durch eine Kombination verschiedener physikalischer Prozesse erklären, von denen hier nur die Bewegung in gekreuzten elektrischen und magnetischen Feldern, die Bewegung in einem vorhandenen Intensitätsgradienten und die feldlinien-parallele Bewegung erwähnt werden sollen. Mit Hilfe von EPD-Daten wurde es ermöglicht, die Anteile dieser einzelnen Komponenten zu bestimmen. Anisotropien für verschiedene Ionensorten und bei verschiedenen Energien ließen die Schlussfolgerung zu, dass die Bewegung in gekreuzten Feldern den größten Anteil hat. Die Geschwindigkeit der energiereichen Teilchen senkrecht zum Magnetfeld kann somit direkt aus der Anisotropie erster Ordnung bestimmt werden. Abb. 40 zeigt die so ermittelten Geschwindigkeitsvektoren in der Äquatorebene von Jupiter, normiert auf die Rotationsgeschwindigkeit des Planeten selbst, der sog. „Korotationsgeschwindigkeit“.

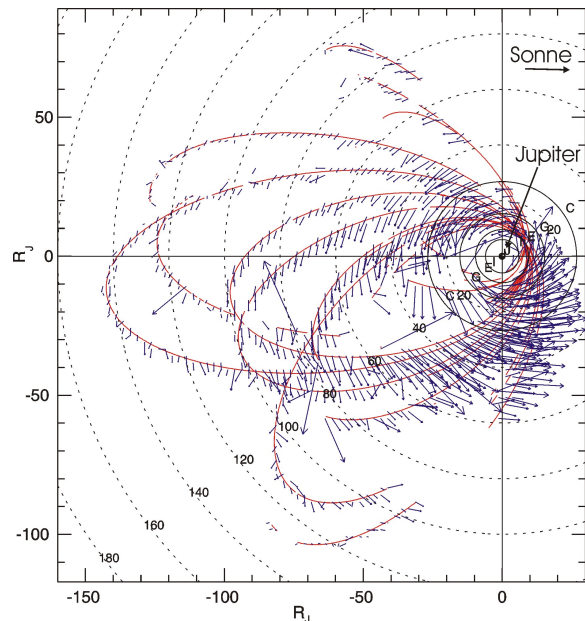


Abb. 40: Globale Geschwindigkeitsverteilungen in der Äquatorebene der Jupitermagnetosphäre. Jupiter befindet sich im Zentrum des Koordinatensystems, dessen x-Achse zur Sonne zeigt.

Die Vektoren zeigen in erster Näherung in Rotationsrichtung des Planeten (Korotationsrichtung),

auch bei Abständen von mehr als  $100 R_J$  im Magnetosphärenschweif. Zusätzlich findet man radiale Komponenten, die lokalzeitabhängig sind. Deutlich sind auf der Morgenseite des Planeten höhere Geschwindigkeiten zu erkennen als bei vergleichbaren Abständen auf der Abendseite. Auf der Morgenseite zeigen die Radialkomponenten vom Planeten weg, auf der Abendseite zum Planeten hin. Diese in-situ-Messungen können nun zum Aufbau von Modellen oder Simulationen der Jupitermagnetosphäre herangezogen werden.

### Dynamische Prozesse in der Jupitermagnetosphäre

Die Jupitermagnetosphäre ist offenbar quasiperiodischen Vorgängen unterworfen, die auf Zeitskalen von 2 bis 3 Tagen ablaufen. In der mittleren Magnetosphäre zeigen sie sich als Variationen des Geschwindigkeitsfeldes und der Plasmaschichtdicke, in der äußeren Magnetosphärenschweifregion als impulsartige Teilchenströme (*Flow Bursts*). Diese *Bursts* haben sich als sehr aussagekräftig in Hinblick auf die in der Jupitermagnetosphäre ablaufenden Prozesse erwiesen. Sie zeigen eine sehr ausgeprägte Lokalzeitverteilung (*local time LT*) mit einem deutlichen Häufigkeitsmaximum zwischen etwa 01:00 LT und 05:00 LT. In diesem Lokalzeitbereich existiert bei etwa  $80 R_J$  auch eine klare Trennungslinie in der Richtungsverteilung der *Bursts*. Innerhalb dieser Linie sind die *Bursts* in der Regel zu Jupiter hin gerichtet, jenseits der Linie strömen sie von Jupiter ab. Ein Beispiel dieser quasiperiodischen *Bursts* ist in Abb. 41 gezeigt. Damit scheinen sich frühere theoretische Modelle zu bestätigen, wonach sich in diesem Lokalzeitbereich der Jupitermagnetosphäre eine quasi-stationäre magnetische Rekonnexionslinie ausbildet. Eine umfangreiche Fallstudie zeigt, dass die *Flow Bursts* Teil eines großskaligen Prozesses sind, der weitgehende Analogien zu den von der Erde bekannten geomagnetischen Teilstürmen aufweist.

Anders als bei der Erde werden diese Prozesse vermutlich aber nicht durch die Wechselwirkung mit dem Sonnenwind getrieben, sondern wesentlich durch die dem Jupitersystem inhärenten Energie- und Massenquellen bestimmt. Ein denkbare Szenario ist die Beladung magnetischer Flussröhren mit Plasma, bis deren magnetische Spannung die durch die schnelle Rotation des Jupiters auftretenden Kräfte nicht länger kompensieren kann. Die Magnetfeldstruktur bricht auf und das Plasma strömt in Form von sog. Plasmoiden, d.h. von der Magnetosphäre dann vollständig abgetrennten

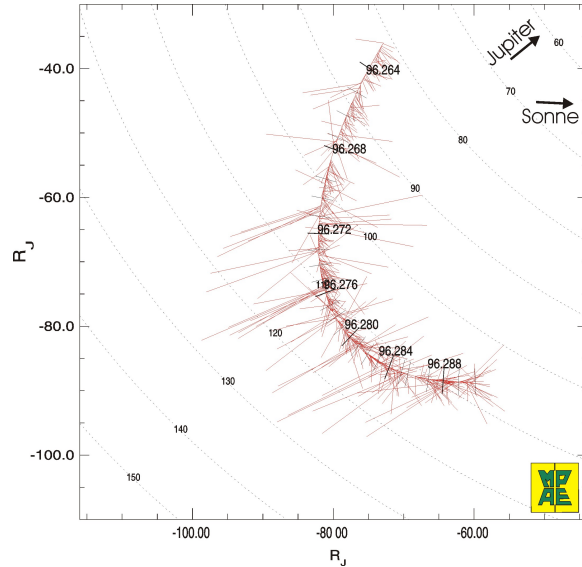


Abb. 41: Quasiperiodisch auftretende Teilchenströme im Magnetosphärenschweif von Jupiter. Die Länge der Vektoren sind ein Maß für die Stärke der *Flow Bursts*, die in diesem Beispiel im wesentlichen von Jupiter weg radial nach außen sind.

Plasmablasen, schweifwärts ab.

### Phasenraumdichten in der inneren Jupitermagnetosphäre

Auf den nunmehr 32 Umläufen der Raumsonde Galileo um den Planeten Jupiter bot sich die Gelegenheit, die Verteilungsfunktionen der energiereichen Ionen in der inneren Magnetosphäre detailliert zu untersuchen. Von besonderer Wichtigkeit für die Beschreibung physikalischer Prozesse ist dabei die Phasenraumdicke. Sie beschreibt die Anzahl energiereicher Ionen pro Volumen- und Impulseinheit. Bestimmte plasmaphysikalische Prozesse, wie zum Beispiel die radiale Diffusion, lassen sich besonders gut durch die Phasenraumdicke und die dafür geltenden Axiome der Hamiltonschen Mechanik beschreiben.

Die Phasenraumdicke wird berechnet, indem man den gemessenen differentiellen gerichteten Teilchenfluss  $j$  durch das Quadrat des Impulses des einfallenden Teilchens  $p^2$  dividiert. Um die berechnete Phasenraumdicke direkt für die Analyse radialer Diffusionsprozesse und zur Bestimmung von Quell- und Verlustregionen heranziehen zu können, wird die Phasenraumdicke als Funktion sogenannter adiabatischer Invarianten angegeben. Anstatt den Ort und den Impuls für jedes einzelne Teilchen zu bestimmen, definieren bestimmte

Werte der drei adiabatischen Invarianten eine sogenannte „Driftschale“, die die Teilchen ohne das Wirken externer Einflüsse nicht verlassen können. Die Teilchen werden damit nicht mehr als einzelne Partikel behandelt, sondern als ein Ensemble mit bestimmten Eigenschaften. In einem dipolähnlichen Magnetfeld werden die drei adiabatischen Invarianten wie folgt definiert:

- Das magnetische Moment  $\mu$  während der Gyration eines Teilchens ist konstant.
- Das Integral über den parallelen Impuls  $J$  entlang der Bahn des Teilchens zwischen den Spiegelpunkten ist konstant.
- Der totale von einer Driftschale eingeschlossene magnetische Fluss  $F$  ist konstant.

Ein radialer Diffusionsprozess sowie globale Quell- und Verlustprozesse beeinflussen nur die dritte adiabatische Invariante, die Diffusionsgleichung kann daher eindimensional betrachtet werden. Zur Lösung der Diffusionsgleichung ist es notwendig, die Phasenraumdichte für konstante Werte der 1. und 2. Invarianten zu berechnen. Die Abb. 42 zeigt den Verlauf der Phasenraumdichten von Teilchen mit unterschiedlichen Werten für die adiabatische Invariante  $\mu$  und der von der Invarianten  $J$  abgeleiteten Größe  $K$  ( $K = J/(2 \cdot \sqrt{2m_0\mu})$ ) als Funktion des McIlwain-Parameters  $L$ . Dieser  $L$ -Wert definiert den radialen Abstand der Driftschale vom Zentrum des Planeten und entspricht in einem reinen Dipolfeld dem Verlauf der Magnetfeldlinien. Der Anstieg der Phasenraumdichte mit zunehmendem  $L$  bedeutet, dass die Quelle der energiereichen Teilchen außerhalb von 15  $R_J$  liegt. Niederenergetische Plasmateilchen, die durch Photoionisation oder Sputtering bei Io oder in der Jupiteratmosphäre produziert werden, wandern für EPD unsichtbar in die mittlere bis äußere Region der Jupitermagnetosphäre, wo sie beschleunigt werden und als energiereiche Teilchen wieder in die innere Jupitermagnetosphäre gelangen. Einen geringen Einfluss auf die Population energiereicher Teilchen hat der Jupitermond Europa. Die Phasenraumdichten bei  $L=9,5$ , der Position von Europa, zeigen kaum Hinweise auf starke Verlust- oder Quellprozesse. Es kann angenommen werden, dass sich die Verluste bei Europa auf den sog. *satellite sweeping*-Effekt, der Vernichtung von Teilchen durch Stöße mit dem Mond, beschränken. Anders ist die Situation bei Io. Der starke Anstieg der Phasenraumdichte zwischen  $L=6$  und  $L=7,5$ , also außerhalb der Umlaufbahn von Io, lässt auf einen effizienten Verlustmechanismus schließen. In Frage kommt ein Verlustprozess durch starke Pitchwinkel-Diffusion, der die

energiereichen Teilchen in den Verlustkegel streut. Innerhalb der Umlaufbahn von Io scheinen Verlustprozesse wieder eine untergeordnete Rolle zu spielen. In diesem Bereich ist die radiale Diffusion wieder der dominierende Prozess, der die Phasenraumdichte mit abnehmendem Abstand kleiner werden lässt.

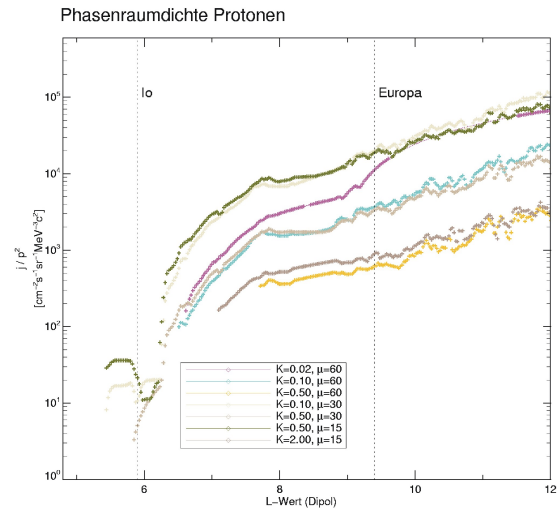


Abb. 42: Phasenraumdichten  $j/p^2$  als Funktion des McIlwain-Parameters  $L$  in der inneren Jupitermagnetosphäre. Gezeigt werden Daten des EPD-Teilchenspektrometers auf der Raumsonde Galileo für den Zeitraum Dezember 1995 bis Dezember 1999.

### Wechselwirkung zwischen der Jupitermagnetosphäre und den Monden

Ein sehr interessantes Teilgebiet der Magnetosphärenphysik ist die Untersuchung der überaus komplexen Wechselwirkung zwischen der Magnetosphäre und den im Strom der Teilchen eingebetteten Monde des Jupitersystems. Teilchenverteilungen energiereicher Ionen und Elektronen können hierbei sehr gut zur Diagnostik der Wechselwirkung herangezogen werden, da sie weniger durch auftretende elektrische Felder beeinflusst werden als niederenergetische Teilchen. Ihre größeren Gyroradien bieten die Möglichkeit, bereits weit vom Mond entfernt dessen Einfluss auf die Teilchenverteilungen zu messen. So kann man beispielsweise die magnetische Topologie des Mondes ebenso wie feldlinienparallelen Iontentransport in der Nähe des Mondes studieren. Erreichen die energiereichen geladenen Teilchen die Oberfläche des Mondes, so schlagen sie dort Sekundärteilchen aus der Oberfläche heraus (*Sputtering*). Indem man diese Sekundärteilchen analysiert, ist

indirekt sogar Oberflächendiagnostik möglich. Im Folgenden sollen einige Beispiele solcher Analysen gegeben werden.

### Io und Io-Torus

Die Bahn der Raumsonde Galileo ermöglichte eine eingehende Analyse der plasmaphysikalischen Vorgänge im Jupiter-umspannenden Io-Torus. Dazu wurden die Verteilungen energiereicher Ionen mit hoher Zeit- und Richtungsauflösung bestimmt. Aus den Charakteristika der Beobachtungen, wie z.B. herabgesetzte Teilchenflüsse entlang der Richtung des Jupitermagnetfeldes und eine Verarmung von Sauerstoff- und Schwefelionen senkrecht zum Magnetfeld, können dann Rückschlüsse auf die Prozesse im Io-Torus gezogen werden (Abb. 43). Liegen bei der Pendelbewegung der geladenen energiereichen Teilchen in einem planetaren Magnetfeld (*bounce motion*) die Spiegelpunkte innerhalb der Jupiteratmosphäre, so werden diese feldlinienparallelen Teilchen nicht mehr gespiegelt und gehen verloren. Die beobachtete Verarmung von Teil-

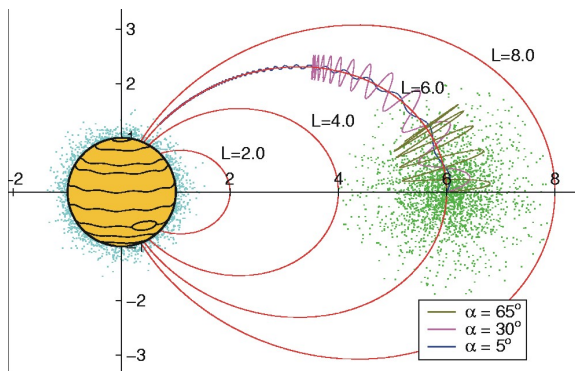


Abb. 43: Teilchenbewegung entlang einer Dipolfeldlinie und Darstellung der Wechselwirkung für 3 verschiedene Pitchwinkel  $\alpha$  im Io-Torus. Dabei ist der Pitchwinkel der Winkel zwischen der Magnetfeldrichtung und dem Vektor der Teilchengeschwindigkeit.

chen senkrecht zum Magnetfeld hingegen kann durch die Wechselwirkung dieser Teilchen mit dem Neutralgas-Torus erklärt werden, z. B. durch einen Ladungstausch zwischen geladenen Teilchen und neutralen Torusteilchen. Mit der Kenntnis der entsprechenden Wirkungsquerschnitte kann damit die Neutraldichte im Io-Torus auf  $18 - 25 \text{ cm}^{-3}$  abgeschätzt werden.

Ein weiteres *Highlight* aus den Beobachtungen des EPD-Experiments ist die Entdeckung von sehr intensiven Elektronenstrahlen (*electron beams*) ent-

lang der Magnetfeldlinien, die Io mit Jupiter verbinden (*Io fluxtube*). Die Energiedichte in diesen Strahlen ist so hoch, dass man damit Polarlichter in der Jupiteratmosphäre erzeugen kann. Diese Polarlichter wurden inzwischen mit dem Hubble Space Telescope beobachtet. Ionenstrahlen wurden nicht beobachtet. Aus einer schwachen Energieabhängigkeit der Elektronenstrahlen lässt sich auch ein oberes Limit für die Dichte der  $\text{SO}_2$ -Atmosphäre bestimmen.

### Ganymed

Die Raumsonde Galileo flog zwischen 1995 und 2000 insgesamt 4 Mal an Ganymed, dem größten Mond in unserem Sonnensystem, vorbei und machte dort eine Entdeckung der besonderen Art: Ganymed hat ein internes Magnetfeld und bildet seine eigene kleine Magnetosphäre innerhalb der Jupitermagnetosphäre. Diese ist etwa so groß wie die Magnetosphäre von Merkur (siehe Abb. 39). Identifiziert wurde die Ganymedmagnetosphäre durch Magnetfeld- und Plasmawellenmessungen. Messungen des EPD-Instruments zeigten, dass energiereiche Ionen in der Nähe des Mondes offensichtlich nicht mehr aus der sog. Korotationsrichtung (also mit Jupiter mitrotierend) kommen, sondern entlang der Ganymedfeldlinien teilweise auf dem Mond verloren gehen. Aus diesen Messungen konnte die Stärke des Ganymedmagnetfeldes auf der Oberfläche des Mondes bestimmt werden.

### Sputtering auf Ganymed und Europa

Aus dem gemessenen Energiespektrum magnetosphärischer Ionen wurde eine Abschätzung der Ionen-Sputteringrate von der Oberfläche der Monde Europa und Ganymed durchgeführt. Bei Ganymed zeigte sich, dass man aus der Ionenzusammensetzung und der massenabhängigen Sputterausbeute eine Gesamtproduktionsrate bestimmen konnte, die für die Erosion und Neustrukturierung der Oberfläche von Bedeutung ist. Auch im Falle Europa ermittelte man einen sehr effektiven Sputterprozess, der zu einer Umverteilung von Masse auf der Oberfläche beiträgt. Die abgeschätzte Netto-Erosionsrate von etwa 20 m pro 100 Mio. Jahre könnte wichtige Folgerungen bei der Altersbestimmung von Europas Eisoberfläche und einem darunter vermuteten Ozean mit flüssigem Wasser nach sich ziehen.

### Zukünftige Erforschung planetarer Magnetosphären

Die Auswertung der Galileo-Daten wird sicher noch viele Jahre in Anspruch nehmen und neue faszinierende Resultate aus der komplexen Welt des Jupitersystems liefern. Dieser reichhaltige Datensatz wird die Basis von Modellen und Simulationen sein. Dennoch werden viele Fragen offen bleiben müssen, die man mit einer Einzelsonde nicht beantworten kann. Im Dezember 2000 flog die Raumsonde Cassini auf ihrem Weg zu Saturn relativ nahe am Jupiter vorbei. Es wird damit möglich sein, mit zwei Raumsonden gleichzeitig das Jupitersystem zu untersuchen: Galileo weit innerhalb der Jupitermagnetosphäre und Cassini im interplanetaren Raum nahe der Magnetopause. Erstmals könnte so der Einfluss des interplanetaren Mediums auf die Jupitermagnetosphäre studiert werden. Des weiteren ist eine Mission zum Mond Europa in Vorbereitung, die eindeutig die Existenz eines unterirdischen Ozeans belegen oder widerlegen soll. Sollte ein solcher Ozean existieren, so drängt sich sofort die Frage nach primitivem Leben auf Europa auf, die dann mit Folgemissionen und Landungen auf Europa beantwortet werden soll. Pläne für solche Missionen existieren bereits. Ein weiterer Mosaikstein in der Erforschung der äußeren Planeten und planetarer Magnetosphären wird die Raumsonde Cassini werden, wenn sie im Jahre 2004 in eine Umlaufbahn um Saturn einschwenkt (Abb. 44). Geplant sind

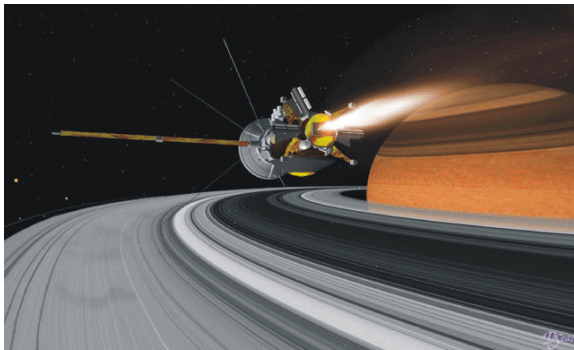


Abb. 44: Die Raumsonde Cassini – ein Meilenstein in der Erforschung des Ringplaneten Saturn.

78 Umläufe in einem Zeitraum von vier Jahren. Diese große Anzahl von Orbits ermöglicht eine sehr gute Datenabdeckung in der Saturnmagnetosphäre sowohl in Lokalzeit als auch in magnetischer Breite und Abstand. Bei Vorbeiflügen an verschiedenen Monden im Saturnsystem werden Messungen mit extrem guter Auflösung möglich sein. Insbesondere sind 44 Vorbeiflüge am Mond Titan geplant, der als einziger Mond in unse-

rem Sonnensystem eine sehr dichte Atmosphäre besitzt. Zusätzlich zum Orbiter wird eine Atmosphärenkapsel mit Namen Huygens auf dem Mond Titan abgesetzt werden. An einem Fallschirm wird Huygens durch die Atmosphäre rasen und u.a. erstmals Bilder der Titanoberfläche zur Erde zurücksenden. Damit ist die Magnetosphärenforschung jedoch nicht abgeschlossen. ESA plant momentan eine Mission zum Merkur, dem innersten Planeten in unserem Sonnensystem. Die Merkurmagnetosphäre ist einzigartig in unserem Sonnensystem, da das Fehlen einer nennenswerten Atmosphäre und Ionosphäre völlig andere Prozesse bei der Übertragung von Energie des Sonnenwindes auf das magnetosphärische Plasma erwarten lässt. Die sehr viel kleinere Dimension dieser Magnetosphäre eröffnet die Möglichkeit, plasmaphysikalische Prozesse auf kürzeren Zeitskalen zu untersuchen. Auch die Erforschung der Erdmagnetosphäre erlebt nach dem Start der Multisatellitenmission Cluster II eine Renaissance, da erstmals 4 Satelliten in einer Tetraeder-Konfiguration durch die Erdmagnetosphäre fliegen.

(N. Krupp, J. Woch, A. Lagg)

### Highlight:

### The Galileo Mission, new insights about planetary magnetospheres

#### Introduction

A new era in the exploration of the outer solar system has begun with the Galileo mission to Jupiter. For the first time ever a manmade space probe (Fig. 36) was put in orbit around a gas giant in our solar system.

Since December 1995 Galileo is orbiting Jupiter, the largest planet in our solar system. Since then fascinating data are received on Earth from Jupiter itself, from the Galilean satellites, and from the Jovian magnetosphere. Galileo has been approved at the end of the 1970's by NASA together with the German space agency DLR. Originally a launch was foreseen for 1982 but technical difficulties caused a delay by almost 4 years. Then in 1986 Galileo was scheduled for lift-off by one of the space shuttles but the Challenger catastrophe put the project again on hold for 3 additional years. Finally the spacecraft was launched in October 1989 onboard the space shuttle Atlantis. The delay caused also a change in the trajectory of the spacecraft. Three planetary swing-bys were necessary to reach the final target Jupiter. Galileo flew-by Venus and twice at Earth to gain energy



Fig. 36: Artistic view of the Galileo spacecraft approaching Jupiter after a 6 years journey through the interplanetary space.

by gravitational assists from those planets. In December 1995 Galileo was put into orbit around the largest planet in our solar system. Soon after, the scientists and engineers were faced with another problem. The high-gain antenna, built as a large umbrella, did not open and only the small low-gain antenna could be used for data transmission and communications. A complete reconfiguration of the spacecraft's flight software and an enormous effort of all instrument teams were necessary to save the mission.

Galileo consists of the main spacecraft (Galileo orbiter) and a small atmospheric probe (Galileo Probe) which was dropped into Jupiter's atmosphere to measure the cloud structure, chemical composition and other parameters as well as their variability. One of the scientific instruments onboard the probe was a lightning detector with significant contributions from MPAE. The outstanding results and healthiness of the spacecraft lead to several mission extensions between 1997 and 2003. Although the spacecraft has accumulated 4 times more radiation than it was designed for, everything is still working and the data quality is excellent (July 2002).

The scientific payload of the Galileo orbiter consists of a whole variety of camera systems for different wavelengths and sometimes spectrometric and interferometric capabilities to study the planet and its moons.

In addition particles and fields measurements are performed to study Jupiter's magnetosphere as a whole, and to study the interaction between magnetospheric plasma and the Galilean moons.

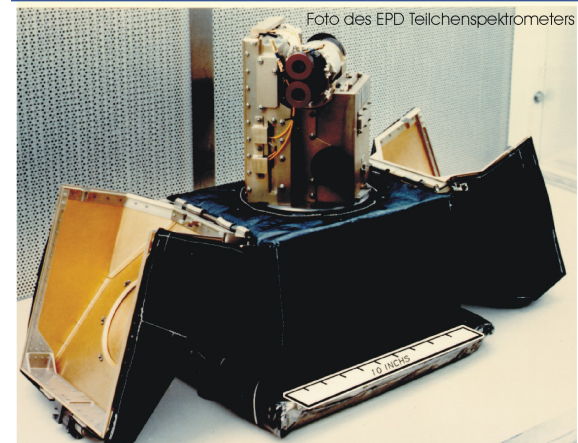
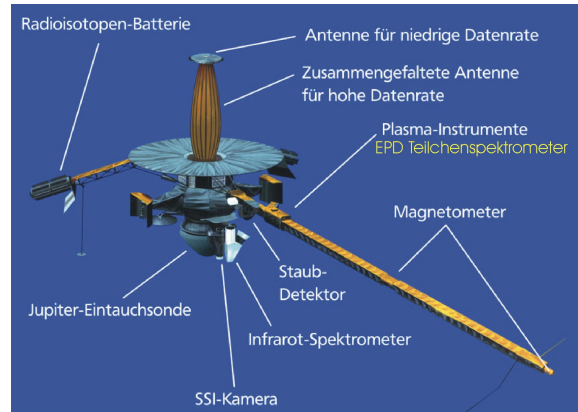


Fig. 37: Scientific payload of the Galileo spacecraft (top) and a picture of the Energetic Particles Detector (EPD) at the bottom.

One of the more complex sensors onboard was partly built at MPAE. The Energetic Particles Detector (EPD) is designed to measure the three-dimensional distributions of electrons and ions, separately, in the energy range between 10 keV and several MeV. These ions which have velocities of several 1000 to several 10000 km/s are very important to understand the dynamics in Jupiter's magnetosphere. Electrons with such energies reach a significant fraction of the speed of light. It is not easy to measure these particles in space and a well designed detector is necessary to distinguish not only the energy but also their mass and their incidence direction. The separation of different ion species and their three-dimensional distributions are indeed very important in Jupiter's magnetosphere and will be described below.

### The magnetosphere

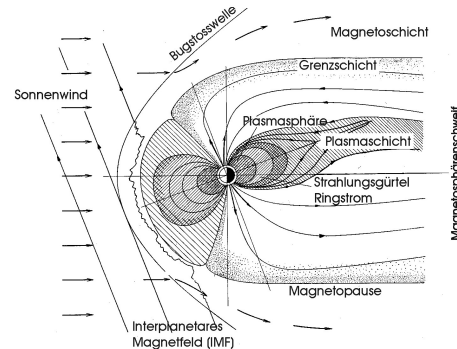
The planets of our solar system are embedded in the solar wind, a stream of particles which is

continuously leaving the corona of the Sun. The Sun's magnetic field is "frozen into" the solar wind and is carried outward from the Sun into interplanetary space. It is known that Mercury, Earth, Jupiter, Saturn, Uranus, and Neptune have their own magnetic field which interacts with the magnetized solar wind plasma. As a reaction, currents are induced and a cavity is formed which separates the internal planetary magnetic field from the interplanetary magnetic field. This cavity is called 'magnetosphere'. During the 1950's when the first satellites have been launched, the existence of the Earth's magnetosphere was proven. Today, the magnetosphere of the Earth is the best understood among all magnetospheres in our solar system. Key regions and processes could be identified. We know that the magnetopause which separates the planetary from the interplanetary magnetic field is approximately 10 Earth radii  $R_E$  ( $1 R_E = 6371 \text{ km}$ ) away from the Earth center (see Fig. 38) in the subsolar hemisphere. In the opposite direction, the so-called magnetotail is stretched into interplanetary space hundreds of Earth radii. In the center of the magnetotail a current sheet is formed to separate magnetic field lines with opposite directions. The current sheet is surrounded by a plasma sheet where most of the plasma and energetic charged particles are found. Even if most of the key regions are known, the investigation of the Earth's magnetosphere is far from being completed. Especially the Cluster mission with 4 identical satellites forming a tetrahedron configuration will help to understand in much more detail the dynamical processes in the system. The question of mass, energy and momentum transfer from the solar wind into the magnetosphere is only one of the scientific goals of Cluster. Another main goal is the investigation of space weather where transient phenomena occurring in the solar corona and their influence on the Earth are studied. One of these phenomena is the better understanding of geomagnetic substorms where stored energy in the magnetotail is released explosively. As a consequence the polar light is enhanced and navigation systems could also be affected. Therefore it is very important to understand these processes. A new program selected by NASA called "Living with a Star" will focus on investigating these complex phenomena. Furthermore it is very important to study the Earth's magnetosphere from an astrophysical point of view.

Magnetospheres are found not only at Earth but at other planets and even our solar system as a whole, called the heliosphere, has a very similar

magnetic structure in the interstellar wind. This is true also for systems in the galaxy. In the past the Earth's magnetosphere was the only magnetosphere where detailed in-situ measurements were possible. Most of the knowledge is based on measurements near Earth. Only a few planetary flybys at other planets provided snapshots from other planetary magnetospheres. The mission Galileo offered for the first time the possibility to study another magnetosphere on longer time scales and to compare the results obtained in Jupiter's magnetosphere with those from Earth.

### Modell der Erdmagnetosphäre



### Modell der Jupitermagnetosphäre

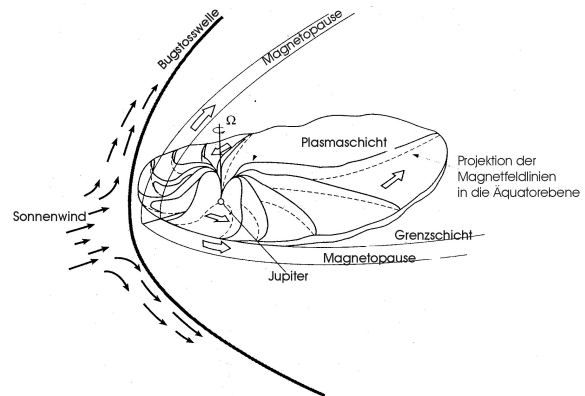


Fig. 38: Schematics of the magnetospheres of Earth and Jupiter.

The Jovian magnetosphere, known from Earth-based radio observations since the 1950's, is the largest magnetosphere in our solar system (see the comparison in Fig. 39). If visible, it would be the largest object in the sky, 4 times larger as the moon or the solar disk. The subsolar distance of the magnetopause from Jupiter can be as far as 100 Jovian radii  $R_J$  ( $1 R_J = 71400 \text{ km}$ ). In addition, Jupiter is a very fast rotator. A Jovian day is only 10 hours long. From Earth we know that the solar wind and the atmosphere are sources

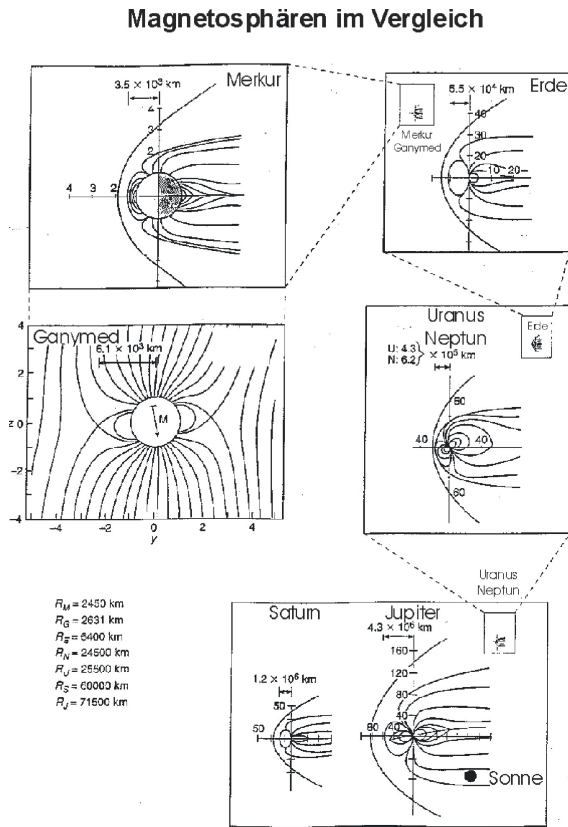


Fig. 39: All known magnetospheres of our solar system and their sizes in comparison.

for the particle population in the magnetosphere. Jupiter's main particle source, however, is in the inner magnetosphere. One of the Galilean moons, Io, the volcanically most active body in the solar system is a very powerful source. Approximately 1 ton each second of material is released into the magnetosphere from that moon. This material, mostly  $\text{SO}_2$ , is being dissociated, ionised, and accelerated in the magnetosphere. This enormous particle source as well as the fast planetary rotation influences the magnetospheric topology and particle motion substantially. Already the first flybys in the 1970's confirmed that the plasma is concentrated in an equatorial pancake-like disk caused by the centrifugal force which stretches the magnetic field lines. The system is even more complex because of the dipole tilt of 9.6 degrees relative to Jupiter's rotation axis. The plasma disk wobbles up and down for an observer fixed at a given latitude in Jupiter's magnetosphere. A detailed study of this configuration was only partly possible before the Galileo era.

### Global motion of energetic particles in Jupiter's equatorial plane

Since December 1995 Galileo is orbiting Jupiter. Since then 32 orbits were performed by the spacecraft. Most of the apogees were in the Jovian magnetotail. The data base of these measurements is unique. One of the unanswered questions to understand Jupiter's magnetosphere before Galileo was the global particle motion, the so-called "global flow pattern". From the flyby missions the particle velocities were only partly known along one single trajectory. With the Galileo data set it is now possible to determine velocity fields in Jupiter's equatorial plane for an extended period of time. To do this the data set of the above described EPD instrument has been used. Spherical harmonic analysis of the directionally resolved particle distributions was used to calculate the velocity fields. The differential particle flux  $j(E, \theta, \phi)$  was described by normalised Legendre polynomials  $P_{nm}$ . The resulting directional anisotropy  $A_{nm}$  is a direct measure of the particle motion. The first-order coefficients  $A_{1m}$  represent particles from one direction, i.e., a particle flow direction. The first-order anisotropy amplitude  $A_1$  determines the speed itself. The first-order anisotropy can be caused by several physical processes like  $E \times B$ -drift, intensity gradients or field-parallel motion. The capabilities of the EPD instrument allowed separating these effects from each other. From the fact that various ion species in different energy ranges showed the same flow velocities it could be concluded that  $E \times B$ -drift is the dominant component of the anisotropy. Fig. 40 shows the global flow pattern in Jupiter's equatorial plane. The flow vectors are normalised to the rigid rotation of the planet at a given distance, the so-called corotation velocity. The deduced flow vectors point predominantly in corotation direction with smaller components in the radial direction. A large dawn-dusk asymmetry is present in the global pattern. The velocities are larger at dawn with larger radial components pointing outwards compared to smaller and radially inward components in the dusk hemisphere. These first global in-situ flow measurements are currently used to improve existing models and simulations of the Jovian magnetosphere.

### Dynamic processes in the magnetosphere of Jupiter

The Jovian magnetosphere is obviously subject to large-scale quasi-periodic processes with typi-

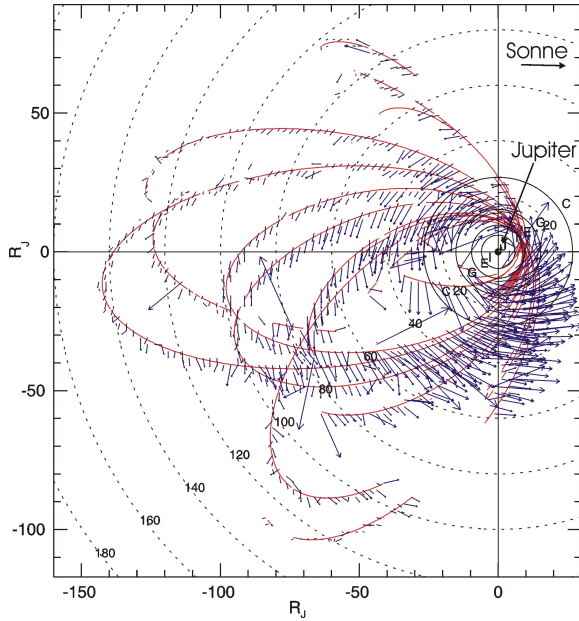


Fig. 40: Global flow pattern in Jupiter's equatorial plane. Jupiter is in the center of that coordinate system, the x-axis points back to the Sun.

cal time scales of 2 to 3 days. In the middle magnetosphere they show up in variations of the plasma flow pattern and of the thickness of the plasma sheet. In the outer magnetospheric tail region recurrent impulsive particle flow bursts are observed. The specific properties of the bursts provide essential information on the physical processes governing the Jovian magnetosphere. They exhibit a pronounced local time (LT) distribution, with a clear maximum of the occurrence frequency between 01:00 LT and 05:00 LT. In this local time sector a separatrix exists in the directional distribution of the bursts at about  $80 R_J$ . Inside this dividing line particle bursts are preferentially directed towards Jupiter, outside this line particles are streaming away from Jupiter. An example of these quasi-periodically reappearing bursts is shown in Fig. 41. The findings seem to confirm earlier theoretical models predicting the formation of a quasi-stationary magnetic reconnection line in this specific local time sector. Furthermore, a comprehensive case study brought conclusive evidence that the flow bursts are part of a large-scale process with notable analogies to the geomagnetic substorms known from Earth. However, in contrast to the Earth's case, the processes are probably not driven by the interaction of the solar wind with the magnetosphere but by energy and mass sources inherent in the Jovian system. A possible scenario is that magnetic flux tubes will be heavily loaded with plasma from internal sources up to

a point where the magnetic stresses are no longer able to compensate forces exerted by the fast rotation of the planet. The magnetic field topology breaks up and plasma is streaming downtail away from the planet within so-called plasmoids, i.e., plasma blobs fully separated from the magnetosphere.

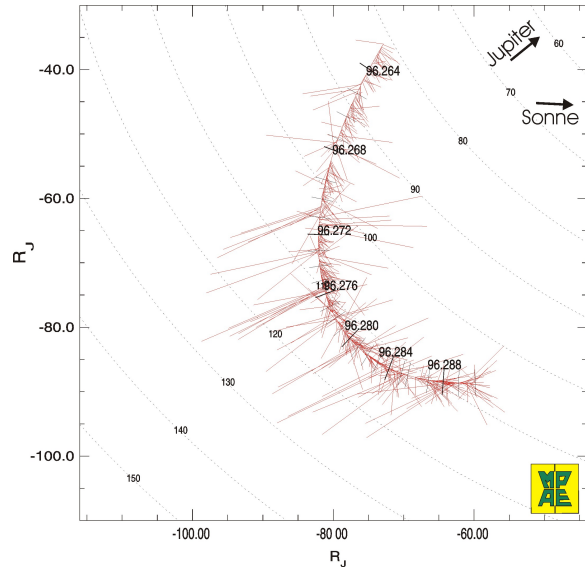


Fig. 41: Quasi-periodic particle streams in the magnetospheric tail of Jupiter. The vector length is a measure of the velocity of the bursts which in this case are directed preferentially radially away from Jupiter.

### Phase space densities in the inner magnetosphere of Jupiter

Based on 32 orbits of the Galileo spacecraft around the planet Jupiter it was possible to investigate in detail the distribution function of the energetic ions in the inner magnetosphere. The phase space density is of specific importance for a description of physical processes. It gives the number of energetic ions within a volume and momentum unit. Certain processes in plasma physics, like radial diffusion, are specifically well treated by the phase space density and the applying axioms of Hamilton mechanics.

The phase space density is determined by dividing the measured directional differential flux  $j$  by the square of the momentum  $p^2$  of the impinging particles. The phase space density is usually expressed as function of the so-called adiabatic invariants which allows to directly analyse radial diffusion processes and to determine source and loss regions. Instead of estimating location and

momentum for each individual particle, explicit values of the three adiabatic invariants define a so-called drift shell, which is impossible to leave for a given particle without external influence. It means that the ions are no longer treated as single particles but as an ensemble with defined properties. In a dipolar like magnetic field the three adiabatic invariants are defined as follows:

- The magnetic moment  $\mu$  is constant during the gyration of the particle.
- The integral of the parallel momentum  $J$  along a particle trajectory between mirror points is constant.
- The total magnetic flux  $F$  confined within a drift shell is constant.

A radial diffusion process as well as global source and loss processes will influence the third adiabatic invariant only. Therefore, the diffusion equation can be treated one-dimensionally. For solving the diffusion equation, it is necessary to calculate the phase space density at constant values of the first and second invariants. Fig. 42 shows the phase space density as function of the McIlwain parameter  $L$  for various values of the adiabatic invariant  $\mu$  and of the parameter  $K$  (where  $K$  relates to the invariant  $J$  with  $K = J/(2 \cdot \sqrt{2m_0\mu_0})$ ). The  $L$  value defines the radial distance of the drift shell from the center of the planet. In a pure dipole field it corresponds to the magnetic field line pattern. The increase of the phase space density with increasing  $L$  means that the source for the energetic particles lies outside of  $15 R_J$ . Plasma of lower energy are produced by photo-ionisation or sputtering at Io or in the Jovian atmosphere. Not visible with EPD, these particles are transported into the middle or outer regions of the Jovian magnetosphere, where they are accelerated and circulated back into the inner magnetosphere as energetic particles. The moon Europa has a minor influence on the energetic particle population. The phase space density at  $L = 9.5$ , the position of Europa, shows hardly any indication for strong source or loss processes. It can be assumed that losses at Europa are restricted to the satellite sweeping effect, i.e., loss of particles through direct impact with the moon. The situation at Io is different. The strong increase of the phase space density between  $L = 6$  and  $L = 7.5$ , i.e., outside of the Io orbit, points to an efficient loss mechanism. A good candidate is a loss process by strong pitch angle diffusion, which scatters particles into the loss cone. Further inward, within the orbit of Io, loss processes seem to be less important. In this region radial diffusion

is again the dominant process, leading to a decrease of the phase space density with decreasing distance from the planet.

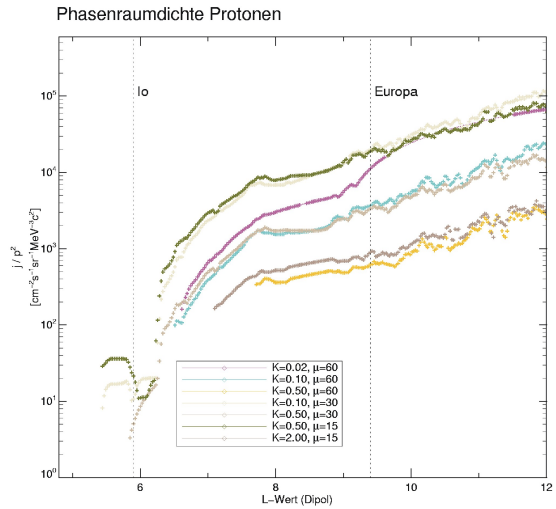


Fig. 42: Phase space densities  $j/p^2$  as function of the McIlwain parameter  $L$  in the inner Jovian magnetosphere. Data from the EPD particle spectrometer on board the Galileo spacecraft are shown for the interval December 1995 to December 1999.

### Interaction between the magnetosphere of Jupiter and its Moons

A highly interesting topic of magnetospheric research is the investigation of the rather complex interactions between the magnetosphere and the moons embedded in the stream of particles. The distributions of energetic ions and electrons are well suited for diagnosing the interactions, since they are less influenced by electric fields than low energy particles. Their larger gyro radii offer the opportunity to measure already relatively far away from the moon their influence on the particle distributions. For example, it becomes possible to study the magnetic topology of the moon and the field-aligned ion transport in the vicinity of the moon. If energetic charged particles reach the surface of the moon, they will sputter secondary particles from the surface. By analysing the secondary particles an indirect diagnosis of the surface is possible. In the following a few examples of such investigations are given.

#### *Io and Io-Torus*

The orbit of the spacecraft Galileo allows to thoroughly analyse the plasma processes in the Io

torus, which surrounds Jupiter. For this purpose the distribution of energetic ions was measured with high spatial and temporal resolution. The characteristic features of the observations, like reduced particle flux along the Jovian magnetic field lines or the abatement of sulfur and oxygen ions perpendicular to the field, yield important implications for processes in the Io torus (Fig. 43). Particles moving parallel to the field will get lost if the mirror points of their bounce motion lie within the atmosphere of Jupiter. The loss of particles moving primarily perpendicular to the field is explained by the interaction with the neutral gas of the torus, e.g., by charge exchange between charged particles and the neutral torus particles. Knowing the cross section of the respective charge exchange reactions the neutral gas density is estimated to be 18 to 25  $\text{cm}^{-3}$ .

A further highlight of the observations with the EPD instrument is the discovery of very intense electron beams along the Io flux tubes, i.e., along the magnetic field lines connecting Io with Jupiter. The energy density of these beams is high enough to generate auroral emissions in the Jovian atmosphere. The aurora at Jupiter has now been observed with the Hubble Space Telescope. Ion beams were not observed. Based on a weak energy dependence of the electron beams an upper limit for the  $\text{SO}_2$  density in the Jovian atmosphere can be estimated.

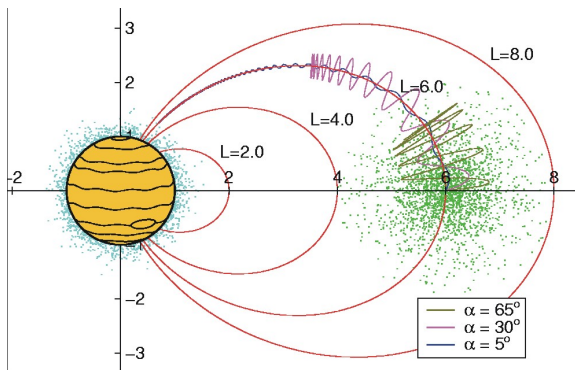


Fig. 43: Particle motion along a dipole field line and an illustration of the interaction in the Io torus for three different pitch angles (the angle between the magnetic field vector and the particle velocity vector).

### *Ganymede*

Between 1995 and 2000 the Galileo spacecraft had four close encounters with Ganymede, the biggest moon in our solar system. This led to a par-

ticular discovery: Ganymede has its own internal magnetic field and forms its own small magnetosphere which is totally embedded within the magnetosphere of Jupiter. The magnetosphere of Ganymede is comparable in size with the magnetosphere of Mercury (Fig. 39). The magnetosphere of Ganymede was identified by magnetic field and plasma wave measurements. The EPD measurements showed that energetic ions are no longer moving along the corotation direction (i.e., rotating with Jupiter), but are moving along Ganymede's magnetic field lines and are partly lost on the moon. It is possible to derive the magnetic field strength of Ganymede from these measurements.

### *Sputtering at Ganymede and Europa*

The ion sputtering rate from the surfaces of Ganymede and Europa can be estimated from the measured energy spectra of magnetospheric ions. Based on the ion composition and the mass dependent sputter yield a net production rate was estimated which is high enough to be considered important for the erosion and re-structuring of Ganymede's surface. Also in the case of Europa a very effective sputter process was inferred which substantially contributes to the re-distribution of surface masses. The estimated net erosion rate of 20 m in 100 million years bears important implication for determining the age of Europa's icy surface and the supposed ocean with fluid water beneath.

### **Future exploration of planetary magnetospheres**

The analysis of the Galileo measurements will certainly continue for several years to come and will deliver new fascinating results from the complex world of Jupiter. The rich data sets will form the base for models and simulations. However, without doubt many fundamental questions will remain open, since they cannot be addressed with a single spacecraft alone. In December 2000 the spacecraft Cassini flew by Jupiter at a relatively short distance. This opened up the opportunity to study the Jovian system simultaneously with two spacecraft - Galileo deep within the magnetosphere of Jupiter and Cassini in interplanetary space at the magnetopause. For the first time, the influence of the interplanetary medium on the Jovian magnetosphere can be studied. Furthermore, a mission to the moon Europa is in preparation with the goal to ultimately proof or disproof the

existence of a sub-surface ocean at Europa. In case such an ocean exists, it will certainly be the prime focus for the search of primitive life in our solar system with new missions including landing probes to come. Such missions are already planned. A further milestone in the exploration of the outer planets and their magnetospheres will be the spacecraft Cassini when injected into orbit around Saturn in 2004 (Fig. 44). It is planned that

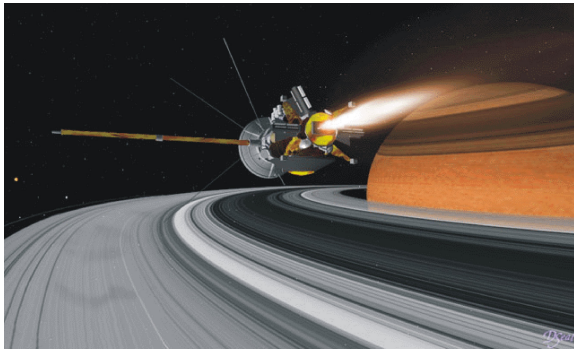


Fig. 44: The spacecraft Cassini – a milestone in the exploration of the ring planet Saturn.

Cassini will orbit Saturn 78 times in a 4 years period. The large number of orbits allows a good coverage of the magnetosphere of Saturn in local time, magnetic latitude and radial distance. Fly-

bys of various moons in the Saturnian system will provide measurements with extremely high resolution. The planned 44 encounters with the moon Titan are of specific interest, since Titan is the only moon in our solar system with a very dense atmosphere. During one of the flybys an atmospheric probe, named Huygens, will be released to parachute through the atmosphere of Titan. Among other things, Huygens will transmit to Earth images from the surface of Titan, for the first time. Magnetospheric research will not end with the Cassini mission. ESA is currently planning a mission to Mercury, the innermost planet of our solar system. The magnetosphere of Mercury is unique since the absence of a significant atmosphere and ionosphere will allow solar wind energy to be transferred to the magnetosphere by processes unknown from magnetospheres studied so far. The comparatively minute dimension of the Hermetian magnetosphere provides the opportunity to study plasma processes on much smaller spatial and temporal scales. With the launch of the multi-spacecraft mission Cluster II, the investigation of the Earth's magnetosphere likewise reaches a new quality. For the first time ever, 4 spacecraft are flying through the Earth's magnetosphere in a tetrahedron configuration allowing temporal and spatial processes to be disentangled.

## Wissenschaftliche Einzelberichte/ Individual scientific reports

(only in English)

### Mars research

#### Martian aerosols and their influence on the spectrophotometry of the surface

It is now well known that aerosols in the atmosphere of Mars scatter incident solar radiation so strongly that the diffuse flux at the martian surface usually is not very much smaller than the direct flux. The spectral characteristics of the diffuse illumination reflect the optical properties of the aerosols and are different from that of the direct solar illumination. Interpreting surface images taken from orbit require careful separation of this atmospheric effect. The required analysis yields, at the same time, information on the compositions and properties of the aerosols.

The ratio between direct and diffuse flux is mainly determined by the optical depth of the atmosphere. In preparation for the analysis of the expected images from the High Resolution Stereo Camera to be flown on the Mars Express Mission we have developed two methods to estimate the optical depth directly from orbiter images. The first of these methods – the so called ‘shadow method’ – may also be applied on images of Mars Express’ spectral imager OMEGA.

The shadow method compares shadowed and illuminated areas of the surface. Whereas only the diffuse light illuminates shadowed regions an estimate of the optical depth with minimal number of assumptions can be made. Effects of shadows on scales beyond the resolution (micro-shadowing) can also be included. We tested our method by comparing the results from Viking orbiter images of the Viking Lander sites with direct data from the landers. The accuracy of the method is shown to be a few percent. In one set of the images of the Viking I lander we are able to identify ground fogs and/or hazes by direct inspection of the images and the variations of the optical depth with wavelength in different parts of the image (different local solar time). These variations correlate with variations measured by the lander.

Another method uses the stereo capabilities of HRSC; stereo images offer another, almost independent, way to retrieve optical depths. Retrieval is possible since the nadir view has a shorter atmospheric path than the forward and backward ones.

Validation of this program will have to wait until HRSC stereo images become available in which the intensities are measured with an accuracy that is better than 1% (Fig. 45).

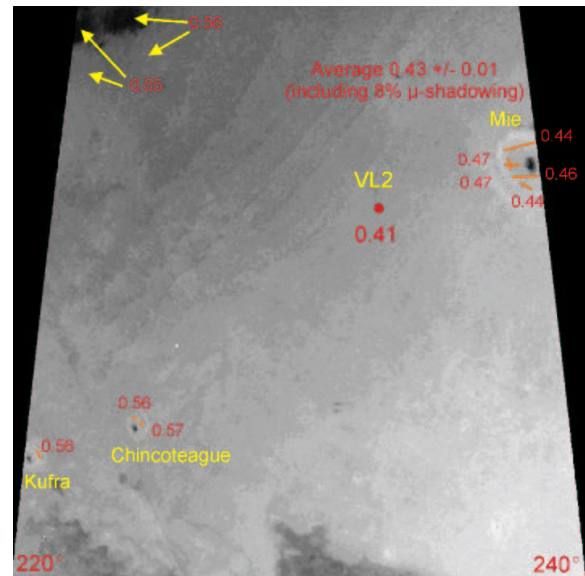


Fig. 45: Optical depths can be retrieved by comparing shadowed with illuminated regions. This image shows the Viking II landing site as observed by the Viking I orbiter. While the lander measured an optical depth of 0.41, comparison of illuminated regions (orange lines) and shadowed regions (black) in Mie crater, some 200 km to the west, suggests optical depths of 0.44-0.46 (0.42-0.44 when assuming that illuminated pixels contain 6-10% unresolved shadows).

(N.M. Hoekzema, H.U. Keller, W.J. Markiewicz)

#### Martian seasonal CO<sub>2</sub> ice in polygonal troughs: Role of the subsurface H<sub>2</sub>O ice

Mars Orbiter Camera onboard of the Mars Global Surveyor has obtained several images of polygonal features in the southern polar region. In images taken during the end of the southern spring, when the surrounding surface is free of the seasonal frost, CO<sub>2</sub> ice still appears to be present within the polygonal troughs (Fig. 46). In Earth’s polar regions, polygons such as these are indicative of water ice in the ground below. We analysed the seasonal evolution of the thermal state and the CO<sub>2</sub> content of these features. Our 2-D model includes condensation and sublimation of the CO<sub>2</sub> ice, a self consistent treatment of the variations of the thermal properties of the regolith, as well as the seasonal variations of the local atmospheric conditions, which we take from the results of a

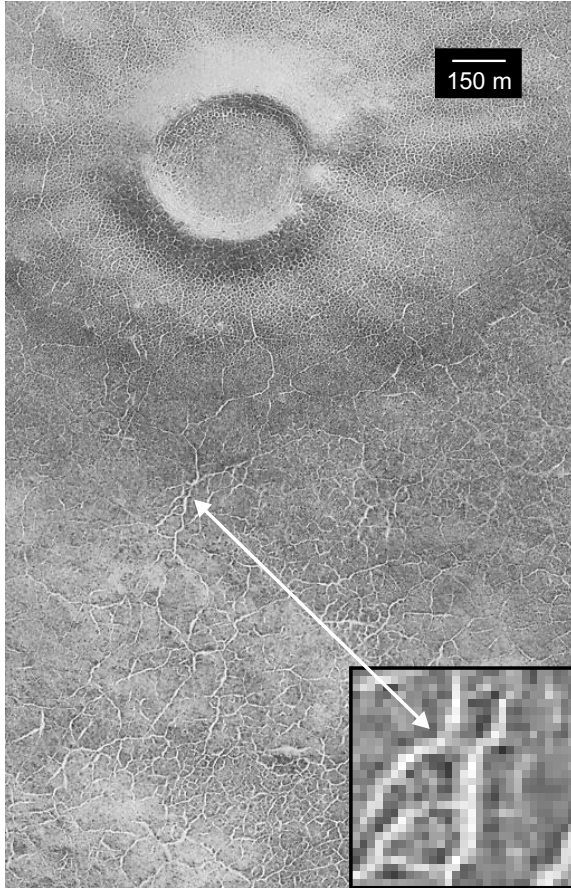


Fig. 46: Section of MOC narrow angle image M01-03306 showing polygonal patterns on Malea Planum during local spring. CO<sub>2</sub> ice appears to be present within the polygonal troughs. In the inset scale of individual pixels is visible. Resolution is 3 m per pixel. Image width is 1.5 km.

general circulation model.

We find that the residence time of seasonal CO<sub>2</sub> ice in troughs depends not only on atmospheric opacity and albedo of the CO<sub>2</sub> ice, but also and most significantly on the distribution of water ice in the regolith (Fig. 47). Optical properties of the atmosphere and surface CO<sub>2</sub> ice can independently be obtained from observations. To date this is not true about the distribution of water ice below the surface. Our analysis quantify the dependance of the seasonal cycle of the CO<sub>2</sub> ice within the troughs on the assumed distribution of the water ice below the surface. We show that presence of water ice in the ground at a depth smaller than the depth of the troughs reduces winter condensation rate of CO<sub>2</sub> ice. This is due to higher heat flux conducted from the water ice rich regolith toward the facets of the troughs. Future images of the polygonal features, obtained during

a period corresponding to  $L_s = 310^\circ - 350^\circ$  are needed to further constrain the problem of distribution of subsurface H<sub>2</sub>O ice using our model.

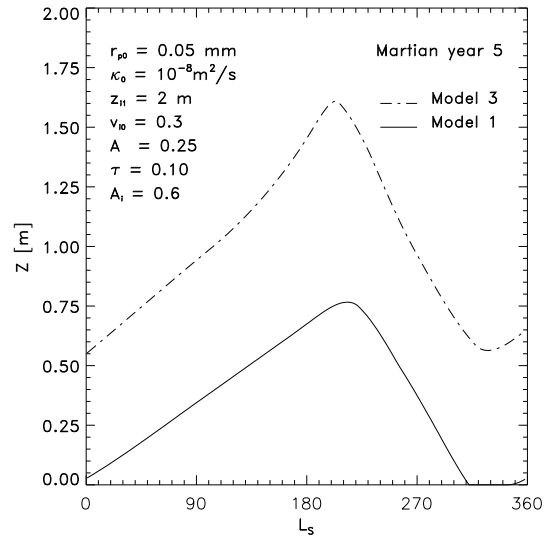


Fig. 47: Thickness  $Z$  of CO<sub>2</sub> ice in the middle of the trough versus time ( $L_s$ ) for one set of parameters and two different models of the water ice table. Model 1 assumes water ice in the regolith to surround the polygonal troughs. Model 3 assumes the regolith to be almost free of water ice.

(W.J. Markiewicz)

### Mars plasma research – an ISSI activity

Three years after launching Mars Global Surveyor (MGS) in an orbit around Mars, a workshop was organised in the International Space Science Institute (ISSI) in Bern (22-26 October, 2001) to discuss ‘Mars Magnetism, and its Interaction with the Solar Wind. A Comparison of MGS and Phobos-2 Mission Data’. Among other, a contentious problem in the field of Mars plasma research was to clarify the physics of the so-called Magnetic Pile-up Boundary (MPB) which was found between the bow shock and the ionopause which is characterised by a jump in the magnetic field intensity (MGS observation) and a change in the ion composition (Phobos-2 results).

The main difficulty arises from the fact that classical one-fluid MHD models fail to explain the MPB. In this respect our own approach (going back to 1994) on the basis of a two-fluid description in which the dynamics of protons and planetary ions are electromagnetically coupled was

recognised as an important step to understand fundamental processes occurring in the martian multi-ion plasma. As a general statement one can note that the presence of a second ion population modifies the plasma properties significantly: New types of nonlinear waves and structures (solitons, oscillitons and boundaries) may arise. The MPB is obviously one example. It offers the limits of one-fluid MHD in cases, where the momentum coupling between two or more ion populations plays a dominant role in the overall plasma dynamics.

To illustrate the formation of a new type of plasma boundary at solar wind interaction with a heavy ion source, results of bi-ion fluid simulations are shown in Fig. 48 for the simple case that there

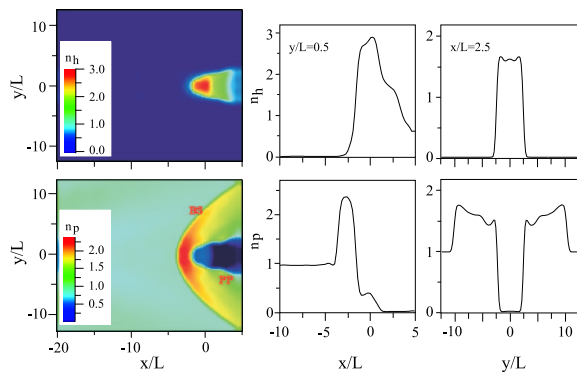


Fig. 48: Bi-ion fluid simulations (without magnetic field) showing the formation of an ion-composition boundary.

is no magnetic field. Then, the coupling between both ion populations is exclusively provided by the electric field  $E \sim \text{grad} p_e$ , where  $p_e$  is the electron pressure. The colour plots of the proton ( $n_p$ ) and heavy ion density ( $n_h$ ) and the corresponding cuts show that a proton flow boundary (protonopause) is formed where the heavy ion density sharply jumps up (ion composition boundary). This transition would be accompanied by an increase of the (convected) magnetic field (magnetic pile-up boundary).

(E. Dubinin, K. Sauer)

## Jupiter research

### Global flows of energetic ions in Jupiter's magnetosphere

Galileo as the first orbiting spacecraft in an outer planet's magnetosphere provides the opportunity

to study global energetic ion distributions in Jupiter's magnetosphere. We calculated directional anisotropies of energetic ion distributions measured by the Galileo Energetic Particles Detector (EPD). The EPD measurements of proton (80-1050 keV), oxygen (26-562 keV/nucleon), and sulfur (16-310 keV/nucleon) distributions cover a wide energy range. Spatially, the data set includes measurements from 6 to 142 Jovian radii ( $R_J$ ), and covers all local times inside the Jovian magnetosphere. For each species, a single detector head scans almost the entire sky ( $\approx 4\pi sr$ ), producing the three-dimensional angular distributions from which the anisotropies are derived. Consequently the resulting anisotropy estimates are both global and robust. Such anisotropies, generally produced by convective flow, ion intensity gradients, and field-aligned components, have long been used to estimate flow velocities and to locate spatial boundaries within magnetospheres. They can therefore provide vital information on magnetospheric circulation and dynamics. We found that the EPD measured anisotropies in the Jovian magnetosphere were dominated by a component in the corotational direction punctuated by episodic radial components, both inward and outward. Under the assumption that anisotropies are produced predominantly by convective flow we derive flow velocities of protons, oxygen ions, and sulfur ions. The validity of that approach is supported by the fact that these three independently derived flow velocities agree to a large extent in this approximation. Thus, for the first time we were able to derive the global flow pattern in a magnetosphere of an outer planet. In a comparison between the first-order EPD flow velocities and those predicted by a magnetohydrodynamic (MHD) simulation of the Jovian magnetosphere we found that qualitatively the directions appear similar, although no firm evidence of steady outflow of ions has been observed at distances covered by Galileo. A first rough comparison indicates that the measured first-order flow velocities are at least by a factor of 1.5 higher than the MHD simulation results.

Furthermore we found a pronounced local time asymmetry in the ion distributions at distances inside 40 Jovian radii especially between the dawn-noon and the dusk-premidnight sector of the magnetosphere. The predominantly first order anisotropies in the co-rotation direction show larger amplitudes with radial outward components in the dawn sector whereas at dusk smaller anisotropies with small radial inward components were observed.

(N. Krupp, A. Lagg, J. Woch, B. Wilken in collaboration with the Johns Hopkins University, Applied Physics Laboratory, Laurel, USA)

**Particle bursts in the Jovian magnetosphere: Evidence for a near-Jupiter neutral line**

In the magnetosphere of Jupiter the plasma convection is driven by the planetary rotation up to considerable distances from the planet. However, at larger distances the rotational flow is often disrupted by explosive events, seen as jets of energetic particles propagating in the radial direction. These events were observed very frequently and can be regarded as intrinsic property of the Jovian system. A statistical survey showed that the burst events were concentrated in the post-midnight tail region. Inward directed bursts dominated closer to the planet, outward directed bursts further away from the planet. The transition from mainly inward to mainly outward directed bursts defines a kind of near-Jupiter neutral line. The findings corroborate early models which postulated that magnetic flux tubes heavily loaded with plasma which originates from the moon Io will be stretched by the centrifugal forces up to such a degree that spontaneous reconnection sets in, which leads to acceleration of plasma and the release of plasmoids into interplanetary space. The process may also drive the recently observed auroral dawn storms at Jupiter.

(J. Woch, N. Krupp, A. Lagg in collaboration with the Johns Hopkins University, Applied Physics Laboratory, Laurel, USA)

**Particle leakage in Jupiter's dusk magnetosphere**

For the first time, two spacecraft, Galileo and Cassini, observed Jupiter's magnetosphere simultaneously for nearly half a year between October 2000 and March 2001. This provided an unprecedented opportunity to disentangle spatial and temporal aspects of the dynamics of the Jovian magnetosphere. We derived new results on the source of the leakage of energetic particles (electrons with energy 15 keV to several MeV and ions with energy > 30 keV) from the dusk side of the magnetosphere. The dual spacecraft measurements showed clearly that magnetospheric particles leak directly into the interplanetary medium from the closed magnetosphere, and are the source for the "upstream" particle events that have been reported from instruments during

prior single spacecraft encounters with the planet. These events, consisting of high-energy particles of Jovian origin, have been observed throughout the heliosphere and their propagation has recently been modelled. Jupiter then is an important contributor to the interplanetary charged particle fluxes, especially within an astronomical unit of the planet.

(N. Krupp, J. Woch, A. Lagg in collaboration with the Johns Hopkins University, Applied Physics Laboratory, Laurel, USA)

**Polarisation and beaming of the jovian bKOM and HOM observed at 5 AU from Jupiter**

A number of analyses of radio observations of Jupiter, made by the Voyager and the Ulysses space missions, were conducted for data taken when the spacecraft were relatively close to the planet. Because of the intensity of the signals this can obscure some of the characteristics of the emission. We have studied observations of the jovian broadband (bKOM) and hectometric (HOM) radio emission made by the Ulysses Unified Radio and Plasma Experiment (URAP), during 1994 and into 1996. At this time the spacecraft was at distances of about 5 AU or more from Jupiter and travelling from south to north of the ecliptic plane between jovicentric latitudes  $-36^\circ$  to  $20^\circ$ . At these large distances, the events were generally weak and were only received occasionally. Much care was needed to find and to identify the emissions. Occurrence probabilities and polarisation were measured and the characteristics of both emissions, HOM and bKOM, were compared and found to be quite different.

The HOM was only observed when Ulysses was between jovicentric latitudes  $-12.2^\circ$  to  $14.7^\circ$ , quite close to the plane of the jovicentric equator, roughly consistent with previous work based upon Voyager and Ulysses observations made relatively close to each encounter. Both senses of polarisation were observed with left-hand (LH) predominant throughout the limited range of jovicentric latitude.

The bKOM was observed at all jovicentric latitudes during the period studied. For the bKOM, however, all but two of the events observed when Ulysses was in northerly jovicentric latitudes were predominantly right-hand (RH) polarised while all of the events recorded when the spacecraft was in southerly jovicentric latitudes were predominantly LH polarised, the changeover taking place

somewhere between jovian latitudes about  $4^\circ$  and  $9^\circ$ , close to  $0^\circ$  jovimagnetic latitude.

While the HOM results appear to be consistent with an emission process due to the cyclotron maser instability (CMI), as suggested by a number of workers in the past, the results for the bKOM present difficulties for the cyclotron maser theory as a possible emission mechanism. This presents a serious theoretical problem for future study.

(C.H. Barrow in collaboration with Observatoire de Meudon, France and Goddard Space Flight Center, USA)

### Resistive MHD simulations of Ganymede's magnetosphere

The interaction of Ganymede, Jupiter's largest satellite, with the Jovian magnetosphere differs from all other satellite-magnetosphere interaction because of the fact that Ganymede possesses a strong internal magnetic dipole field. The surface field of about 750 nT at the equator is much larger than Jupiter's background field of about 112 nT and should thus considerably modify the interaction. This was certainly one of the most surprising discoveries of the Galileo mission and rises a lot of important questions. One of the most interesting topics is in how far the intrinsic dipole influences Ganymede's surface structure. The superposition of the magnetic fields of Jupiter and Ganymede leads to a structure which is closed near Ganymede's equator but open near the poles. Since charged particles can reach Ganymede's surface only along the open field lines, the structure and the time variation of the polar caps, i.e. the boundaries between open and closed field lines, is of particular interest. The locations of these boundaries were computed by means of MHD simulations of three flybys (G2, G7, and G8) of the Galileo spacecraft. Due to the dipole tilt of the Jovian background field and magnetospheric disturbances, the magnetic field has to be computed separately for each flyby. The polar caps on the northern (left panel) and the southern (right panel) hemisphere are shown in Fig. 49. The colours represent the individual flybys (G2 in green, G7 in red, and G8 in blue). The figure shows that there are significant variations of the shapes of the polar caps, whereas their sizes change much less. In a next step, these results have to be compared with the highly resolved images of Ganymede's surface which were also taken during the Galileo mission. The MHD simulations moreover show how the Birkeland currents flow

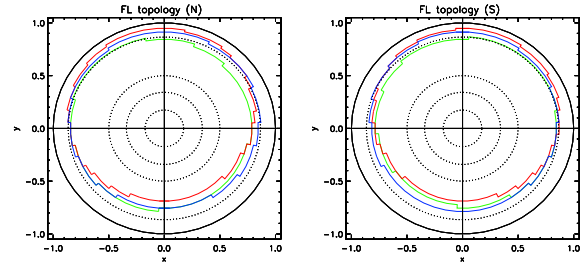


Fig. 49: Polar caps at Ganymede.

into the Jovian ionosphere essentially along the separatrices between the open field lines, connecting Jupiter and Ganymede, and those which are only connected to Jupiter.

(A. Kopp, W.-H. Ip)

### Magnetic induction effects at Europa

One of the most interesting results of the Galileo mission to the Jovian system was the possible discovery of a subsurface ocean on Europa. This, however, was not a direct detection, but a derivation from the magnetic field measurements which were explained with the presence of an induced dipole field due to Jupiter's dipole tilt. Such a field can only be built up if the conductivity of the satellite's interior is sufficiently high. In order to investigate whether the assumption of such an induced dipole field can be justified, three-dimensional, resistive MHD simulations of the interaction of Europa with the Jovian magnetosphere were carried out. The goal of these investigations was to simulate both the case with and without an induced dipole field and to compare the results with the Galileo measurements for several encounters. To allow such a detailed comparison, the O<sub>6</sub> model for the magnetic field was used, which, however, does not consider magnetospheric disturbances. These were taken into account in the present simulations by the addition of homogeneous fields whose free parameters were determined by the Galileo data at the beginning and the end of the respective flyby, far away from the closest approach. For the present study, four encounters (E4, E11, E12 and E14) could be taken into account. For each of these flybys, the three components and the amount of the magnetic field were evaluated along the spacecraft trajectory. Fig. 50 shows a superposition of the data (grey solid curve) and simulation results (black curves: solid=with and dashed=without an induced dipole field) for flyby E4 (December 19, 1996) of the Galileo spacecraft. As the comparison shows, only the case with an induced dipole

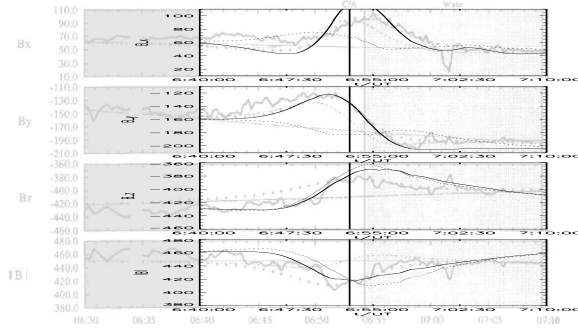


Fig. 50: Data and simulation results for flyby E4.

field agrees with the measurements, in particular in the first two components. For the three other encounters, similar results were obtained. Thus, the assumption of an induced dipole field at Europa is strongly supported by these simulations.

(A. Kopp, W.-H. Ip)

### Observations of the Io torus on Pik Terskol with the Two-Channel Focal Reducer

The Io torus is a ring of heavy ions (mostly sulphur and oxygen) surrounding Jupiter at about the distance of Io, the innermost Galilean satellite of Jupiter. Its origin is related to the interaction of Io and its volcanoes with the Jovian magnetosphere. The Two-Channel Focal Reducer of MPAE provides means to suppress the bright scattered light of Jupiter and therefore allows observations of the faint emissions of the Io torus with ground-based telescopes. This torus was observed at Pik Terskol Observatory (Northern Caucasus) from October 8 to November 11, 1999 and from November 2 to 20, 2000. Narrow-band images of the torus in the light of the forbidden lines of  $S^+$  and  $S^{++}$  were taken in order to determine the electron density and temperature and the morphology of the torus in its inner, cooler (“cold torus”), and outer, hotter (“ribbon”) parts. The torus structure was surprisingly different in the two years. In 1999 the torus was unusually bright. In 2000 it was about five times fainter, and the electron density was smaller. In contrast to fall 1999 in fall 2000 cold torus and ribbon were separated by a gap. More work is needed to quantify electron temperature and density and to relate the measured quantities to the observed torus morphology and to measurements of the Galileo space probe.

(K. Jockers in collaboration with I. Kulyk, Main Astronomical Observatory, Goloseevo, Kiev, Ukraine)

### Observations of the inner Jovian satellites Methis, Amalthea and Thebe on Pik Terskol with the Two-Channel Focal Reducer

Measurements of the Galileo spacecraft reveal the inner moons of Jupiter as sources for the Jovian ring. Therefore the question of existence and nature of regolith on the surface of these moons, which experience heavy bombardment by energetic particles of the Jovian magnetosphere, should receive more attention. Using the Two-Channel Focal Reducer of MPAE at the 2m Zeiss telescope of Pik Terskol Observatory (Northern Caucasus) with its possibilities to suppress the glare of Jupiter’s disk we were able to measure the opposition surge of the inner satellites and the ring for the first time. About 400 images of Amalthea, Thebe, Metis and the Jovian ring ansae were acquired in the methane absorption band at 890 nm at solar phase angles between  $1.6^\circ$  and  $5.2^\circ$ . As a byproduct the relative astrometric positions of the inner Jovian satellites with respect to the Galilean ones were measured. Good agreement with the predictions of the Horizons Ephemeris System ([horizons@ssd.jpl.nasa.gov](mailto:horizons@ssd.jpl.nasa.gov)) was achieved. Bad weather prevented extension of the observations to smaller and larger phase angles. Therefore we must continue such observations in the future.

(K. Jockers in collaboration with I. Kulyk, Main Astronomical Observatory, Goloseevo, Kiev, Ukraine)

### Saturn research

#### A new spherical model for computing the internal radiation field of Titan

Sunlight plays a key role in driving many important physical processes in planetary atmospheres. Optical measurements made inside a planetary atmosphere can reveal a great deal about many physical processes occurring there. In January 2005, the Huygens probe will descent through Titan’s atmosphere and the Descent Imager Spectral Radiometer (DISR) will perform upward and downward looking observations at various spectral ranges and spatial resolutions and some of this measurements will include polarisation. To prepare for that arrival, we have developed a new spherical model able to compute the internal polarised radiation field of Titan.

Several methods exists for finding the distribution

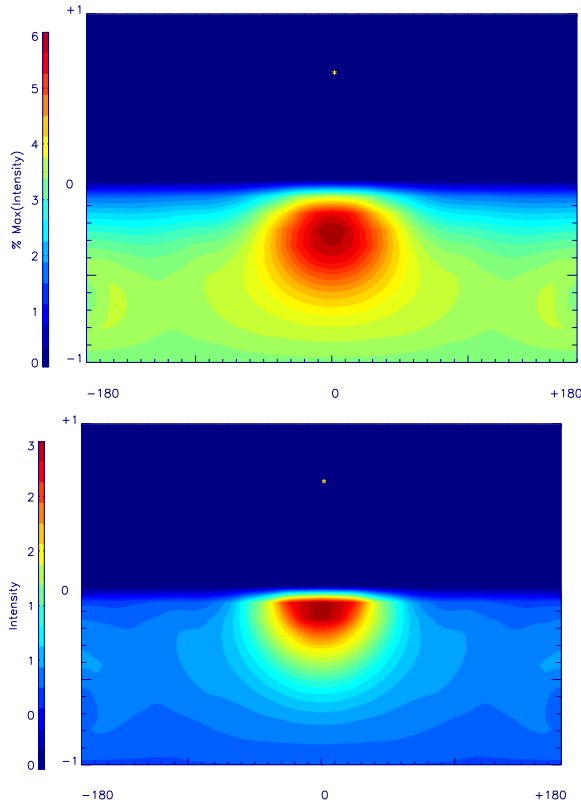


Fig. 51: Radiation intensities from spherical calculation (above), and the % differences compared with a plane-parallel model (below), for 500 nm,  $50^\circ$  solar zenith angle, side looking with  $360^\circ$  field of view, entering the haze layer at 278 km altitude. The dot in each plot indicates the sun position.

of scattered radiation in a plane-parallel atmosphere illuminated by plane-parallel solar beams. However, for large solar zenith angles, a solution of the radiative transfer equation valid for a spherical atmosphere is required. We use the plane-parallel solution, based in the doubling and adding algorithm, as a lower order intensity field with the direct solar beam calculated in spherical geometry, combined with the perturbations method described by Dahlback (1991). This perturbation technique allows to solve the radiative transfer equation for a spherical shell geometry since it accounts for the angular variation along the line of sight (Fig. 51). In these calculations it was assumed that gas absorption, temperatures, optical properties of each shell-layer are known. Phase functions and opacities of the haze were prescribed using the fractal aggregates aerosol model of Lemmon (1993).

(S. Salinas, B. Grieger, W. J. Markiewicz, H. U. Keller)

### Inverse radiation modelling of Titan's atmosphere to assimilate Solar Aureole Imager data from Huygens/DISR

Saturn's satellite Titan is the only moon in the solar system with a considerable atmosphere. In 1997, the Cassini/Huygens mission was launched and the Cassini spacecraft will deliver the Huygens probe to Titan in January 2005. Starting at an altitude of about 160 km, the Descent Imager/Spectral Radiometer (DISR) will perform upward and downward looking measurements at various spectral ranges and spatial resolutions. This internal radiation density could be estimated by radiative transfer calculations, but in order to do this, the optical properties have to be prescribed at every altitude, and these are a priori not known. Therefore an inverse approach has been developed, which retrieves the single scattering albedo and the phase function of the aerosols from DISR observations. The method uses data from a DISR subinstrument, the Solar Aureole Imager (SA). One frame of the SA nominally maps to a  $6^\circ \times 50^\circ$  field of view in azimuth and zenith angle, respectively, which is vertically centred around the nominal solar zenith angle of  $50^\circ$ . In an observation cycle, two frames are taken during one rotation of the probe, one almost towards the sun and the other in the direction opposite to the sun. In order to reconstruct the optical properties of the scattering particles, we assume them to be constant between the altitudes of two successive observation cycles. The thickness of such a layer will typically be about 4 km. The method is tested in a simulated radiation density scenario for Titan, which is based on a microphysical aerosol model for the haze layer. Together with the phase functions, the corresponding radiation density field in the atmosphere is estimated. An example is shown in Fig. 52. In these reconstructions it was

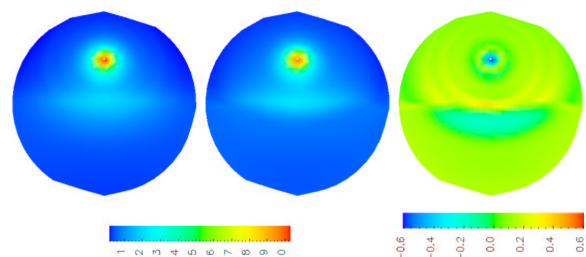


Fig. 52: Simulated radiation intensities (left), reconstructed intensities (center), and the differences (right), at 500 nm, side looking with  $180^\circ$  field of view, at an altitude of 160 km.

assumed that the opacity of the considered layer was known. Phase functions and opacities can simultaneously be reconstructed by combining data from the SA and another DISR subinstrument, the Upward-Looking Visible Spectrometer.

(B. Grieger, W. J. Markiewicz, H. U. Keller)

### D/H ratio determination

The deuterium in the universe was produced shortly after the big bang. The process  $^2\text{H} + ^1\text{H} \rightarrow ^3\text{He} + \gamma$  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. Its 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.

Measurements of Jupiter's D/H ratio were made during Cassini's Jupiter flyby in December 2000 and January 2001. Due to the unfavourable conditions in this case (broadening of Jupiter's H Lyman- $\alpha$  line, strong emission of Jupiter's aurora) only a weak absorption is registered by the HDAC instrument. But this is in agreement with model calculations done at the DLR Institute for Space Sensor Technology. Reasonable results as predicted by model calculations can be expected at Titan, where conditions are much better. In this case a reliable determination of the D/H ratio will be possible. During Cassini's cruise phase measurements of interplanetary Lyman- $\alpha$  are made using the HDAC instrument as a photometer. The results of these are used together with measurements of the CASSINI-UVIS/FUV channel to calibrate the instrument and to validate models of interplanetary Lyman- $\alpha$  radiation.

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  $\text{MgF}_2$  windows. In the hydrogen and deuterium cells a hot tungsten filament dissociates the  $\text{H}_2$  and  $\text{D}_2$  molecules into atoms producing an atomic density dependent on the filament temperature. These atoms resonantly absorb the hydrogen and deuterium Lyman- $\alpha$  lines, located at 1215.67 Å and 1215.34 Å, 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 1100 and 2300 Å.

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

### General planetary studies

#### On the problem of light scattering by planetary regolith

The reflectance of a flat regolith layer composed of particles with specified physical properties (size, refractive index, and packing density) has been computed with an accurate radiative transfer algorithm. Using the geometric optics approximation, we have found that a shape mixture of randomly oriented spheroids can successfully model the single scattering phase function of soil grains. In order to take into account the effect of packing density in a regolith layer, the concept of the so-called static structure factor was used. The main effect of increasing packing density is to suppress the forward-scattering peak of the phase function and to increase the surface albedo. We also investigated the influence of fine dust on the reflected light. An addition of small particles not only increases the surface albedo, but also changes the shape of the brightness profile and enhances the back-scattering. Shadow hiding is also shown to increase the back-scattering but the effect persists over a wider range of emission angles. The exact procedure used here allows us to fit observa-

tion data with a set of real characteristics of the regolith rather than with abstract parameters of the widely used approximations. We compared the exact method with the Hapke approximation. The error of using the Hapke bidirectional function can be larger than 300% depending on the viewing geometry and the single scattering properties of the grains composing the regolith. Full report of this research can be found in Petrova et al., *Solar System Research*, 35, 278–290, 2001. Here we only highlight some of the results.

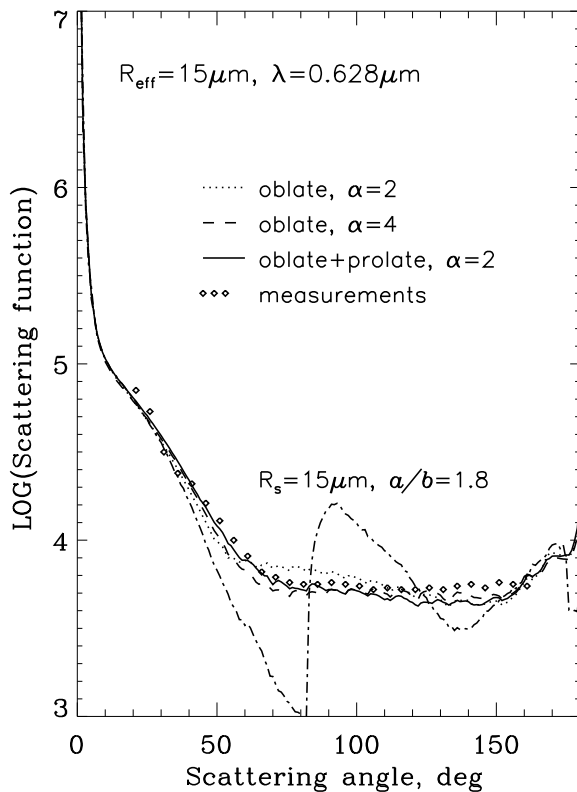


Fig. 53: The measured intensity and linear polarisation of light scattered by quartz particles (Weiss-Wrana, 1983, *Astron. Astrophys.*, 126, 240-250) fitted with model results for a shape mixture of spheroids. The scattering function of a single spheroid is also shown.

The radiance factor of the reflected light is highly dependent on the form of the phase function for single scattering by the regolith particles. Thus, in order to model the reflectance from regolith correctly, one must first know the scattering function of the individual soil particles. We used the geometric optics (GO) approximation to compute the single scattering characteristics of regolith grains. Since the GO computations for simple geometries are much faster than for complex shapes and the regolith grains are more or

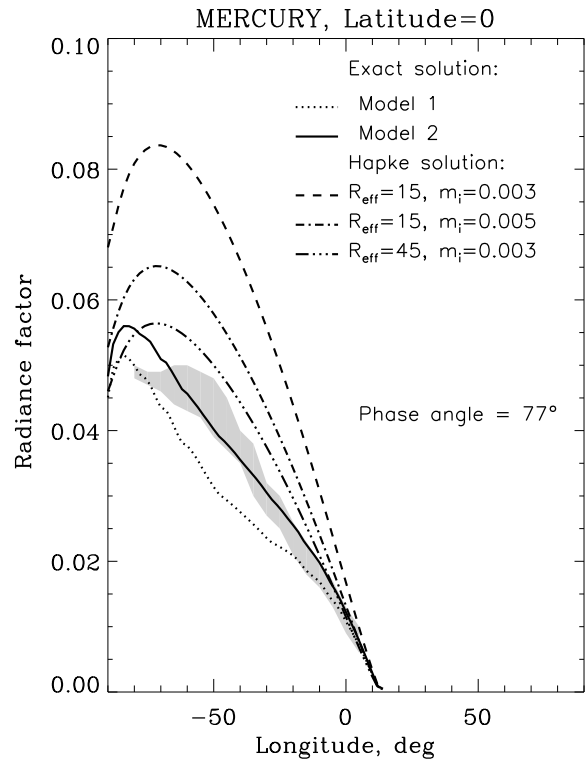


Fig. 54: The radiance factor along the Mercury equator at the phase angle of about  $77^\circ$ . The shadowed area corresponds to the values measured by Mariner-10. Two models calculated by the exact numerical method for a mixture of spheroids are over-plotted (solid and dotted lines). Model 1 is for grains with  $R_{\text{eff}} = 9 \mu\text{m}$  and  $m_i = 0.003$ , and a filling factor  $f = 0.1$ . Model 2 is for a mixture of grains with  $R_{\text{eff}} = 12 \mu\text{m}$  (a fraction of 10% by number) and fine particles with  $R_{\text{eff}} = 1.6 \mu\text{m}$ .  $f$  is 0.4 for both fractions. The other three models are the results of the Hapke approximation using the single scattering properties for the particles with the sizes and the imaginary part of the refractive index listed in the legend.

less equi-dimensional we attempt to model their scattering properties assuming a shape mixture of randomly oriented polydisperse spheroids. A comparison of our model results with the measurements of Weiss-Wrana (1983) are shown in Fig. 53 together with an image of the particle used in her experiments. We calculated the phase matrix for a power law size distribution of randomly oriented spheroids with one axis fixed and the axis ratio,  $a/b$ , ranging from 1.1 to 2.4. The size of the “fixed” axis is always chosen so that the effective radius of the distribution,  $R_{\text{eff}}$ , is  $15 \mu\text{m}$ , the average radius of the experimental particles. We obtain a satisfactory fit for distributions of both

oblate spheroids and a mixture of oblate and prolate spheroids with the power index  $\alpha = 2$  and 4. For completeness and comparison over-plotted in Fig. 53 is the phase function of a single particle with the sphere equivalent radius of  $15 \mu\text{m}$  and  $a/b = 1.8$ . We used the above approach to study the dependence of the reflectance function on the various physical properties of the regolith. Next we present an example of the use of the above models by fitting the measured brightness reflected from the surface of Mercury. The data is from the equator and the phase angle is about  $77^\circ$ . Data as well as model fits are shown in Fig. 54. The shadowed area in the plot corresponds to that of the values of brightness measured by Mariner-10. Model fits in Fig. 54 calculated with the exact method are for two models: 1) a mixture of spheroids ( $m_i = 0.003$ ) with an effective radius  $R_{\text{eff}} = 9 \mu\text{m}$  and a filling factor of 0.1, and 2) a mixture of small,  $R_{\text{eff}} = 1.6 \mu\text{m}$ , and large  $R_{\text{eff}} = 12 \mu\text{m}$ , spheroids with a ratio by number of 0.9/0.1, and the filling factor of 0.4. We did not attempt to find an exact agreement between the calculated and the measurements because the models used do not take into account such important factors as the possible presence of crystals in the regolith and the macroscopic roughness of the surface. Additionally, the derived set of parameters is not unique. We only intend to illustrate the general capability of the exact method in an inverse problem of estimating the physical characteristics of particles composing the surface regolith. It should be noted that a good agreement to the same measurements is found within the framework of the Hapke approximation as shown in his original plot (Hapke, 1993, Theory of Reflectance and Emittance Spectroscopy, Cambridge Univ. Press, New York). However, except for the roughness parameter no other regolith parameters are given. To demonstrate the potential error in using the Hapke approximation we calculated three different models using his formulation. The results are over-plotted in Fig. 54. The Hapke model requires much larger and/or more absorbing particles than the exact calculations to give a reasonable fit for the measured profile at least in this specific geometry.

(W.J. Markiewicz, E.V. Petrova, Space Research Institute, Russian Academy of Sciences, Moscow, Russia)

## Cometary research

### Observations of comets on Pik Terskol with the MPAE Two-Channel Focal Reducer

In 1996 the Two-Channel Focal Reducer of the MPAE was brought to Pik Terskol Observatory in the Northern Caucasus. The focal reducer is used at astronomical telescopes and allows to take images in two spectral windows of the wavelength range  $350 - 1000 \text{ nm}$  simultaneously. A contract grants 40 observing nights at the 2-m-Zeiss-Telescope of Pik Terskol Observatory per year for MPAE scientists. The following comets were observed in the time of this report: Comet C/1999 S4 (LINEAR), comet 19P/Borrelly, and comet C/2000 WM1 (LINEAR). Comet C/1999 S4 disintegrated at the end of July 2000 shortly after perihelion passage. Dynamical studies of cometary orbits and their comparison with comet statistics demand that the disintegration of cometary nuclei, which are known to be fragile and volatile, is a rather frequent event. Nevertheless it is not observed too often. Comet S4 was not only observed at Pik Terskol but, in the framework of a long-standing cooperation, also with a similar 2m-telescope and similar equipment at the Bulgarian National Observatory. Our observations were aimed to study the spatial distribution of cometary dust colour (dependence of the reflectivity of cometary dust on wavelength). The observations of the two observatories very nicely cover the period of disintegration of this comet. Two outbursts preceded the disintegration. During the outbursts the dust tail became significantly bluer. After the last outburst the comet faded and its dust colour became strongly red. This is interpreted as a release of small grains during the outbursts. The small particles are accelerated by solar radiation pressure and therefore leave the field of view after the last outburst. After termination of dust production the remaining dust cloud loses the small grains through solar radiation pressure and the large particles with red colour remain. From this behaviour conclusions on the internal structure of the cometary nucleus can be drawn.

Comet C/2000 WM1 (LINEAR) passed perihelion at 0.56 AU on January 22, 2002. It was observed in November and December 2001, when it was still outside the Earth's orbit and was observable at phase angles Sun-comet-earth ranging from  $13^\circ$  to  $56^\circ$ . The comet was observed in continuum windows from  $443 \text{ nm}$  up to  $853 \text{ nm}$ . The observations are intended to determine the

phase dependence of colour and polarisation and the wavelength dependence of polarisation (polarisation colour) of cometary dust. The polarisation of cometary dust is negative at small phase angles. This phenomenon is poorly understood. We think that it is caused by the fact that cometary dust grains have structures of the scale of the wavelength of visual light. If this is correct, the observed polarisation should be less negative at 858 nm in the near infrared wavelength range as compared to 443 nm (Fig. 55).

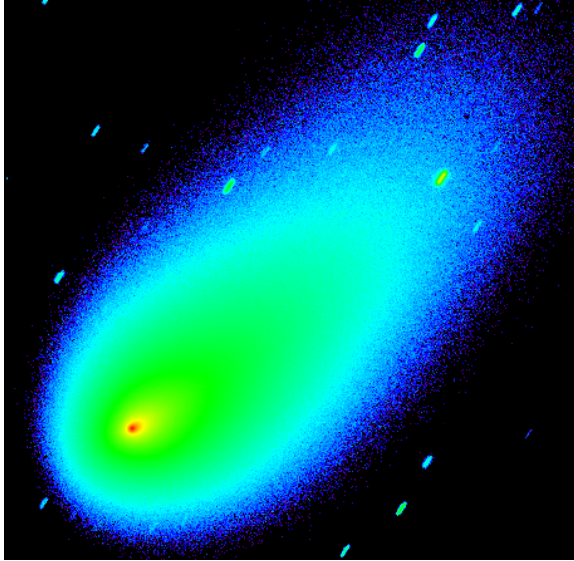


Fig. 55: False colour image of Comet C/2000 WM1 (LINEAR), obtained on December 1, 2001 in red light. The field is 7 arcmin wide ( $\approx 10^5$  km at the comet). At the time of the observation the comet was at a heliocentric distance of 1.22 au and a geocentric distance of 0.32 au.

(K. Jockers, T. Bonev, N. Kiselev, Tra Mi Ho)

#### Scattering properties of aggregate particles and their relation to cometary dust and to regolith on atmosphereless solar system bodies

Much progress has been achieved in recent years concerning the calculation of light scattering properties of individual small particles like cometary dust grains and of particle assemblies (regolith, “sand”) on atmosphereless bodies (the presence of an atmosphere provides additional scattering and therefore seriously alters the scattering properties of dust grains). An understanding of the scattering properties of dust grains is essential for the interpretation of remote observations of comets, asteroids and natural satellites by astronomical

means from the ground or with space probes. Observable quantities are brightness (reflectivity), colour (change of reflectivity with wavelength), and polarisation, and they all depend on phase angle, i.e. on the angle between illumination direction (Sun), object, and observer. New data of this kind are available from own observations. The polarisation of cometary grains and planetary regolith is negative at small phase angles (so-called negative branch of polarisation). In order to investigate why this is the case we have calculated the light scattering properties of particle aggregates consisting of spheres. The negative branch appears only if the monomers are about of wavelength size. The negative branch is more pronounced if the particles are more transparent and/or more densely packed.

As an extension we have calculated the scattering properties of a regolith consisting of such aggregate particles. In this calculation the mutual interaction of the regolith grains was neglected in a first step. The negative branch of polarisation is preserved but becomes much weaker. This is in qualitative agreement with observations of comets and asteroids.

(E. Petrova, K. Jockers)

#### Comet Borrelly encountered by Deep Space 1

Deep Space 1 is part of NASA’s New Millennium Program. It was launched from Cape Canaveral on October 24, 1998. Its main objective was to test 12 advanced, high-risk technologies for future missions. Some of the advanced technologies included: *Solar Electric Propulsion*, *Solar Concentrator Arrays*, *Autonomous Navigation*, *Miniature Integrated Camera and Imaging Spectrometer (MICAS)*, *Ion and Electron Spectrometer*.

On July 28, 1999, Deep Space 1 flew by asteroid 9969 Braille. The closest approach distance was 27 km. The results were disappointing because the spacecraft tracking system failed to lock onto the target and hence, the best images of the asteroid were rather poor and of low resolution. After Deep Space 1 completed its successful primary mission in 1999, the spacecraft was re-directed to comet 19P/Borrelly (Fig. 56). On 22nd September 2001, Deep Space 1 encountered Borrelly at a closest distance of 2174 km at 22:30 UT yielding pictures of the nucleus and other scientific data, e.g. energy spectra taken from the ion and electron instruments. The relative velocity at the time of the encounter was  $16.5 \text{ km s}^{-1}$ ; the phase angle



Fig. 56: An enhanced image taken of comet P/Borrelly by MICAS which reveals dust being ejected from the nucleus. The nucleus size is about  $8 \times 4 \times 4$  km.

was  $88^\circ$ . The comet was 1.362 AU away from the Sun, while the distance between the Earth and the comet was 1.473 AU. The phase angle Earth-comet-Sun was  $41.2^\circ$ .

During the initial phase of the encounter the viewing direction of DS1 and the ground based observations to the nucleus were roughly orthogonal to each other. This provides a powerful tool for the study of the inner coma of Borrelly. As the spacecraft range to the comet decreased within half an hour of the closest approach, the spacecraft began to turn to keep tracking the nucleus and the viewing direction changed. This fact gives us additional information about the 3D dust distribution of the coma. The Max-Planck-Institut für Aeronomie is involved in the data analysis of the CCD images of MICAS experiment onboard DS1. In particular we are studying the dust distribution around the coma, the geometry of the dust jets observed on the images and differences in their appearance. We want to understand the physical processes on the nucleus which produce these emission features, to establish evidence of acceleration processes, fragmentation and expansion. To be able to constrain these points we will connect data of MICAS, ground-based observations of Borrelly at Mauna Kea and Pik Terskol. By averaging the azimuthal intensity distribution around the nucleus, we have also been able to compare the observed dust brightness of comet Borrelly with observations of comet 1P/Halley made

by the HMC experiment on Giotto. We could estimate that the dust emission from Borrelly was at least a factor of 40 lower than Halley.

(T.-M. Ho, K. Jockers, N. Thomas in collaboration with US Geological Survey, Flagstaff, USA, South West Research Institute, San Antonio, USA, University of Hawaii, USA, Institute of Astronomy, Sofia, Bulgaria and University of Maryland, USA)

### The temperature and bulk flow speed of a gas effusing or evaporating from a surface into a void after reestablishment of collisional equilibrium

Molecules effusing, evaporating, or sublimating from a surface into a void are initially not in equilibrium and therefore do not obey the Maxwell velocity distribution function. Starting with a Maxwell transmission distribution of speeds, we calculate from conservation of momentum and energy the temperature and centre-of-mass speed of a drifting Maxwell distribution after equilibrium has been reestablished by collisions in the limit of negligible return flux. The drift (bulk flow) speed corresponds to a Mach number larger than 1. As opposed to effusion, vaporisation and sublimation are two-phase processes that restrict the pressure and thus the molecular flux, but without influencing the temperature or bulk flow speed. Assume that gas with the number density  $n$  and pressure  $P$  in thermodynamic equilibrium at temperature  $T$  is on one side of a surface in the  $x-y$  plane that divides space into two parts. Thus the gas molecules of mass  $m$  have speeds that can be described by the three dimensional Maxwell distribution. We assign the  $+z$  direction outward. Then the flux of molecules striking the surface is

$$\begin{aligned} \Phi &= n \left( \frac{m}{2\pi kT} \right)^{1/2} \int_0^\infty v_z \exp\left(-\frac{mv_z^2}{2kT}\right) dv_z \\ &= n \frac{\bar{v}}{4}, \end{aligned}$$

where  $\bar{v} = (8kT/\pi m)^{1/2}$ , is the the mean gas speed at temperature  $T$ . If the molecules collide with a small area  $A$ , on the surface, then the number of molecules striking this area per unit time is  $An\bar{v}/v$ . Furthermore, if  $A$  is the area of a hole in the surface, with the largest linear dimension small compared to the mean free path of the gas (Knudsen flow), then the number of molecules striking the hole and escaping into the vacuum part of the half-space is also  $An\bar{v}/4$ . In some applications it has been assumed that  $\bar{v}/4$  is the

speed of the escaping gas. We show that this is too small by a factor  $\pi$ . The details of the analysis are given in Huebner and Markiewicz (Icarus, 148, 594–596, 2000), here we only present the results of this study. After the gas passes through the hole it equilibrates into a Maxwell distribution (primed variables) at temperature  $T'$ , drifting with the centre-of-mass speed  $v'_{0z}$ . Let us assume that the number of excited rotational and vibrational degrees of freedom in the gas before it moves through the hole is  $f_{rv}$ . Then, based on equipartition among the excited degrees of freedom, the rotation-vibration energy is  $f_{rv}nkT/2$ . If the same number of degrees of freedom remains excited and the total energy is conserved then

$$T' = \frac{8 + 2f_{rv} - \pi}{2(f_{rv} + 3)},$$

and

$$v'_{0z} = \left[ \frac{kT'\pi(f_{rv} + 3)}{m(8 + 2f_{rv} - \pi)} \right]^{1/2}.$$

In terms of the sound speed,  $v'_s = (\gamma kT'/m)^{1/2}$ , the Mach number is

$$M' = \frac{v'_{0z}}{v'_s} = \left[ \frac{\pi(f_{rv} + 3)}{\gamma(8 + 2f_{rv} - \pi)} \right]^{1/2}.$$

The fraction of energy in bulk motion relative to the total (kinetic and thermal) energy is obtained from the ratio of

$$\frac{1}{2}mv'^2_{0z} / \left( \frac{1}{2}mv'^2_{0z} + \frac{f_{rv} + 3}{2}kT' \right).$$

Table I summarises results for  $f_{rv} = 0$  (monatomic gas),  $f_{rv} = 1$  (diatomic gas),  $f_{rv} = 2$  (e.g. polyatomic gas with three rotational degrees of freedom excited.)

Table I

$f_{rv}$	$T'/T$	$v'_{0z}/\bar{v}'$	$M'$	Bulk motion/total
0	0.8097	0.8728	1.079	0.3927
2	0.8858	0.8345	1.125	0.2795
3	0.9049	0.8257	1.141	0.2443

The processes for vaporisation and sublimation are similar to those of effusion, except the number of molecules in the vapour phase, and thus the gas flux, is restricted by the vapour pressure as determined from the Clausius-Clapeyron equation. No such restriction applies to effusion. In summary, the gas effusing, evaporating, or sublimating from a surface into void may reestablish a Maxwell velocity distribution after many collision mean free paths from the surface. Its final temperature can

then be as low as about 0.81 of its original temperature and its bulk speed will be  $\pi\bar{v}/r$ . These values do not depend on the enthalpy of vaporisation (or sublimation). However, when a gas evaporates or sublimates from a surface, its flux will depend on the saturation vapour pressure. After reestablishment of the Maxwell velocity distribution, up to about 40% of the energy of the gas is in bulk motion and the rest is in thermal energy.

(W.J. Markiewicz, W.F. Huebner)

### Cometary theoretical work

During the last two years we provided a synthesis between two major lines of development in the understanding of mass and heat transfer in a volatile porous medium. We developed a combined consistent model, which uses the macroscopic heat transfer equation and kinetic solution for the gas flow. Special emphasis was attributed to the influence of recondensation to the energy balance. It was found that there exist areas of net recondensation along the walls of ice channels, which might act as interior heat sources. This recondensation region coincides with the experimentally observed one of the steepest temperature gradient. We also demonstrated that at least in first order the difference between the temperature of a sublimating ice front and the surface temperature of an overlying porous dust mantle is independent of the thickness of the non-volatile layer. Experimental data obtained from previous comet simulation experiments (KOSI and related laboratory experiments) were reconsidered. In particular, temperature profiles and gas fluxes from the KOSI-9 experiment were interpreted in terms of the kinetic approach.

In parallel we developed the first numerical model of the light-absorption surface layer of a cometary nucleus. Optical characteristics of media were evaluated for a large number of different regolith types by using a combination of Mie theory, the discrete dipole approximation, Hapke theory, and numerical solutions to the equation of radiative transfer. In addition, wavelength-integrated directional-hemispherical albedos and flux attenuation profiles in the regolith have been calculated as functions of depth in order to improve the energy budget and treatment of energy boundary conditions in thermal models of cometary nuclei. Obtained results are compared with spectra and colours of observed cometary nuclei. Our main conclusions are that only regolith consisting of relatively large core-mantle grains, or clusters of

smaller core-mantle grains, are capable of reproducing the red colours seen in comets; that ice-dust mixtures actually can be darker than ice-free regolith under certain circumstances; and that solar radiation sometimes penetrates to a depth that is comparable to the region in which diurnal temperature variations occur.

The classical way to treat absorption of solar light in thermophysical modelling of cometary nuclei, has been to assume complete opaqueness of the surface material. However, as we show, substantial light penetration can occur in porous ice even if it is very dusty, implying that gradual absorption of energy in a surface layer should be accounted for. We presented a thorough comparison between a surface absorption model and a layer absorption model, for various combinations of heliocentric distances, conductivities, opacities, pore sizes and rotational periods relevant for cometary nuclei, by fully solving the coupled differential equations of heat transfer and gas diffusion. We found substantial differences between the models in terms of gas production rate, thermal lag angle, surface temperature, and the origin of coma molecules. For example, the surface absorption model overestimates the total gas production by a factor 2-7 and places the origin of coma molecules at the surface, instead of the near-surface interior.

As an important application the quasi-stationary temperature distribution and gas flux and sublimation rate were computed for a nucleus model of comet 19P/Borrelly at the Deep Space 1 (DS1) encounter. The surface temperature of the layer-absorbing model as well as the gas production rate are significantly smaller than the ones in the surface-absorbing model. An active fraction as large as 40-50% of the total surface would be required to explain the observed water production rate of P/Borrelly with our layer-absorption model at the time of the DS1 encounter.

(H.U. Keller, W.J. Markiewicz, Yu.V. Skorov)

## The Earth's moon

### On the creation of electric fields around the moon – applications to remote sensing of electric conductivities

The electrostatic potential around the Moon determines all electrodynamical processes in the

plasma environment close to the Moon. In the past, work centred on the sunlit hemisphere where photoelectrons are emitted from the lunar surface due to solar UV photons. Since the photoemission rate is much greater than the rate of electron accretion from the solar wind, the surface becomes positively charged, pulling most emitted photoelectrons back. Since the average photoelectrons do not have the energy to rise against electrostatic forces, an electron layer forms just above the lunar surface. This so-called lunar photoelectron layer (PEL) is an example of what is generally called a double layer, a region of non-neutral plasma consisting of two adjacent space charge layers, one positively and one negatively charged. In the context of lunar research, these double layers are considered interesting for three reasons. First, they can yield information about the lunar surface. Second, they can alter ion trajectories and energies, and third, they can lead to electric charging of dust and its transport. Our research investigated the mechanisms by which electric potentials arise on the nightside of the Moon and the determination of a representative analytical model.

While the solar UV photons are responsible for the lunar potential on the sunlit side, the suprathermal part of the ions and electrons is able to penetrate into the shadowed region of the Moon. It is an inequality of the electron and ion fluxes in the rarefaction region which is the ultimate cause of the creation of an electric field on the nightside of the Moon. A numerical estimation shows that the transversal electric field of polarisation just behind the Moon is large enough ( $\sim 1-10$  mV/m) to be easily measured. The fact that the measurable electric potential is directly linked with the conductivity gives an opportunity for the application of our results. The decrease in the electron flux behind the Moon is determined by the negative electric potential. From measurements of electron fluxes in different energy ranges, the distribution of the potential can be recovered. This opens the road to remote explorations of crustal conductivities not only of the Moon, but also for various large, nonmagnetised solar system bodies.

(U. Mall, N. Borisov, Radio Waves Propagation (IZMIRAN, Russia))

## Future projects in planetary and cometary science

### **BEPICOLOMBO: Mission to Mercury**

The next major planetary cornerstone in ESA's programme (following Rosetta) is called Bepi-Colombo and comprises a planetary orbiter, a lander and a magnetospheric orbiter which will investigate the properties of the innermost planet, Mercury. It is expected that proposals for investigations will have to be made in 2003 with launches due to occur in 2010 and 2011. MPAAE is currently studying possible participation in the main imaging system, a laser altimeter system (for the investigation of gravitational anomalies and surface structure) and a laser mass spectrometer (for detailed studies of the surface composition).

(N. Thomas)

### **VENUS EXPRESS: A proposed European mission to Venus in 2005**

Venus Express is an orbiter mission to Venus in 2005 proposed in response to the ESA Call for Ideas for re-use of the Mars Express bus. The proposal aims at the global investigation of the Venus atmosphere and plasma environment and addresses important aspects of the geology and surface physics. The mission re-uses the Mars Express spacecraft and ground segment of Mars Express project with minor modifications. Nine instruments, most of which are spare models of Mars Express and Rosetta instruments, form the payload that is capable to achieve the scientific goals. The proposal has successfully passed the selection procedure and is included in the list of potential ESA missions.

The first phase of Venus spacecraft exploration (1962-1985) by the Venera, Pioneer Venus and Vega missions established a basic description of the physical and chemical conditions prevailing in the atmosphere, near-planetary environment, and at the surface of the planet. At the same time, they raised many questions on the physical processes sustaining these conditions, most of which remain as of today unsolved. Extensive radar mapping by Venera-15,-16 and Magellan orbiters, combined with earlier glimpses from landers, have expanded considerably our knowledge of Venus' geology and geophysics. A similar systematic survey of the atmosphere is now in order. This particularly concerns the atmosphere below the cloud tops, which, with the exception of local measure-

ments from descent probes, has escaped detection from previous Venus orbiters. Many problems of the solar wind interaction, in particularly those related to the impact on the planetary evolution are still not resolved.

The fundamental mysteries of Venus are related to the global atmospheric circulation, the atmospheric chemical composition and its variations, the surface-atmosphere physical and chemical interactions including volcanism, the physics and chemistry of the cloud layer, the thermal balance and role of trace gases in the greenhouse effect, the origin and evolution of the atmosphere, and the plasma environment and its interaction with the solar wind. Besides, the key issues of the history of Venusian volcanism, the global tectonic structure of Venus, and important characteristics of the planet's surface are still unresolved. Beyond the specific case of Venus, resolving these issues is of crucial importance in a comparative planetology context and notably for understanding the long-term climatic evolution processes on Earth.

The above problems can efficiently be addressed by an orbiter equipped with a suite of adequate remote sensing and in situ instruments. Compared with earlier spacecraft missions, a breakthrough will be accomplished by fully exploiting the existence of spectral "windows" in the near-infrared spectrum of Venus' nightside, discovered in the late '80'-s, in which radiation from the lower atmosphere and even the surface escapes to space and can be measured. Thus, a combination of spectrometers, spectro-imagers, and imagers covering the UV to thermal IR range, along with other instruments such as a radar and a plasma analyser, is able to sound the entire Venus atmosphere from the surface to 200 km, and to address specific questions on the surface that would complement the Magellan investigations. This mission will also tackle still open questions of the plasma environment focusing on the studies of nonthermal atmospheric escape. This issue will be addressed via traditional in situ measurements as well as via innovative ENA (Energetic Neutral Atom) imaging techniques.

The following instruments, most of which are available as spare models from the Mars Express and Rosetta missions, will form the payload: ASPERA – a combined energetic neutral atom imager, electron, and ion spectrometer, MAG – a magnetometer, PFS – a high-resolution IR Fourier spectrometer, SOIR – a very high-resolution IR spectrometer for solar occulta-

tions, SPICAM – a versatile UV-IR spectrometer for nadir observations and solar/stellar occultations, VENSIS – a radar for subsurface and ionospheric sounding, VeRa – a radio science experiment, VIRTIS – a sensitive visible spectro-imager and mid-IR spectrometer, and VMC – a wide-angle monitoring camera. Taken together, these experiments can address all the broad scientific problems formulated above. The Mission Definition Study demonstrated the feasibility of the proposed mission to Venus in 2005. The Mars Express spacecraft can accommodate the above mentioned experiments with minor modifications. The launch with Soyuz-Fregat can deliver the payload to a polar orbit around Venus with a pericenter altitude of  $\sim 250$  km and apocenter of  $\sim 50\,000$  km. This orbit will provide complete coverage in latitude and local solar time. It is also well suited for atmospheric and surface sounding, as well as the studies based on solar and radio occultations. The proposed duration of the nominal orbital mission is two Venus days (sidereal rotation periods) equivalent to  $\sim 500$  Earth days. The Venus Express mission will achieve the following “firsts”:

- first global monitoring of the composition of the lower atmosphere in the near IR transparency “windows”,
- first coherent study of the atmospheric temperature and dynamics at different levels of the atmosphere from the surface up to  $\sim 200$  km,
- first measurements of global surface temperature distribution from orbit,
- first study of the middle and upper atmosphere dynamics from  $O_2$ ,  $O$ , and  $NO$  emissions,
- first measurements of the non-thermal atmospheric escape,
- first coherent observations of Venus in the spectral range from UV to thermal infrared,
- first application of the solar/stellar occultation technique at Venus,
- first use of 3D ion mass analyser, high energy resolution electron spectrometer, and energetic neutral atom imager,
- first sounding of Venusian topside ionospheric structure,
- first sounding of the Venus subsurface.

Together with the Mars Express mission to Mars and the Bepi Colombo mission to Mercury, the proposed mission to Venus, through the expected quality of its science results, would ensure a coherent program of terrestrial planets exploration and provide Europe with a leading position in this

field of planetary research. The international cooperation formed in the framework of the Mars Express and Rosetta missions will be inherited by the Venus Express and will include efforts of the scientists of European countries, USA, Russia, and Japan. The Venus Express orbiter will play the role of pathfinder for future, more complex missions to the planet, and the data obtained will help to plan and optimise future investigations. Venus studies can have significant public outreach given the exotic conditions of the planet and the interest in comparing Venus to Earth, especially in a context of concern with the climatic evolution on Earth.

(D.V. Titov, H.U. Keller, W.J. Markiewicz, N. Thomas, J. Woch, N. Krupp, P. Hartogh and the Venus Express team)

### **MARS EXPRESS: The first European mission to Mars**

In June 2003, the European Space Agency will launch its first mission to Mars, Mars Express. The spacecraft carries a lander called Beagle 2 which is designed to bounce onto the surface of Mars on Christmas Day, 2003.

#### *The Beagle 2 microscope*

The lander has a robotic arm on which there are several instruments including a microscope provided by MPAE. The microscope for the Beagle 2 lander on ESA’s Mars Express mission is derived from a design originally proposed for the Mars Environmental Compatibility Assessment (MECA) experiment package in which MPAE was heavily involved. This package was to fly on NASA’s Mars ’01 lander mission. After the failure of Mars Climate Orbiter and Mars Polar Lander, NASA performed a re-evaluation of their programme and eventually MECA and the entire 2001 lander mission were cancelled. MECA was to carry some highly sophisticated instrumentation. The optics of the microscope were designed by a team led by Peter Smith from the Lunar and Planetary Laboratory (LPL) at the University of Arizona. The detector for the MECA microscope was to be similar to the one flown on Mars Pathfinder and supplied by MPAE. MPAE has a world-wide reputation for supplying detectors and associated read-out electronics of the highest quality. The MECA charge-coupled device (CCD) was part of batch of CCDs originally procured for the Descent Imager/Spectral Radiometer experiment which is currently flying to the Saturnian moon, Titan,

on board ESA's probe Huygens. Like the IMP, this experiment was part of a highly constructive partnership between LPL and MPAE. LPL would supply the optics and an illumination system. The CCD package would be provided by the Centre Suisse d'Electronique et de Microtechnique SA (CSEM). This system was already highly miniaturised and had been tested under an ESA Technical Research Programme contract in preparation for a Mars surface mission. MPAE would lead the team, perform the integration of the microscope, test it, and calibrate it.

The result of this collaboration has been sensational. The microscope will be the highest resolution optical experiment ever to reach Mars with a pixel scale of 4.07 microns per pixel with a spatial resolution of 6 microns over an area of roughly 4 mm × 4 mm. Even the micro-imagers for NASA's rovers for 2003 only have scales of around 30 micron per pixel. The microscope can image surfaces in 3 colours using super-bright light emitting diodes (LEDs) which are individually switchable. A set of 3 ultra-violet LEDs have been incorporated to stimulate fluorescence. The whole microscope (Fig. 57) is cantilevered off a stepper

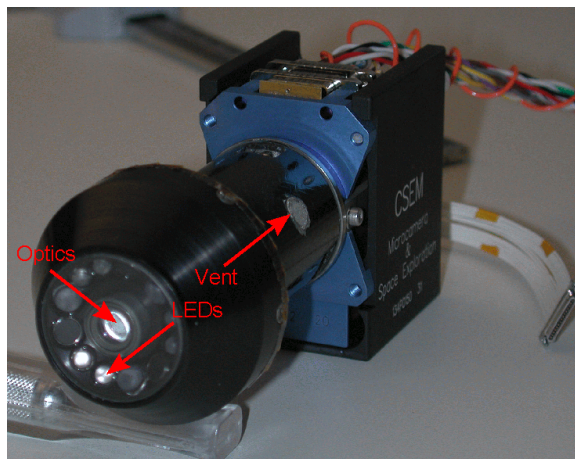


Fig. 57: The flight model of the Beagle 2 microscope. The instrument is 11.5 cm long. Here one can see the entrance aperture of the microscope which is surrounded by 12 super-bright LEDs to illuminate the target. The detector is held in a protective cover in this picture.

motor which is used to focus the microscope. This motor as part of the Beagle 2 robotic arm (called the PAW), has to be very accurate because the depth of focus of the microscope is only about 40 microns. This has been achieved within a mass of just 240 grams. Special software has been written to reconstruct a scene from an imaging sequence which is taken at different focus positions. Hence,

we are able to get the entire imaged area in focus and at the same time construct a depth map so that we can study the rock structure in 3D (Fig. 58).

The microscope has several scientific objectives. It will be used to

- look at rock surfaces to investigate how weathering on Mars affects their structure,
- image rock interiors to search for evidence of how the rocks was formed (e.g. Are they sedimentary or igneous? Do they show layering?),
- determine dust and soil particle sizes and shapes which is needed to constrain models of light scattering by particles in the atmosphere of Mars,
- and then there is the question of life.



Fig. 58: An image of a sample of sedimentary rock from Piz Alv in Switzerland taken with the Beagle 2 microscope. MPAE has a collaboration with the Natural History Museum in Bern, Switzerland (B. Hofmann) to investigate Mars analogues with the microscope.

Many people ask whether one can identify bacteria or fossils with the microscope. The answer is not straightforward and it is highly unlikely that the microscope will give scientific proof but it can give indications. Fossilised bacteria and other primitive lifeforms do produce characteristic structures in rocks. However, it is extremely difficult to eliminate the possibility that geological processes produced those structures. Similarly, inducing a structure to fluoresce might be an indication of organic material (e.g. chlorophyll) but

then again there are several fluorescent inorganic rock types on the Earth. The answer that the microscope provides is therefore likely to be ambiguous. On the other hand, such a detailed study of martian surfaces is bound to provide answers to questions we haven't even thought about yet.

(N. Thomas, A. Basilevsky, S.F. Hviid, H.U. Keller, W.J. Markiewicz in collaboration with LPC, CSEM, University of Leicester, United Kingdom)

### Mars advanced radar for subsurface and ionospheric sounding, MARSIS

The primary purpose of MARSIS, a radar experiment on the Mars Express spacecraft, is to attempt to identify ice or water under the surface of Mars. There is ample evidence that water must have flown over the surface of Mars in abundance in the past. The escape mechanisms are believed to be inadequate for the water to have escaped, and the consensus now is that the water exists under the surface. If so, the subsurface water or ice will create a situation where the refractive index changes with depth, which will give rise to reflection of penetrating electromagnetic waves. Subsurface water or ice layers have therefore been revealed as echoes from below the surface. There are several problems which must be overcome when searching for these echoes. The radar frequency must be chosen low enough for the waves to penetrate with little attenuation. The surface must be smooth enough for the subsurface echoes not to be confused by off nadir surface echoes and coherent Doppler filtering must be used to reduce the surface clutter. Another problem stems from the dispersive effects of the martian ionosphere which will distort and broaden the short pulses needed to identify subsurface layers. The dispersion is determined by the total integrated electron content between the surface and the orbiting spacecraft. The maximum electron density defines the minimum frequency which can be employed in the radar system, and there is a strong preference for night time observations when the electron content in the ionosphere is the lowest. Reflection at the top of the ionosphere at frequencies below the maximum plasma frequency will be used to derive the electron density profile of the upper ionosphere and the results will be used in studies of the interaction of the martian upper atmosphere with the solar wind. The MPAE team is at present engaged in the development of models of the subsurface, the surface and the ionosphere in anticipation of the data which will become avail-

able after the arrival of the spacecraft at Mars in December 2003.

(T. Hagfors, J. Ilyushin, E. Nielsen, J.-S. Wang)

### Analyser of space plasmas and energetic atoms (ASPERA-3) for Mars Express

The general scientific objective of the ASPERA-3 (Fig. 59) experiment is to study the solar wind – atmosphere interaction and characterise the plasma and neutral gas environment in the near-Mars space through energetic neutral atom (ENA) imaging. The main scientific objectives can be subdivided into specific scientific tasks:

- determine the instantaneous global distributions of plasma and neutral gas near the planet,
- study plasma induced atmospheric escape,
- investigate the modification of the atmosphere through ion bombardment,
- investigate the energy deposition from the solar wind to the ionosphere.

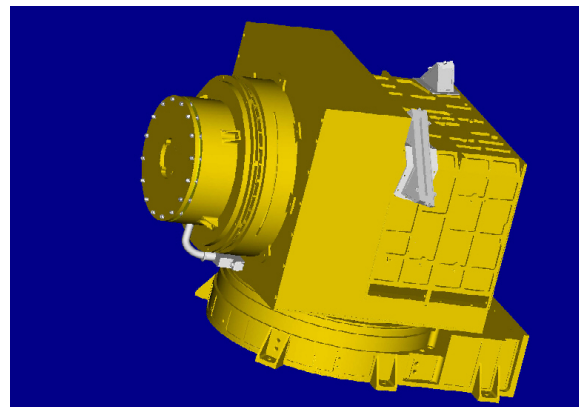


Fig. 59: Part of the ASPERA-3 instrument.

The studies to be performed address the fundamental question: *How strongly do the interplanetary plasma and electromagnetic fields affect the martian atmosphere?* This question is directly related to the problem of martian dehydration. Where is the martian water? Is it lost or frozen and buried? If it is the former, what could produce such an effective escape mechanism? If the latter, where is this tremendous amount of water stored? Since liquid water is the fundamental requirement for life, a clear understanding of the fate of the martian water is a crucial issue in resolving the problem *whether or not life existed on Mars in the past*. No instrumentation with similar scientific objectives has or is planned to be flown to Mars.

(J. Woch, N. Krupp, in collaboration with IRF, Kiruna, Sweden)

### **MAMBO: Mars Atmosphere Microwave Brightness Observer**

#### **Scientific Objectives :**

The microwave sounder MAMBO aims to characterise the dynamic and the composition of the martian atmosphere, with an unprecedented sensitivity. For this purpose, we propose to analyse the thermal emission of the atmosphere at microwave frequencies using heterodyne spectroscopy, for the first time from orbit around another planet. In practice, MAMBO will perform measurements at the atmospheric limb and at nadir using a receiver dedicated to the monitoring of selected lines of key molecule around 320-350 GHz: H<sub>2</sub>O, CO, <sup>13</sup>CO, HDO, O<sub>3</sub>. In such conditions, the instrument performance will allow the 3D mapping, with an excellent spatial coverage, of the following characteristics :

**Wind :** The high spatial resolution allows to make use of the line profiles and their Doppler shift. Limb viewing thus allows the first direct measurements of the winds on Mars from orbit from 20 to 110 km with a vertical resolution better than 10 km and an accuracy of about 15 m/s. Such a measurement will provide key information on the atmospheric dynamic.

**Temperature :** The temperature profile will be retrieved with high vertical resolution (5 km) without regard to dust opacity and season. A unique characteristic of Microwave sounding is the ability to profile temperature up to 120 km, compared to 70 km for previous sounders.

**Water Vapour :** Near the surface up to 60 km, with a sensitivity and vertical resolution (5 km) much better than previous experiments, without regard to dust opacity and season.

**D/H Ratio :** This isotopic ratio will accurately be mapped from 0 to 40 km by simultaneous spectroscopy of H<sub>2</sub>O and HDO. Mapping the variation D/H ratio is a key investigation to understand the evolution of water on Mars, escape processes, and Mars cloud microphysics.

**Hydrogen Peroxyde (H<sub>2</sub>O<sub>2</sub>) :** These species have never been observed on Mars, yet. However, several models have shown its key importance for the photochemistry of the martian atmosphere (control of H<sub>2</sub>, O<sub>2</sub> and CO) and for its role (thought to be major) in oxydising the martian soil, a problem of key interest for exobiology.

**Ozone :** Ozone profile will be measured accurately up to 70 km, simultaneously with water va-

por. This will allow us to better understand the relationship between the two species.

**Carbon Monoxyde :** The variations of these species will be monitored up to 120 km, providing important clues on the meridional transport in the martian atmosphere.

**Surface Science :** MAMBO will perform a dedicated mapping of the surface microwave emission. By observing both the horizontal and vertical polarisation and using varying viewing angles and local time, we will map the variations due to 1) subsurface ice contents 2) surface roughness 3) CO<sub>2</sub> ice cap characteristic variations, and 4) variation of the temperature sensing depth.

Overall, the combination of these measurements provide us a complete view of Mars' atmospheric dynamics, water cycle, and atmospheric photochemistry. In such a context, strong synergy with the Netlander mission and the other Premier Orbiter instruments are identified.

(P. Hartogh, in collaboration with colleagues from France, USA and Sweden)

### **MAOAM: The Martian Atmosphere: Observation and Modelling**

Future microwave experiments operating in the mm- and sub-mm range will strongly improve our knowledge of the structure, dynamic and chemistry of the martian atmosphere. Limb sounders in low orbits will provide highly resolved altitude 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 atmospheric interactions makes in general a simple interpretation of such data difficult. Therefore models for the descriptions of atmospheric processes are required.

In this project we will use Mart-ACC (Martian Atmosphere – Circulation and Climate Model) describing the general circulation of the martian atmosphere in the altitude range of 0–130 km. Mart-ACC has been developed in context with the Mars96 mission and our plan is to upgrade it to Mart-ACC-CT (chemistry and transport). Mart-ACC-CT will contain a coupled system of dynamics and chemistry, describe radiative processes under conditions of non local thermodynamical equilibrium (NON-LTE) and apply new data assimilation techniques. Newest findings from Earth mesospheric chemistry and dynamic will be included. It is planned to use the results of Mart-

ACC-CT for microwave radiative transfer modelling and the preparation of observing strategies for the above mentioned microwave experiments.

(P. Hartogh, C. Jarchow)

### MARVEL: Mars Volcanic Emission and Life

The MARVEL Scout mission is a carefully focused study of Mars that complements the primary elements of the NASA Mars Exploration Program. The launch is planned for 2007 and its scientific operation from 2008 until 2012. MARVEL will obtain unique observations, over one Mars year, of the temporal and spatial variability of major, minor, and trace chemical constituents, a comprehensive analysis of the Mars atmosphere not accomplished by any previous Mars mission and not currently planned for any future mission. Such an investigation is a prototype for planned NASA Origins Program missions seeking to detect habitable extrasolar terrestrial planets and determine whether they are inhabited. The Mars atmosphere is a virtually unexplored realm for the objectives of astrobiology. The MARVEL science goals are

- to completely characterise the chemistry of the atmosphere of Mars and, on the basis of this understanding, to seek to identify atmospheric signatures of extant volcanic activity and extant life,
- to map surface sources of water and other chemical species identified in the atmosphere that might emanate from the surface, which would be indicative of local abodes supportive of life or where life itself might be present,
- to characterise the composition and vertical distribution of atmospheric clouds and aerosol particles,
- to characterise the vertical structure of the upper atmosphere.

Marvel consists of 3 instruments:

- Mars Imager for Clouds and Aerosols (MICA),
- Mars Atmospheric Occultation Spectrometer (MATMOS),
- Submillimeter Instrument for Gauging the Natural Abundance of Life (SIGNAL).

The MPAAE contribution will focus on SIGNAL (Fig. 60) which is a novel implementation of technologies developed for other missions (MIRO and HIFI). SIGNAL will provide global maps of the

near-surface abundances of water and other atmospheric chemical constituents. SIGNAL is a

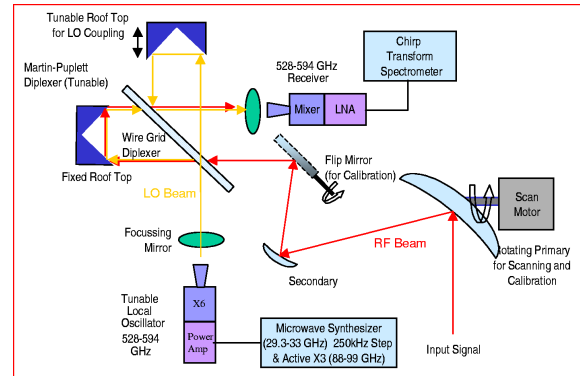


Fig. 60: Signal block diagram.

very flexible instrument, i.e. the spectral range can be adjusted in order to respond to previously acquired results of HIFI, GREAT and MATMOS.

(P. Hartogh, in collaboration with colleagues from USA and Canada)

### SOFIA: Stratospheric Observatory for Infrared Astronomy

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  $\mu\text{m}$  and 600  $\mu\text{m}$ , 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 characterises 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 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 centre 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 (Fig. 61).



Fig. 61: Boeing 747 carrier for SOFIA experiment.

#### **GREAT: German Receiver for THz Astronomy**

GREAT (Fig. 62) 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 is a high resolution Chirp Transform Spectrometer. Although the spacial resolution and sensitivity of SOFIA will be worse compared to the Herschel Space Observatory, we will try to cover part of the same science. For the firsts flights which are planned for 2004 we will focus on water in the martian atmosphere.

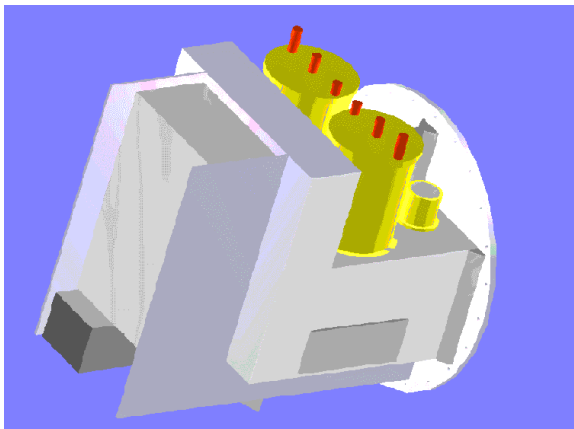


Fig. 62: GREAT instrument.

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

#### **HERSCHEL Space Observatory (former Far Infrared Space Telescope – FIRST)**

The Herschel Space Observatory (Fig. 63) – the mission formerly known as FIRST – will perform photometry and spectroscopy in the 60–670  $\mu\text{m}$  range. It will have a radiatively cooled tele-

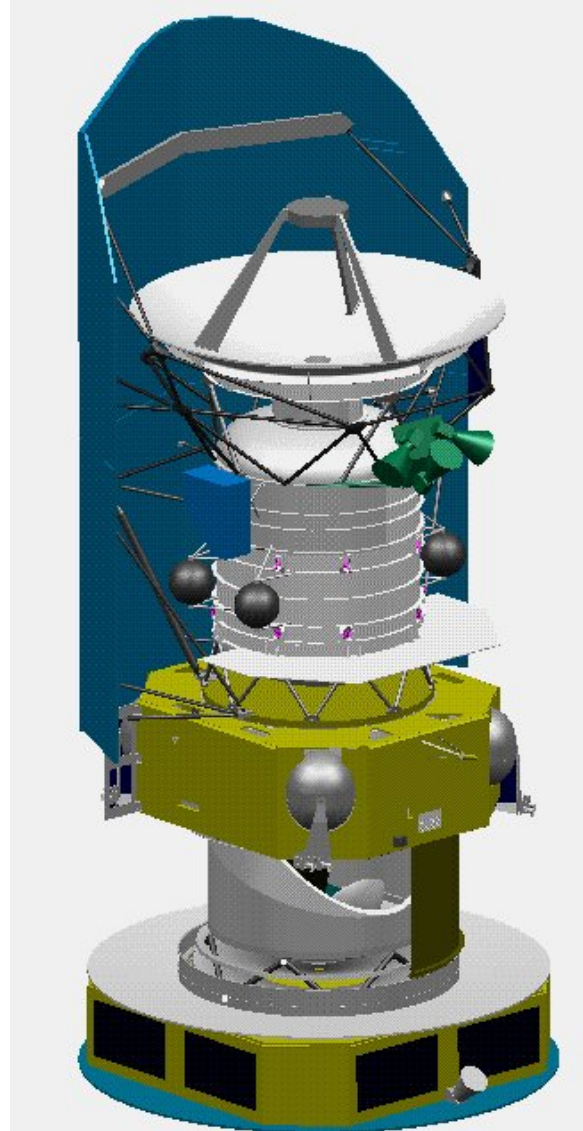


Fig. 63: Herschel Space Observatory.

scope 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. 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 these 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 its 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. Outside the solar system we are interested to study the formation of planetary nebulae and their evolutionary history beginning from the protoplanetary phase. 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, P. Börner, W. Boogaerts, C. Jarchow, W.H. Ip, W. Marciewicz, S.K. Solanki, N. Thomas, E. Steinmetz, I. Héjja, A. Loose, M. Clement, U. Strohmeyer, W. Wunderlich)

### ROSETTA: Mission to comet 46P/Wirtanen

In January, 2003 Rosetta (an ESA corner stone mission) will be launched from Kourou on an Ariane 5 carrying MPAE's two major experiments, the RoLand lander and the OSIRIS high resolution imaging system for the orbiter. Further MPAE participation in the CONSERT, MIRO, and ROSINA experiments will ensure that the first half of 2003 will highly be active as the experiments are switched on and tested for the first time in flight. The first science data from the orbiter experiments (OSIRIS, MIRO and ROSINA) will be acquired during the Mars fly-by in 2005.

### CONSERT: Cometary Nucleus Sounding Experiment by Radiowave Transmission

CONSERT is a radio wave experiment in the ROSETTA mission to be launched by ESA in 2003. A spacecraft will orbit the cometary nucleus, and another spacecraft, a Lander, will settle on its surface. In the CONSERT experiment 90 MHz radio waves will be transmitted through the comet between the two spacecraft. The experiment is designed to sound the interior of a comet to determine spatial structures and the electrical properties of the cometary material. The experiment is a joint project between French and German scientists. MPAE is responsible for the antenna systems on both spacecraft. The low mass allocated to the experiment means that no mechanically or electronically steerable narrow main antenna lobe can be contemplated. The antennas must have a wide antenna lobe centred on the comet, such that the whole comet is continuously illuminated. This will ensure the best possible signal intensity on the direct ray between orbiter and Lander. On the orbiter a turnstile antenna with reflectors was selected. Essentially, the antenna is constructed of 10 rods (4 dipole elements (aluminum), 4 reflector elements (aluminum), 2 masts (carbon fiber)). The rods are appropriately connected to each other by springs. The rods are placed parallel to each other in launch position, and near their centre they are lashed with a steel wire to a support mounted on the spacecraft body. Once in interplanetary space the wire will be cut by a pyro device; this releases the antenna which then deploys automatically under the action of the spring forces, and locks into place. The antenna mass is  $\sim 1.5$  kg. The spatial variations of the directional antenna gain of the antenna mounted on a spacecraft was calculated (using NEC), and

compared to experimental measurements of the radiation diagram made in an anechoic chamber at ASTRUM in Porthmouth, UK. The measurements confirmed the designed performance of the antenna system. On the Lander the antenna is composed of two crossed monopoles, which extend perpendicular away from the Lander body (parallel to the comet surface). Each monopole is mounted with a spring to the body, which allows it to lie folded back along the body during launch and until the Lander is released from the orbiter. The antenna mass is 200 g. The spatial variations of the directional antenna gain of the antenna mounted on the Lander in free space were calculated (using NEC), and compared to experimental measurements of the radiation diagram made between the roofs of two high buildings at Ruhr University Bochum (RUB), Germany. The measurements confirmed the designed performance of the antenna system. The flight models of the antennas were essentially ready by the end of 2001. They have been delivered to ESA and are integrated on the spacecraft.

(E. Nielsen)

#### **ROSINA: Rosetta Orbiter Spectrometer for Ion and Neutral Analysis**

The international Rosetta comet rendezvous mission represents an extraordinary opportunity to perform a detailed investigation of a primitive object in our solar system. As part of the core payload for this mission, the Rosetta Orbiter Spectrometer for Ion and Neutral Analysis (ROSINA) proposed here will answer outstanding questions concerning the main objectives of the mission. The primary measurement objective of the spectrometer is:

- to determine the elemental, isotopic and molecular composition of the atmospheres and ionospheres of comets,
- to determine the global molecular, elemental, and isotopic composition and the physical, chemical and morphological character of the cometary nucleus,
- to determine the processes by which the dusty cometary atmosphere and ionosphere are formed,
- to investigate the origin of comets,
- to investigate possible asteroid outgassing.

(A. Lagg, A. Korth, in collaboration with University of Bern, Switzerland)

#### **MIRO: Microwave instrument for the ROSETTA-Orbiter**

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. 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 and mass per spectrometer channel. The delivery of the flight model to JPL happened in spring 2000 and it has successfully been tested. The completion of the flight spare has been postponed by more than a year caused by a lack of funding and workforce.

(P. Hartogh, K. Fischer, W.H. Ip, C. Jarchow, C. Römer, L. Song, E. Steinmetz, U. Strohmeyer, M. Thiele, W. Wunderlich)

#### **OSIRIS: Camera system on ROSETTA**

The Optical, Spectroscopic, and Infrared Remote Imaging System (OSIRIS) is the scientific imaging system onboard the Rosetta spacecraft. The main science objectives are to characterise the cometary nucleus and its immediate environment. The synoptic observations during the rendezvous from the onset of activity at a heliocentric distance of about 4 AU to perihelion of comet Wirtanen will reveal the physical properties of active areas and the physics of cometary activity. Scientific results are also expected during the fly-bys of the planets Mars and Earth and from the fly-bys of two asteroids on the way of Rosetta to comet Wirtanen. OSIRIS is comprised of two optical systems: a wide angle camera (WAC) and a narrow angle camera (NAC) providing 5 times better resolution. Both systems are advanced tilted mirror (2 for the WAC, 3 for the NAC) designs avoiding obscurations within the field of views and provide thus low straylight levels and a high dynamic range. Matching CCD detectors and readout electronics have been developed providing 2k x 2k back illuminated pixels with antiblooming. This yields high quantum efficiency (peak > 90%) extending well into the ultra violet (250 nm) wave-

length range. Overexposed pixels (e.g., the bright illuminated limb of the nucleus) will not influence other parts of an image (e.g., displaying faint dust activity). The cameras use identical subsystems, such as shutters and filter wheels. The filters themselves are, however, optimised for the specific science objectives of coma (WAC) and nucleus (NAC) observations. The resolving power of the NAC is deliberately restricted to 20 rad per pixel (slightly worse than that of the Halley Multicolour Camera of the Giotto mission). This translates to a geometric scale of 2 cm per pixel from a distance of 1 km but at the same time provides a field of view of the WAC of 20 m squared. The Rosetta spacecraft is supposed to approach the nucleus of comet Wirtanen even closer than 1 km and therefore we can expect images of the nuclear surface with a resolution of a few centimetres. The data volume that will be transmitted strongly restricts the number of scientific images. A digital terrain model (DTM) of the nucleus with an accuracy of about 1 m can be achieved applying strong onboard data compression. The overall scientific yield applying all 28 different filters will heavily depend on optimised onboard data handling within the OSIRIS digital processing unit (DPU). Images or parts of images with interesting content have to be automatically (pre-) selected and appropriately compressed to reduce the overall data volume of OSIRIS to about 1 Gbyte. Development of the commanding and data handling software for OSIRIS has started in 2001 (responsibility of MPAE in co-operation with IDA).

OSIRIS has been developed and built by a large European team including scientists from Holland (ESA/ESTEC), Germany, France, Italy, Spain, and Sweden under the leadership of MPAE (PI H.U. Keller). The cameras were calibrated at MPAE in autumn 2001 and delivered to ESA by the end of 2001, nearly one year behind the original schedule. The flight spare systems and subsystems are currently being built. The development of a simulator software program as a planning tool for the observation strategy and appropriate procedures essentially stopped when L. Jorda left the institute in early 2001.

(H.U. Keller, N. Thomas and the OSIRIS team)

### Impact on a comet: Rosetta Lander simulations

In the year 2012 the Rosetta Lander will be ejected from the Rosetta orbiter and, after a descent time of up to 3 h, touch the surface of

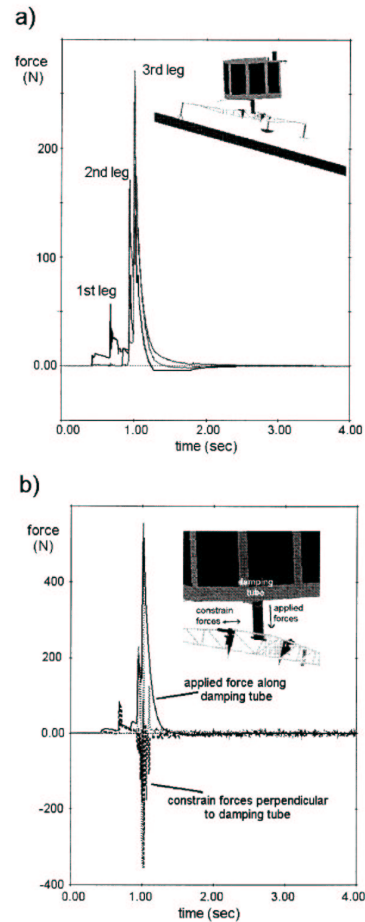


Fig. 64: Applied forces on the Lander legs (elasticity). The contact of the 1st foot with the comet surface results only in a minor force of about  $10 \pm 50$  N while the main impact of the 2nd and 3rd leg about 0.45 s later gives rise to 170 N or 260 N, respectively. (b) applied and constrain forces along and perpendicular to Lander damping tube during impact. The constrain forces are due to the decelerating of the lateral velocity component caused by the foot-surface friction forces.

comet 46P/Wirtanen. The objective of the simulations of the landing on a comet is the analysis and understanding of the dynamics of the Rosetta Lander on impact on the comet surface. The Lander properties are well known prior to launch. The data on the comet surface are far less familiar and must be described within an envelope covering a range of possible physical surface parameters. The kinetic energy of the Lander is damped on impact in less than 1 s and the Lander must be secured on the cometary surface. The 3D simulations are carried out in the frame of a multibody analysis and the positions, velocities, applied and con-

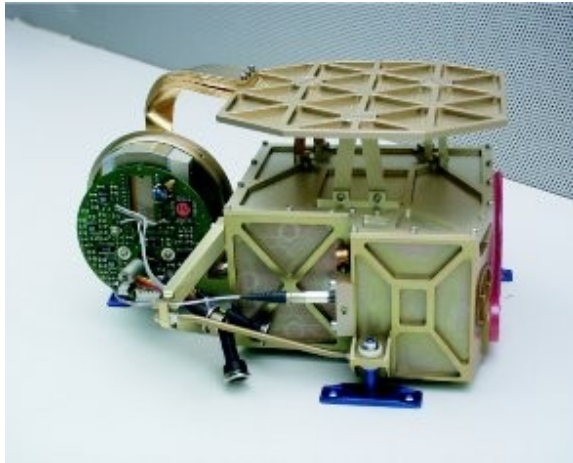


Fig. 65: SIR consists of an optic box and an attached spectrometer. The spectrometer contains a quartz body on whose end an aberration corrected concave grating sits, an optical fiber, which transmits the optical input signal to a photo diode linear array, which records then the spectrum.

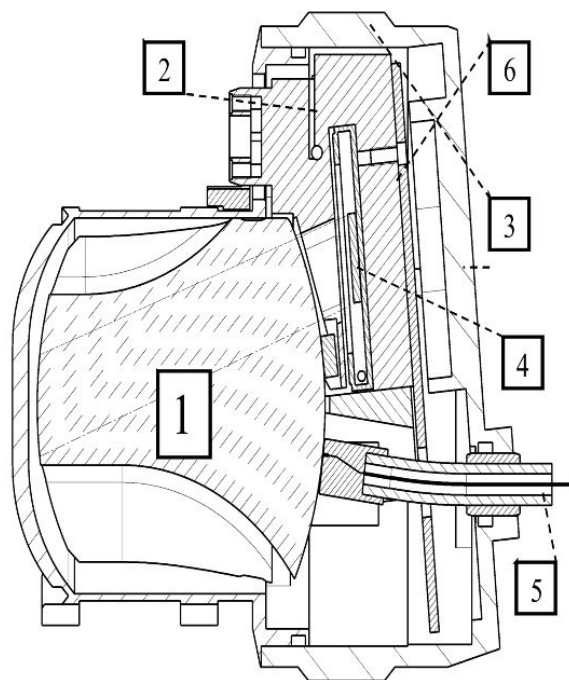


Fig. 66: Cross section of sensor head. 1: Quartz body; 2: Internal cooling finger; 3: Al shielding; 4: Sensor; 5: Optical fiber; 6: Printed circuit board.

strain forces are analysed (Fig. 64).

(M. Hilchenbach, O. Küchemann, H. Rosenbauer)

### SMART-1 (Small Missions for Advanced Research in Technology)

SMART-1 is the first of a new series of small technical missions with the goal to test a new propulsion system, to be used later in a mission to fly to Mercury. The SMART-1 spacecraft will be tested in 2003 when it will take off to fly to the Moon where it will observe the lunar surface over a period of six months from an orbit of 300-10 000 km with a period of 14-15 hours.

### SIR

Included in the 15 kg heavy payload is the instrument SIR (see Fig. 65 and Fig. 66), built by a MPAE led consortium. It is a non-imaging, near-infrared reflexion spectrometer operating between a 0.94 and 2.4  $\mu\text{m}$  wavelength with a resolution of 6 nm. Despite numerous flown lunar missions, our knowledge of the lunar composition is heavily biased. From the 9 in-situ explored regions on the Moon, only two are located in the lunar highlands, which cover 80% of the Moon's surface, while the rest covered the Mare regions. The prime purpose of the instrument is to globally explore the mineralogy of the lunar surface. This information, combined with the in-situ measurements from the Apollo and Luna missions, is necessary for testing petrological models based on lunar formation theories against the observed mineralogical distribution. This knowledge will then ultimately allow us to infer some of the parameters of the current generally accepted Giant-Impact model.

(H.U. Keller, U. Mall, W. Markiewicz, A. Nathues, N. Thomas, T. Bluemchen, A. Dannenberg, H. Perplies)

### Concluding remarks

There are several other opportunities for MPAE investigators coming up in the near future. In general, there are usually more possibilities than there are resources available and hence we continue to be in the happy position of being able to pick and choose which experiments are of most interest to us. This in turn allows us to maintain a highly active and visible profile within the planetary community.

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

#### Schwerpunktthema der Magnetosphärenforschung:

#### Die Cluster-Mission

(English version see page 96)

Unsere Erde ist durch mehr als nur Licht und Wärme mit der Sonne verbunden. Ein kontinuierlicher Strom von Ionen und Elektronen, der *Sonnenwind*, expandiert als neutrales Plasma mit einer Geschwindigkeit von 300–1000 km/s von der Sonne aus ins All und strömt damit auch auf die Erde zu. Das Leben auf unserem Planeten wurde erst dadurch möglich, dass die Erde uns und unsere Atmosphäre durch ihr Magnetfeld vor den anströmenden energiereichen Teilchen schützt. Wie variabel solche Schutzschilde sind, wird uns wohl am besten bewusst, wenn wir an die spektakulären Nord- und Südlichterscheinungen oder an die Zerstörung der Ozonschicht in der Stratosphäre denken. Die Variabilität der Magnetosphäre rührt daher, dass sie dynamisch auf Änderungen der mittels des Sonnenwinds vermittelten Aktivitäten der Sonne reagiert. Wie strukturiert sich nun aber die Magnetosphäre?

#### Die Erdmagnetosphäre

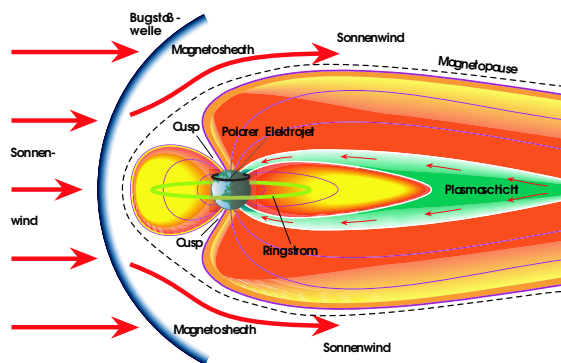


Abb. 67: Schematische Darstellung der Erdmagnetosphäre.

Das Magnetfeld der Erde (Abb. 67) stellt ein Hindernis für den sich mit Überschall ausbreitenden Sonnenwind dar. Infolgedessen kommt es zur Ausbreitung einer Bugstoßwelle im Abstand von  $\sim 12$ – $15$  Erdradien ( $1 R_E = 6371$  km) vor der Erde, hinter der der Sonnenwind mit Unterschallgeschwindigkeit langsamer und aufgeheizt weiterfließt. Erst hinter einer weiteren Grenzschicht, der *Magne-*

*topause*, die als Grenzschicht zwischen magnetosphärischem und interplanetarem Plasma dient und sich auf der der Sonne zugewandten Seite der Erde in einem Abstand von etwa  $10 R_E$  ausbildet, beginnt dann die eigentliche Magnetosphäre, die sich nachts ähnlich einem Kometenschweif bis zu einigen Millionen Kilometern dahinstreckt. Der Bereich zwischen Bugstoßwelle und Magnetopause wird als *Magnetosheath* bezeichnet. Die Teilchen, die dort beobachtet werden, stammen vor allem aus dem Sonnenwind, wie man an Hand ihrer Zusammensetzung schließen kann.

Die Magnetopause trennt eine Region, wo das Magnetfeld eine variable Richtung hat, von einer Region, wo das Magnetfeld seine fest vorgegebene magnetosphärische Orientierung annimmt. Wäre die Magnetopause stationär, so würde ein Satellit mehrere Minuten benötigen, um diese zu durchqueren. In Realität sind Magnetopausendurchgänge wesentlich kürzer, da die Geschwindigkeiten der Satelliten grundsätzlich langsamer sind als die Bewegung der Grenzschicht, die sich sowohl zur Erde hin als auch von der Erde weg bewegen kann. Erste Abschätzungen ihrer Dicke beruhten darauf, dass unter Annahme einer sinusförmigen Bewegung der Magnetopause aus Mehrfachdurchgängen eines Satelliten eine Geschwindigkeit von  $\sim 10$  km/s ermittelt wurde, was einer Schichtdicke von 10–1000 km entspricht. Erst 1977 kam man durch simultane Messungen der beiden Raumsonden ISEE 1 und 2 zu einer zuverlässigeren Messung ihrer Dicke, aber auch wiederum nur unter der Annahme, dass die Magnetopause sich lokal planar und mit konstanter Geschwindigkeit bewegt.

Gerade im Zusammenhang mit der Magnetopause, die als eine der wenigen *in situ* beobachtbaren Plasma-Grenzschichten in der Natur zur Verfügung steht, gibt es eine ganze Reihe ungelöster Probleme. Hier sticht sicher die Frage, wie der Transport durch Grenzen des zellulär strukturierten Weltraumplasmas vonstatten geht, heraus. Hat man die Magnetopause durchquert, so befindet man sich in der eigentlichen Magnetosphäre, die selbst angefüllt ist mit heißen ionisierten Gasen, die einerseits aus dem Sonnenwind stammen, andererseits ihren Ursprung in der Ionosphäre, dem oberen Teil der Erdatmosphäre haben. Wichtige Gebiete der Magnetosphäre sind zum Beispiel die *Plasmasphäre*, das ist der Teil

der Magnetosphäre, der wie unsere Atmosphäre noch mit der Erde korotiert, die *Strahlungsgürtel*, in denen hochenergetische Teilchen im Magnetfeld der Erde gespeichert sind, der nachtseitige *Magnetosphärenschweif* oder die tagseitige *Cusp-Region*, in der Erdmagnetfeldlinien in den interplanetaren Raum austreten.

Man darf sich durch die obige Klassifizierung der magnetosphärischen Regionen nicht dazu verleiten lassen, anzunehmen, dass die Abgrenzung dieser Bereiche untereinander einfach entlang scharf gezeichneter Grenzen verläuft. Alle diese Regionen sind im ständigen dynamischen Wandel begriffen und zeigen dadurch auch eigene Strukturen. Es sind daher gerade all diese Grenzschichten, die von besonderem Interesse für die Magnetosphären-Forschung sind. Genauso wie ein Seefahrer alleine nicht feststellen kann, ob sich sein Schiff auf eine gegebene Wellenstruktur zubewegt oder aber die Struktur sich auf das Schiff hinbewegt, so wenig ist es mit einem einzelnen Raumschiff möglich, räumliche und zeitliche Strukturen in der Magnetosphäre voneinander zu trennen. Erst mit einer Art Triangulation, wo 4 Satelliten gleichzeitig in einer Tetraederformation durch den Weltraum fliegen, wird das möglich.

### Auf dem Weg zu Cluster

Schon während der Missionen GEOS 1/2 und ISEE 1/2, die Ende der siebziger Jahre die Erdmagnetosphäre auf äquatorialen Bahnen durchflogen und wesentlich zu unserem heutigen Verständnis der Magnetosphäre beigetragen haben, wurde, wie schon oben bei der Schilderung der Bestimmung der Schichtdicke der Magnetopause erläutert wurde, deutlich, dass mehrere, mindestens aber vier Satelliten erforderlich sind, um räumliche von zeitlichen Variationen in der Magnetosphäre zu trennen.

Es war in der Tat gerade diese Erkenntnis, die zum Vorschlag der Cluster-Mission im November 1982 als offizielle Antwort auf eine Ausschreibung der ESA für zukünftige wissenschaftliche Missionen führte. Ende 1985 stellten ESA und NASA die Studienergebnisse der wissenschaftlichen Öffentlichkeit zur Diskussion vor. Gemeinsam mit dem *Solar and Heliospheric Observatory* (SOHO) ist Cluster dann von ESA und NASA als erster *Cornerstone* des ESA Programms *Horizon 2000* im Februar 1986 ausgewählt worden.

Eine gemeinsame ESA/NASA-Ausschreibung für 11 wissenschaftliche Experimente erfolgte im

März 1987 und führte ein Jahr später zur Auswahl von 11 Experimentgruppen für die Nutzlast. Die Cluster Instrumentierung deckt alle wichtigen Messungen der Plasmaforschung ab: elektromagnetische Felder und Wellen über einen breiten Frequenzbereich und geladene Teilchen in verschiedenen Energiebereichen.

### Der Beitrag des MPAE

Basierend auf den Beiträgen, die das MPAE vor 1986 bei der Entwicklung der sogenannten Flugzeitspektroskopie für die Anwendung in Satelliteninstrumenten geleistet hatte, war es nur natürlich, dass man sich bei der Clustermission an den Teilchenmassenspektrometern mit Flugzeitmessung beteiligen würde. Das MPAE hat dies an zwei der drei geflogenen Teilchenspektrometer getan: Als PI-Institut für RAPID und als Col-Beteiligung für CIS.

Es ging bei diesen Entwicklungen nicht darum, die Flugzeitmessung als Methode neu zu erfinden. Dass aus der unmittelbaren Messung der Teilchengeschwindigkeit  $V$  (oder der Flugzeit  $T$  für eine bekannte Strecke  $s$ ) und der Energie  $E$  eine eindeutige Bestimmung der Teilchenmasse resultiert, war ja schon lange in anderen Zweigen der Physik zur Anwendung gekommen. Vielmehr mussten für die Anwendung in der Weltraumphysik, die Zeitmessungen im  $10^{-9}$ -s-Bereich benötigt, Instrumentierungen gefunden werden, die leicht, nicht aufwendig und nicht leistungshungrig waren. Die zwei Teilchenspektrometer CIS (Ionen mit  $E \sim 0$  bis 40 keV/e) und RAPID (Elektronen 30 bis 450 keV, Ionen 50 keV bis 1,5 MeV) sind aus diesen Anstrengungen entstanden und ergänzen sich, indem sie lückenlos den wichtigen Energiebereich für Ionen im Erd-Weltraum abdecken. Darüber hinaus verfügt RAPID über ein lineares Ablenssystem in einem Kollimator, das alle geladenen Teilchen unterhalb von 300 keV eliminieren kann und nur neutrale Atome passieren lässt. RAPID kann also zusätzlich zu den Ionen und Elektronen noch neutrale Atome identifizieren und analysieren.

Die Abb. 68 zeigt das CIS (*Cluster Ion Spectrometry*)-Instrument, das aus zwei Sensoren CIS-1/CODIF (*Composition and Distribution Function Analyzer*) und CIS-2/HIA (*Hot Ion Analyzer*) und einer Datenverarbeitungseinheit (DPU) besteht. Die DPU bildet mit dem CODIF-Sensor (links) eine Einheit. Der HIA-Sensor hat seine Apertur ganz rechts.

Die Abb. 69 zeigt die Front-Ansicht des RAPID-

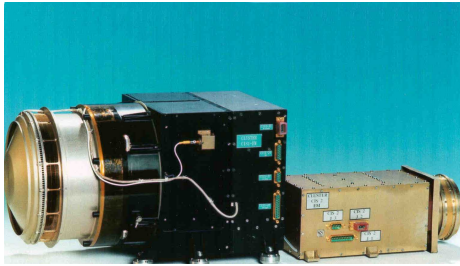


Abb. 68: Ansicht des CIS-Instrumentes (*Cluster Ion Spectrometry*).

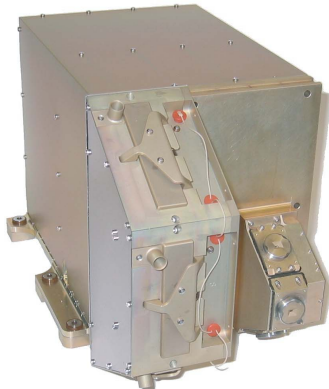


Abb. 69: Ansicht des RAPID-Instrumentes (*Research with Adaptive Particle Imaging Detectors*).

Sensors: links das Ionenmassenspektrometer IIMS (*Imaging Ion Mass Spectrometer*) und rechts das Elektronenabbildungssystem IES (*Imaging Electron Spectrometer*).

Geflogen werden die Instrumente auf allen vier Cluster-Satelliten, die von zylindrischer Gestalt, 1,3 m hoch und 2,9 m im Durchmesser sind (Abb. 70). Die Gesamtmasse jedes einzelnen Raumfahrzeuges beläuft sich auf  $\sim 1270$  kg. Die Nutzlast beträgt 72 kg und verteilt sich auf die 11 wissenschaftlichen Geräte. Alle vier Satelliten sind identisch gebaut und tragen eine identische Nutzlast.

Der Start fand am 4. Juni 1996 mit dem ersten Qualifikationsflug der Ariane-5 statt. Die durch einen Fehler in der Flugsoftware der Ariane hervorgerufene Katastrophe beendete jäh alle Hoffnungen der Magnetosphärenphysiker. 14 Jahre harter Arbeit waren in 40 s vernichtet. Doch schon am 3. April 1997 beschloss die ESA wegen der Relevanz, die sie der Mission beimaß, den Nachbau der durch die Explosion zerstörten Cluster-Satelliten.

Mit dem erfolgreichen Start auf zwei Sojus-Fregat-Raketen am 16. Juli und am 9. August 2000 hat

Europa dann doch noch nach fast zwanzigjähriger Vorbereitung mit den 4 Satelliten Rumba (C1), Salsa (C2), Samba (C3) und Tango (C4) ein neues Kapitel in der Erforschung unserer Erdmagnetosphäre und damit auch der solar-terrestrischen Beziehungen aufgeschlagen. Zum ersten Mal wird es nun möglich, Raum- und Zeit-Effekte bei komplexen plasmaphysikalischen Vorgängen in unserer Magnetosphäre zu trennen.

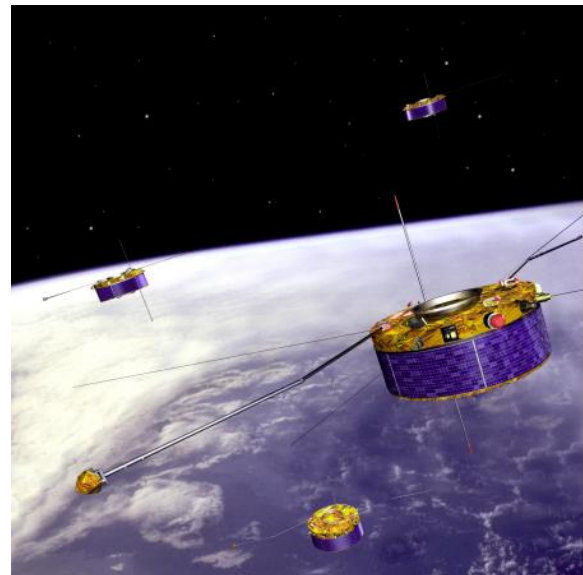


Abb. 70: Die 4 Cluster-Satelliten Rumba, Salsa, Samba, Tango untersuchen die Dynamik der solar-erdischen Verhältnisse.

Die Cluster-Satelliten Rumba, Salsa, Samba und Tango (Abb. 70) fliegen auf polaren Bahnen um die Erde. Perigäum und Apogäum liegen bei 4,0 und 19,7  $R_E$ , d.h. 25500 km und 125500 km, die Umlaufbahndauer liegt bei 57 Stunden. Das Apogäum befand sich Ende August 2000 von der Sonne aus gesehen hinter der Erde und bewegt sich innerhalb eines Jahres einmal um die Erde. Während dieser Zeit werden die Satellitenabstände zwischen einigen Hundert und einigen Tausend Kilometern, je nach Region der Magnetosphäre, verändert. Die Konfiguration der Vierlinge wird dabei nicht immer die ideale Form eines Tetraeders haben, sondern sehr unterschiedliche Formen annehmen, da sich alle vier Satelliten natürlich entlang der ihnen eigenen Keplerbahn bewegen. Da der Treibstoff an Bord begrenzt ist, können die Satelliten nicht beliebig verschoben werden, um jede gewünschte Formation zu erreichen. Die Wissenschaftler sind also auch darauf angewiesen, dass die jeweiligen Konfigurationen sich optimal zur Untersuchung der jeweils interessanten Magnetosphärenregionen und -prozesse

ergeben. Bei etwa 600 geplanten Umläufen um die Erde dürfte dies kein Problem sein. Während dieser Zeit wandern die Satellitenbahnen zusammen mit der Erde im Verlauf eines Jahres um die Sonne. Dabei sind die Bahnen, bezogen auf die Himmelskoordinaten, raumfest, während die ebenfalls mit der Erde umlaufende Magnetosphäre stets in Sonnenrichtung orientiert ist. Dadurch erfasst die Cluster-Flotte im Verlauf eines Jahres alle erdnahen Bereiche der Magnetosphäre von der sonnenzugewandten Bugstoßwelle bis zum sonnenabgewandten Magnetosphärenschweif.

### Erste Ergebnisse

Für die Mission sind vier Bereiche der Magnetosphäre von herausragender Bedeutung: die Bugstoßwelle, die Cusp-Region, die Magnetopause und der Schweif der Magnetosphäre. Dazu kommen drei Prozesse, die im Zentrum des wissenschaftlichen Interesses sind: Die magnetische Feldlinienverschmelzung (Rekonnexion), ein Prozess, bei dem sich die Feldlinien des interplanetaren Magnetfeldes mit den Feldlinien des Erdmagnetfeldes verbinden, der magnetosphärische Teilsturm, ein Phänomen der nachtseitigen Magnetosphäre, der zu einem Kollaps des Magnetosphärenschweifes ähnlich den Schweifabtrennungen bei Kometen führt und die stoßfreie Wechselwirkung in extraterrestrischen Plasmen.

Wenn wir das Bild der Magnetosphäre (Abb. 67) genauer betrachten, so sehen wir, dass die Magnetfeldlinien der Erde einerseits von den Polen der Erde in Richtung Sonne zur sogenannten Tagseite und andererseits zu der der Sonne abgewandten Seite hin, der Nachtseite, in den Magnetosphärenschweif hin verlaufen. Fast überall ist das Magnetfeld der Erde tangential zur Magnetopause orientiert. Nur in zwei Gebieten steht es fast senkrecht zur Magnetopause. Man nennt diese beiden Bereiche (in der Nähe des Nord- und Südpols der Erde), wo die Magnetfeldlinien von der Tag- und Nachtseite trichterförmig zu den beiden Polen verlaufen, auch die polaren Cusp-Regionen. Diese Regionen zeichnen sich unter anderem dadurch aus, dass sie den geladenen Teilchen, die ursprünglich aus dem Sonnenwind stammen, direkten Zugang zur Magnetosphäre erlauben. Weil der Sonnenwind mit unterschiedlicher Geschwindigkeit auf die Erde zuströmt, ist die Lage dieser Cusp-Regionen sehr variabel. Die äußere Cusp ist insgesamt ein turbulentes Gebiet mit Wirbeln im Plasmafluss. Nach neueren Erkenntnissen findet man in den Cusp-Regionen neben Ionen niedriger Energie auch Ionen, die 1000 mal mehr Ener-

gie aufweisen. Man bezeichnet diese Teilchen auch als *Cusp Energetic Particles* (CEPs). Um der Fragestellung näher zu kommen, ob diese Teilchen in der Cusp-Region selbst auf die hohen Energien beschleunigt werden oder ob sie schon mit den hohen Energien dort ankommen, interessiert natürlich zuerst die Frage, welche Dimensionen die Cusp-Regionen haben und wie groß deren zeitliche Variabilität ist. Wohl gibt es statistische Untersuchungen zur Ausdehnung und Lage der Cusp-Regionen, basierend auf den Messungen einzelner Satelliten, aber noch nie zuvor wurde simultan mit mehr als zwei Satelliten die Dynamik der Cusp studiert. Es ist nun gerade die 90°-Neigung der Cluster-Trajektorie relativ zum Äquator, die hier zum Zuge kommt. Verglichen mit früheren Missionen werden wir in der Lage sein, viele Cusp-Durchgänge im Detail zu untersuchen.

Die Abb. 71 zeigt die Energiespektren für Protonen im Energiebereich von 30 eV bis zu 37 keV von drei Cluster-Satelliten bei einem Durchgang durch die Cusp am 30. August 2001. Die gemessenen Protonen-Flüsse sind farbkodiert gegenüber der Zeit aufgetragen (rot sind hohe Flüsse, blau sind niedrige Flüsse). Alle Cluster-Satelliten (C1 bis C4) bewegen sich im Perigäum der Erdumlaufbahn wie Perlen auf einer Kette hintereinander nach Norden (siehe Bahnskizze mit Modellmagnetosphäre (grüne Feldlinien)). Die Satelliten C4, C2 und C1 liegen sehr dicht beieinander und C3 hat einen Zeitabstand von ~45 Minuten. Für Satellit C2 liegen für diese Zeit keine Daten vor. Die Satelliten C4 und C1 treten zuerst und fast gleichzeitig gegen 15:40 h aus der Magnetosphäre in die Cusp ein. Zu diesem Zeitpunkt gehen die höherenergetischen Protonen (um 10 keV) verloren, und wir sehen einen starken Anstieg der niederenergetischen Protonen, deren Energie immer niedriger wird (Dispersion), wenn die Satelliten sich weiter nach Norden bewegen. Satellit C3 ist zu dieser Zeit noch in der Magnetosphäre. Er erreicht die Cusp erst 45 Minuten später und findet eine Doppelstruktur der Cusp vor. Dieses Beispiel zeigt sehr deutlich, wie mit Cluster die Bewegung der Cusp-Region und Änderungen in der Cusp mit dem Sonnenwind beobachtet werden können. Mit Hilfe von Modellrechnungen wird es schließlich möglich werden, der Frage nachzugehen, ob die großskaligen Strukturen räumliche Strukturen in bezug auf ionosphärische Konvektionsmuster oder zeitliche Strukturen bezüglich der *Rekonnexion* auf der Tagseite der Magnetosphäre sind.

Dem in der Abb. 67 dargestellten Erdmagnet-

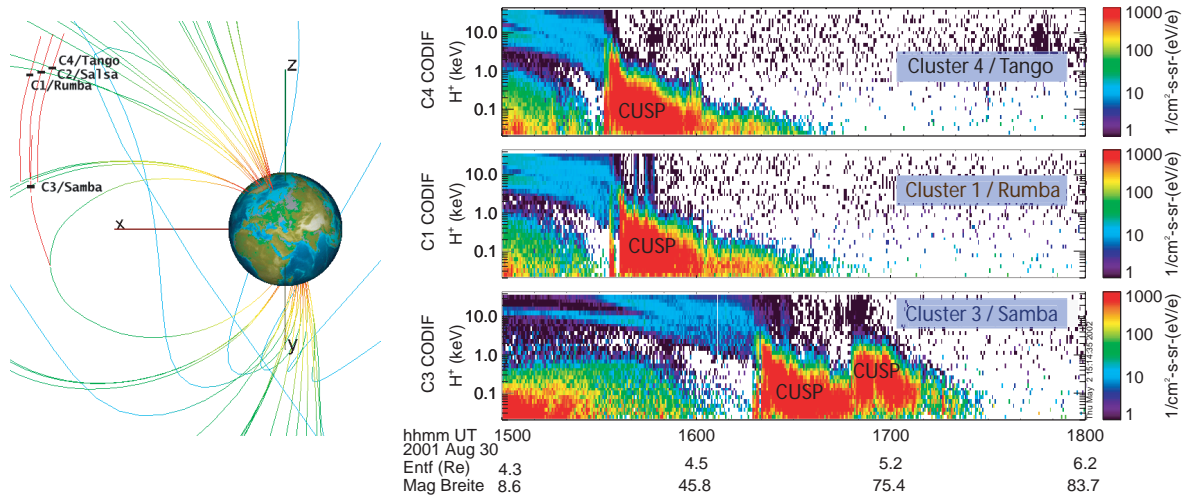


Abb. 71: Durchflug von drei Cluster-Satelliten durch die mittlere Cusp bei etwa fünf Erdradien Abstand am 30. August 2001.

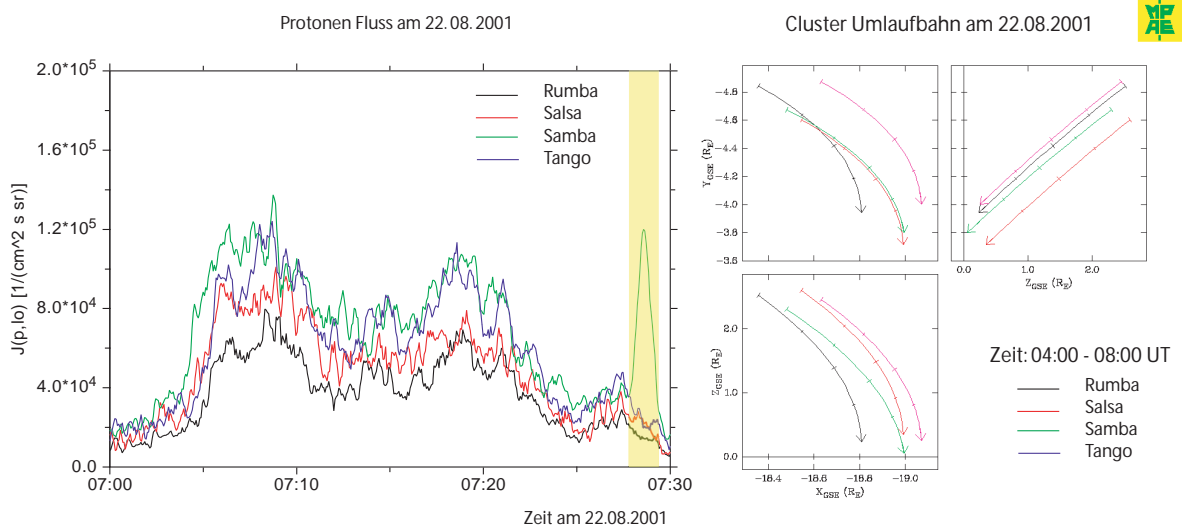


Abb. 72: Omnidirektionaler Ionenfluss aller vier RAPID-Instrumente und Position der Satelliten in GSE-Koordinaten.

schweif kommt ebenfalls eine besondere Bedeutung zu, weil er als eine Art Energiereservoir für die Magnetosphäre dient und daher eine wesentliche Rolle bei den dynamischen Vorgängen in der Magnetosphäre spielt. Wir wissen, dass in der nördlichen Hemisphäre des Erdmagnetschweifes das Magnetfeld in Richtung Erde und in der südlichen in der umgekehrten Richtung verläuft. Zwischen diesen Bereichen, befindet sich in der äquatorialen Region die sogenannte Plasmaschicht, die von heißem Plasma erfüllt ist. In diese Schicht, die

notwendig ist, um dem magnetischen Druck der beiden Lobe-Regionen entgegenzuwirken, verläuft ein elektrischer Strom von der Morgen- zur Abendseite. Innerhalb der Plasmaschicht konvektiert das Plasma in der erdnahen Zone zur Erde hin, während im entfernteren Teil es in Richtung des Schweifes konvektiert. Es hat sich herausgestellt, dass dem sich mit dem Sonnenwind auf die Erde zubewegenden interplanetaren Magnetfeld eine entscheidende Rolle für die dynamischen Vorgänge in der Magnetosphäre zukommt.

Zeigt das interplanetare Magnetfeld nach Süden, so wird Energie im Erdmagnetschweif gespeichert, die später explosionsartig in einer Reihe von Vorgängen, die als Teilsturm bezeichnet werden, wieder abgebaut wird. Dabei wird der größte Teil der Energie durch schweifwärts beschleunigte Plasmoiden in das interplanetare Medium zurückgeführt. Obwohl das Phänomen der Rekonnexion, welche die gespeicherte Energie im Magnetosphärenschweif freisetzt, allgemein akzeptiert ist, wird ihre Relevanz bei den Teilstürmen weiter diskutiert. Es wurden sowohl experimentelle als auch theoretische Bedenken gegen die Rolle der plötzlichen Rekonnexion für das Auslösen eines Teilsturmes im erdnahen Teils des Schweifs vorgebracht.

Die Vielfach-Satellitenkonstellation von Cluster kommt genau bei solchen Fragestellungen und Untersuchungen zum Zuge, da sich aus dem Beobachtungsvergleich der vier Satelliten eine Charakterisierung des Plasmazustandes ergibt, der zu diesen Ereignissen führt. Als Beispiel dafür, wie sich die dynamischen Veränderungen in der Plasmaschicht mit Cluster beobachten lassen, sei Abb. 72 gezeigt. Dargestellt ist links im Bild der Teilchenfluss, den die vier RAPID-Instrumente beim Durchgang durch die Plasmaschicht am 22. August 2001 aufgezeichnet haben. Deutlich sichtbar ist eine starke Erhöhung des Protonenflusses, die vom RAPID-Instrument auf Samba um 07:29 h registriert wird. Rechts im Bild sind die Umlaufbahnen der Satelliten während dieses Zeitabschnittes in einem geozentrischen-solar-ekliptischen Koordinatensystem gezeigt. Eine nähere Analyse der Daten lässt darauf schließen, dass nicht die Art, wie sich die Raumsonden durch die Plasmaschicht bewegten, für diese Flusserhöhung verantwortlich ist, sondern sich vielmehr durch die Bewegung einer scharfen Grenzschicht, die über einen der Satelliten lief, erklären lässt.

Die Auswertung der Cluster-Daten ist noch in der frühen Phase der Mission und hat, bedingt durch die Mannigfaltigkeiten der benötigten Software, gerade erst begonnen. Die soweit schon erzielten wissenschaftlichen Ergebnisse sind zur Zeit noch mehr beschreibender als quantitativer Art. Dennoch ist schon jetzt zu erkennen, dass die wissenschaftliche Ausbeute der Cluster-Mission von zentraler Bedeutung für ein Verständnis des ernen Weltraumes ist und als Wegweiser für die künftigen sich schon zum Teil in Planung befindlichen Viel-Satelliten-Projekte dienen wird.

(P. W. Daly, U. Mall, A. Korth)

## Highlight of magnetospheric research:

### The Cluster mission

The Earth receives more than just light and warmth from the Sun. A continuous stream of ions and electrons, the *solar wind*, expands as a neutral plasma from the Sun out into space with speeds between 300–1000 km/s, and thus also engulfs the Earth. Life on our planet is only possible because the Earth protects us and the atmosphere from these incoming energetic particle by means of its magnetic field. How variable these protection shields can be, is shown by the dramatic phenomena known as northern and southern lights, or by the alarming destruction of the stratospheric ozone layer. The variability of the *magnetosphere* results from the fact that it reacts very dynamically via the solar wind to any activities on the Sun. Just how is the magnetosphere made up?

### The terrestrial magnetosphere

The Earth's magnetic field acts as an obstacle for the expanding solar wind, as indicated in Fig. 44. As a result, a bow shock wave is established at

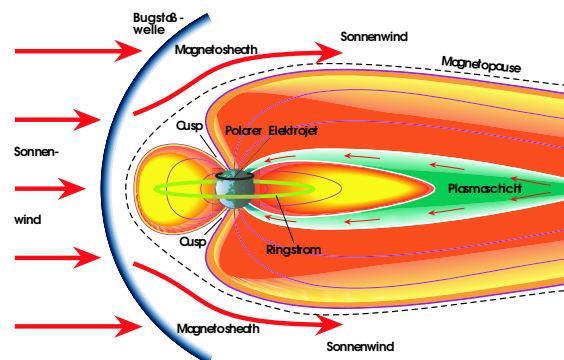


Fig. 44: Schematic diagram of the Earth's magnetosphere.

a distance of  $\sim 12\text{--}15 R_E$  ( $1 R_E = \text{Earth radius} = 6371 \text{ km}$ ) from the Earth, behind which the solar wind is decelerated and heated, but continues to flow with supersonic speed. It is only at a second boundary, the *magnetopause*, which separates magnetospheric and interplanetary plasmas, at about  $10 R_E$  on the sunward side of the Earth, that the actual magnetosphere begins; on the nightside, the magnetosphere stretches out like a comet's tail for millions of kilometres. The region between the bow shock and the magnetopause is called the *magnetosheath*. Particles observed there, originate predominantly from the so-

lar wind, which one can establish from their composition.

The magnetopause separates a region where the magnetic field has a variable direction from one in which the field exhibits a distinct magnetospheric orientation. If the magnetopause were motionless, a satellite would require several minutes to traverse it. In reality, magnetopause crossings are considerably shorter, since the satellite speeds are much slower than those of the boundary motions, which move both towards and away from the Earth. The first estimates of the magnetopause thickness were based on multiple crossings by a satellite with a speed of  $\sim 10$  km/s, assuming a sinusoidal movement for the boundary, yielding a thickness of 10–1000 km. Only with simultaneous measurements by the ISEE 1 and 2 spacecraft in 1977 was it possible to achieve reliable estimates of the thickness, but even then only by assuming the boundary was locally planar and moving at constant speed.

Especially with the magnetopause, one of the few natural plasma boundaries that can be observed *in situ*, a large number of questions remain to be answered. In particular, how does the transport of cellularly structured space plasma through the boundary occur? On crossing the magnetopause, one is in the actual magnetosphere, which itself is filled with hot, ionised gases, which on the one hand originated out of the solar wind, but whose immediate source is the ionosphere, the upper region of the Earth's atmosphere. Important regions of the magnetosphere are, for example, the *plasmaphere*, that is the part that like the atmosphere corotates with the Earth, the *radiation belts*, in which highly energetic particles are trapped in the Earth's magnetic field, the *night-side magnetotail*, or the *dayside cusp region*, where magnetic field lines from the Earth extend into interplanetary space.

One should not view the above classification of the magnetospheric regions as meaning that they are separated by sharp, well-defined boundaries. All of these regions are subject to constant, dynamic changes and therefore exhibit structures of their own. Thus all these boundary layers are of special interest for magnetospheric research. In the same way that a single sailor cannot tell if his ship is approaching a wave structure or if the structure is coming towards him, so is a single spacecraft unable to distinguish between spatial and temporal changes in the magnetosphere. It requires a type of triangulation with 4 satellites in a tetrahedron formation flying through space

to accomplish that.

### The road to Cluster

Already during the GEOS 1/2 and ISEE 1/2 Missions at the end of the seventies, which flew on equatorial orbits through the terrestrial magnetosphere and which led to much of our present understanding of its regions, it was clear that multiple satellites, at least four, were needed to separate spatial and temporal variations in the magnetosphere, as indicated by the above example with the magnetopause thickness.

It was this realisation that led to the proposal for the Cluster Mission in November 1982, as official response to the ESA's search for future scientific missions. The ESA and NASA presented the results of the study phase to the public at the end of 1985. Together with the *Solar and Heliospheric Observatory* (SOHO), Cluster was selected by ESA and NASA as the first *Cornerstone* of the ESA *Horizon 2000* program in February 1986.

A cooperative ESA/NASA Announce-of-Opportunity followed in March 1987, and led to the selection of 11 experimental groups for the payload a year later. The Cluster instrumentation covers all the important observations for plasma research: electromagnetic fields and waves in a broad spectrum, and charged particles in various energy regions.

### Contributions from MPAE

Based on the achievements of MPAE prior to 1986 in the development of so-called time-of-flight spectroscopy in satellite applications, it was natural to expect a participation in the Cluster Mission with particle mass spectrometers with time-of-flight measurement. The MPAE is involved in two of the three particle spectrometers on board: as PI Institute for RAPID and as Co-I participation for CIS.

This development was not a question of reinventing the time-of-flight method. That a particle mass could be determined by measuring its speed  $V$  (or rather its flight time  $T$  over a known distance  $s$ ) and its energy  $E$ , had long been used in other branches of physics. For its application in space physics, it is necessary to make time measurements of  $10^{-9}$  s precision, to find instrumentation that is light, inexpensive, and not power hungry. The two particle spectrometers CIS (Ions with  $E \sim 0$  to 40 keV/e) and RAPID (electrons 30

to 450 keV, ions 50 keV to 1.5 MeV) have resulted from this endeavour and complement each other in that they cover the entire energy spectrum for ions in the terrestrial space environment. Furthermore, RAPID possesses a linear deflection system inside a collimator that can eliminate all charged particles below 300 keV, letting only neutrals through. That means, RAPID is also in the position to identify and analyse neutral atoms, in addition to ions and electrons.

Fig. 45 shows the CIS (Cluster Ion Spectrometry) instrument, consisting of two sensors CIS-1/CODIF (Composition and Distribution Function Analyzer) and CIS-2/HIA (Hot Ion Analyser) and a data processing unit (DPU). The DPU plus CODIF sensor make up one unit (left). The HIA sensor has its aperture at the far right.

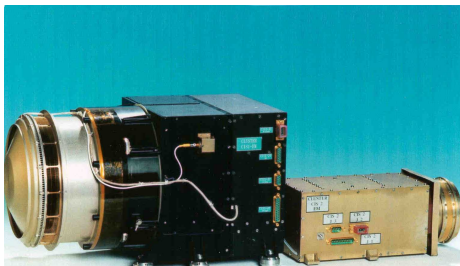


Fig. 45: View of the CIS instrument (Cluster Ion Spectrometry)

Fig. 46 presents the front view of the RAPID experiment. At the left is the ion mass spectrometer IIMS (Imaging Ion Mass Spectrometer) and at the right is the electron imaging system IES (Imaging Electron Spectrometer).



Fig. 46: View of the RAPID instrument (Research with Adaptive Particle Imaging Detectors)

These instruments are flown on all four Cluster satellites, which are of cylindrical shape, 1.3 m high and 2.9 m in diameter (Fig. 47). The total

mass of each spacecraft is  $\sim 1270$  kg. The payload weighs 72 kg and is distributed among the 11 scientific instruments. All four spacecraft are identically built and carry identical payloads.

The launch occurred on June 4, 1996 with the first qualification flight of the Ariane-5. Due to a bug in the Ariane guidance software, the flight turned into disaster, ending all the expectations of the magnetospheric community. Fourteen years of hard work was destroyed in 40 s. However, because of the great importance it attached to the mission, the ESA resolved on April 3, 1997, to rebuild the lost Cluster satellites.

With the successful launches on two Soyuz-Fregat rockets on July 16 and August 9, 2000, of the 4 satellites Rumba (C1), Salsa (C2), Samba (C3) and Tango (C4), after almost 20 years of preparation, Europe has finally begun a new chapter in the exploration of our terrestrial magnetosphere and thus also for solar-terrestrial relationships. For the first time, it will be possible to distinguish spatial and temporal effects in the complex plasma processes occurring in our magnetosphere.

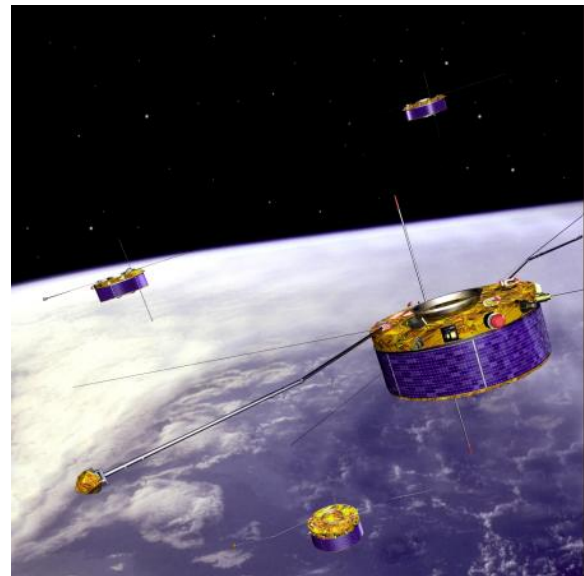


Fig. 47: The 4 Cluster satellites Rumba, Salsa, Samba, Tango investigate the dynamics of solar-terrestrial relationships.

The Cluster satellites Rumba, Salsa, Samba, and Tango (Fig. 47) are circling the Earth on polar orbits with perigee and apogee at  $4.0$  and  $19.7 R_E$ , that is between 25 500 km and 125 500 km, with a period of about 57 hours. At the end of August 2000, apogee was located on the side of the Earth directly opposite the Sun, and moves in the course

of a year once around the Earth. The satellite separations vary between a few hundred to several thousand kilometers, according to magnetospheric region investigated. Thus the configuration of the quadruplet will not always be that of the ideal tetrahedron, but will take on various forms as the satellites move along their independent Kepler orbits. Since the fuel on board is limited, it is not possible to reconfigure the spacecraft to every desired formation. The scientists must therefore decide on the optimal configurations for the investigations of the most interesting magnetospheric regions and processes. With 600 planned orbits, this should not be difficult. Over a year, the satellite orbits revolve with the Earth around the Sun. Viewed from a fixed celestial coordinate system, the orbits are stationary, while the magnetosphere rotates to have the same orientation with respect to the Sun. The Cluster fleet thus passes through all the near-Earth regions of the magnetosphere within a year, from the bow shock on the sunward side, to the magnetotail on the opposite side.

### First results

There are four magnetospheric regions of especial importance to the mission: the bow shock, the cusp region, the magnetopause, and the magnetotail. Furthermore, there are three physical processes central to the scientific interests: magnetic field line reconnection, by which interplanetary and terrestrial field lines are merged, the magnetic substorm, a phenomenon on the nightside that leads to the collapse of the magnetotail similar to a cometary tail separation, and collisionless interactions in extraterrestrial plasmas.

If we look closely at the picture of the magnetosphere (Fig. 44), we see that the Earth's magnetic field lines run on the sunward (dayside) from the north and south poles, while on the opposite side (nightside) are drawn out into a long magnetotail. The field is almost always tangential to the magnetopause. There are only two areas where it is almost perpendicular to the magnetopause, called the polar cusp regions, where the day and nightside field lines come together in a funnel-like form. These regions are special because it is here that charge particles originating in the solar wind are allowed direct access to the magnetosphere. The exact location of the cusps is variable depending on the solar wind speed. The outer cusp is a turbulent region for plasma flux. Current knowledge indicates that the cusps contain not only low-energy ions, but also those with 1000 times greater energies. These particles are designated as *Cusp*

*Energetic Particles* (CEPs). To answer the question as to whether these cusp particles were locally energised or whether they arrived with their high energies, it is first necessary to determine the dimensions of the cusp regions and their temporal variability. Previous statistical studies of the cusp extension and location were based on measurements by single satellites, but the dynamics of the cusp has never been investigated simultaneously with more than two satellites. It is the 90° inclination of the Cluster orbit relative to the equator that permits it to make so many passages through the cusp regions, compared with earlier missions.

Fig. 48 shows the energy spectrum of protons in the range 30 eV to 37 keV from 3 Cluster satellites during a cusp passage on August 30, 2001. The measured ion fluxes are plotted colour-coded against time (red means high, blue low fluxes). All Cluster satellites (C1 to C4) move as on a string-of-pearls through perigee from south to north (see orbit plot with model magnetosphere with green field lines). Satellites C4, C2, and C1 are close together along the orbit while C3 trails by ~45 minutes. There are no data for C2 at this time. Satellites C4 and C1 exit the magnetosphere almost simultaneously at 15:40 UT and enter the cusp. At this time, the higher energy protons (about 10 keV) vanish and we see a sharp increase in low energy protons, whose energy decreases (dispersion) as the satellites move further north. C3 is still in the magnetosphere at this time. It encounters the cusp 45 minutes later and a double structure there. This example shows clearly how Cluster can observe the motion of the cusp and its changes with the solar wind. With the aid of model calculations it will finally be possible to approach the question of whether the large-scale structures are spatial, depending on ionospheric convection patterns, or temporal, being related to reconnection on the dayside of the magnetosphere.

The terrestrial magnetotail in Fig. 44 also has a special importance, because it serves as an energy reservoir for the magnetosphere and thus plays an essential role in the magnetospheric dynamic processes. We know that the magnetic field in the northern part of the magnetotail is directed towards the Earth, and is the other way around in the southern part. In between these parts, in the equatorial region, there is the so-called plasma sheet, filled with hot plasma. In this layer, which is necessary to counteract the magnetic pressure of the two lobe regions, there flows an electric current from the dawn to dusk

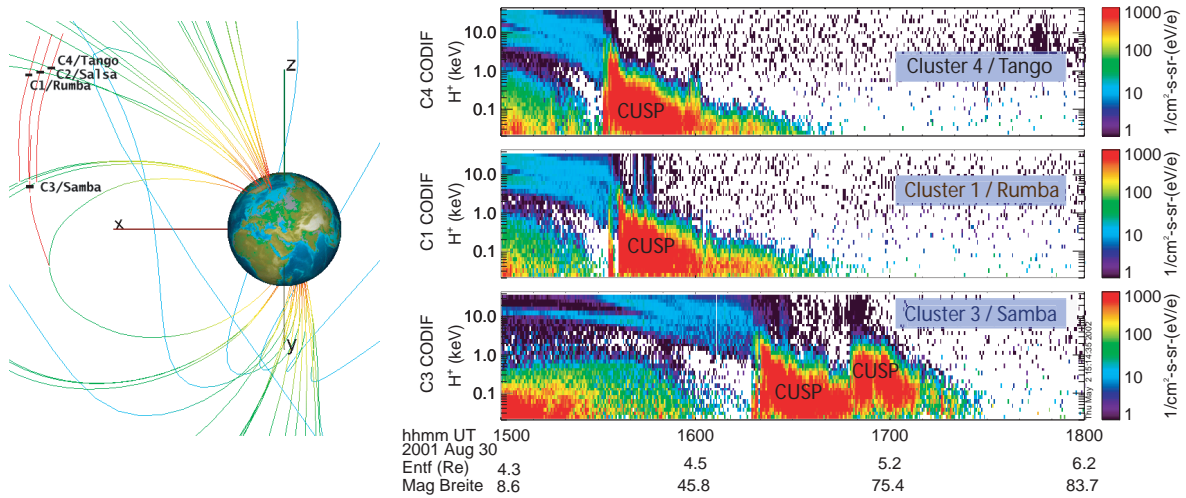


Fig. 48: Passage of 3 Cluster satellites through the central cusp at a distance of five Earth radii on August 30, 2001.

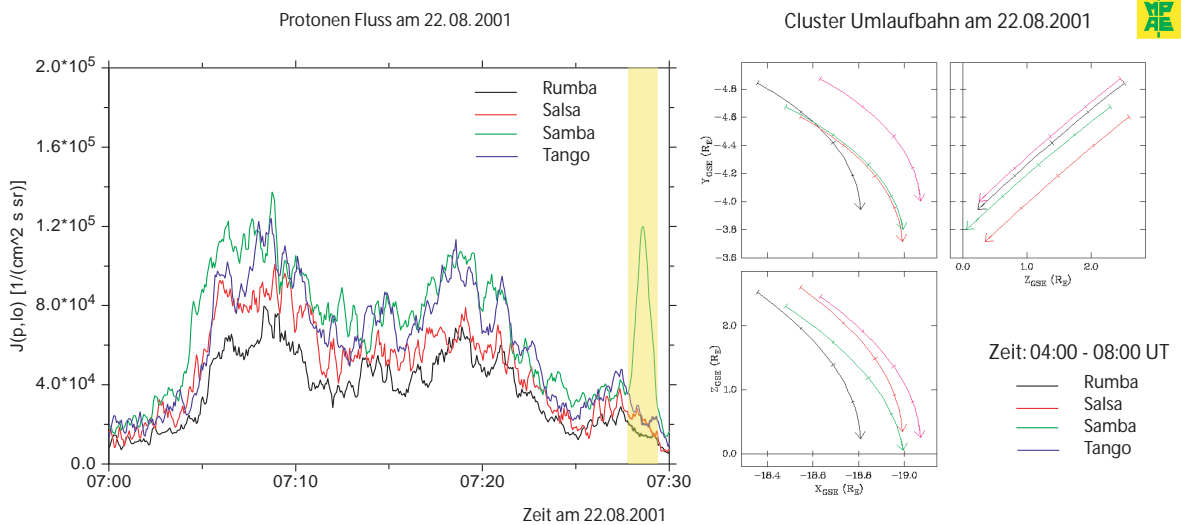


Fig. 49: Omnidirectional ion fluxes from all 4 RAPID instruments and the location of the satellites in GSE coordinates.

sides. Plasma convects within this sheet towards the Earth on the near side, and away from the Earth into the magnetotail in the more distant parts. It has been established that the interplanetary magnetic field transported by the solar wind to the Earth plays a decisive role in the dynamic processes. When the interplanetary field points southwards, energy is stored in the magnetotail, which is later released in an explosive sequence of processes, known as substorms. The greater part of this energy is injected back into the interplan-

etary medium via tailward accelerated plasmoids. Although the phenomenon of reconnection, which converts the energy in the magnetotail, is generally accepted, its relevance to substorms is still a matter of debate. There are experimental as well as theoretical arguments against sudden reconnection as the trigger for a substorm in the near-Earth part of the magnetotail.

Cluster's multiple-satellite constellation is appropriate for just such investigations, since comparisons of the observations from 4 satellites yield

a characterisation of the plasma state leading to these events. Fig. 49 shows an example of how the dynamic changes in the plasma sheet can be observed with Cluster. To the left are plotted the particle fluxes from 4 RAPID instruments during a crossing of the plasma sheet on August 22, 2001. There is a very pronounced increase in the proton flux measured on Samba at 07:29 UT. To the right are diagrammed the orbits of the satellites during this time interval in the geocentric-solar-ecliptic coordinate system (GSE). A closer inspection of the data reveals that the flux increase results not so much from the way in which the satellites move through the plasma sheet, but rather from the motion of a sharp boundary layer over only one of the

satellites.

The analysis of the Cluster data is still in the early phase of the mission, and, due to the complexity of the necessary analysis software, has really only just begun. The scientific results achieved so far are thus more descriptive than quantitative. Nevertheless, it is already clear, that the scientific exploitation of the Cluster Mission will be of central importance for the understanding of the near-Earth environment and is an indicator for future multi-spacecraft missions, some of which are already being planned.

(P.W. Daly, U. Mall, A. Korth)

## Wissenschaftliche Einzelberichte/ Individual scientific reports

(only in English)

### Research projects in the neutral atmosphere

#### Structure and dynamics of the atmosphere – SOUSY

Using the SOUSY Svalbard Radar (SSR) at Longyearbyen (78°N, 16°E), VHF radar observations of the mesosphere, stratosphere and troposphere have been made during the years 1999, 2000 and 2001. The main emphasis was given to the vertical and temporal variations of polar mesospheric summer echoes (PMSE) and the mean winds derived therefrom. The typical height variation of the echo intensity is characterised by a double layer structure during June and July which is much more pronounced than at latitudes 10° further south. At the beginning and the end of the PMSE season in May and August, however, the two layers merge. These features together with the observed changes in the meridional wind component appear to be related to the annual temperature variation in the mesopause region.

The evaluation of PMSE observed simultaneously by the SSR and the EISCAT Svalbard Radar (ESR) in a common volume yielded radar reflectivities of  $10^{-15} - 10^{-14} \text{ m}^{-1}$  at 53.5 MHz and  $10^{-20} - 10^{-19} \text{ m}^{-1}$  at 500 MHz indicating a strong dependence of the reflectivity on the radar frequency. Estimating the turbulence dissipation rate from the spectral widths observed at both radar frequencies and the electron concentration from the ESR observations yields Schmidt (Prandtl) numbers larger than 100. The high Schmidt numbers are a consequence of the presence of electrically charged ice particles giving rise to ambipolar electric fields and consequently to electron diffusivities that are two orders of magnitude smaller than the diffusivity of the neutral gas. Common volume observations of PMSE are seldom successful because they require high D region ionisation.

The SSR and the ESR were also operated simultaneously during the extraordinarily strong ionospheric disturbance event Bastille-II in the middle of July 2000, which resulted from a unique coronal mass ejection on the sun. These combined observations allowed to measure electron density and electric fields and their relation to polar meso-

sphere summer echoes. A temperature increase of several Kelvin per day was observed in the upper mesopause region, which caused a disappearance of polar mesosphere summer echoes. This is taken as a further proof of the temperature dependence of these radar echoes, which are related to ice particles.

Lidar observations of noctilucent clouds (NLC) performed by the Institute for Atmospheric Physics on the Norwegian island Andøya (69°N, 16°E) were used for comparison with a model developed at the Institute for Aeronomy. These observations result from backscattered light from ice particles in the polar mesopause region and show that the diurnal variations of the NLC altitude

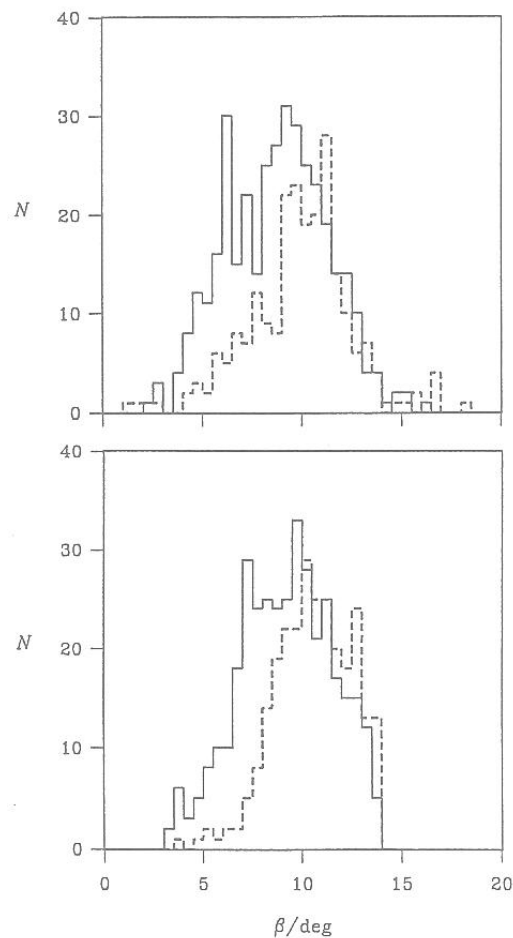


Fig. 50: Top: Histograms of the solar depression angles  $\beta$  observed at the first sighting of NLCs in the evening twilight for the periods 1964-1974 (dashed lines) and 1985-1994 (continuous lines) (data from M. Gadsden, private communication, 2000). Bottom: Histograms of solar depression angles simulated for NLC samples with low (dashed lines) and high (continuous lines) mean luminous intensities.

and backscatter ratio are dominated by a 12-h component although the mean semidiurnal tidal temperature variation seems to be much smaller than the diurnal one. Measured tides, however, exhibit a strong day-to-day variability. Taking into account the tidal variability in the SOUSY-NLC model can in fact reproduce the observed NLC behaviour mainly because the response of NLCs to temperature changes is highly nonlinear.

In the last ten years, the question whether a roughly 30 years spanning time series of ground-based NLC observations contains evidence of a decadal brightness increase or not, has been answered contrarily by different authors. For a re-investigation, a statistical photometric model including the solar depression angle as a proxy for the twilight sky brightness has been set up. It clearly demonstrates that the NLC brightness increased by a factor of about 5 between the periods 1964-1974 and 1985-1994, and that the brightness increase went along with a significant lengthening of the NLC season. Fig. 50 shows a comparison of histograms of the observed solar depression angles at the first sighting of NLCs in the evening twilight together with the histograms of simulated solar depression angles for NLC samples with low and high mean luminous intensities. The brightness increase is, in all probability, caused by an increase of the water vapour concentration rather than a decrease of the temperature in the arctic mesopause region.

The SSR was also operated in extended campaigns to study the structure and dynamics of the troposphere and lower stratosphere. Synoptic-scale disturbances (planetary waves) and their frontal systems propagate to the high latitude of the polar vortex over Svalbard. Fig. 51, upper graph, shows a frontal passage over Svalbard on 13-14 November 1999 which is characterised by superimposed downward stretching mesoscale disturbances. Related tropopause folding events, which would be characterised by a break of the enhanced streak of radar echo power around 7-12 km altitudes, did not occur as dramatically over Svalbard as at mid-latitudes. During these events potential vorticity and aerosol particles are transported between these altitudes. Such radar observations yield information about the relevance of troposphere - stratosphere exchange at high polar latitudes.

Whereas the vertical wind component (the upper panels of the two graphs in Fig. 51), which is measured with the SSR, was very weak on 13-14 November, strong velocity variations were detected on the following day. The vertical velocity

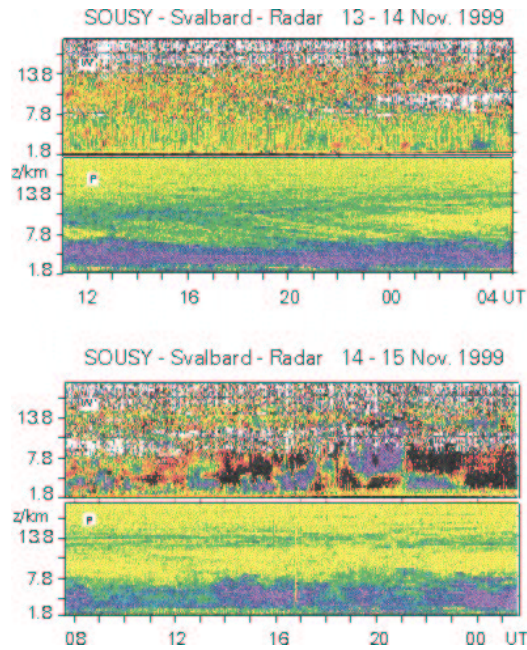


Fig. 51: Lower stratosphere and troposphere observations with the SSR on two successive days in November 1999. The lower panels show the variation of radar echo power (P) as function of time and height. The color scales cover two orders of magnitude, where yellow is the noise level. These plots indicate atmospheric structures, such as fronts and the tropopause. The upper panels show the simultaneously measured vertical velocity (w) with maximum amplitudes of 1 m/s upward (magenta) and 1 m/s downward (black). These plots indicate velocity variations, which are mostly caused by atmospheric waves.

reached amplitudes of more than  $\pm 1$  m/s resulting from mountain lee waves. The archipelago of Svalbard is a pronounced obstacle in the Arctic Ocean, where strong winds blowing over the mountainous terrain generate such strong atmospheric waves. These can propagate into the stratosphere and mesosphere, and act as transport mechanisms of energy and momentum from low to high altitudes. Studies are underway to parameterise these wave transport mechanisms, which are required for atmosphere modelling.

(P. Czechowsky, J. Klostermeyer, J. Röttger, R. Ruster and G. Schmidt)

### Thunderstorms, lightning and solar activity – middle Europe –

Thunderstorm – solar activity relationships have been studied in the past mostly with records of

audible thunder correlated with sunspot number (R). Our study is new in two aspects: firstly it uses measured lightning frequency, and secondly these records are correlated not only with R but also with other parameters characterising solar activity, namely Ap, F10.7 and cosmic ray flux. With data from the German lightning detection system BLIDS we obtain a significant correlation of lightning frequency with Ap and R, and a significant anti-correlation with cosmic ray flux (Fig. 52). A

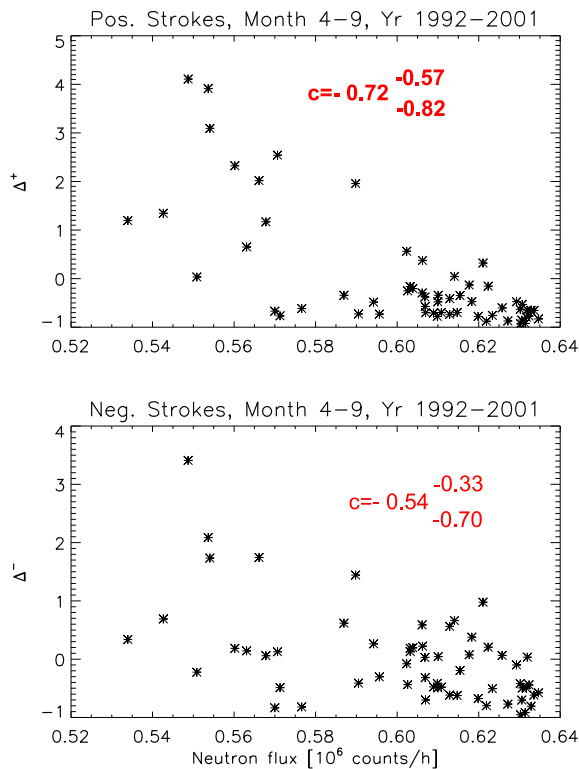


Fig. 52: Scatter plot of the monthly number of positive and negative lightning strokes and neutron counts (as a proxy of cosmic ray flux). The correlation coefficients together with confidence limits are also given.

similar analysis with data from the Austrian system ALDIS yielded inconclusive results. Both observations and earlier findings of spatially varying correlation coefficients between R and thunderstorm frequency can probably be reconciled invoking new ideas about the transmission of a solar activity signal to the lower atmosphere by planetary waves.

(K. Schlegel in collaboration with G. Diendorfer, ÖVE-ALDIS, Wien, Austria, S. Thern, Siemens AG, Karlsruhe, and M. Schmidt, Northeim)

### Value added validation and more efficient use of remote sensing data from the Earth atmosphere

This international MPAE research project was very successfully terminated in September 2000 with the publication of the DUST-2 CD ROM “Improved Interactive Access to Information about the Earth Atmosphere” (DUST: Data Utilisation and Software Tools; ISBN 3-9804862-3-0). This CD – bilingual in English and German – can be started with the command `index.html`. The project dealt with a more profound documentation and validation of ozone and water vapour data from the Earth Atmosphere, especially those which have been measured with the Microwave Atmospheric sounder (MAS) successfully flown as a core payload of the NASA ATLAS Space Shuttle Missions 1, 2, and 3 in 1992, 1993, and 1994. – <http://www.linmpi.mpg.de/english/projekte/masnew> These results have been presented at various international conferences even after the Principal Investigator (PI) G.K. Hartmann became pensioner in November 2000.

The continuation of the DUST-2 concept towards the broader ADLATUS concept – especially aimed for an additional more concrete interactive use in schools – could not be continued as an official MPAE project, because the MPAE research of the Earth atmosphere has been terminated in favour of solar research. Nonetheless this work was and will be continued but without direct financial support by MPAE.

ADLATUS will include further geophysical data of the Earth atmosphere (UV-B radiation, climate, space weather and also consider besides these global and regional data local data, including those obtained by the schools. A project has been started in 2001 together with the Konrad Adenauer School (KAS) in Seligenstadt (Hessen) under the title: “ADLATUS interface CD for schools using as an example data from the Earth atmosphere. A pilot project”.

It will be presented at various conferences in 2002 and fundraising has been started. A similar project, however, dealing with drinking water, is since 2001 under discussion with the “German Islamic Institute for Scientific and Cultural Cooperation e.V.” (DII) in Celle.

These topics have been also presented in 2000 and 2001 at various locations in Europe, the USA and in South America in continuation of the previous bilateral MPAE co-operation.

(G. K. Hartmann, M. L. Richards, A. Nölle, R. Leitinger, E. Putz, G. Dettmer)

### The WASPAM experiment

The WASPAM (*Wasserdampf- und Spurengasmessungen in der Atmosphäre mit Mikrowellen*) experiment is located at the Arctic Lidar Observatory for Middle Atmospheric Research (ALOMAR) in Northern Norway since 1995. It

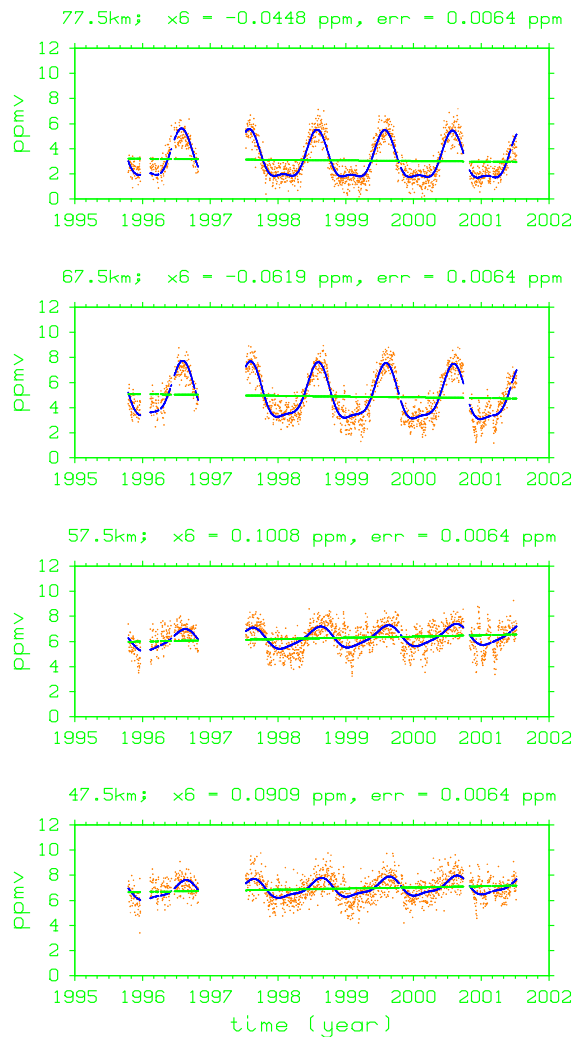


Fig. 53: Water vapour variation since 1995 detected by WASPAM at ALOMAR in Northern Norway.

provides water vapour profiles from 40 to 85 km altitude. In 2000 we participated with WASPAM in the WMO/SPARC Water Vapour ASsessment (WAVAS) of the Upper Tropospheric and Stratospheric Water Vapour. WAVAS evaluated all available data since the 1950s and found the extremely high increase of 50-100% of stratospheric

water vapour up to today. Maximum half of the increase can be explained by the increase of methane in the middle atmosphere. The reason for the other half is not clear yet. According to the SPARC report, an increase of the tropical tropopause temperature, controlling the vapour pressure in the main entry area of tropospheric water into the stratosphere, can be excluded. Instead an unidentified troposphere-stratosphere mixing process may be most likely responsible. An increase of water vapour in the stratosphere causes a temperature decrease of several °C. As a result the PSC probability will increase. Models show for this scenario a 50% ozone column depletion in arctic spring. Our dataset starts at the last solar minimum and shows an average increase of about 0.1 ppm/year in the stratosphere, peaking with about 0.13 ppm/year in the stratopause region. Above 60 km this reverses into an average decrease of about 0.05 ppm/year in the mesosphere. We speculate that the decrease is caused by the increased Lyman-alpha radiation towards the Solar maximum and that it will reverse into a strong increase towards the next minimum. After HALOE on UARS was switched off, WASPAM is the only sensor monitoring the stratospheric and mesospheric water vapour in the polar regions (Fig. 53).

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

### Trace gases in the atmosphere

#### *Cryogenic sampling in the stratosphere*

With two cryosampler flights in India and France the very successful MPAE stratospheric air sampling program was terminated in 1999. Starting in 1976, a total of 27 balloon flights were carried out at midlatitudes (Gap and Aire sur l'Adour, France, 44°N), in polar regions (Kiruna, Sweden 68°N) and in the tropics (Hyderabad, India, 17.5°N). With different gaschromatographic analytical techniques, vertical distributions of up to 30 compounds were determined, with special emphasis on halogenated hydrocarbons (CFCs, HCFCs, Halons, etc.), thus providing important information for modelling stratospheric ozone chemistry. A final check and review of all these data has been started to present a reliable database on the MPAE web page soon.

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

### Antarctic glacier ice samples

Ice cores from Greenland or Antarctica contain unique information about ancient climate and composition of the atmosphere. In general ice samples come from deep drilling stations. In contrast to these measurements work now has been started to analyse glacier ice samples from Glacier Island Galindez, western coastal Antarctica (Ukrainian research station 65°S, 64°W). The age of these ice samples varies between 12 and about 4000 years. A so called wet extraction method was developed to extract the gases. Analyses were performed using GC/MS-systems (gaschromatograph/mass spectrometer). Compounds of special interest were bromine, chlorine, iodine and sulphur containing species.

First analyses of the extracted air yielded high enrichment relative to ambient atmospheric concentrations for many compounds like CO<sub>2</sub>, OCS, CH<sub>3</sub>Cl, CH<sub>3</sub>Br, CH<sub>3</sub>I and C<sub>2</sub>H<sub>5</sub>I. Most probably this enrichment is due to the fact that this part of Antarctica is not permanently frosty. During arctic summer temperatures can rise above 0 °C. Thus periods of snowfall and growing ice change with periods of rain and melting ice. As significant amounts of gases can be solved in water due to Henry's law, enrichment processes are evident and in addition older ice can be "contaminated" by percolating young water through fissures of the glacier. Quantitative interpretation of the data will be difficult but interesting.

(R. Borchers in cooperation with V. Bogillo, Institute of Geological Sciences, Kiev, Ukraine)

### Volcanic gases

Investigations in this field of research (see annual report 1999/2000) will continue. In 2001 a cooperation has started with the Sonderforschungsbereich (SFB) 574 of the University of Kiel "Volatiles and Fluids in Subduction Zones: Climate Feedback and Trigger Mechanisms for Natural Disasters". The SFB 574 examines the return flow and impact of water, carbon, sulfur and halogens at the subduction zone of Nicaragua in order to evaluate the effects of volatiles on climate, the geochemical characterisation of the hydrosphere and atmosphere. Investigations on minor constituents, especially non reactive halogen containing species, will be performed at MPAE with GC/MS-techniques. So far one set of samples from different volcanoes was analysed with the intention to check the procedures for sampling and

analysing and to get a first impression about special properties of the volcanoes.

(R. Borchers in cooperation with M. Frische, SFB 574, University of Kiel)

## Ionospheric research: EISCAT and STARE

### Diurnal harmonics in Schumann resonance parameters observed on both hemispheres

Diurnal harmonics of Schumann Resonance (SR) parameters have been studied for the first time using data obtained at two sites on opposite hemispheres, Antarctica and Greenland. Schumann resonances are resonant electromagnetic waves in the Earth-ionosphere cavity with a fundamental frequency of about 8 Hz and higher order modes. They have been predicted and theoretically discussed by Schumann in 1952. It is commonly assumed that lightning discharges from global thunderstorm activity are the main excitation sources. SR can be fully characterised by three parameters, amplitude, centre frequency and spectral width. Signatures of a 24-h, a 12-h, and a 8-h harmonic are clearly discernible in both data sets, but with

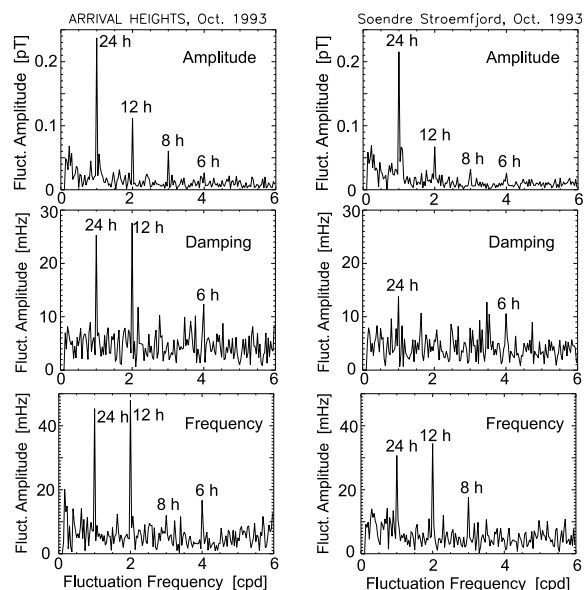


Fig. 54: Spectra of the time series of three SR parameters covering October 1993 for the southern hemisphere station Arrival Heights (left column) and the northern hemisphere station Søndre Strømfjord (right column). The fluctuation amplitude is measured in the units of the respective SR parameters, the fluctuation frequency is given in cycles per day.

different strength. The amplitude of the harmonics changes with season as well. The data can partly be explained on the basis of current understanding of Schumann resonances. Their properties are determined by the global lightning activity and by the condition of the upper boundary of the Earth-ionosphere wave guide. Since atmospheric tides are very important for the dynamics of the D region/mesosphere, some of the results may be explained in terms of these waves (Fig. 54).

(K. Schlegel in collaboration with Martin Füllekrug, Institut für Meteorologie und Geophysik, Universität Frankfurt/Main)

### A D-region conductivity model from EISCAT VHF measurements

An easy-to-use model to evaluate conductivities at high and middle latitudes in the height range 70 – 100 km is presented. It is based on electron density profiles obtained with the EISCAT VHF radar during 11 years and on the neutral atmospheric model MSIS95. The model uses solar zenith angle, geomagnetic activity and season as input parameters. The motivation for this work was the need for easy-to-use, but reliable conductivity profiles in the D region for Schumann-resonance (SR) studies. Current theories show that SR parameters strongly depend on the conductivity of the lower D region, i.e. the upper boundary of the Earth-ionosphere wave guide. Reliable conductivity profiles are therefore important to estimate these parameters and in turn to describe the behaviour of SR (Fig. 55).

(K. Schlegel in collaboration with Martin Füllekrug, Institut für Meteorologie und Geophysik, Universität Frankfurt/Main)

### Auroral E-region electron density gradients measured with EISCAT

In the theory of E-region plasma instabilities, the ambient electric field and electron density gradient are both included in the same dispersion relation as the key parameters that provide the energy for the generation and growth of electrostatic plasma waves. While there exist numerous measurements of ionospheric electric fields, there are very few measurements and limited knowledge about the ambient electron density gradients,  $\nabla N_e$ , in the E-region plasma. In this work, we took advantage of the EISCAT CP1 data base and studied statistically the vertical electron density gradient length,  $L_z$ , at auroral E-region heights during

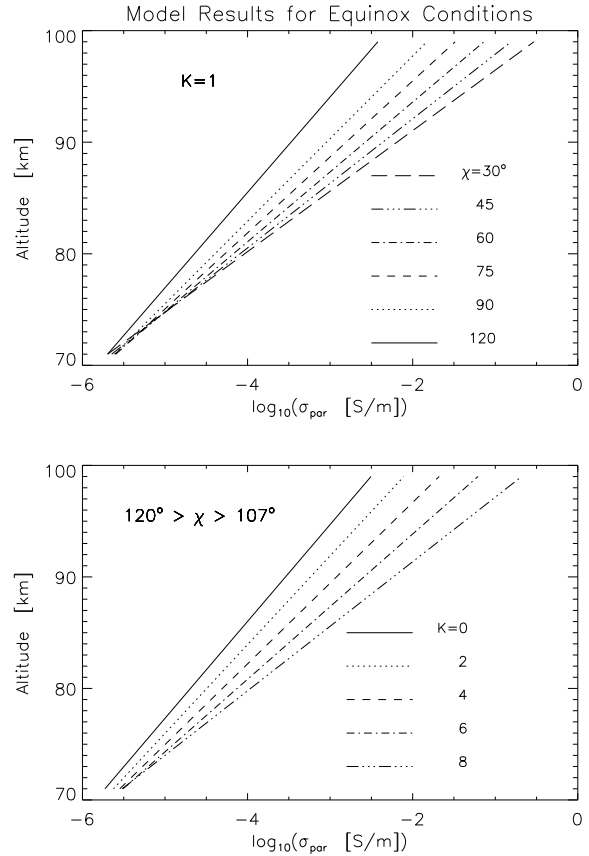


Fig. 55: Examples of conductivity variations with solar zenith angle (upper panel) and with geomagnetic activity (lower panel), both for equinox conditions as obtained with the conductivity model.

both eastward and westward electrojet conditions and different ambient electric field levels. Overall, the prevailing electron density gradients, with  $L_z$  ranging from 4 to 7 km, are found to be located below 100 km, but to move steadily up in altitude

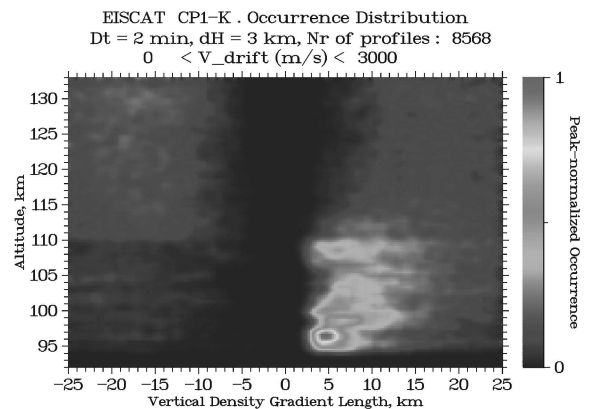


Fig. 56: Normalised distribution of occurrence of the measured vertical electron density scale lengths, as a function of auroral E-region altitude.

as the electric field level increases. The steepest density gradients, with  $L_z$  possibly less than 3 km, occur near 100 km mostly in the eastward electrojet during times of strong electric fields. The vertical gradients can strongly destabilise the plasma at long wavelengths (tens to hundreds of metres) in the bottomside E region during times of low electric fields, but only in the eastward electrojet. The bottomside gradients are expected to be strongly stabilising in the westward electrojet when the electric field is southward. This suggests that the unstable state of the low E-region auroral plasma may be drastically different for the eastward and westward electrojets (Fig. 56).

(K. Schlegel in collaboration with C. Haldoupis, Physics Department, University of Crete, Iraklion, Greece and G. Hussey, Department of Physics and Engineering Physics, University of Saskatchewan, Canada)

### Conductivity gradients in field-aligned current measurements

STARE gives two-dimensional maps of the ionospheric electric field with good spatial ( $20 \times 20$  km) and temporal (10 sec) resolution over a large area ( $13.5 - 26.0^\circ\text{E}$ ,  $67.6 - 72.6^\circ\text{N}$ ). The SMA consists of a two-dimensional array of magnetometers, giving equivalent current distributions, with a spacing of  $\sim 120 \times 120$  km within STARE's field of view, operating with 10 sec time resolution. Using Ohm's law in the ionosphere, the field-aligned current (FAC) can be estimated which depends on the gradient of Pedersen and Hall conductance (Fig. 57).

The data examined here were obtained at 21:35 UT on 15 January 1980 with  $K_p = 1^+$  and a quiet arc present over northern Scandinavia. Fig. 57 shows the FACs computed when conductance gradients are ignored and when they are included. The lower border of an auroral arc, projected at 100 km altitude, is also shown. Clearly, including the conductance gradients has significantly broadened the spatial distribution of the FACs. This will always be a natural consequence of auroral precipitation.

(M. J. Kosch, O. Amm and E. Nielsen)

### A self-consistent estimate of $\text{O}^+ + \text{N}_2$ -rate coefficient and total EUV solar flux with $\lambda < 1050 \text{ \AA}$ using EISCAT observations

The ionising solar EUV flux with  $\lambda < 1050 \text{ \AA}$  and the main  $\text{O}^+ + \text{N}_2$ -reaction rate coefficient in

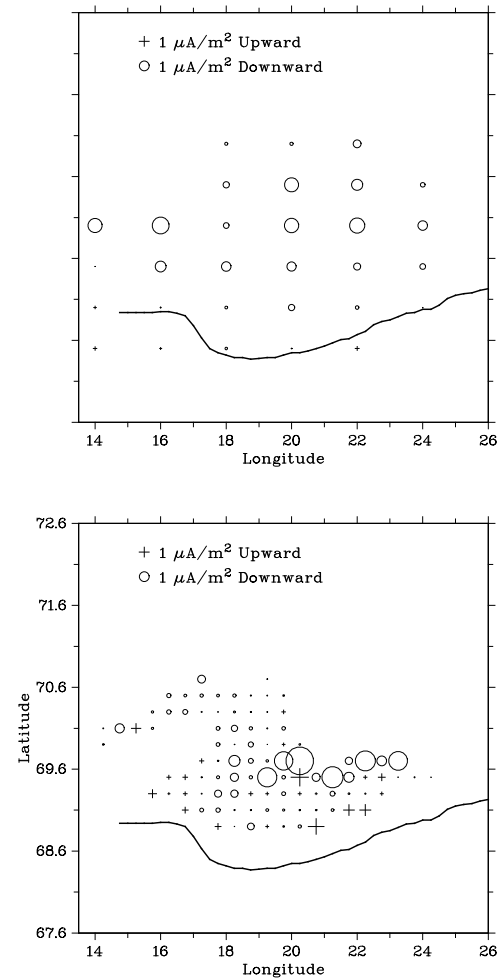


Fig. 57: Total field-aligned current distribution including (upper panel) and ignoring (lower panel) conductance gradients.

the F2 region together with the neutral composition are known to be crucial parameters for adequate modelling of the ionospheric F2 region. Unfortunately, there are serious discrepancies both between existing models of solar EUV and between different laboratory measurements of the  $\text{O}^+ + \text{N}_2$ -rate coefficient. Therefore, aeronomic estimates of these parameters may be useful for qualifying the existing EUV models and laboratory measured  $\text{O}^+ + \text{N}_2$ -rate coefficients. A modified self-consistent method for daytime F2-region modelling developed by Mikhailov and Schlegel was applied to EISCAT observations (32 quiet summer and equinoctial days) to estimate the set of main aeronomic parameters. Three laboratory measured temperature dependencies for the  $\text{O}^+ + \text{N}_2$ -rate coefficient (McFarland et al., St.-Maurice and Torr, and Hierl et al.) which were used in our calculations to find self-consistent fac-

tors both for this rate coefficient and for the solar EUV flux model from Nusinov. Independent of the rate coefficient used, the calculated values group around the temperature dependence recently measured by Hierl et al. in the 850-1400 K temperature range (Fig. 58). Therefore, this rate coefficient may be considered as the most prefer-

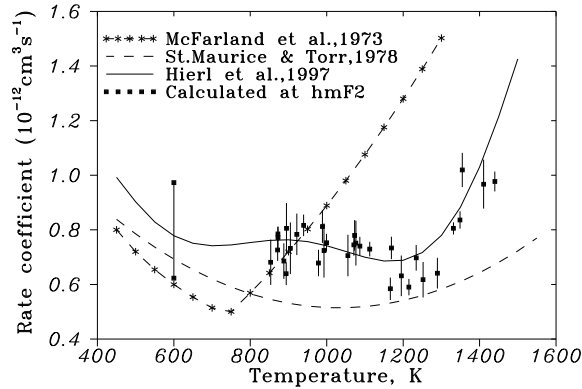


Fig. 58: Calculated  $O^+ + N_2$ -reaction rate coefficients for three different laboratory-measured temperature dependencies in comparison with our results (dots with error bars).

able and is recommended for aeronomic calculations. The calculated EUV flux shows a somewhat steeper dependence on solar activity than both, the Nusinov and the EUVAC models predict.

(K. Schlegel in collaboration with A.V. Mikhailov, Institute of Terrestrial Magnetism, Ionosphere and Radio Wave Propagation, Troitsk, Moscow Region, Russia)

### Equinoctial transitions in the ionosphere and thermosphere

Equinoctial summer/winter transitions in the parameters of the F2 region are analysed using ground-based ionosonde and incoherent scatter observations. Average transition from one type of diurnal NmF2 variation to another takes 20-25 days, but cases of very fast (6-10 days) transitions are observed as well. Strong daytime NmF2 deviations of both signs from the monthly median not related to geomagnetic activity are revealed for the transition periods. Both longitudinal and latitudinal variations take place for the amplitude of such quiet time NmF2 deviations. The summer-type diurnal NmF2 variation during the transition period is characterised by decreased atomic oxygen concentration [O] and a small equatorward thermospheric wind compared to winter-type days with strong poleward wind and increased [O]. Molecular  $N_2$  and  $O_2$  concentrations

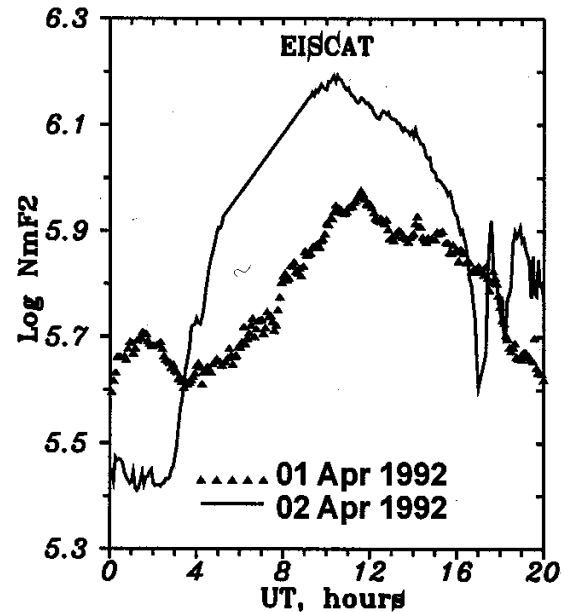


Fig. 59: Diurnal NmF2 variation for a winter-like (Apr 02, 1992) and a summer-like (Apr 01, 1992) day.

remain practically unchanged in such day-to-day transitions. The main cause of the F2-layer variations during the transition periods is the change of atomic oxygen abundance in the thermosphere related to changes of global thermospheric circulation (Fig. 59).

(K. Schlegel in collaboration with A.V. Mikhailov, Institute of Terrestrial Magnetism, Ionosphere and Radio Wave Propagation, Troitsk, Moscow Region, Russia)

### The high latitude thermospheric ion-drag time constant

Magnetospheric convection effectively controls the thermospheric wind system. The neutral winds at F-region heights follow but generally lag behind the two-cell ion drift pattern of magnetospheric convection. Satellite observations of ionospheric convection and thermospheric winds have clearly shown that both gas motions are closely linked. In all cases, the ion velocity is much more variable than the neutral velocity due to the very much greater density of neutrals over ions. At F-region altitudes the basic balance of forces on the neutrals is between ion-drag and thermal pressure with advection, coriolis and viscous forces generally playing a secondary role. Ion-drag dominates the total momentum forcing on the upper thermosphere in the vicinity of the auroral oval.

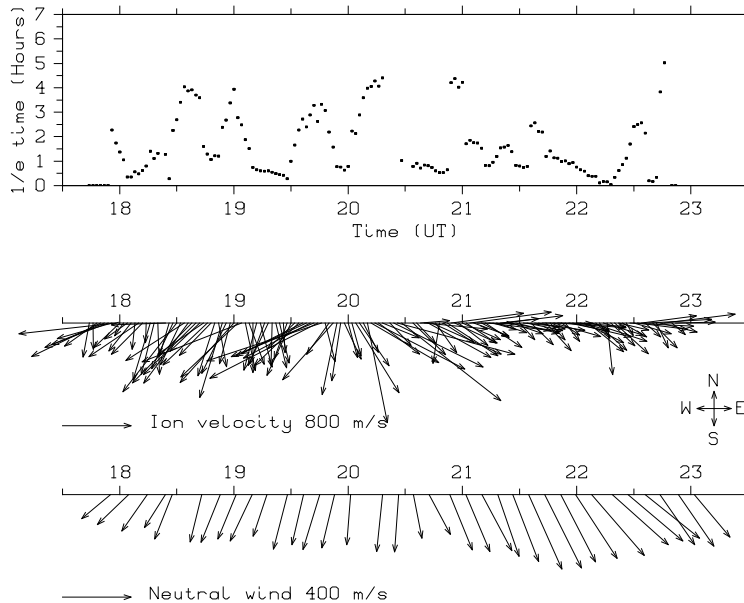


Fig. 60: For November 9, 1998, the e-folding time (top panel), the EISCAT ion velocity vectors at 250 km altitude (middle panel), and the FPI neutral wind vectors in the upper thermosphere (bottom panel).

From this balance of forces a time constant for the ion-neutral coupling can be derived which defines the  $1/e$  time required for the neutral thermosphere to accelerate from one steady state to another in response to a step change in the ion-drag momentum forcing. Satellite measurements have found typical values to be in the range 0.5–3.5 hours. For 250 km altitude we measured the ion velocity with EISCAT and the neutral velocity with the Fabry-Perot interferometer (FPI). The FPI is located at Skibotn (69.35°N, 20.36°E), Norway, about 50 km east of EISCAT. Observations are made at 630 and 557.7 nm wavelengths, corresponding to the upper ( $\sim 250$  km) and lower ( $\sim 115$  km) thermosphere, respectively. Neutral winds and temperatures are derived from the Doppler shift and broadening, respectively, of the selected airglow/auroral emissions.

On 9 and 10 November 1998, a coordinated EISCAT-FPI experiment was performed. The first night was very disturbed with  $K_p = 7^- - 5^-$  while the second night was very quiet with  $K_p = 0^+ - 0$ . Fig. 60 shows the time constant (top panel), EISCAT  $\mathbf{V}_i$  at 250 km altitude (middle panel), and the FPI  $\mathbf{U}_n$  in the upper thermosphere (bottom panel) for November 9, 1998. The time constant varies between 0.5 and 5 hours and has an average of 1.8 hours, which is consistent with previous satellite measurements of 0.5–3.5 hours. For November 10, 1998, it varies between 0.5 and 6.5 hours with an average of 3.3

hours. These are the first ground-based high-latitude observations of the upper thermospheric ion-drag e-folding time using EISCAT and the Fabry-Perot interferometer.

(M. J. Kosch, K. Cierpka, M. T. Rietveld, T. Hagfors and K. Schlegel)

### EISCAT observation of a high-latitude ionisation trough associated with a reversed westward plasma flow in the pre-noon sector during southward IMF

The high latitude ionosphere is closely coupled with the magnetosphere through geomagnetic field lines and directly controlled by the solar wind and interplanetary magnetic field (IMF). Due to different competitive processes, the resulting plasma densities in the high latitude ionosphere show a strong irregular behaviour in space and time. In recent decades, in-situ satellite and ground-based radar observations have revealed a variety of large-scale plasma structures in the high-latitude F-region, for instance, the high-latitude trough, a depletion of electron density in the region of the auroral oval and the polar cap. Trough-like plasma structures in the high-latitude ionosphere near the polar cap boundary are investigated with EISCAT CP3 data and in-situ satellite observations. Emphasis is placed on one interesting event occurring in the morning

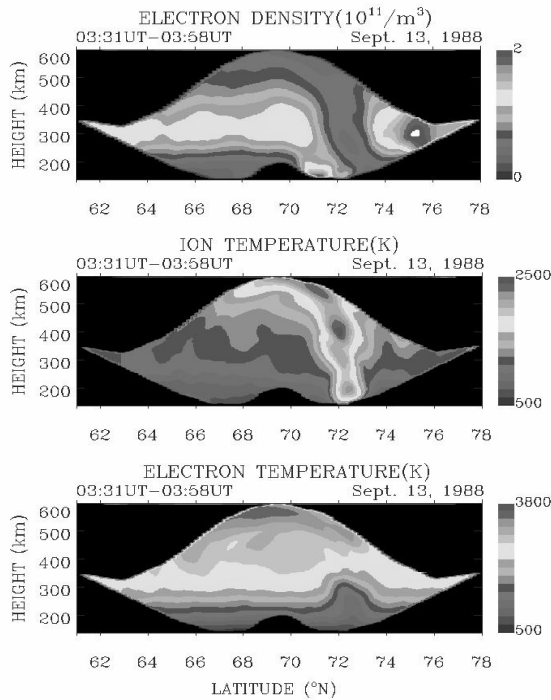


Fig. 61: Example of a trough-like feature in the EISCAT-derived electron densities, ion temperatures and electron temperatures.

sector during the recovery phase of a moderate magnetic storm. The event features are probably ionospheric signatures of cusp processes caused by magnetic reconnection on the dayside magnetopause (Fig. 61).

(K. Schlegel in collaboration with S.-Y. Ma and P. Liu, Department of Space Physics, Wuhan University, Wuhan, China)

### Diurnal, seasonal, and geomagnetic variations of large field-aligned ion upflows in the high-latitude ionospheric *F* region

In the past decades, upward flowing ions have been proved to play an important role in the ionosphere-magnetosphere coupling. The occurrence frequency of upward flowing  $O^+$  ions was found to increase with the  $K_p$  index and the solar flux. A seasonal variation exists as well, in favour of the summer solstice.

A statistical analysis was carried out to investigate the morphology of large field-aligned ion upflows in the high-latitude *F* region ionosphere, by using both the European Incoherent Scatter mainland radar (called EISCAT in the following) and the EISCAT Svalbard Radar (ESR). By binning data

with respect to geomagnetic conditions, significant differences are found between quiet and disturbed periods in the morphology of field-aligned upflows obtained by EISCAT around solar maximum: (1) the occurrence frequency on the night-side is more than 3 times higher during disturbed times than during quiet times; (2) the starting altitude of upflows lowers from 350 – 400 km under quiet conditions to 200 – 250 km under disturbed conditions; (3) the magnetic local time (MLT) distribution of the occurrence frequency of upflows exhibits a dawn-dusk asymmetry above 400 km altitude. It favours the dusk sector under quiet conditions but favours the dawn sector under disturbed conditions; (4) the disturbed-time upflow occurrence frequency exhibits a semi-annual variation above 400 km, with higher values around equinoxes. ESR observations during the rising phase of the solar cycle reveal some preliminary features of upflows in comparison to EISCAT observations: (1) the occurrence frequency of upflows on the dayside becomes significantly noticeable at about 200 km altitude, which is lower than that at EISCAT; (2) the upflow occurrence frequency above 400 km exhibits an obvious MLT distribution, with higher values during 0400 – 1500 MLT, in contrast to 1800 – 0200 MLT at EISCAT; (3) the upflow occurrence frequency above ESR is higher than that above EISCAT during 0700 – 1500 MLT but is lower during 2000 – 0200 MLT.

(H. Liu and K. Schlegel in collaboration with S.-Y. Ma, Department of Space Physics, Wuhan University, Wuhan, China)

### Positive storm effects in the dayside polar ionospheric *F*-region observed by EISCAT and ESR during the magnetic storm of May 15, 1997

Ionisation enhancements in the ionospheric *F*-region responding to magnetic storms are usually called a positive ionospheric storm. In the polar *F*-region this phenomenon is often associated with soft particles precipitating from magnetospheric source regions. EISCAT/ESR radar data and in-situ FAST and POLAR satellite observations are coordinately analysed to investigate positive ionospheric storm effects in the dayside upper *F*-region in both the polar cap and the auroral oval during the magnetic storm of May 15, 1997. An ionisation enhancement lasting for 2.5 hours appeared first over the EISCAT site around magnetic noon (Fig. 62); about one hour later a similar ionisation enhancement was

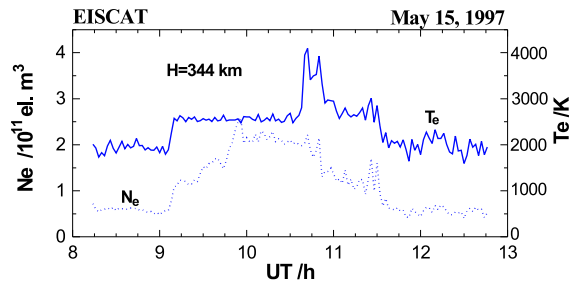


Fig. 62: Increased electron density and electron temperature measured with EISCAT during the magnetic storm of May 15, 1997.

also seen over ESR. During the concerned time period ion energy spectra measured on board FAST show clearly continuous energy-latitude dispersion when the satellite passed over the EISCAT latitude. This implies that EISCAT was located under the polar cusp region which was highly active and expanded greatly equatorwards during a long-lasting southward IMF interval. Simultaneously soft particles of the magnetosheath precipitated into the F-region ionosphere and caused the positive storm effects over EISCAT. The coincident increase of electron temperature at EISCAT gives additional evidence for soft particle precipitation. Consistently, POLAR UV images show strong dayside aurora extending to as low as  $62^\circ\text{N}$  magnetic latitude. The ionisation enhancement over ESR had a different origin, it was probably a polar patch originating from the cusp region and travelling to the ESR site.

(K. Schlegel and H. Liu in collaboration with S.-Y. Ma, Department of Space Physics, Wuhan University, Wuhan, China)

### Combined ESR and EISCAT observations of the dayside polar cap and auroral oval during the May 15, 1997 storm

The ionospheric storm is a chain of events caused by energy transfer from the solar wind to the magnetosphere during periods of southward interplanetary magnetic field (IMF). The negative storm phase is usually caused by changes in the thermospheric composition and the positive one by elevated F-region heights driven by disturbed thermospheric winds. The high-latitude ionospheric response to a major magnetic storm on May 15, 1997 is studied and different responses in the polar cap and the auroral oval are highlighted. Depletion of the F<sub>2</sub>-region electron density occurred in both the polar cap and the auroral zone, but due

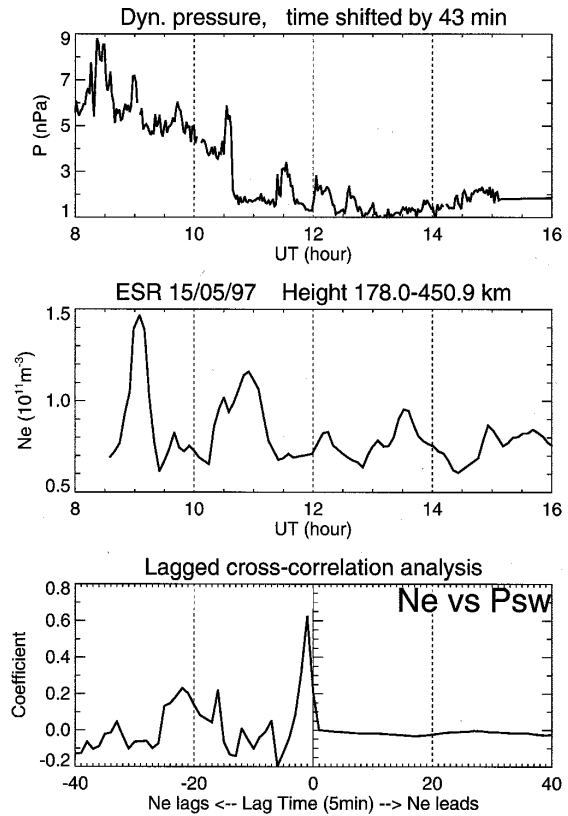


Fig. 63: The solar wind dynamic pressure, the height-averaged electron density and their cross-correlation coefficient.

to different physical processes. During the main phase and the beginning of the recovery phase enhanced electron densities due to soft particle precipitation in the polar cap showed a clear relation to the dynamics pressure of the solar wind, with a maximum cross-correlation coefficient of 0.63 at a time lag of 5 min (Fig. 63).

(H. Liu and K. Schlegel in collaboration with S.-Y. Ma, Space Physics Department, Wuhan University, Wuhan, China)

### Penetration of auroral electric fields to the equator during a substorm

The negative magnetic bay associated with the substorm that occurred on April 20, 1993 was studied and it was found that it is markedly enhanced at the daytime dip equator, coherent with that at afternoon subauroral latitudes. The amplitude of the negative bay decreases monotonically with latitude, but it is amplified at the dip equator by a factor of 2.5 compared to the low-latitude negative bay. This latitudinal profile implies that in addition to the three-dimensional cur-

rent system in the magnetosphere, DP ionospheric currents originating in the polar ionosphere contribute greatly to negative bays. Penetration of the convection electric field and the effect of a shielding electric field due to Region 2 (R2) field-aligned currents (FACs) are examined on the basis of European Incoherent Scatter (EISCAT) and International Monitor for Auroral Geomagnetic Effects (IMAGE) magnetometer observations made in the afternoon sector. The northward electric field at EISCAT (66° corrected geomagnetic latitude (CGMLAT)) is well correlated with the magnetic field X component at Nurmijärvi (56° CGMLAT) during the presubstorm period, but the coherency breaks down during the substorm cycle. By assuming that the R2 FACs intensify the northward electric field at EISCAT but reduce it at Nurmijärvi, we demonstrate that the R2 FACs grow concurrently, although delayed by some 17 min, with the convection electric field. Our analytical results indicate that the convection electric field decreases abruptly during the substorm and that the shielding electric field overcomes the convection electric field at around the peak of the negative bay, owing to its delayed reaction. The equatorial negative bay is thus due to an overshielding effect caused by the electric field associated with the R2 FACs.

(K. Schlegel in collaboration with T. Kikuchi, Communications Research Laboratory, Tokyo, Japan and H. Lühr, GeoForschungsZentrum, Potsdam)

### Scandinavian Twin Auroral Radar Experiment (STARE)

By the end of 2001 the STARE system was transferred to our long-time collaborators at the Finnish Meteorological Institute, Finland. They will continue the operation of the radar system, and MPAE continue to have access to all observations. So far STARE observations have resulted in ~150 publications in refereed journals from MPAE. The data were also used in 10 Ph.D. theses and in 8 M.Sc. theses. The outstanding property of the STARE radar system is that it provides observations of the spatial ionospheric flow pattern over ~200 000 km<sup>2</sup> in Northern Scandinavia with a resolution of 20×20 km, and with a time resolution of 20s. The STARE system has opened a window through which the interaction of a stellar wind (the solar wind) with a strongly magnetised planet (the Earth) can be observed. The parameters measured by the system are: backscatter intensity, Doppler velocity, and auto-correlation

function (or power spectra). These measurements are also used to study the plasma physics of the processes in the E region giving rise to the radar backscatter signal.

As the solar wind blows past the Earth field aligned currents are induced to flow between the magnetosphere and ionosphere. STARE observations were used to determine the statistical average of these currents. The currents were calculated from the rotation of the ionospheric electric fields derived from STARE observations. The results compare very favourably to other ground-based and satellite measurements.

The magnetosphere/ionosphere system continuously reacts to changing conditions in the solar wind and transfers dynamically towards the new equilibrium state. One physical mechanism by which such transfers are accomplished is geomagnetic pulsations. For example, if a sudden pressure pulse in the solar wind interacts with the magnetosphere, then short lived and wide band Pc5 pulsations can be excited. We have studied how such pulsations are attenuated. An interplanetary shock interacted with the Earth on February 18, 1999 and excited an intense transient Pc5 pulsation. Analysis of the spatial variations and of the time variations of the electron drifts induced by the pulsation in the high latitude ionosphere, allows a deduction of the latitudinal variation of the height integrated Pedersen conductivity. It is concluded that ionospheric Joule heating losses are sufficient to account for the attenuation of the pulsation. It is also shown that for a pulsation event of this type use of magnetometer observations lead to an overestimate of the attenuation, or, equivalently, to an underestimate of the ionospheric Pedersen conductivity.

(E. Nielsen)

### Ionospheric modification

#### DASI observations of artificial airglow from heating

The EISCAT HF-facility is capable of transmitting up to 240 MW of power into the ionosphere at 4.04 MHz. During such O-mode transmissions, F-region electrons were accelerated sufficiently to excite the oxygen atoms, resulting in observable optical emissions. The O<sup>1</sup>D and O<sup>1</sup>S emissions at 630 and 557.7 nm are stimulated by electrons with energies above 1.96 and 4.17 eV threshold, respectively. The airglow observations were made

by DASI. It has been found that the O<sup>1</sup>D emission maximises near the magnetic field aligned direction for all HF beam pointing directions used. This phenomenon is not observed at lower latitudes and remains unexplained.

A very faint O<sup>1</sup>S emission has been observed for the first time at high latitudes, indicating the presence of a smaller population of higher energy electrons. This fact suggests that simple thermal enhancement by HF pumping of a Maxwellian distribution of background electrons is unlikely because of the very high temperatures needed. Stepping the heater frequency through the third gyroharmonic results in a weakening of the optical intensity. This fact suggests that electron acceleration by Langmuir wave turbulence is not the dominant mechanism of artificial airglow production. The results point to upper hybrid wave turbulence.

(M. J. Kosch, M. T. Rietveld, T. Hagfors in collaboration with F. Honary, Department of Communications Systems, Lancaster University, UK)

#### **New EISCAT VHF radar observations of PMSE echoes**

Polar Mesospheric Summer Echoes (PMSE) are strong, largely unexplained echoes observed in the 80-90 km height range by VHF radars in summer at polar latitudes. Experiments were made in June 2001 with the EISCAT 224 MHz radar using the newly upgraded data processing system to measure PMSE with a very high range resolution of tens of metres using multiple frequencies in the Range IMaging (RIM) technique.

During the same campaign further attempts were made to observe the effects of powerful HF waves on PMSE. This time the effects of the HF waves were not obvious, unlike the results of July 1999 reported previously. It is unclear whether the difference in results are caused by different geophysical conditions, something that will be investigated in new experiments in the summer of 2002.

(M.T. Rietveld, in collaboration with P. Chilson, University of Colorado, USA, R. Palmer, University of Nebraska-Lincoln, USA, E. Belova and I. Häggström, Swedish Institute of Space Physics, Sweden)

#### **ULF wave excitation observed on FAST satellite**

The HF facility in Tromsø was used to inject 3 Hz ULF waves into the magnetosphere by modulated heating of the auroral electrojet. Local electric field oscillations associated with the artificially stimulated ULF waves were detected on board the FAST satellite at an altitude of 2550 km. In addition, a modulated downward flux of electrons was detected. The artificially excited waves, together with these energised downward electrons were detected on board the spacecraft in a narrow region only a few tens of km across the geomagnetic field. Furthermore, the downward flux exhibited energy dispersion in a manner that was consistent with the artificially excited waves having followed the geomagnetic field out beyond the spacecraft, where they appear to have stimulated electron precipitation back down the field line.

(M.T. Rietveld, in collaboration with T. Robinson et al., University of Leicester, UK, and R. Strangeway, UCLA, USA)

#### **EISCAT measurements of powerful HF pump-induced electron temperature enhancements and radio-induced airglow**

An experiment was performed on October 7, 1999 whereby the UHF radar antenna scanned through three positions between vertical and geomagnetic field-aligned in a 4-minute cycle, while the heating facility at 4.544 MHz was switched 8 minutes on and 4 minutes off. The HF beam was also tilted between the same three zenith angles as the UHF radar, but changing every 12 minutes. Surprisingly, the electron temperature enhancements were always stronger in the field-aligned direction, for all three directions of the HF beam, as is shown in Fig. 64.

At the same time radio-induced airglow, measured in the 630 nm red oxygen line, was produced which also stayed near the field-aligned position in spite of the HF beam scanning. Upper hybrid wave turbulence which is thought to be responsible for energising the electrons producing the increased temperatures, the airglow, and small-scale electron density irregularities or striations, is excited by the component of the pump electric field which is perpendicular to the geomagnetic field. It is unclear why these phenomena show a strong dependence on the direction of the HF ray to the magnetic field.

(M.T. Rietveld, in collaboration with M. Kosch,

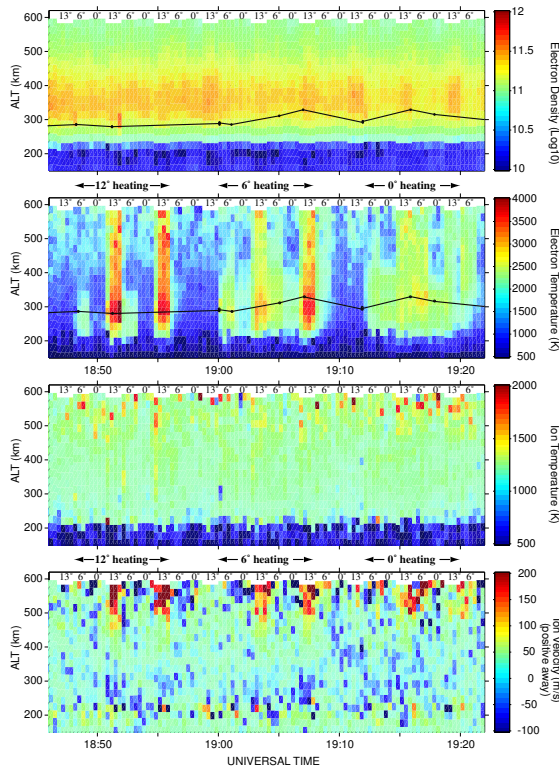


Fig. 64: Data from the EISCAT UHF radar at Tromsø on October 7, 1999, analysed with 20 s integration time, showing the effects of HF pumping. The HF was cycled 8 min on, 4 min off, with the beam directed at southward zenith angles shown below the upper and above the lowest panels. The UHF antenna was continually scanned in a 4-min cycle between almost the same positions, 6°, 0°, 12.8° zenith angles, which are shown inside each panel at the top. The solid line in the upper two panels connects points indicating the HF enhanced ion line height which should be close to but below the HF reflection height.

University of Lancaster, T.B. Leyser, Swedish Institute of Space physics, Sweden, and N. Blagoveschenskaya, Arctic and Antarctic Research Institute, Russia)

### Directional SEE and artificial ionospheric irregularity measurements

In previous years we have reported various HF induced effects which appear to show a preference for directions between the Spitze (6° south) and the magnetic field (13° south). Such effects are the strength of HF enhanced ion and plasma lines, and the presence of topside lines, and HF induced air-

glow. An attempt was made to determine whether Stimulated Electromagnetic Emissions (SEE) produced by powerful HF waves also show such a directional dependence. A two-element interferometer was built near Tromsø and operated in June 2001 during a heating campaign. Analysis of the results is underway and new measurements are planned. During the same campaign a chain of three satellite beacon receivers were used to measure amplitude and phase scintillations caused by HF induced ionospheric irregularities, from which a tomographic analysis will be attempted.

(M.T. Rietveld, T. Hagfors, in collaboration with B. Isham, EISCAT and C. La Hoz, University of Tromsø, Norway, B. Khudukon and E. Tereschenko, Polar Geophysical Institute, Russia)

### EISCAT measurements of plasma and ion lines from powerful HF pumping of the E-region and from coherent echoes associated with an auroral arc

During an experiment in November 1999, the EISCAT 224 MHz radar and sometimes the 931 MHz radar were used to obtain measurements of incoherent scatter ion and plasma lines. Artificially enhanced spectra of E-region plasma waves were measured for the first time at auroral latitudes with both radars. Fig. 65 shows detailed spectra of the HF induced echoes. During periods with suitable peak E-region electron density, Z-mode propagation of the HF pump wave to the topside E-region occurred, and topside instability-enhanced plasma waves were observed. In addition to HF pump-induced effects, an unusual F-region echo was seen in both the ion and plasma line channels, which appears to be due to an instability caused by an auroral arc intersecting the radar beam. These echoes are the first plasma line signals seen from such natural coherent echoes which are the subject of much study.

(M.T. Rietveld, T. Hagfors, in collaboration with F. Honary and M. Kosch, University of Lancaster, UK, B. Isham, EISCAT, Tromsø, Norway, T. Grydeland and C. La Hoz, University of Tromsø, Norway, H. Ueda, University of Chiba, Japan, T. B. Leyser, Swedish Institute of Space physics, Sweden)

### Ionospheric modification experiments with the Russian SURA facility

During the period of this report, two campaigns have been carried out with the SURA ionospheric

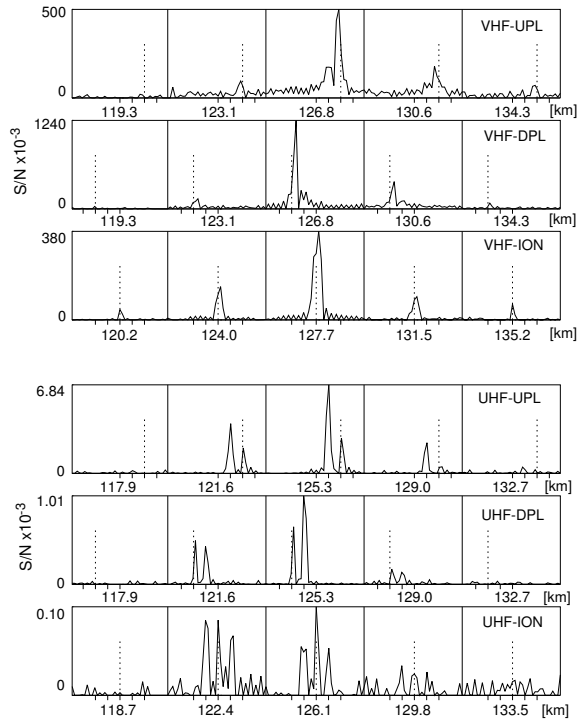


Fig. 65: VHF and UHF spectra from HF enhanced ion and plasma lines in the E-region at 18:08:00 to 18:08:10 UT on 11 Nov 1999. The tic marks are at 5-kHz intervals. The numbers below each spectrum show the altitude in km. The dotted lines in the UPL and DPL spectra indicate the HF pump frequency. The VHF plasma line spectra show mainly the decay line whereas the UHF spectra show both the decay and the modulational instability lines. The ion acoustic frequency is about 5 kHz and 1.2 kHz at the UHF and VHF radar k vectors, respectively.

modification facility, focusing on SEE experiments (SEE = Stimulated Electromagnetic Emissions).

The SEE phenomenon has been discovered in experiments with the MPAE heating facility at Tromsø, Norway: A powerful electromagnetic O-mode wave, with a frequency below the maximum F-region plasma frequency, generates secondary electromagnetic waves in a frequency range of up to a few hundred kHz around the frequency of the primary wave. These secondary waves possess a variety of characteristic maxima in the frequency spectrum. All spectral features depend sensitively on the pump frequency choice relative to a harmonic of the electron gyrofrequency, and some of the SEE maxima occur only if the pump frequency is close to a gyroharmonic.

In the SEE experiments, the ionosphere is used as a plasma laboratory. Since the properties of the

ionosphere at mid-latitudes are more favourable for these experiments than those at auroral latitudes, the activities in this field have been shifted in recent years from Tromsø to the SURA heating facility, located near Nizhny Novgorod, Russia. The experiments have focused on the detailed dependencies of the SEE features on the pump frequency, especially near gyroharmonics, and on the properties of the background plasma. Special emphasis has been placed on the temporal evolution of the various SEE features and their development toward saturation.

(P. Stubbe, in cooperation with V.L. Frolov, E.N. Sergeev and E.N. Ermakova, Radiophysical Research Institute (NIRFI), Nizhny Novgorod, Russia)

## Magnetosphere

### RAPID experiment on Cluster

The RAPID spectrometer (Research with Adaptive Particle Imaging Detectors) measures 3-dimensional suprathermal plasma distributions in the energy range from 20–400 keV for electrons, 30 keV–1500 keV for hydrogen, and 10 keV – 1500 keV/nucleon for heavier ions. Three detector heads cover 180° in a plane containing the spin axis, while the satellite rotation provides azimuthal scanning. Identification of the ion species is based on a two-dimensional analysis of the particle’s velocity and energy. Electrons are identified by the well-known energy-range relationship. Table 2 list the main parameters of the RAPID instrument.

Ion spectral counts are sorted into 8 energy bins, 12 polar angle segments, 16 azimuthal sectors, and 3 mass ranges. Higher energy and mass precision is obtained with so-called “direct events”. Electron counts are similarly sorted into 8 energy bins, 9 polar segments, and 16 azimuthal sectors.

Table 2: Specifications for RAPID.

Energy:	H	30–1500 keV
	He	100–1500
	CNO	105–1500
	e <sup>-</sup>	20–400
Masses:		1, 4, 12–16, 28–56 amu
Res. ( $A/dA$ ):	O	4
FOV:	ions	$\pm 3^\circ \times 180^\circ$
	e <sup>-</sup>	$\pm 17.5^\circ \times 180^\circ$
Geom. factor:	ions	$2.6 \times 10^{-2} \text{ cm}^2 \cdot \text{sr}$
	(for 180°) e <sup>-</sup>	$2.0 \times 10^{-2}$

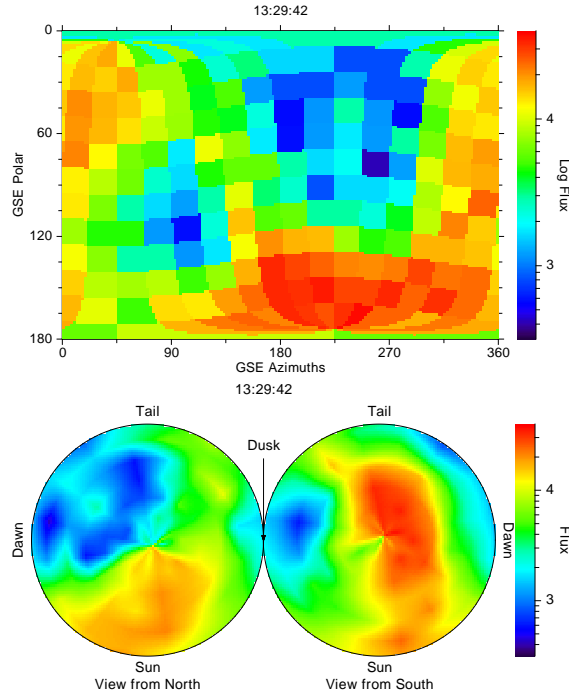


Fig. 66:  $H^+$  fluxes in GSE coordinates as measured by RAPID-3 on January 14, 2001, at 13:29 UT. The upper plot is a simple 2-D array, showing the 192 “pixels” mapped into GSE; the lower plot shows the same data but smoothed, in a double hemispherical representation.

Fig. 66 illustrates a sample angular distribution of  $H^+$  flux in  $12 \times 16 = 192$  pixels on the unit sphere, in two different representations, with and without smoothing. In this example, the flux is predominantly towards the south, and slightly to the dawn side.

(P.W. Daly, U. Mall)

### High-latitude dayside flux transfer event

Flux transfer events (FTEs) are instances of interconnection between magnetospheric and solar wind plasmas, local holes in the magnetopause. Previous studies have concentrated on FTEs near the equatorial plane where they are believed to originate. Cluster is in an ideal position to investigate these events at high latitudes. The Cluster fleet allows for the exploration of spatio-temporal structures of FTEs. With four spacecraft close by, taking measurements simultaneously, it becomes possible to investigate the structure and dynamics of FTE signatures.

RAPID on Cluster has made the first multi-spacecraft energetic particle observations of an FTE observed at high latitudes between 00:46 UT

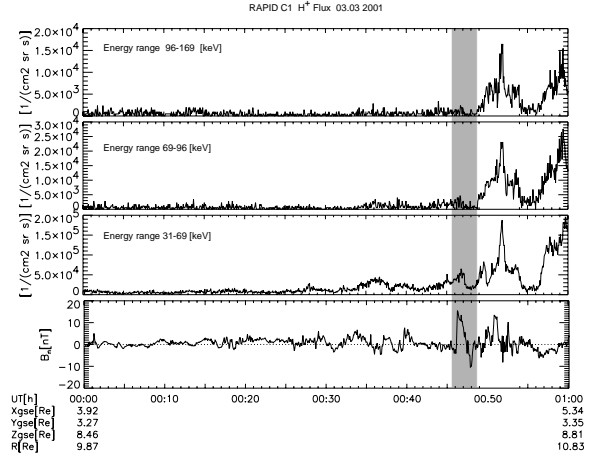


Fig. 67: Time development of the omnidirectional fluxes of the first three energy channels of RAPID and the magnetic field component normal to the magnetopause plane at Cluster 1.

and 00:49 UT on March 3, 2001 (lower panel of Fig. 67). The grey area in this plot indicates the typical bipolar signature for FTEs in the

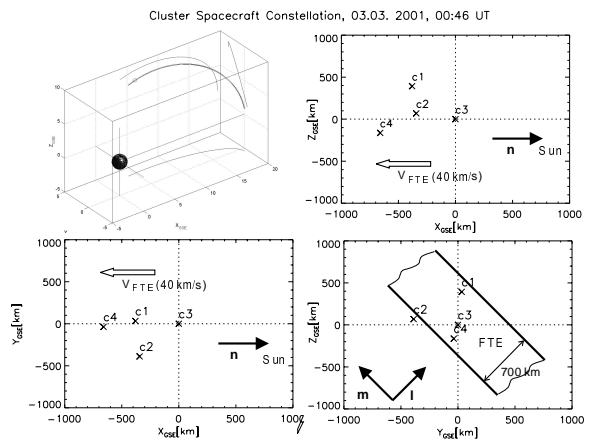


Fig. 68: The geometrical configuration for the four Cluster spacecraft on March 3, 2001 (upper left panel). Spacecraft positions relative to Cluster 3 in GSE-coordinates at 00:46 UT (beginning of the grey shaded region of Fig. 67). The boundary normal coordinate system ( $l, m, n$ ) is marked by the solid arrows, the velocity component of the FTE motion  $V_{FTE}$  is marked by an open arrow. Further, a schematic plot of the FTE in the  $Y$ - $Z$  plane is given.

component of the magnetic field perpendicular to the magnetopause. Prior to this time, the  $B_z$ -component of the interplanetary magnetic field had been negative for four hours. Hence, reconnection at the dayside magnetopause is very probable. The enhancements of the proton fluxes for the first three energy channels during the first half

of the bipolar magnetic signature (upper panels of Fig. 67) confirm the identification of the FTE.

The 4 Cluster spacecraft have a separation of about 600 km at this time. A geometrical study of the time differences of the FTE passage over the spacecraft leads to the results for the orientation and motion as shown in Fig. 68.

(P.W. Daly, U. Mall, B. Nikutowski)

### Cluster magnetopause observations

One important open question of space physics is that of the transport mechanism through magnetic boundaries. The Earth's magnetopause provides an example of an *in situ* observable boundary. The Cluster mission allows, for the first time, its systematic multi-point investigation. As we had started investigating the magnetopause by EQUATOR-S (see annual report 1998/1999) we continued the search for evidence of reconnection opening the magnetopause, now by multi-spacecraft observations.

We observed numerous transient flux transfer events (FTE), which witness reconnection at the dayside magnetopause via connected flux tubes convected over the spacecraft in the anti-sunward direction. During FTEs the MPAE time-of-flight spectrometer RAPID observed energetic protons in the range 30 – 410 keV leaking out from the magnetosphere parallel to the magnetic field. The multi-spacecraft configuration allowed us to estimate independently size (from dozens to hundreds of kilometres) and speed of the observed magnetic FTE tubes (e.g. 40 km/s, i.e. much slower than the ambient solar wind due the anchoring of FTE in the conducting ionosphere).

Occasionally we also observed local acceleration events. In these cases RAPID observed protons only in its lowest energy channel (28 – 69 keV) and in the direction perpendicular to the magnetic field.

Fig. 69 illustrates a typical observation of this kind: The lower panel depicts the magnetic field evolution. Reconnection signatures (bipolar variations in the magnetic field component normal to the current sheet) are highlighted by grey bars. After three FTE traversals were encountered during the fourth reconnection signature, marked by a red cross on the magnetic field plot, only spacecraft C1 and C3 (upper two panels) observed parallel flows while C4 (third panel) sees also ions streaming perpendicular to the magnetic field (at 01:12:14 UT).

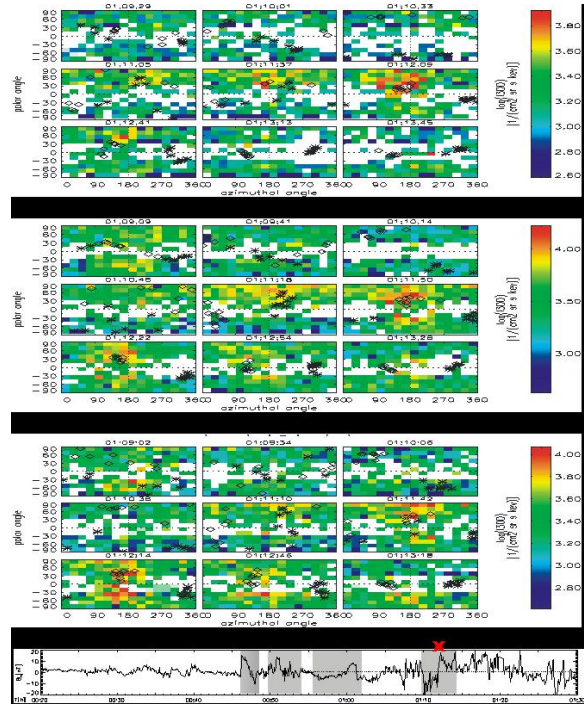


Fig. 69: Energetic proton fluxes near the magnetopause, observed by Cluster/RAPID three-dimensional directional plot of energetic proton flows and magnetic fields.

From the details of our observations we conclude that the observed local acceleration events correspond to small scale three-dimensional kinetic reconnection as we earlier predicted theoretically.

(J. Büchner, P.W. Daly, U. Mall, B. Nikutowski, in collaboration with A. Balogh, London, UK, K.H. Fornacon and K.H. Glaßmeier, Braunschweig)

### CIS experiment on Cluster

Onboard the four Cluster spacecraft the Cluster Ion Spectrometry (CIS) instrument measures the full 3D ion distribution of the major magnetospheric ions as  $H^+$ ,  $He^+$ ,  $He^{++}$ , and  $O^+$  in the energy range from 30 eV to 40 keV. The instrument consists of two sensors:

1. a COmposition and DIstribution Function analyser (CODIF or CIS-1) giving the mass per charge composition and
2. a Hot Ion Analyser (HIA or CIS-2) measuring all ions with a better angular resolution than CODIF. Each analyser has two different sensitivities in order to increase the dynamic range.

(A. Korth, M. Fränz, F. Frutos-Alfaro)

### Magnetic storm ion outflow and dispersed tail injections

The Cluster orbits are excellent to study auroral plasma outflow and plasma sheet dynamics at radial distances of 4–6 Earth radii ( $R_E$ ) in the nightside auroral zones. Due to their geometry the four Cluster satellites traverse the auroral field lines consecutively at almost the same magnetic local time separated in time by a few minutes. The consecutive traversal makes it possible for the first time to study in situ the temporal/spatial evolution of auroral plasma acceleration processes. As an example we took a highly disturbed period during a large magnetic storm (Dst min  $\sim -400$  nT). The traversal from the ra-

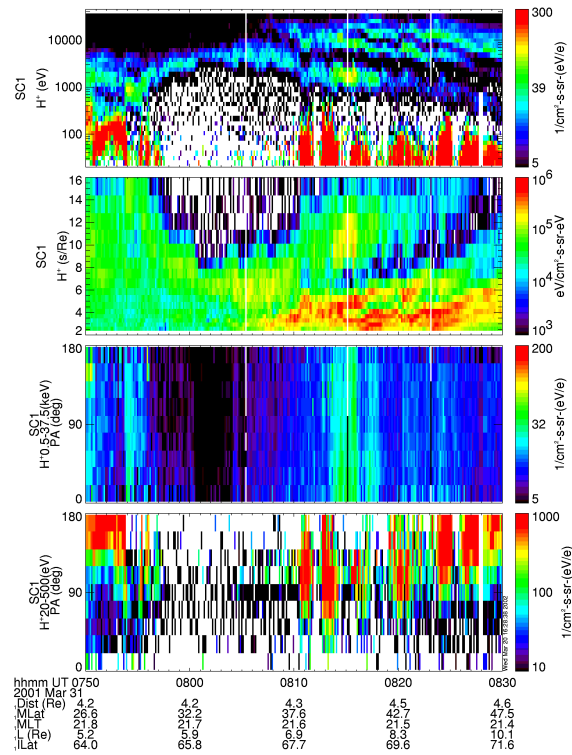


Fig. 70: Energy spectrogram (top panel), inverted velocity spectrogram (second panel), and pitch angle distributions for two energy ranges (lower panels) measured by Rumba (Cluster 1) on March 31, 2001 from 7:50 – 08:30 UT.

diation belt into the auroral acceleration region with spacecraft 1 (Rumba) on March 31, 2001 from 07:50 to 08:30 UT is given in Fig. 70. Panel 1 shows the  $H^+$  ion spectrogram from 30 eV to 40 keV. Besides the outflow of  $H^+$  ions which is

limited to energies up to 400 eV we observe dispersed  $H^+$  ion features which are originating in the tail plasma sheet. Several bands are observed simultaneously. They are launched by a large substorm and intensifications of that substorm. The substorm is observed in the midnight sector from the Alaskan magnetometer chain. The different energy dispersed bands are identified as the direct injection of the substorm and 3 and 5 bounces. Three bounces can be explained by an injection to the southern hemisphere and a reflection to the northern hemisphere. The two lower panels of Fig. 70 show the pitch angle distribution for two energy ranges (outflow ions and plasma sheet ions) and give the directions with respect to the magnetic field from where the particles are arriving. In the following we will add some other findings not shown in figures:

- the upward acceleration of ionospheric ions is quite dynamic
- the field-aligned upward acceleration is clearly mass dependent, with heavier ions acquiring higher peak energies
- the  $O^+/H^+$  ion density ratio is as high as 18 for this large storm
- downward plasma sheet ion beams are generally seen in the same region as upgoing ion beams. The downgoing beams have higher energies than the upgoing beams.
- the downgoing  $H^+$  ion beams are coming from a distance of about 40  $R_E$  at the beginning of the recovery phase of this large storm.

(A. Korth, M. Fränz, F. Frutos-Alfaro)

### Magnetic depressions in the solar wind

Between January and May 2001 the four Cluster spacecraft encountered the Solar wind upstream of the Earth bow-shock for several hours per orbit. During these periods many Solar wind flow-structures could be observed for the first-time with a set of four spacecraft. One of these structures are sudden drop-outs of the magnetic field strength. When these drop-outs have an extent in time of less than about 30 seconds they are usually called magnetic holes which have been explained by kinetic instability models similar to mirror-modes in planetary magnetospheres or by MHD solitary waves. While mirror-mode structures are pressure balanced by an anisotropic proton distribution, solitary waves are balanced by a

plasma-density increase and show proper motion with respect to the surrounding plasma.

We currently try to detect these properties in a common project between the Cluster ion, electron, electric field and magnetic field investigations. Due to the small extent in time of these structures the CIS instrument can – with a typical time-resolution of 16 seconds for a 3D distribution – only take a supporting role. There are indications that magnetic depressions of larger extent are caused by different physical processes. One specific class are depressions of the field strength when crossing the heliospheric current sheet (HCS).

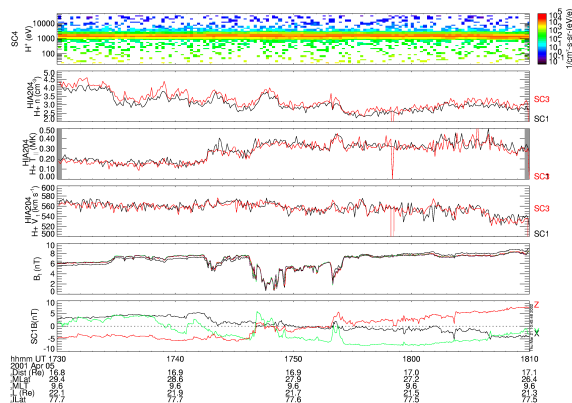


Fig. 71: Heliospheric current sheet crossing observed by Cluster.

An example of this class is shown in Fig. 71. The panels show from top to bottom: The proton spectrum measured by CIS CODIF on Cluster 4, the ion density, field-parallel temperature and velocity measured by CIS HIA on Cluster 1 (black) and 3 (red), the magnetic field strength measured by the FGM instrument on all 4 spacecraft (overplotted), and the field vector components in GSE measured on Cluster 1.

We observe that the field drop-outs show a weak correlation with ion density increases. There is an open debate whether the field annihilation in the HCS is caused by reconnection. Drop-outs are not always observed in HCS-crossings. The 4-point measurements of the Cluster mission allow us to investigate the relation between field annihilation, electric currents and plasma instabilities. We expect that this will elucidate the role of reconnection in large field drop-outs and their relation to magnetic holes.

(A. Korth, M. Fränz, F. Frutos-Alfaro)

## Determination of the scalar and vector field gradients from the CIS data

One of the fundamental ideas of the Cluster mission is, for the first time, to separate spatial and temporal effects in the terrestrial magnetosphere. This separation and the tetrahedral fly formation of the four Cluster satellites make possible the gradient determination from the Cluster data in all directions. A problem with which we are confronted is that the CIS instrument in the Cluster 2 (Salsa) is not operating due to failures in the power supply. In spite of this problem it is possible to determine the gradients in all directions.

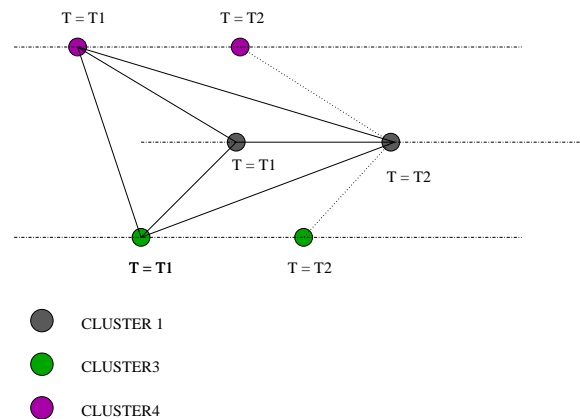


Fig. 72: Tetrahedral reconstruction to measure the density gradient.

In order to find the spatial gradients of scalar (i.e. density) and vector fields (i.e. magnetic field) we have to minimise least square functions which depend on the position of the satellite and the scalar or vector fields. The obtained gradient is always expressed in terms of the inverse of a symmetric tensor (the volumetric tensor) depending upon the relative positions of the spacecraft. This is the conventional way to find out the gradient components. Due to the spacecraft 2 problem we have to modify the way to calculate the density gradients. There are different possibilities to obtain these gradients without taking into account Cluster 2. One way is to reconstruct the tetrahedron (see Fig. 72) from the other three satellites and the other way is to take multiple spacecraft measurements at different times. There exists the possibility of using the WHISPER density data to determine the density gradients. We are exploring these possibilities and are implementing a program under IDL to calculate these gradients from the Cluster data.

(A. Korth, M. Fränz, F. Frutos-Alfaro)

**Cluster observations of thin current sheet dynamics in the Earth's magnetotail**

Utilising Cluster multi-point observations we found evidence for the formation of very thin current sheets in the Earth's magnetotail. The existence of current sheets whose thickness approaches the ion gyro scale has been theoretically conjectured for some time. In particular we have simulated the dynamic consequences of sheet thinning forced by external pressure increase: sausage mode wave generation and reconnection (cf. previous MPAE annual report). Using Cluster magnetic field data we could now directly determine the current sheet thickness evolution by comparing the observations on different spacecraft. One example is shown in Fig. 73 which depicts how on September 9, 2001 the tail current sheet thins from 10000 km down to the ion gyroscale of 500 km (at 21:00 UT).

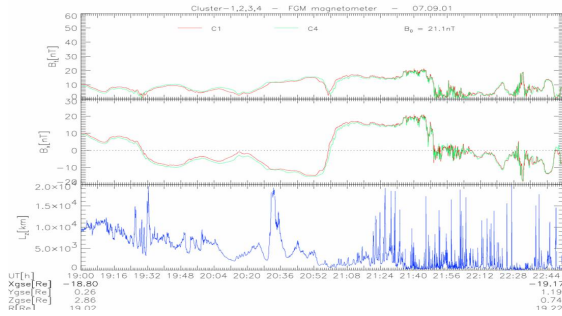


Fig. 73: Total magnetic field,  $B_x$  component measured on September 9, 2001 by the four Cluster spacecraft and current sheet thickness (bottom panel)

The thinning of the tail current sheet was immediately followed by the generation of current sheet bulk mode waves. We compared the observed features with signatures of thin current sheet instabilities and reconnection we obtained by kinetic plasma simulation. Using the information of all four spacecraft we could show that the wave characteristics correspond to those of the predicted drift sausage mode. After the waves grew enhanced flows of energetic protons were observed. Thus our Cluster observations indicate that first thin current sheets develop. As a result unstable wave modes are generated propagating in the current flow direction which then trigger reconnection and an outbreak of energetic protons.

(J. Büchner, P.W. Daly, U. Mall, B. Nikutowski, in collaboration with K.H. Glaßmeier and K.H. Fornaçon, Braunschweig and A. Balogh, London, UK)

**Reconnection in surface waves: EQUATOR-S observations and simulations**

EQUATOR-S was a small spacecraft mission operating from December 1997 till May 1998. The mission was unique by its nearly equatorial orbit with an apogee of 67000 km and due to the fast spin rate (40/min) of the spacecraft. The orbit allowed investigations of the rarely visited equatorial magnetopause, the divide between solar wind and magnetosphere. The spin rate of the spacecraft provided high resolution measurements in three dimensions. Unfortunately the unexpected short lifetime of the mission did not let the spacecraft reach the near Earth tail plasma sheet. All our efforts were, therefore, concentrated on the magnetopause passages. Our first results, reported in the 1998/1999 annual report, were concerned with dayside reconnection.

In addition we now investigated strong oscillations in the Pc5 frequency range. We found them mainly at radial distances larger than  $7 R_E$  being dominated by poloidal modes. We identified them as surface waves generated by a Kelvin-Helmholtz (wind-over-ocean) type instability KHI. The toroidal wave components also seen in the power spectra of the magnetic field oscillations receive their energy by coupling to the poloidal mode.

Following these waves propagating downtail we found inside the structures bipolar variations of the  $B_y$  magnetic field component. We interpret them as reconnection signatures. Indeed, during these intervals the Walen test for rotational discontinuities was well fulfilled (see Fig. 74 for an example).

We verified our interpretation by magnetohydrodynamic (MHD) simulations. Starting at initial conditions close to the observed ones the simulations showed that the dominant oscillations in the Pc 5 range are driven by a linear KHI while reconnection embedded in those oscillations developed in the nonlinear phase of the surface wave evolution inside the resulting vortices.

The frequent encounters of such reconnection signatures at the dawn flank magnetopause indicate a considerable amount of mass transport from the solar wind into the magnetosphere.

(J. Büchner, A. Korth, B. Nikutowski, in collaboration with K. H. Glaßmeier, Technical University Braunschweig and A. Otto, Geophysical Institute, University of Alaska, USA)

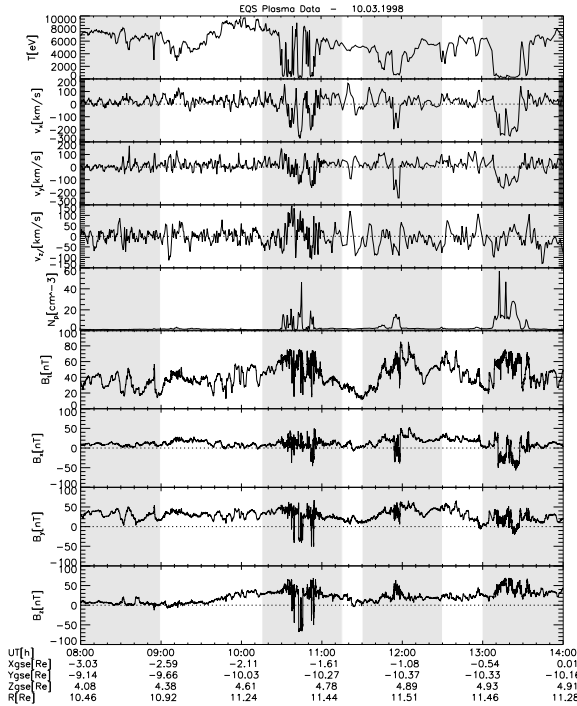


Fig. 74: Shaded regions indicate magnetopause reconnection regions embedded in surface waves – Equator-S observations

### INTERBALL observations of magnetic bubbles in the turbulent boundary layer

Using INTERBALL data we investigated hot plasma flows over the polar cusps of the Earth's magnetosphere. The entry of this solar wind plasma into the near Earth space result either from plasma percolation through the magnetopause or from secondary reconnection of fluctuating magnetic fields at high latitudes. In fact, along a turbulent boundary layer we observed ion thermalisation accompanied by the generation of coherent Alfvén waves on scales comparable with the ion gyroradius and by diamagnetic bubbles containing demagnetised heated plasma. The fluctuations inside the hot plasma of the bubbles exhibit a frequency spectrum quiet different from the Kolmogorov power law with slopes ranging from -1.2 to -2.4 (see Fig. 75).

We carried out three-dimensional fully kinetic electromagnetic plasma simulations to understand the observations. We found that the observed power law spectra can be obtained as a result of a transitional process from unstructured plasma turbulence to structure formation by three-dimensional kinetic reconnection coupled to current instability generated plasma waves. 3D reconnection would also explain the formation of

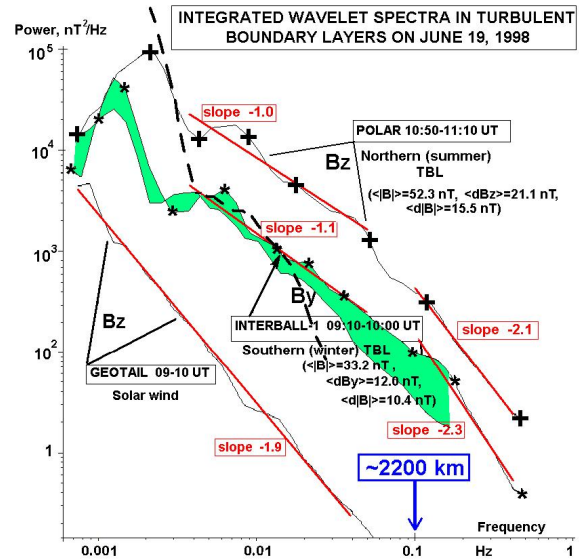


Fig. 75: INTERBALL wavelet integrated spectra in the turbulent boundary layer in comparison with and POLAR and GEOTAIL observations in the solar wind.

magnetic bubbles (cavities) and the generation of small scale (kinetic) Alfvén waves.

(J. Büchner, E. Dubinin, B. Nikutowski, in collaboration with S. Savin, L.M. Zelenyi, Space Research Institute Moscow, Russia, E. Amata, Frascati, Italy, J.A. Sauvaud, Toulouse, France)

### ATIC (Advanced Thin Ionisation Calorimeter): A balloon experiment for high energy cosmic ray research

ATIC is a large balloon-borne instrument for the observation of high energy cosmic rays out to about  $10^{14}$  eV per particle. A number of observations up to nearly this energy have been reported, but with conflicting results. Using basically established techniques but a somewhat novel instrument design, an ionisation calorimeter consisting of a totally active scintillating material as absorber, ATIC will attempt to clarify the issue of how much the spectra of protons and heavier nuclei in cosmic rays spread apart at higher energies. The MPAE is involved in simulation calculations of the instrumental response, in software development, and in test and calibration measurements taken at CERN in September 1999 and their data analysis, and in flight data analysis. One interesting result of our simulation calculations, which was confirmed by CERN data analysis, is that primary electrons can be filtered out of the much more abundant proton flux with very good effi-

ciency. This runs contrary to expectation as ATIC by design has been optimised for the detection of nuclear primary particles without any consideration of electron detection. The electron spectra at very high energies (TeV and higher) may yield special astrophysical information not derivable from proton and heavier nuclei spectra. The first circumpolar flight of 16 days (!) duration at residual atmospheric pressure below 4 mb took place from December 28, 2000 to January 13, 2001 over Antarctica. Although the data have not yet been fully calibrated we have been able to confirm that primary electron events can be filtered out from the flight data. After repeated long duration balloon flights this program will yield the statistically most significant data set yet for high energy cosmic ray electrons at the top of the atmosphere.

(W.K.H. Schmidt and J. Chang (guest scientist of the Purple Mountain Observatory, Nanjing, P.R. China) as part of a collaboration with Louisiana State University, Baton Rouge, LA, USA (Lead Institution, Principal Investigator: J.P. Wefel); Naval Research Laboratory, Washington, DC, USA; University of Maryland, College Park, MD, USA; Moscow State University, Moscow, Russia; Southern University, Baton Rouge, LA, USA; Seoul National University, Seoul, South Korea)

### **Energetic particle measurements during the CASSINI Earth swing-by**

Energetic particle measurements from the Low Energy Magnetospheric Measurement System (LEMMS) on board the CASSINI spacecraft during the Earth swing-by maneuver in August 1999 have been analysed. LEMMS is capable to identify the incidence energy and incidence direction of energetic ions and electrons with energies of a few tens of keV to several tens of MeV. CASSINI flew by the Earth with a velocity of 16 km/s or 9 Earth radii per hour which means that the entire dayside magnetosphere was passed within one hour. This fast flyby trajectory of the spacecraft provided a unique snapshot of the Earth's magnetosphere where key regions were passed within a few hours instead of normally tens of hours or days for orbiting spacecraft. The snapshot-like measurements provide a means to test models of energetic particle distributions within the Earth's magnetosphere. The inbound pass along the 13:00 magnetic local time meridian through the Earth's radiation belts was characterised by trapped and butterfly pitch angle distributions which can be explained by drift shell-splitting. Close to the

plasmopause LEMMS observed field-aligned bi-directional distributions which also cannot be explained by that process. Inside the plasmasphere butterfly distributions could be observed. During the outbound pass through the dawnside magnetosheath at 01:30 MLT the pitch angle distributions again went bi-directional for short periods of several minutes. Shortly after a substorm onset, identified by observations on board the Polar spacecraft, LEMMS observed an energy-time dispersed enhancement in the differential flux of low energy electrons.

In addition signatures of the Earth magnetotail were observed at distances beyond 5000 Earth radii when CASSINI passed through the Earth's downstream region. LEMMS measured a series of particle increases during that time. The angular distributions during these enhancements show that most of these particles arrived from the nominal Parker spiral direction and could not be related to magnetospheric particles from Earth.

(N. Krupp, J. Woch, A. Lagg, in collaboration with the Johns Hopkins University Applied Physics Laboratory, USA)

### **Research with the suprathermal plasma instrument package SMS on WIND**

Our understanding of the origin and evolution of planetary atmospheres relies heavily on our knowledge of the composition, dynamics, source, and loss mechanisms currently operating. Therefore, it is of paramount importance to measure the composition of present-day planetary atmospheres with the best available precision and to try to unravel in detail how atmospheric constituents (especially the heavy ones) can be created and removed selectively. In particular, we need to understand to what extent various factors are involved, for example, what is the effect of a change in solar activity on atmospheric-ionospheric-magnetospheric composition and dynamics? Intimately related to this problem are the questions of how the ionosphere is formed and how the loss (and gain) of ions due to space plasma acceleration processes alters the atmosphere's evolution.

In this context we investigate a solar cycle dependence of singly charged nitrogen and oxygen over a five year period from 1995-2000 on the nightside of the Earth's magnetosphere using instrumentation on the WIND spacecraft (Fig. 76). We show that  $N^+$ , another heavy ion that is of terrestrial origin,

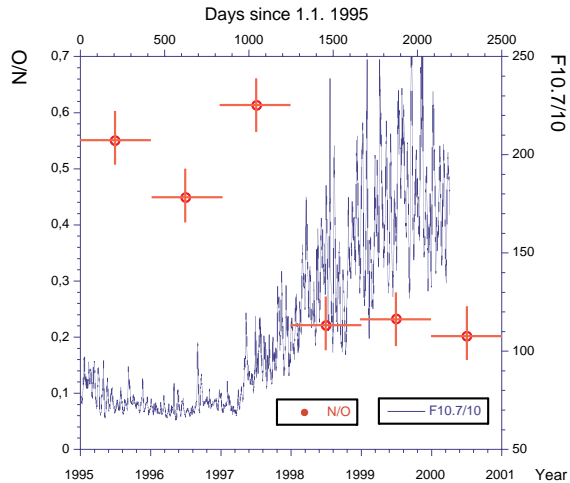


Fig. 76: The  $N^+/O^+$  ratio measured with the WIND STICS instrument for the years 1995 to 2000 (left scale) and the 10.7 cm flux shown on the right scale.

is a large fraction of  $O^+$ , and it contributes significantly to magnetospheric plasma. We find that the  $N^+/O^+$  ratio has a solar cycle relationship with a higher value of this ratio at solar minimum than at solar maximum. We examine the  $N^+/O^+$  ratio against thermospheric N/O MSIS 86 model calculations which exhibit no solar cycle variation. Our research suggests that both ionospheric and magnetospheric  $N^+$  should be investigated more thoroughly.  $N^+$ , as a result of its large mass, is possibly an important moderating participant in magnetospheric dynamics, due to its less extreme response to solar/geomagnetic stimuli when compared with the more robustly responsive  $O^+$ .

(U. Mall, E. Kirsch)

### Multiple plasmoids in the magnetotail

In contrast to the old paradigm, Cluster observations hint at multiple energy release events during substorms rather than at single plasmoid reconnection. Distant tail observations by GEOTAIL agree with a hypothesis of multiple reconnected structures moving away from the Earth after substorms.

To verify the hypothesis of multiple reconnection in the tail 2.5-dimensional MHD simulations were carried out starting from quiet magnetotail equilibrium configurations. Different types of initial cross-tail magnetic field perturbations  $B_y$  and initial density profiles were used to investigate the influence of the pre-substorm situations. The simulations revealed, indeed, intermittent and re-

peated formations of small plasmoids (see Fig. 77). The inflow due to a solar wind generated electrical field imposed on the boundary controls the recurrent formation of small plasmoids which are all large-density and high-temperature regions. Thus, we conjecture that in the course of substorms large amounts of the energy stored in the magnetotail are gradually dissipated by repeatedly ejecting a number of smaller size plasmoids rather than creating a single large plasmoid.

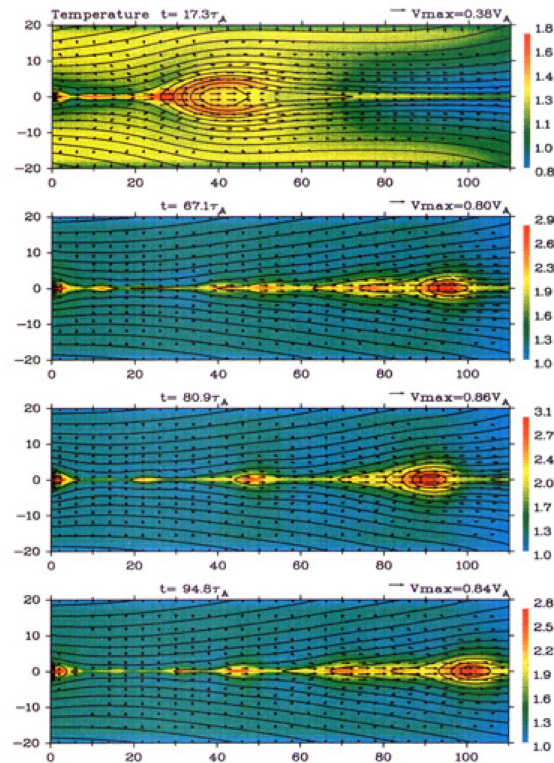


Fig. 77: Multiple plasmoid formation in the tail.

(J. Büchner, B. Wilken, in collaboration with S.-P. Jin and X.-P. Hu, University Hefei, China)

### Evolution of magnetic helicity in the course of kinetic magnetic reconnection

Most solar system plasmas from the solar corona to planetary magnetospheres are nearly ideal and the magnetic field is practically frozen in. In a strictly ideal plasma magnetic topology changes would be impossible and phenomena like magnetic reconnection could not occur. At the same time the magnetic helicity would be conserved exactly.

A strictly ideal plasma, however, does not exist in nature and thus magnetic reconnection is possible in principle. It has been conjectured by Tay-

lor (1974) that the magnetic helicity, nevertheless, might be approximately conserved during relaxation processes involving magnetic reconnection and topology changes. Since a conservation of magnetic helicity would provide a powerful tool for predicting the dynamical evolution of solar system plasmas, we investigated the evolution of magnetic helicity densities in the course of 2D and 3D kinetic magnetic reconnection through collisionless thin current sheets.

We carried out 2D plasma simulations with a newly developed Vlasov-code and 3D simulations using the particle-in-cell code GISMO. We found that in 2D the helicity density near a reconnection X-line becomes purely quadrupolar. In 3D an additional dipolar structure arises. This dipolar structure is related to kinetic current instabilities and becomes dominant for spontaneous 3D reconnection. For a variety of different initial magnetic helicities (co-helicity, counter-helicity) we obtained that taking into account possible collective plasma dissipation the rate of helicity change still remains much smaller than the magnetic energy dissipation rate.

(J. Büchner, T. Wiegelmann)

### Instability of collisionless current sheets to obliquely propagating waves

Boundaries in magnetised space plasmas are current sheets. Their stability properties determine the interaction between the adjacent plasma regions. In the past usually either reconnection (tearing mode) or current instabilities were considered separately. Among them recently several nonlocal theories of global current sheet instabilities were published which claim that current directed instabilities exist only for unrealistically small mass ratios. To understand the reason for this counter-intuitive conclusion which, if true, would have far reaching consequences for the stability and dynamics of boundaries in space plasma, we derived a linear dispersion relation for modes, propagating at an arbitrary angle to the magnetic field in the limit of symmetric across the sheet perturbations and for long wavelengths (Silin et al., Phys. Plasmas, 9, 1–9, 2002). Solving this dispersion relation we have shown that indeed and in contrast to the tearing-mode instability electrostatic effects damp the linear instability of long wavelength oblique modes beginning with propagation angles of about  $30^\circ$  from the magnetic field direction. In order to make sure not to have neglected important influences beyond the

linear theory approach we verified our results by kinetically simulating the limiting cases of tearing and sausage instabilities separately.

Using a 2D Vlasov code we obtained for the tearing mode a perfect agreement between theory and simulation for all considered artificial ion-to-electron mass ratios  $M_i/m_e$ . For the current instability our long-wavelength linear theory predicts a fast stabilisation of the modes for mass ratios  $m_i/m_e \geq 10$ . Our nonlinear simulations showed, however, that in the current direction strongly unstable waves are generated. It appears that for realistic mass ratios the wavelength is shorter than assumed in the existing linear theories. Therefore we could show that the existing linear theories do not apply to the reality of shorter wavelength unstable current waves which are generated nonlinearly. In a next step we are investigating the properties of the nonlinearly excited waves in order to compare them with the observations of the Cluster mission.

(J. Büchner, I. Silin, in collaboration with L. M. Zelenyi, Moscow Space Research Institute, Russia)

### 3D kinetic reconnection — simulation and visualisation

Recently we had shown that spontaneous reconnection in collisionless plasma is an essentially three-dimensional process (see annual report 1998/1999).

Continuing this work we have now succeeded in investigating the natural reconnection modes through the thin current sheets of collisionless plasmas. Most naturally spontaneous collisionless reconnection appeared to be due to the coupling between unstable wave modes propagating in the current direction and reconnection. By means of our three-dimensional fully kinetic electromagnetic particle-in-cell (PIC) code GISMO we showed that after a current instability has linearly started out of fluctuations it develops into a nonlinear drift kink or sausage mode. The latter directly couples to reconnection. The resulting structure of 3D reconnection depends on whether a symmetric (drift sausage) or asymmetric (drift kink) mode dominates.

The results of these theoretical predictions are currently compared with Cluster spacecraft measurements.

Fig. 78 depicts the particular case of reconnection coupling to a current sheet kink instability mode.

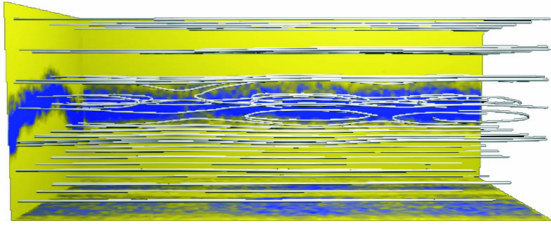


Fig. 78: Three-dimensional reconnection due to the coupling to a drift-kink mode

In this case reconnection forms three-dimensional magnetic islands embedded in a waving current sheet. In the presentation of Fig. 78 the kinking sheet can be seen only by carefully combining the density information from the midbox cutting planes projected onto the walls of the simulation box.

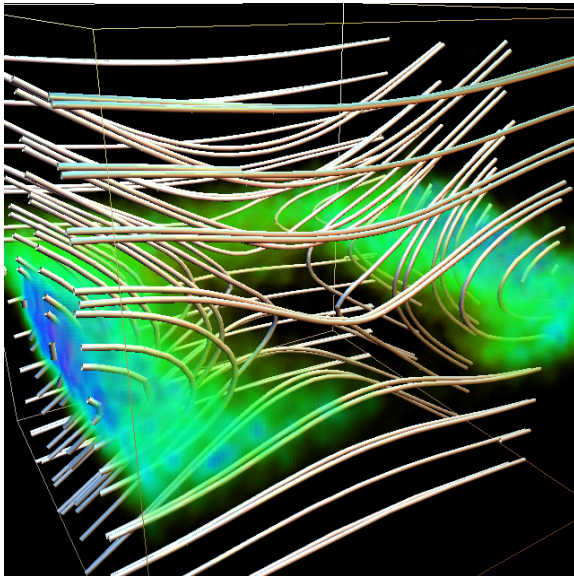


Fig. 79: Three-dimensional volume rendering of the plasma density distribution embedded in the magnetic vector field lines of kinetic reconnection

Aiming at a better visualisation of the consequences of three-dimensional plasma dynamics we developed new visualisation methods including newly developed tools for direct volume rendering of three-dimensional scalar fields and of line integral convolution techniques for depicting 3D vector fields.

Fig. 79 demonstrates how a true volume rendering of the density profiles can provide much more clear information about the spatial density distribution in the course of 3D reconnection and how well it allows a direct comparison with the corresponding vector magnetic field. These methods,

originally developed for the visualisation of simulated data, are currently transferred to be used for experimental data presentation tools as well.

(J. Büchner, B. Nikutowski, in collaboration with J.-P. Kuska, Leipzig)

### Oscillitons as origin of coherent waves in space plasmas: application to “Lion Roars”

An analysis of the coupled nonlinear fluid equations for a plasma with two ion populations revealed a new class of stationary wave solutions, called oscillitons (Sauer et al., 2001). In contrast to normal solitons, the structure of oscillitons exhibits spatial oscillations superimposed on the  $\text{sech}^2$ -type soliton profile. Linear dispersion theory provides the necessary condition for an oscilliton, namely the existence of a point (other than the origin) in the  $(\Omega - k)$  diagram at which the phase- and group velocities coincide. In a bion plasma such points arise due to the splitting of the “individual wave modes” near cross-over frequencies, forming throat-like dispersion curves.

A similar feature exists in dispersive electron whistlers propagating parallel to the magnetic field near  $\Omega_e/2$  ( $\Omega_e$ : electron cyclotron frequency) where the phase velocity has a maximum and is also equal to the group velocity. Recently, the properties of whistler oscillitons related to this dispersive feature of the whistler mode have been studied. From the linear dispersion characteristics of electron whistlers in a cold plasma the necessary condition for the existence of an oscilliton have been derived. The spatial structure of whistler oscillitons is then calculated from the solution of the stationary, nonlinear equations governing the coupled motion of the protons and electrons in the self-consistent wave field. This shows that coherent wave packets, resulting from the interplay between the proton and electron dynamics via the wave Lorentz force, can be obtained under certain conditions. The criteria for the appearance of whistler oscillitons under more realistic plasma conditions in a warm plasma have been analysed for different values of the parameters  $\beta_e$ , the temperature anisotropy  $T_{\parallel e}/T_{\perp e}$  and the propagation angle  $\theta$  with respect to the magnetic field. Generally, the frequency of the coherent wave decreases with increasing  $\beta_e$  down to about  $0.1 \Omega_e$ . Finally, we applied the oscilliton concept to the observed properties of coherent wave emission in the whistler frequency branch, known as ‘lion roars’. This approach shows how the principal mecha-

nism of coherent whistler wave generation can be understood by the selection of a relatively sharp frequency band from a broad spectrum of excited waves.

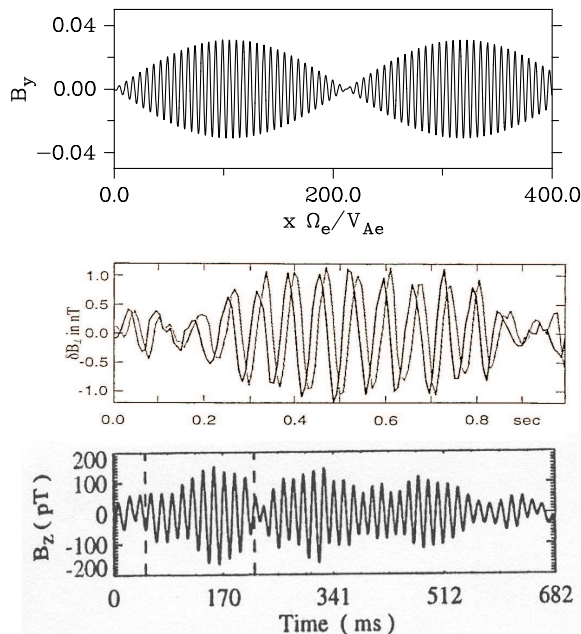


Fig. 80: Whistler oscillitons and “lion roars” observation.

Fig. 80 shows spatial profiles of the wave magnetic field of whistler oscillitons (on top) and two observations of ‘lion roars’.

(K. Sauer, E. Dubinin, J.F. McKenzie)

**A SCHWARM of small satellites for the investigation of collisionless plasma turbulence and magnetic reconnection – scientific motivation and requirement specification study**

Together with the Kayser-Threde company a phase A study was carried out for a multi-spacecraft mission investigating the basic properties of collisionless turbulence and magnetic reconnection in space plasmas.

The suggested mission looks for the empirical information necessary to understand the fundamentals of collisionless space plasma processes controlling the dynamics of the hot plasmas of the Universe after current theoretical and experimental investigations have indicated that the coupling with small scale processes determines the turbulence and magnetic reconnection in collisionless plasmas. While the first true multi-spacecraft mission Cluster-II aims at the investigation of

macroscopic processes with inter-spacecraft distances and time resolutions able to resolve fluid processes, SCHWARM addresses kinetic scales (just tens of kilometres, microseconds). It consists of at least four spacecraft approaching each other as close as 10 km (see Fig. 81). Our phase A study

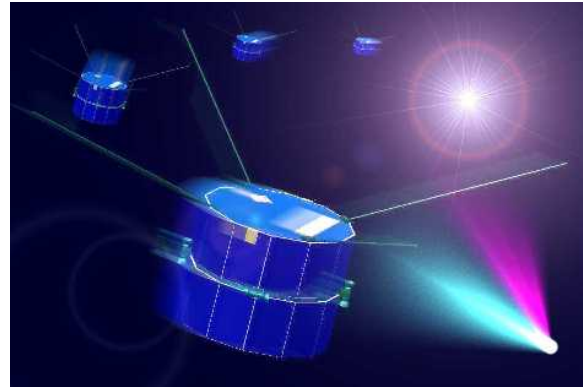


Fig. 81: Four SCHWARM spacecraft.

describes the rationales and the scientific goals of the mission as well as the specifics of its tasks. It contains the targets and the mission design for a launch together with a Russian ROY-mother-spacecraft as well as for other launch options. Options for the payload of four or more identical small spacecraft are discussed. The project follows the cost-saving principles of the DLR small s/c program.

In August 2001 the SCHWARM requirement specification (phase A) study was successfully defended at the German Space Agency DLR in Bonn. As a result the DLR supports a bridging-phase-B study which will be carried out in 2002.

(J. Büchner, B. Nikutowski, in collaboration with the Kayser-Threde GmbH)

**From RELIKT-2 to INTERBALL-3**

Relikt-2 was supposed to be launched by the Russian Space Agency to an orbit around a Lagrangian point behind the Earth. The aim of the mission was to investigate the cosmic background radiation as well as the plasma dynamics in the heliosphere responding to changes at the sun.

At MPAE a plasma device was prepared for Relikt-2 and numerical simulations were carried out to model the possible spectra of plasma fluctuations in the heliosphere.

Currently the Russian Space Agency has changed the target of the mission to observations of the

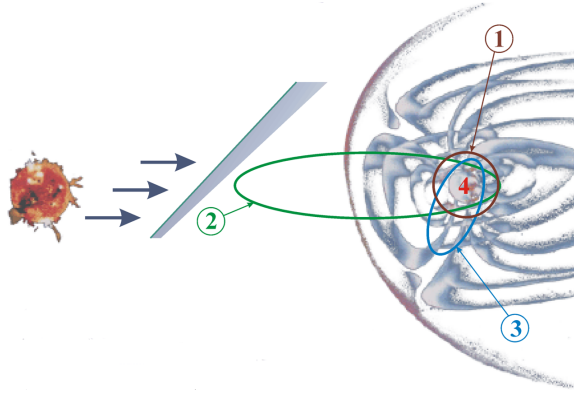


Fig. 82: Orbits for Solar and space weather research.

solar sources and the heliospheric plasma response on an orbit with an apogee above 60 Earth radii (see Fig. 82). Orbit 2 in Fig. 82 depicts the trajectory of the Relikt-2 follow-up mission. The mission was temporarily given the name “INTERBALL-3” since it uses INTERBALL components and Prognoz spacecraft buses.

Orbits 1 and 3 illustrate how the mission combines with space weather oriented ones.

(J. Büchner, B. Nikutowski, H. Timpl, in collaboration with L. Zelenyi, A. Petrukovich, Moscow, Russia)

### Storm-substorm relationships in the inner magnetosphere measured with the CRRES S/C. $O^+$ transport into the ring current

The importance of ionospheric oxygen ions during storms has been well documented. Substorms oc-

curing during the main phase of storms may have a pronounced effect on the storm-time buildup of  $O^+$  in the ring current, being well correlated with the steepest decline in  $D_{st}$  during the main phase. The oxygen to hydrogen ratio ( $O^+/H^+$ ) is investigated during six large storms of the solar cycle 22, at solar maximum between January 12, 1991 and August 20, 1991 (see Fig. 83). For this study we use CRRES  $H^+$  and  $O^+$  ions and electric field data as well as indicators for storm ( $D_{st}$ ) and substorm (AE) activity. In general, storm-time substorms are much more effective in transporting  $O^+$  into the ring current region. We investigate the relative contribution of storms versus substorms to the observed buildup of the  $O^+/H^+$  ratio during these six storms by developing a *measure* of the storm ( $\sum D_{st}/\text{hour}$ ) and substorm ( $\sum AE/\text{hour}$ ) contribution to  $O^+$  transport. We find a virtually linear dependence of the  $O^+/H^+$  ratio on the strength of a storm, with no saturation effects, indicating a limitless reservoir of  $O^+$  in the near-Earth plasma sheet, while substorms only seem effective in adding to the  $O^+/H^+$  ratio for small to medium sized storms. Much of the effectiveness of substorms during storms can be explained by the ion outflow composition which favours  $O^+$  over  $H^+$  for most levels of AE activity, and the fact that ionospheric  $O^+$  is preferentially transported closer to the Earth than ionospheric  $H^+$ , where it becomes available for subsequent substorm energisation and transport.

(A. Korth, F. Frutos-Alfaro)

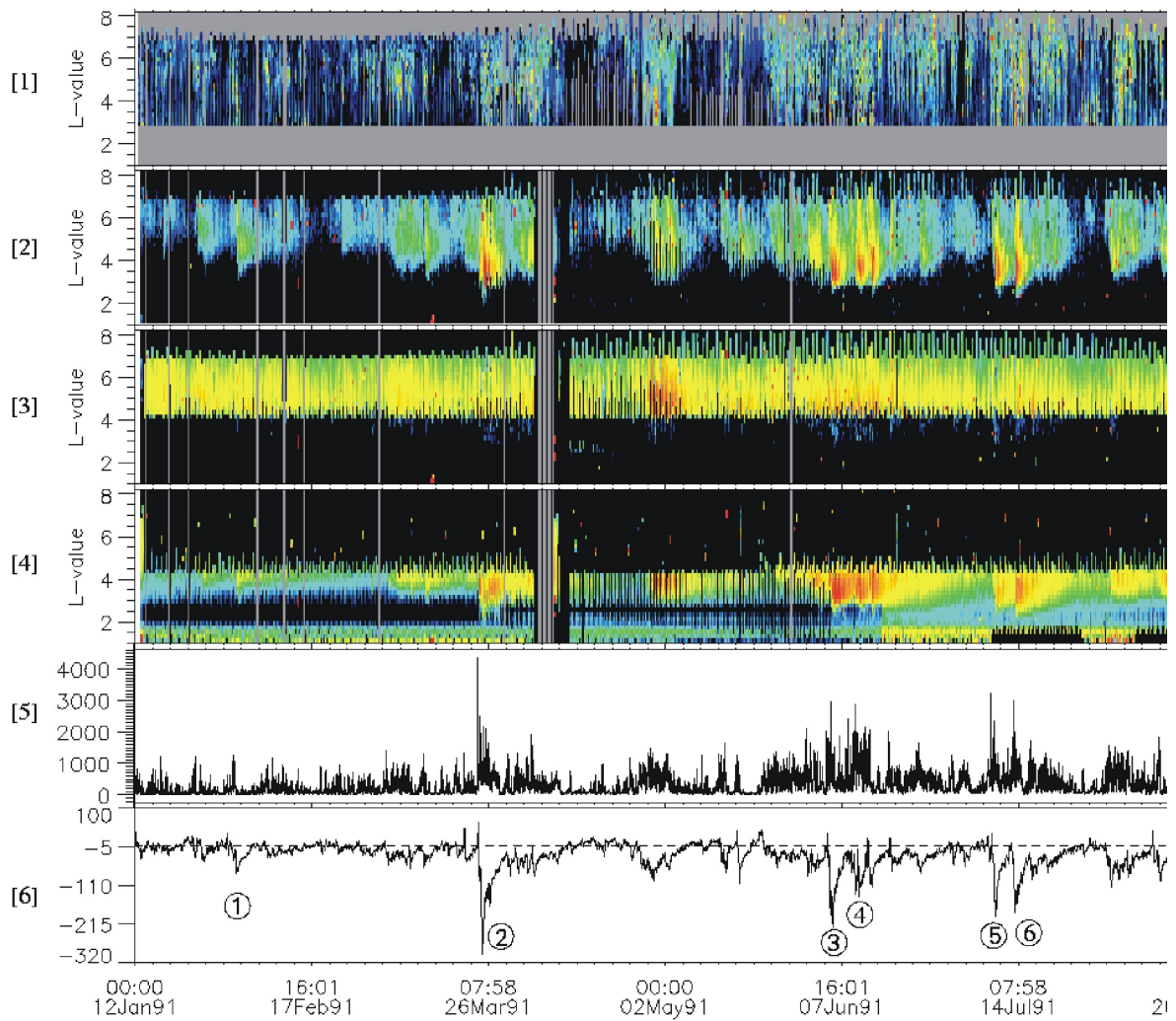


Fig. 83: L (McIlwain parameter) sorted data for 527 CRRES orbits from January 12, 1991 to August 20, 1991. Panel 1: dawn-dusk electric field; panel 2, 3, 4: energy density of  $O^+$  and  $H^+$  in different energy ranges; panel 5, 6: AE and  $D_{st}$  index.



### III. Abteilung Rosenbauer/Department Rosenbauer

#### Einleitung

(English version see page 138)

Seit 1994 befasst sich die Abteilung Rosenbauer in der Hauptsache mit dem Entwurf, dem Bau und der Ausstattung des Rosetta Landers, mit dessen Hilfe erstmals die chemische Zusammensetzung, die physikalischen Eigenschaften, Struktur und Morphologie sowie Aktivität und Entwicklung eines Kometenkerns (P/Wirtanen) in situ bestimmt werden sollen. Das Hauptinteresse der Arbeitsgruppe gilt dabei der Suche nach großen „organischen“ Molekülen und deren Identifizierung sowie der Bestimmung von deren Chiralität. Zur Verfolgung dieser Interessen wurde das Experiment COSAC entworfen und gebaut. Von Anfang an lag auch die wissenschaftliche Leitung des Lander-Projekts bei der Abteilung (H. Rosenbauer „Lead Scientist“). Gegenwärtig wird sie mit einem französischen Kollegen geteilt, wobei die Sprecherrolle jährlich wechselt.

Da im Tätigkeitsbericht 98/99 bereits ausführlich über die wissenschaftliche Zielsetzung des Unternehmens, die Experimentphilosophie, die verwendeten Messprinzipien und die Instrumente selbst berichtet wurde, wird darauf hier nicht mehr ausführlich eingegangen.

Vielmehr wird stattdessen über die in den letzten beiden Jahren erreichten Ziele und Verbesserungen bei den Projekten sowie die gewonnenen wissenschaftlichen Erkenntnisse berichtet.

#### Zusammenfassung

##### Projekte

In den Berichtsjahren wurden die Vorbereitungen für die in situ-Erforschung eines Kometenkerns (46P/Wirtanen) mit Hilfe des Rosetta Landers fortgesetzt und größtenteils abgeschlossen. Neben unserer Instrumentenpackung „COSAC“ (Cometary Sampling and Composition-Experiment) (Abb. 84), die aus einer Pyrolyseeinheit, einem Mehrkanal-Gaschromatographen und einem Flugzeit-Massenspektrometer für das

Auffinden und die Identifizierung großer „organischer“ Moleküle besteht, mussten auch die von uns übernommenen Subsysteme für den Lander, das so genannte Landegestell, die Einrichtungen zum Festhalten und zielgenauen Abstoßen des Landers vom Orbiter und das umfangreiche System zur Erzeugung und Verteilung der benötigten elektrischen Leistung entworfen, gefertigt und getestet werden. Wegen des Ausscheidens eines Konsortiumsmitglieds mussten wir zusätzlich noch die Fertigstellung und weitere Betreuung von dessen Beiträgen, den Verankerungsharpunen und der zentralen Datenverarbeitungsanlage, übernehmen. Auch die Wahrnehmung der Pflichten der wissenschaftlichen Leitung (in Zusammenarbeit mit einem französischen Kollegen) und des Nutzlastingenieurs sowie die Mitwirkung im Projektmanagement, bei der Integration der Subsysteme und Experimente sowie der Unterhalt des Lander-Servers und die Finanzabwicklung verlangten erheblichen Aufwand. Mehrere technische und organisatorische Probleme sowie Verzögerungen im Projekt, die zu mehrfachen Umstellungen der Zeitpläne führten, waren zu bewältigen. Der vorgesehene Starttermin im Januar 2003 kann jedoch voraussichtlich eingehalten werden, und die Aussichten, dass alle Lander-Subsysteme und die 10 Experimente rechtzeitig fertiggestellt werden und funktionieren, sind gut.

Parallel zu den Arbeiten für den Rosetta Lander und unser COSAC-Experiment engagierten wir uns auch bei der wissenschaftlichen Nutzlast des Landers „Beagle 2“ der ESA-Mission Mars Express. Unser Beitrag zum Gasanalyse-Experiment umfasst Konstruktion und Beistellung der für die Bodenanalyse benötigten Pyrolyseöfen, des Karussells für die Probenverteilung und der so genannten Zapfstation, mit der die Öfen verschlossen, die Heizenergie zugeführt, die Temperatur gemessen und das erhaltene Gas abgeführt werden können. Auch diese Arbeiten, die uns die uneingeschränkte Beteiligung bei der Datenauswertung dieses Experiments sichern, konnten im Berichtszeitraum weitgehend abgeschlossen werden.



Abb. 84: Ein Blick auf das COSAC-Experiment, das bereits im Lander montiert ist. Die halbkugelförmigen Gasflaschen in der Bildmitte enthalten das für den Gaschromatographen erforderliche Helium-„Trägergas“. Der Gaschromatograph selbst ist direkt darunter montiert. Das längliche Gebilde rechts davon ist das Gehäuse des Flugzeit-Massenspektrometers. Die Elektronikplatinen befinden sich zum großen Teil in den schwarzen Gehäusen darüber.

### Wissenschaftliche Arbeiten und Datenauswertung

Mit Bedauern muss festgestellt werden, dass die wissenschaftlichen Tätigkeiten unter der Flut der für die Projekte notwendigen Ingenieur- und Management-Arbeiten gelitten haben. Dies musste jedoch in Kauf genommen werden, weil ohne den großen technischen Einsatz unsere wissenschaftlichen Ziele, die erstmalige in-situ Untersuchung eines Kometenkerns in Hinblick auf chemische Zusammensetzung und physikalische Eigenschaften sowie Aktivität und Evolution, keine Realisierungschance gehabt hätten.

Trotz der Notwendigkeit, uns weitgehend auf die Technik des komplexen Rosetta Lander-Projekts zu konzentrieren, gelang es uns, zusammen mit Kollegen aus den Universitäten Leiden und Bremen und dem Centre de Biophysique Moléculaire

in Orléans, durch Laborexperimente zu zeigen, dass wichtige Bausteine des Lebens bis hin zu Aminosäuren durch Photosynthese im Weltraum spontan entstehen und deshalb in kometarer Materie vorhanden sein sollten. Diese Entdeckung hat in der Fachwelt große Beachtung gefunden und zu einer „nature“-Veröffentlichung geführt (G.M. Muñoz Caro, U.J. Meierhenrich, W.A. Schutte, B. Barbier, A. Arcones Segovia, H. Rosenbauer, W.H.P. Thiemann, A. Brack, J.M. Greenberg: Amino acids from ultraviolet irradiation of interstellar ice analogues. In: nature Vol. 416, p. 403-406, 28 March 2002). Darauf wird im Folgenden unter „Laborergebnisse“ näher eingegangen. Über die Ergebnisse der Datenauswertung der SOHO-Experimente CELIAS und STOF (M. Hilchenbach) sowie die andauernde Auswertung der interstellaren neutralen Helium-Daten aus dem GAS-Experiment auf Ulysses (M. Witte) wird im Ab-

schnitt „Sonne und Heliosphäre“ berichtet.

### Laborergebnisse

Um die analytischen Fähigkeiten unseres COSAC-Instruments testen zu können, brauchten wir idealerweise ein Gemisch aus Atomen und Molekülen, das der (unbekannten !) Substanz, aus der Kometenkerne bestehen, zumindest ähnlich ist. Wir wollten versuchen, ein solches Gemisch durch die Simulation der Prozesse, die sich in Sternentstehungsgebieten im Kosmos abspielen, zu synthetisieren.

In Zusammenarbeit mit deren Universitäten wurden deshalb die Promotionsarbeit von Herrn Muñoz Caro, Leiden, die sich mit der Simulation von Weltraumbedingungen und der Synthese großer Moleküle unter solchen Bedingungen befassen sollte, und die Habilitationsarbeit von Dr. Meierhenrich, Bremen, bei der es u.a. um die Verbesserung gaschromatischer Analyseverfahren geht, betreut und teilweise finanziert.

Gemeinsam wurde beschlossen, nur von einfachen Molekülen auszugehen, deren Vorkommen in Sternentstehungsgebieten mit astronomischen Mitteln bewiesen worden war, nämlich Wasser, Kohlendioxid, Kohlenmonoxid, Methylalkohol und Ammoniak. Mit Ausnahme von Wasser, von dem die Zugabe doppelt so hoch war, wurde von allen anderen Substanzen gleich viel (d.h. gleich viele Moleküle) eingesetzt. Dieses Gemisch wurde in Gasform langsam in eine Vakuum-Apparatur eingelassen, in der sich ein so genannter „cold finger“, in unserem Fall ein auf die Temperatur von flüssigem Helium gekühlter kleiner Aluminiumwürfel, befand. Bei einer derartigen Anordnung schlägt sich die eingelassene Gasmischung als dünne Eisschicht auf der Oberfläche des Würfels nieder.

Während des ganzen Vorgangs wurde der Würfel mit einer Wasserstoffentladungslampe bestrahlt, weil auch im Weltraum Wasserstoffstrahlung ( $\text{Ly-}\alpha$ ) fast überall vorhanden ist und davon ausgegangen werden muss, dass sie sowohl für die Synthese von Molekülen als auch deren Zerfall als Energielieferant von Bedeutung ist.

Wir hatten erwartet, dass sich in dem Rückstand auf dem Würfel nach dessen Erwärmung auf Zimmertemperatur nicht die gleiche Molekülmischung finden würde, die eingelassen worden war. Wir hatten auch gehofft, dass die von Muñoz Caro und Meierhenrich mit modernstem Gerät durchgeführten Analysen einige große „organische“ Moleküle ergeben würden, die als Bausteine für Leben in

Frage kämen. Ziemlich verblüfft waren wir aber, als (nach Durchführung einer klassischen Hydrolyse) neben vielen weiteren interessanten Verbindungen nicht weniger als 12 Aminosäuren gefunden wurden, die ja die unverzichtbaren Bausteine für Eiweißsubstanzen und damit für Leben - wie wir es kennen - darstellen und von denen auch einige in biologischem Material auf der Erde und sogar in menschlichem Gewebe vorkommen.

Wir sind also durch das Ergebnis des Laborversuchs, bei dem die chemischen Vorgänge im Weltraum, insbesondere in dichten Gaswolken simuliert wurden, und der zunächst nur Material zum Testen unseres COSAC-Experiments hatte liefern sollen, in die ungewöhnliche und unerwartete Lage gekommen, schon vor Beginn der Rosetta-Mission mit einiger Wahrscheinlichkeit zu wissen, welche Arten von Verbindungen wir auf dem Kometenkern zu erwarten haben, wenngleich uns auch bewusst ist, dass Verbindungen im Kometenmaterial eine sehr viel längere und komplexere Geschichte haben als unsere im Labor erzeugten, und wir deshalb den Beweis für die Relevanz unserer Laborergebnisse erst noch durch die geplanten Messungen auf dem Kometenkern erbringen müssen.

Wir meinen jedoch schon jetzt, dass einige weitreichende Folgerungen aus den Laborexperimenten zulässig sind. Wenn wir lediglich annehmen, dass die Situation in Sternentstehungsgebieten durch die Versuche von Muñoz Caro einigermaßen richtig simuliert worden ist, dann sollten in sehr vielen Gebieten jeder „normalen“ Galaxie ähnliche Verbindungen, wie Muñoz Caro und Meierhenrich sie gefunden haben, entstehen.

Wenn wir des weiteren annehmen, dass das Vorhandensein, insbesondere aber die Ansammlung von Molekülen, die als „Bausteine“ von Lebewesen von der „Natur“ (und unsere Erde ist dabei nur ein Beispiel für „Natur“, die in Wirklichkeit sehr viel anders als die auf unserer Erde sein kann) verwendet werden, auch der Entstehung von Leben förderlich sind, dann folgert daraus, dass für die Entstehung von Leben günstige Bedingungen in jeder Galaxie an vielen Stellen in großen Gebieten und über große Zeitabschnitte (Mrd. Jahre) hinweg vorhanden sind und deshalb die Wahrscheinlichkeit für die Entstehung von Leben entsprechend hoch ist. Es muss jedoch eingeräumt werden, dass die Quantifizierung der tatsächlichen Wahrscheinlichkeit nicht einfach ist.

## Das Landegestell (LG) als Gerät zur Unterstützung der Kometenforschung

Das Rosetta Lander-Projekt ist oft als Unternehmung „von Wissenschaftlern für Wissenschaftler“ bezeichnet worden. Was mit dieser Aussage gemeint war, ist, dass dieses Projekt - zumindest in seiner frühen Phase - von der ESA nicht ernsthaft unterstützt worden ist; es war eine lediglich eine „Einladung“ ergangen, ein Landegerät als eines der Rosetta-Experimente anzubieten, das jedoch nur unterstützt werden sollte, wenn die finanzielle Ausstattung aller anderen Orbiter-Experimente sichergestellt war. Daher ist das Lander-Projekt über einen längeren Zeitraum hinweg nur durch den Enthusiasmus einiger wissenschaftlicher Institute am Leben erhalten worden.

Dann wurde ein Konsortium gebildet, und jedes Mitglied konnte freiwillig, seinen Fähigkeiten entsprechend, etwas zu dem Unternehmen beitragen. Ein Hauptauftragnehmer aus der Industrie wurde wegen des Fehlens von Finanzmitteln nicht in Anspruch genommen. Wirklich eine ungewöhnliche Projektstruktur!

Jetzt, etwa 8 Jahre später, ist es interessant, nachzusehen, ob dieser ungewöhnliche Ansatz tatsächlich dazu geführt hat, dass bestmögliche Bedingungen für die wissenschaftlichen Experimente geschaffen wurden (wenn man davon absieht, dass Mittel- und Zeitknappheit das Erreichen von absoluter Perfektion praktisch nie zulassen).

Wir werden als Beispiel das sogenannte „Landegestell“ benutzen, ein Gerät, von dem man auf den ersten Blick sicherlich nicht annimmt, dass es sehr viel mit Wissenschaft zu tun hat.

Bei diesem, vom MP Ae entwickelten und beigegebenen Landegestell (LG) handelt es sich um eine Dreibein-Struktur, die die mechanische Schnittstelle zwischen dem unteren Teil der Lander-Grundplatte und dem Landeplatz darstellt. Es besteht aus einem Mittelteil aus Kohlefaser-Rohren, die über Aluminiumstücke verbunden sind und ein steifes sternförmiges Fachwerk bilden. An den Enden der drei Fachwerkstrukturen, die den Radius des Landers nur sehr wenig in der Länge überragen, sind die sogenannten Beine angelenkt, die aus einzelnen, aber dickeren Rohren bestehen. Die Gelenke ermöglichen es, die Beine außerhalb des Landers parallel zu seiner „Haube“ während des Starts und in der Flugphase nach oben zusammengefaltet zu halten. Vor der Landung werden die

Beine auf einen Steuerbefehl hin entfaltet, wobei sich gleichzeitig die sogenannten Füße nach unten entfalten, die die Aufgabe haben, die Enden der Beine nach dem Aufsetzen ca. 20 cm über dem Boden zu halten.

Neben dieser Schnittstellenfunktion hat das LG aber viele andere Aufgaben und dazugehörige Eigenschaften erhalten, die die wissenschaftlichen Möglichkeiten der Lander-Mission sicherzustellen bzw. zu verbessern helfen.

Die wichtigste Aufgabe des LG, ja die Voraussetzung für eine erfolgreiche Mission überhaupt, ist es, nach Möglichkeit eine sichere Landung zu gewährleisten, was vor allem bedeutet, die Wahrscheinlichkeit sowohl eines Umkippen als auch eines Zurückprallens beim Aufprall so klein wie möglich zu halten. Hierzu müssen angesichts der geringen Schwerkraft, die der kleine Kometenkern (Durchmesser ca. 1 km) erzeugt, besondere Maßnahmen getroffen werden, denn der 100 kg-Lander, (Abb. 85), würde auf dem Kometenkern nur einige Gramm wiegen.)

Um den Lander gegen die oben genannten Unfallarten zu schützen, wurde er mit folgenden Eigenschaften ausgestattet:

Gegen Umkippen:

1. lange, nach dem Entfalten flach ausgebreitete Beine, die nur durch die Maße des Landers begrenzt werden,
2. ein niedriger Schwerpunkt, der durch Fernbedienung noch abgesenkt werden kann,
3. Verlängerung der Beine während des Entfaltens durch eine besondere Kinematik,
4. eine nur geringe Umsetzungsrate von linearem zu Rotationsmoment beim Aufprall, die durch die Fähigkeit der LG-Beine, sich an die Bodenmorphologie anzupassen, gewährleistet wird.

Gegen Rückprall:

1. Maximierung der Steifigkeit des LG, so dass nur ein sehr kleiner Teil der Landeenergie beim Aufprall in den Beinen gespeichert wird,
2. Dämpfung der Aufprallenergie, was durch ein besonderes elektromechanisches Dämpfungsgerät erreicht wird, das eine zur Geschwindigkeit proportionale und dadurch asymptotisch auf Null absinkende Bremskraft erzeugt.

Sowohl die Wahrscheinlichkeit eines Umkippen als auch die eines Rückpralls werden auf wirksa-



Abb. 85: Der Lander beim Zusammenbau. Die Schutzplatten (schwarz) über dem empfindlichen Solargenerator sind schon montiert. Zwei „Beine“ des Landers aus schwarzen Kohlefaserrohren werden gerade mit der Grundplatte des Landers verschraubt. Die „Füße“ und „Eisschrauben“ sind rechts im Bild zu erkennen.

me Weise durch „Eisschrauben“ verhindert. Diese sind in jedem Fußsystem derart eingebaut, dass die Hälfte der Bremskraft beim Aufprall auf die Eisschraube wirkt und die andere Hälfte auf beide „Füße“. Da der Querschnitt der Eisschrauben viel kleiner ist als der der „Füße“, sollten die Eisschrauben mit hoher Wahrscheinlichkeit in den Boden getrieben werden. Da der größte Teil der Aufprallenergie beim Eindringen der Eisschrauben und durch den elektromagnetischen Dämpfer verbraucht wird, dürfte der kleine verbleibende Rest nicht ausreichen, die Eisschrauben, deren Drehbewegung in Rückwärtsrichtung durch einen Freilaufmechanismus blockiert wird, wieder zu lösen.

Die bisher beschriebenen Eigenschaften des LG unterstützen nur das notwendigste Erfordernis der Mission, die sichere Landung. Andere eingebaute Eigenschaften und Fähigkeiten erhöhen direkter ihr wissenschaftliches Potential.

Zum Beispiel ermöglichen die „Füße“, die die Unterseite des Landers vom Boden fernhalten, dass die bisher nie gesehene unberührte Oberfläche eines Kometenkerns von der nach unten gerichteten ROLIS-Kamera inspiziert und von anderen nach unten orientierten Instrumenten untersucht werden kann. Die Fähigkeit des LG, den gesamten Lander anzuheben und abzusenken, ist u.a. bei der genauen Fokussierung der Kameras hilfreich.

Am wichtigsten ist jedoch sicher die Fähigkeit des LG, den gesamten Lander bis zu 360° um seine vertikale Achse zu drehen. Diese Eigenschaft macht den wissenschaftlich entscheidenden Unterschied aus zwischen einer Einpunktmessung, die notwendigerweise viele Fragen offen ließe, und der Möglichkeit einer Untersuchung über einen Streifen von mehr als einem Meter Länge hinweg, die nicht nur die Inspektion auffälliger Punkte, sondern Studien der Homogenität bzw. Variabilität des Materials der Kometenoberfläche erlaubt.

Um die Rotationsfähigkeit des Landers für wissenschaftliche Untersuchungen effizient auszunutzen zu können, wurde ein „gemeinsamer Arbeitskreis“ definiert, auf dem alle nach unten gerichteten Instrumente, das APX, die ROLIS-Kamera, die CIVA Infrarot-Kamera und das Probenentnahmegerät montiert sind, so dass die gleichen Stellen des Bodens nacheinander von allen einschlägigen Instrumenten untersucht werden können.

Auch andere Instrumente, wie die CIVA-Kameras, profitieren zumindest bei Ausfällen von der Drehbarkeit des Landers. Diese Fähigkeit hilft auch dem ROMAP-Experiment, seine Detektoren zu kalibrieren und erlaubt dem MUPUS-Experiment, einen optimalen Ort für die Messungen des Penetrators auszuwählen. Für die Experimente COSAC und PTOLEMY ist es nicht nur wichtig, dass Proben an mehreren Stellen genommen werden können, sondern auch, dass das Bohr- und Probenentnahmesystem vor der Messung im Schatten gehalten werden kann, da es ansonsten durch Sonnenbeleuchtung aufgeheizt und die Probe teilweise verdampft werden könnte, was die Messungen der Zusammensetzung verfälschen würde.

Zur Durchführung einer wissenschaftlich erfolgreichen Langzeit-Mission, die die einzige Möglichkeit darstellt, die Natur der kometaren Aktivität und Veränderungen der Morphologie durch Erosion zu studieren, muss der Wärmeverlust minimiert und die Gewinnung elektrischer Energie optimiert werden, um die Elektronik des Landers (besonders die Batterien) vor Unterkühlung zu schützen. Dies kann durch angemessene Drehung des Landers erreicht werden.

Zusätzlich zur Möglichkeit, den Lander zu drehen, bietet das Landegestell auch die Möglichkeit, ihn zu kippen, was die durch die Drehung gegebenen Möglichkeiten noch deutlich vergrößert. So wird z.B. Bohren oder Sammeln von Proben in Schrägrichtung möglich, und es werden generell zwei zusätzliche Freiheitsgrade eröffnet, die für alle Arten der Forschung, die von der Ausrichtung des Landers abhängen, von Bedeutung sind. Zum Beispiel kann das Strahlungsdiagramm der CONSERT-Antenne, das von der relativen Ausrichtung der CONSERT-Antenne zu den LG-Beinen beeinflusst wird, durch Ausnutzung der Dreh- und Kippbarkeit des Landers optimiert werden.

Jedoch bietet das LG noch andere wichtige Dienste für das Lander-System sowie für die wissenschaftlichen Instrumente an. So wird z.B. der Aufsetzpuls vom LG erzeugt, der den Abschuss

der Verankerungsharpunen veranlasst, die Andrückdüse öffnet und den „Startschuss“ für den Beginn der Messungen gibt. Der Puls basiert auf Signalen von drei voneinander unabhängigen Teilen der LG-Elektronik:

- dem Dämpfungsmotor, der eine Spannung beim Aufprall liefert,
- und zwei Accelerometern, die auf die Verringerung der Landegeschwindigkeit reagieren.

Da die drei Signale logisch „geodert“ werden, wird der Landeimpuls mit dreifacher Redundanz, d.h. sehr zuverlässig, erzeugt. Während die oben erwähnten Eigenschaften des LG mehr oder weniger allgemeine Dienste für das Lander-System oder die Experimente darstellen, ist die spezielle Unterstützung eines Experiments, nämlich SESAME, es wert, besonders erwähnt zu werden, weil sich an ihm zeigt, in welchem Ausmaß das LG auf die Unterstützung der Wissenschaft hin entworfen und gebaut wurde und wie weitgehend das Subsystem LG und das wissenschaftliche Experiment SESAME miteinander verschlungen sind.

Das SESAME-Experiment hat das Ziel, die elektrischen sowie die mechanischen Eigenschaften von Kometenmaterie in der unmittelbaren Nähe des Landers (innerhalb eines Gebietes von ca. 1 bis 4 Meter) zu messen. Hierzu werden aktive und passive Schallausbreitungsexperimente durchgeführt. Von besonderem Interesse für beide Arten von Experimenten ist die Suche nach reflektierenden Schichten, Spalten, Höhlen oder anderen Inhomogenitäten, die einen Einblick in die innere Struktur eines Kometenkerns erlauben. Zur Erkennung solcher Unregelmäßigkeiten verwendet der CASSE-Teil des Experiments Schallsender und -empfänger und der elektrische PP-Teil entsprechende elektrische Geräte. Die Mehrheit der Sender und Empfänger (3 von 4) sind in den „Sohlen“, den Endstücken der LG-„Füße“, untergebracht. Um das SESAME-Experiment möglich zu machen, war es nötig, das LG in vielerlei Hinsicht zu modifizieren:

- „Sohlen“ mussten entworfen und gebaut werden, die einerseits stabil genug sein mussten, um die Aufprallkräfte zu überstehen, andererseits weich genug, um als Membrane für die Tonübermittlung zu dienen.
- Um eine räumliche Trennung zwischen Empfängern und Sendern zu erreichen und einen guten Bodenkontakt zu gewährleisten (besonders wichtig für den CASSE-Teil), mussten für jedes Bein zwei „Füße“ und ent-

sprechende SSohlenöntworfen, gefertigt und getestet werden, die mit gleicher Kraft auf den Boden drücken.

- Da auch Schallausbreitungsmessungen geplant sind, musste die Schallausbreitung über die LG-Struktur durch spezielle Dämpfungselemente minimiert werden.
- Lange, teilweise triaxiale Kabel mussten von der gemeinsamen Elektronikbox durch mehrere Teile des LG hindurch zu den Sendern und Detektoren geführt werden. Dies war besonders schwierig, weil Schleifen notwendig waren, die einerseits die Beweglichkeit des LG nicht wesentlich beeinträchtigen, aber andererseits die Schüttelbelastung beim Start aushalten.
- Sogar eine Art Blitzableiter musste verwirklicht werden, um die SESAME-Elektronik zu „erden“.

Das Landegestell unterstützt jedoch nicht nur die Lander-Mission und die wissenschaftlichen Möglichkeiten einiger der Instrumente, sondern es trägt auch direkt zur wissenschaftlichen Ausbeute der Mission bei, dadurch, dass die Daten des normalen Accelerometers beim Aufsetzen registriert werden. Dadurch erhält man Informationen über die Komprimierbarkeit des Kometenmaterials an der Landestelle.

Es gibt noch eine Reihe andere Dienste, die vom LG für das System und die Experimente geleistet werden:

- Das LG dient auch als Startrampe für die Harpunen. Dies ist keine triviale Aufgabe, weil die Schockbeschleunigung an der Startrampe mehr als 5000 g beträgt.
- Die ROMAP-Instrumente sowie die CONSERT-Antennen werden von den Beinen des LG in der Start- und Reiseposition gehalten und zusammen mit diesen ausgefaltet.

Aber auch andere Subsysteme, deren Verantwortliche sich besonders intensiv für die wissenschaftlichen Belange der Mission eingesetzt haben, könnten genannt werden. So lieferte z.B. das „Power Subsystem“ (Szemerey und Uni Budapest) viele speziell angefertigte Energieversorgungen, z.B. für die CIVA-Kameras und die Harpune. Die für die Common Electronics Box (gemeinsame Elektronik-Box) zuständige Gruppe übernahm Sonderanfertigungen für viele Elektronikgehäuse, um Wissenschaftlern zu helfen. Vom

DLR-Institut für Planetenerkundung in Berlin wurde eine standardisierte Datenverarbeitungsanlage für den Lander entwickelt, die sowohl für Subsysteme als auch für Experimente eingesetzt werden kann. Aber die Wissenschaftler halfen sich auch gegenseitig. So liefert z.B. ROMAP die Energie, die für den COSAC-Drucksensor erforderlich ist, und viele Lander-Arbeitsgruppen halfen sich mit seltenen Elektronikteilen wie FPGAs aus.

Daher glaube ich, es ist richtig, zu sagen: Das Rosetta Lander-Projekt war zu einem großen Teil wirklich ein Unternehmen von Wissenschaftlern für Wissenschaftler, so wie wir es uns ursprünglich vorgestellt hatten. Das hat oft die Arbeit zur Freude gemacht, und diese gute Grundstimmung hat sicher das Gelingen des Projekts gefördert.

Ich danke allen, die dazu beigetragen haben.

Helmut Rosenbauer

## Weitere Projekte

### Laufende:

- CELIAS ist eine Kombination eines Ionen-Massenspektrometers und eines UV-Spektrometers auf SOHO, das für die Heliosphärenforschung eingesetzt wird (Hilchenbach).
- MIRAS ist ein RAMAN-Spektrometer für die in-situ-Messung von planetaren und asteroidalen Oberflächen, das gemeinsam von einer RAMAN-Spektroskopie-Gruppe an der Universität Würzburg und unserer Abteilung entwickelt wird. Eingeschlossen ist die Entwicklung einer Datenbank für RAMAN-Daten von Mineralien (Hilchenbach).
- PATIB (Planetary Deep Driller) ist ein Projekt, bei dem in Zusammenarbeit mit der Industrie ein Gerät zum Tiefbohren (1,5 Meter) entwickelt wird, das in der Planeten- und Asteroidenforschung Anwendung findet (Hilchenbach).
- MORE ist ein Projekt in der Konstruktionsphase, das gemeinsam von der Industrie und unserer Abteilung entwickelt wird und das eine verbesserte Version des COSAC-Experiments für chemische in-situ-Analysen beinhaltet. Dieses Experiment ist in der Modell-Nutzlast eines geplanten großen Exobiologie-Projekts der ESA enthalten (Goesmann, Hilchenbach, Roll).

### Zukünftige:

Grundregel: Die Entscheidung über die Aufnahme jedes neuen Projekts wird durch den neuen Direktor für Planetologie getroffen. Mitglieder der Abteilung Rosenbauer unterstützen ihn nach besten Kräften. Zukünftige ESA-Projekte, die in Frage kämen, sind z.B. BepiColombo und Solar Orbiter.

Potentielle zukünftige Projekten auf neuen Gebieten (ECOS und ECOL) sind noch nicht diskussionsreif.

## Introduction

Since 1994 the Department Rosenbauer is mainly concentrating on design, construction and instrumentation of the Rosetta Lander and its payload by which, for the first time, the chemical composition, physical properties, structure and morphology as well as activity and surface erosion of a cometary nucleus (P/Wirtanen) shall be investigated in situ. The scientific interest of the group is concentrated on search and identification of large „organic” molecules. The COSAC experiment was specially designed to not only detect such molecules, but also to determine their chirality. From the beginning, the Lead Scientist function was with the department (H. Rosenbauer Lead Scientist); at present, it is shared with a French colleague. The speaker function is changing annually.

Since in the last report (1998/1999), the scientific goals of the project, the experiment philosophy, the measurement principles employed and the individual experiments have been described in detail, we do not repeat this but rather just report on the general status of the project and the scientific progress.

## Executive summary

### Projects

During the period covered by this report, the preparations for the in situ investigation of a cometary nucleus (46P/Wirtanen) by means of the Rosetta Lander were continued and for the most part concluded. Besides our cluster of analytical instruments “COSAC” (Cometary Sampling and Composition Experiment), (Fig. 84), consisting of a pyrolysis unit, a

multi-channel gas chromatograph and a Time-of-Flight mass spectrometer for detection and identification of large “organic” molecules, we had also to take care of the subsystems of the Lander we had taken responsibility for. These were the so-called Landing Gear, the devices required for the Lander’s fixation to and release from the Orbiter as well as the push-off mechanism which has to bring the Lander accurately on the right descent trajectory. The complex system for generation and distribution of electrical power was under our responsibility, too. In addition, we had to take over the responsibilities for two more subsystems, namely the anchoring subsystem and the central data management system, due to the drop-out of the responsible Consortium Member. The scientific leadership (in collaboration with a French colleague), the payload engineering as well as the participation in project management, subsystem and experiment integration, operation and maintenance of the central Lander server and financial management belonged to our duties as well. Several technical and organisational problems and project delays resulting in schedule revisions had to be overcome. The planned launch date in January 2003 can however be met with high probability, and the prospects for all Lander subsystems and the 10 experiments to get finished on time and work well are good.

In parallel to the major contributions to the Lander and the realization of our COSAC experiment, we also engaged ourselves in the scientific payload of the lander “Beagle 2” of the ESA Mars Express mission by design and contribution of the pyrolytic ovens, the turn-table for sample distribution and the so-called tapping station which serves to close the ovens, supply the heating power, measure the temperature and deliver the obtained gas to the analytical instruments. Also this branch of our work by which we obtain the unrestricted access to the data of the Experiment “Gas Analysis Package” could be completed in time.

### Scientific activities and data evaluation

To our regret, the scientific activities have suffered from the flood of engineering and managerial work necessary for the projects. However, this had to be accepted because without the extensive technical efforts, our scientific goals, the first in-situ investigation of a comet’s nucleus with respect to chemical composition and physical characteristics as well as activity and evolution, would have had no chance to be realized. Despite the necessity to concentrate mainly on technical aspects of the



Fig. 84: A view of the COSAC experiment already mounted on the Lander. The hemispherical pressurised bottles in the centre contain the helium “carrier gas” required for the gas chromatograph. The gas chromatograph is mounted just below. The long device to its right is the housing of the Time of Flight mass spectrometer. Most of the electronics is housed in the black boxes above the pressurised bottles.

complex Rosetta Lander project, we succeeded, however, together with colleagues from the Universities of Leiden and Bremen and the Centre de Biophysique Moléculaire in Orléans, in demonstrating by laboratory experiments that important building blocks of life up to amino acids are generated spontaneously by photosynthesis under conditions existent in dense molecular clouds. Amino acids should therefore be abundant in cometary matter. This detection has attracted lively interest among experts and led to a publication in “nature” (G.M. Muñoz Caro, U.J. Meierhenrich, W.A. Schutte, B. Barbier, A. Arcones Segovia, H. Rosenbauer, W.H.-P. Thiemann, A. Brack, J.M. Greenberg: Amino acids from ultraviolet irradiation of interstellar ice analogues. In: nature Vol. 416, p. 403 - 406, 28 March 2002) (for details see “Laboratory results” below). Results of data evaluation of the SOHO experiments

CELIAS and STOF (M. Hilchenbach) as well as of the continuing evaluation of the interstellar neutral Helium data obtained from the GAS Experiment on Ulysses (M. Witte) may be found in the section “Sun and Heliosphere” of the General Department’s report.

### Laboratory results

In order to test the analytical quality of our COSAC-Instrument, we needed a mixture of chemical compounds which was at least similar to the (unknown!) substance cometary nuclei consist of. Therefore we tried to synthesize in collaboration with more chemically oriented groups such a mixture by the simulation of processes which occur in the star creation regions in space. Together with their universities, the Ph.D. thesis of

Mr. Muñoz Caro, Leiden, which was intended to deal with photosynthesis under simulated space conditions, and the postdoctoral lecture qualification thesis of Dr. Meierhenrich, Bremen, devoted to improving of gaschromatographic procedures by derivatisation and other methods, have been co-supervised and partly funded.

It was jointly decided to use as starters only simple molecules whose presence in dense gas clouds has been proven by astronomical means, namely water, carbon dioxide, carbon monoxide, methylalcohol and ammoniak. With the exception of water, of which the double amount was used, of all other substances, the same quantity was employed. This gaseous mixture was slowly released into a vacuum chamber equipped with a so-called "cold finger", in our case a small aluminium cube at 12 K. With such an arrangement, the gas mixture introduced is frozen out on the surface of the cube in a thin layer. During the whole procedure, the cube was irradiated by a hydrogen discharge lamp, because also in space, the hydrogen radiation is almost omnipresent and provides energy for the synthesis of molecules as well as for their destruction.

We had expected that, after warming-up of the cube to room temperature, the residue would not show the same mixture of molecules which had been let in. We had also hoped that the analyses performed by Muñoz Caro and Meierhenrich with state-of-the-art devices would show some large "organic" molecules which might be candidates for building-blocks of life. But we were rather puzzled when (after performance of a classical hydrolysis) among many other interesting compounds, as many as 12 amino acids were found which are indispensable building-blocks of proteins and thus for life (as we know it) and some of which are also existing in biological material on Earth and even in human tissue.

The result of this laboratory experiment which at the beginning should only supply us with material for testing of our COSAC experiment, put us in the exceptional and unexpected situation to know before the beginning of the Rosetta mission with some probability which kinds of compounds we can expect to find on the comet's nucleus. However, we are aware that compounds in cometary matter have a much longer and more complex history than ours created in laboratory, and that we therefore have to provide evidence for the relevance of our laboratory results by means of the planned measurements on the cometary nucleus.

Already now, however, we believe that some further reaching conclusions may be allowed. If we only assume that the situation in star forming regions has been reasonably accurately simulated by Muñoz Caro's experiment, compounds similar to the ones found by Muñoz Caro and Meierhenrich should spontaneously develop in many regions of every "normal" galaxy.

If we furthermore assume that the existence of such molecules is supportive for genesis of life, then it can be concluded that conditions beneficial for the development of life are prevailing at many locations in the universe and that therefore the probability for the development of life is correspondingly high. However, it has to be admitted that the quantification of the actual probability is difficult.

### **The Landing Gear (LG) as a science support device**

The Rosetta Lander has often been said to be an endeavour from scientists for scientists. What was meant is that this project – at least at its early stages – was not seriously supported by ESA, it was rather just invited as a potential "Experiment" which should only be supported when funding of all other Orbiter Experiments had been secured. It was therefore kept alive and further for quite a while only by the enthusiasm of a few scientific institutes. Then a Consortium was formed, and all members could voluntarily contribute to the undertaking according to their abilities. An industrial prime contractor was not involved because of lack of funding. An unusual project structure indeed !

Now, about 8 years later, we feel it is worth taking another look at this project to see whether its astounding concept was not only feasible, but even particularly favourable for science as it was originally intended. We use as an example the so-called "Landing Gear", a device which at first glimpse is probably not considered as being very close to science. This device, designed and provided by the MP Ae, is a tripod structure realizing the mechanical interface between the lower part of the Lander's baseplate and the landing ground. It consists of a central part made of carbon fiber tubes interconnected by aluminium pieces to form a stiff star-shaped framework. To the outer ends of the three framework structures which only slightly exceed in length the radius of the Lander, the so-called legs are hinged which are made of single but thicker tubes. Hinges make it

possible to keep the legs folded upward in parallel to the Lander's "hood" during launch and throughout the cruise phase. Prior to landing, the legs are unfolded upon command, releasing simultaneously the so-called feet which have the task to keep the outer ends of the legs appr. 20 cm above ground at impact.

Beyond this interface function, the LG was given many other tasks and corresponding characteristics helping to ensure and enhance the scientific opportunities of the Lander mission. The most important, actually vital task of the Lander, (Fig. 85), is to ensure safe landing, which mainly means to keep the probability of both, turn-over and rebound upon impact as small as possible.

The probability of turn-over is minimized by the following characteristics:

1. Long folded legs whose length is only limited by the Lander dimensions,
2. the possibility to lower the Lander's center of gravity by telecommand,
3. extension of the legs during unfolding by a special kinematic feature,
4. an only small transformation rate of linear to angular momentum at impact which is accomplished by the ability of the LG's legs to adapt themselves to ground morphology.

The probability of rebound is minimized by:

1. maximizing the stiffness of the LG so that only a very small fraction of the impact energy gets stored in the legs,
2. damping of the impact energy which is realized by a special electromechanical damping device which provides a velocity-proportional deceleration force which results in an asymptotical approach to zero of the landing speed.

The probabilities of turn-over and rebound are both effectively impeded by "ice screws". These are mounted at the end of each "leg" in the so-called "foot" systems in such a way that half of the deceleration force at impact acts on the ice screw and the other half on both "feet" in a balanced manner. Since the cross-section of the ice screws is many times smaller than that of the "feet", the ice screws should be driven into ground with a high probability. As most of the impact energy will be dissipated in the penetration of the ice screw and the electromechanical damper, the small remaining residue should not suffice to extract the ice

screw, whose backward rotation is blocked by a free-wheeling mechanism.

The LG features described by now just support the most basic needs of the mission, the safe landing. Other implemented features and abilities support more directly the scientific potential of the mission. For example, the "feet" which keep the base plate of the Lander off the ground so that the untouched surface of a cometary nucleus, never seen before can be inspected by the "downward-looking" ROLIS camera and investigated by other downward-oriented instruments. The LG's ability to lift and lower the whole Lander helps to focus the camera exactly. The same feature makes it possible to obtain vertically stereoscopic images with every single one of the CIVA panoramic cameras.

Most important, however, is certainly the ability of the LG to rotate by nearly 360° the whole Lander about its vertical axis.

To employ this possibility most efficiently, a "common working circle" has been defined on which all downward-looking instruments, the APX, the ROLIS camera, the CIVA infrared camera and the sample device SD<sup>2</sup>, can inspect the same features on ground. This LG feature makes the important difference between a one-point investigation which would necessarily leave many questions open and a real scan over a stripe of more than a meter length which allows studies of special "suspicious" points and an investigation into the homogeneity or variability, respectively, of cometary surface material. Also other experiments, as the panoramic and stereoscopic CIVA cameras, in particular, in case of failure of one or more of them profit from the Lander's rotatability. The rotation feature also helps the ROMAP experiment to calibrate its detectors and allows the MUPUS experiment to choose an optimum location for its penetrator measurements. For the COSAC and PTOLEMY experiments, it is important to keep the Drill and Sampling System in shadow before the measurement, because otherwise, the sampling device could be heated by sunshine, which would falsify the composition measurements. For conducting a scientifically successful long-term mission, which provides the only possibility to study the nature of cometary activity and alteration of the morphology with time, the loss of heat must be minimized and the collection of electrical power optimized to keep alive the Lander's electronics (in particular the batteries). This can be accomplished by appropriate rotation of the Lander.

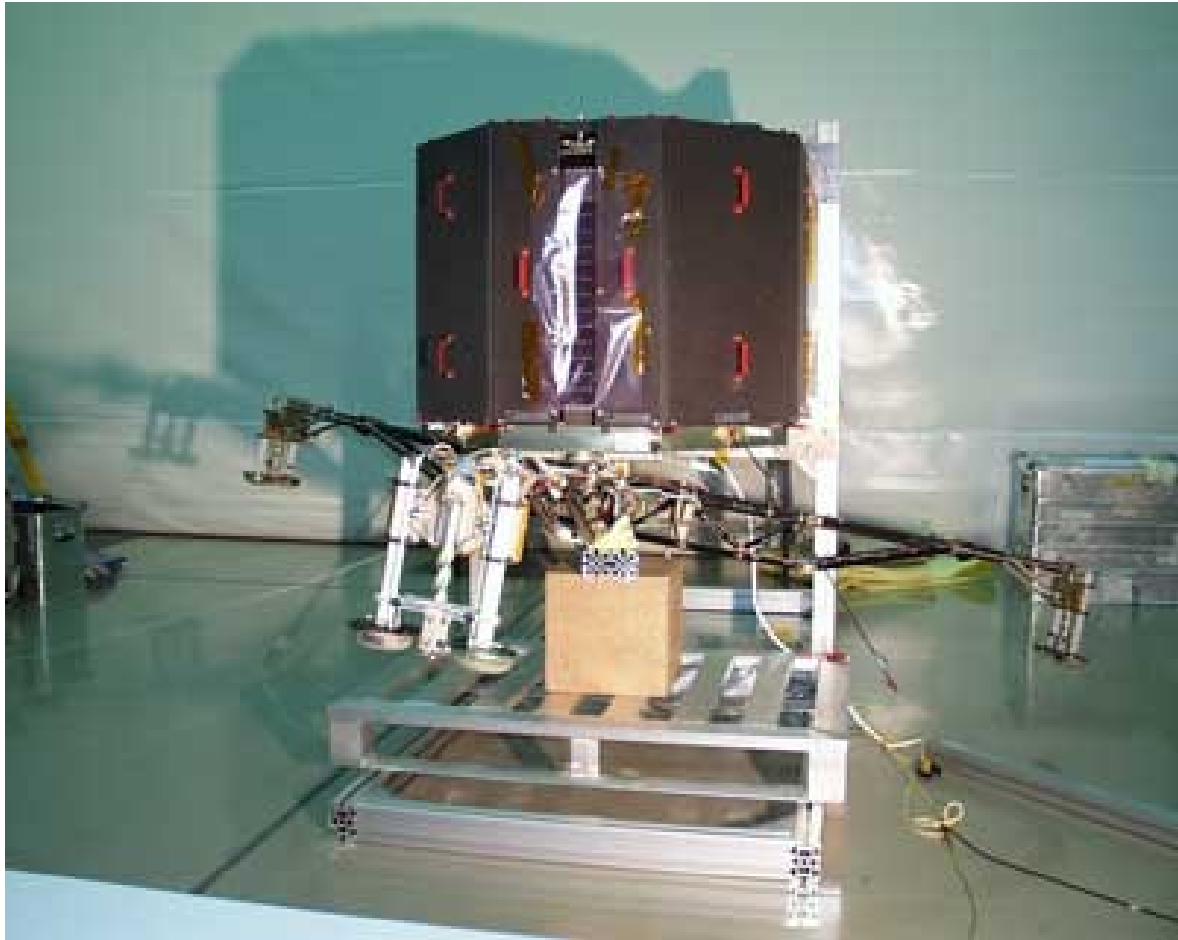


Fig. 85: The Lander during assembly. The protective covers (black) are already mounted. Two legs of the Lander (black tube structures) are about to be mounted to the lower side of the Lander. The feet and ice screws are visible at the ends of both legs.

In addition to the possibility to rotate the Lander, the LG makes it possible to also tilt it, which increases even further the opportunities provided by rotation. E.g. oblique drilling or sampling in oblique directions becomes possible. In general, two more dimensions of freedom for all kinds of research depending on directions become available. E.g. the antenna pattern of the CONSERT experiment which is affected by the relative direction between the CONSERT dipole antennas and the legs of the Lander can be optimized employing the Lander's rotatability and tiltability.

However, the LG provides still more important services to the Lander system as well as to the scientific instruments. E.g. the so-called touch-down pulse is generated which, among else, initiates the launching of the anchoring harpoon(s), the hold-down thruster and the first series of measurements. It is based on three independent sources in the LG electronics:

- the damping motor providing a voltage upon impact,
- the main and
- the wide range accelerometers providing signals which indicate the decrease of the Lander. All these signal are logically ored. This way, the Lander's touch-down pulse is created in a reliable, triple redundant, way.

While the above features of the LG are more or less general services to the Lander system or the experiments, a special service for one experiment, namely SESAME, is worth being mentioned, because it shows to which extent the LG has been designed to support science and how intimately Lander needs and science requirements are intermingled.

The SESAME experiment aims at measuring the electrical as well as the mechanical characteristics of cometary matter in the vicinity of the Lan-

der (within a range of appr. 1 to 4 meters) by performing active and passive sounding experiments. Of particular interest for both types of experiments is the search for layers or other inhomogeneities giving insight into a nucleus' internal structure. For detecting mechanical inhomogeneities, the CASSE part of the experiment employs sound transmitters and receivers and the electrical PP part corresponding electrical devices. The majority of the emitters and receivers (3 out of 4) are housed inside the "soles", the end pieces of the "feet" of the LG. In order to make the SESAME experiment feasible, it was necessary to modify the LG in several respects:

- "Soles" had to be designed and built, strong enough to withstand the impact forces but soft enough to serve as membranes for sound transmission.
- For achieving a spatial separation between receivers and transmitters, and ensuring a good contact to ground (particularly important for the CASSE part), for each leg two mechanically balanced "feet" and corresponding "soles" had to be designed, constructed and tested.
- As sound propagation tests are planned to be performed, the sound propagation through the LG had to be minimized by special damping elements.
- Long, in part triaxial, cables had to be routed from the Common Electronics Box in the center of the Lander through several parts of the LG structure to the emitters and detectors. This was particularly difficult because loops for extensions and rotations allowing for corresponding motions of the LG structure had to be built and mounted.
- Even a kind of lightning rod had to be realized for "grounding" of the SESAME electronics.

The Landing Gear does, however, not only support the Lander mission and the scientific opportunities of several of the instruments, but it contributes to the mission's scientific output directly by monitoring the output of its "normal" accelerometer during touch-down. In this way, information on the compressibility of the cometary matter is obtained. There are still more services provided to the experiments:

- The LG also serves as launch pad for the harpoons. This is not a trivial task because

the shock acceleration at the position of the launch pads exceeds 5000 g.

- The ROMAP instruments as well as the CONSERT antennas are held in storage position by the LG legs and are released together with them.

But also other subsystems and their "responsibles" supporting science with extra efforts could be mentioned: E.g. the power subsystem (Szemeredy and Uni Budapest) provided many custom-made power supplies, e.g. for the CIVA cameras and the harpoon. The Common Electronics Box team custom-tailored and changed many compartments to help scientists. DLR Berlin designed, built and distributed the Lander Common DPUs. But also scientists mutually helped each other. E.g., ROMAP provides the power required for the COSAC pressure sensor, and many Lander Teams helped each other out with rare electronics parts, as FPGAs. Therefore, I think it is correct to say: The Rosetta Lander Project was to a large deal an endeavour from scientists for scientists, as it was meant to be, and it is a joy for me to state this. Thanks to all who contributed. Helmut Rosenbauer

## Further projects

### Ongoing:

- CELIAS is a combination of an ion mass spectrometer and a UV spectrometer on the SOHO spacecraft which is used for heliospheric research (Hilchenbach).
- MIRAS is a RAMAN spectrometer for in-situ measurements of planetary and asteroidal surfaces which includes the development of a data bank for RAMAN data of minerals to be jointly developed by our department and a RAMAN spectroscopy group at the University of Würzburg (Hilchenbach).
- PATIB (Planetary Deep Driller) is a project for development together with industry of a deep (1.5 meter) drilling device for application in planetary and asteroidal research (Hilchenbach).
- MORE is a project in the design phase to be jointly developed by industry and our department which includes an improved version of the COSAC experiment for in-situ chemical analyses. This experiment is included in

the model payload of a planned big exobiology project by ESA (Goesmann, Hilchenbach, Roll).

**Future:**

Basic rule: The adoption of any new project will be decided by the new Director for Planetology. Members of the Department Rosenbauer are keen to give all possible support. forthcoming ESA projects which could be considered are e.g. Bepi-Colombo and Solar Orbiter.

Potential future projects in new fields (ECOS and ECOL) are not yet ripe for discussion.

## Anhang

(English version see page 146)

Table 3: Personalübersicht

Name	I/P*	Hauptverantwortlichkeit
Bitterlich, Hartmut	P	Entwicklung, Bau + Tests CDMS
Borchers, Dr. Reinhard	I	Beiträge zu COSAC GC
Chares, Bernd	P	Konstruktion Landegestell + „Common Electronics Box“
Ebert, Steffen	P	Mech. Konstruktion COSAC
Enge, Rainer	I	Elektronik-Entwicklung
Engelhardt, Wolfgang	I	Konstruktion MSS
Erdmann, Manfred	I	Entwicklung, Bau + Tests CDMS
Fischer, Henning	P	Elektronik-Entwicklung + Test
Goesmann, Dr. Fred	P	Projektwissenschaftler COSAC
Gräve, Bernhard	I	Verkabelung Lander
Haas, Kurt	P	Mechanische Integration
Hartwig, Hermann	I	Mech. Entwicklung + Test, Konstruktion MSS
Hemmerich, Peter	I	Technical Division manager, Nutzlast-Ingenieur
Hilchenbach, Dr. Martin	P	Simulation LG, Studien, Datenauswertung
Jakob, Hendrick	I	Elektronik-Bauteile, Platinenfertigung, Bestückung
Jung, Hans Jürgen	P	Tests von Mechanismen
Kaufmann, Susanne	I	Direktions-Sekretariat
Koscielski, Olaf	P	Mechanische Konstruktion
Küchemann, Oliver	P	Software-Entwicklung, Web-Server, Lander Check-out and Operations
Kühne, Wolfgang	I	Lander Abstoßmechanismus, Elektronikentwicklung
Oberländer, Helga	P	Sekretariat (Teilzeit), Technische Assistentin
Richards, Michael-L.		Lander AIV + QA, Check-out and Operations
Roll, Dr. Reinhard	P	Projektmanager COSAC
Rosenbauer, Dr. Helmut	I	Lead Scientist ROSETTA Lander, Principal investigator COSAC
Rustenbach, Jürgen	I	Elektronik-Entwicklung CDMS
Schäfer, Rolf	P	Elektronik-Bauteile
Schlemm, Gustav	I	Elektronik-Bestückung, Bauteile, Platinenfertigung
Sperling, Michael	I	Lander-Elektronik-Bestückung, Bau + Tests Common Electronics Box
Spilker, Ute	I	Projekt-Sekretariat
Szemerey, István	P	Lander Leistungsversorgung
Timpl, Dr. Hellmuth	I	AIV / Antriebe
Wedekind, Jürgen	P	Bau und Tests MSS
Windler, Daniel	P	Elektronik COSAC
Witte, Dr. Manfred	I	Betreuung GAS Experiment

Table 4: Gäste, Post-Docs und Doktoranden.

Name	I/P*	Hauptverantwortlichkeit
Casares, Antonio	I	Entwicklung Massenspektrometer COSAC
Héjja, Dr. István	I	Post-Doc, Entwicklung Elektronenemitter
Kholomeev, Alexander	I	Elektronik Massenspektrometer COSAC
Meierhenrich, Dr. Uwe	I	Entwicklung GC für Chiralität
Munoz-Caro, Guillermo	I	Synthese von Kometenmaterie
Remizov, Dr. Anatoli	I	allgemeine Ingenieur-Arbeiten

\* I = aus Institutsmitteln bezahlt, P = aus Projektmitteln bezahlt.

## Appendix

Table 3: Staff

Name	I/P*	Main responsibility
Bitterlich, Hartmut	P	Lander Central Data Management System
Borchers, Dr. Reinhard	I	Support of COSAC GC design
Chares, Bernd	P	Design Landing Gear + „Common Electronics Box“
Ebert, Steffen	P	Mech. design COSAC
Enge, Rainer	I	Electronics design
Engelhardt, Wolfgang	I	Design push-off mechanism
Erdmann, Manfred	I	Development, construction + testing Central Data Management System
Fischer, Henning	P	Electronics development + testing
Goesmann, Dr. Fred	P	Project scientist COSAC
Gräve, Bernhard	I	Harness Lander
Haas, Kurt	P	Mechanical integration
Hartwig, Hermann	I	Mech. development + testing of Push-off Mechanism
Hemmerich, Peter	I	Technical Division Manager, Payload Engineer
Hilchenbach, Dr. Martin	P	Landing Simulation, scientific studies + data evaluation
Jakob, Hendrick	I	Electronics layouts and population
Jung, Hans Jürgen	P	Testing of mechanisms
Kaufmann, Susanne	I	Secretary to Director
Koscielski, Olaf	P	Mechanical design Lander feet and legs
Küchemann, Oliver	P	Software development, server, Lander check-out and operations
Kühne, Wolfgang	I	Electronics of Lander push-off mechanism
Oberländer, Helga	P	Secretary + technical assisant (part-time)
Richards, Michael-L.		Lander AIV + QA, Check-out and operations
Roll, Dr. Reinhard	P	Projekt manager COSAC
Rosenbauer, Dr. Helmut	I	Lead Scientist ROSETTA Lander, Principal investigator COSAC
Rustenbach, Jürgen	I	Electronics development of Central Data Management System
Schäfer, Rolf	P	Electronics parts and population
Schlemm, Gustav	I	Electronics parts and population
Sperling, Michael	I	Electronics parts and population, design and testing of Common Electronics Box
Spilker, Ute	I	Project secretary
Szemerey, István	P	Lander power supply
Timpl, Dr. Hellmuth	I	AIV / motors, mechanisms
Wedekind, Jürgen	P	Construction and testing of push-off mechanism
Windler, Daniel	P	Electronics for COSAC
Witte, Dr. Manfred	I	Operations and data evaluation of Ulysses GAS Experiment

Table 4: Guests, postdocs and doctorands

Name	I/P*	Main responsibility
Casares, Antonio	I	Development COSAC MS
Héjja, Dr. István	I	Post-Doc, development of electron source
Kholomeev, Alexander	I	Electronics of COSAC MS
Meierhenrich, Dr. Uwe	I	Contributions to COSAC GC, analyses of synthetic comet material
Munoz-Caro, Guillermo	I	Synthesis and analysis of artificial cometary material
Remizov, Dr. Anatoli	I	Integration, testing + calibration of ROMAP spectrometer

\* I = payed by institute fonds, P = payed by project fonds.

# IV. Rechenzentrum, Elektroniklabor und Werkstätten/ Computer Centre, Electronic Laboratory and Workshops

## Rechenzentrum/Computer Centre

(I. Pardowitz und Mitarbeiter)

### *Internet und Sicherheit*

Bereits in den letzten Jahren hat das Internet in seinen verschiedenen Aspekten die Aktivitäten des Rechenzentrums wesentlich geprägt. Während zunächst die technischen Gesichtspunkte (Betrieb des Webservers, Erhöhung der Zugangsbandbreite) vorherrschend waren, traten im Berichtszeitraum die Themen Sicherheit und die wissenschaftliche Nutzung in den Vordergrund.

Im Laufe des Jahres 1999 wurden mehrere kleine Angriffe aus dem Internet auf Rechner des Institutes registriert und analysiert. Um größere Schäden, wie sie später in anderen Instituten auch eingetreten sind, zu vermeiden, wurde neben den sofort eingeleiteten institutsinternen Maßnahmen im Herbst 1999 damit begonnen, zusammen mit den anderen Göttinger Instituten ein Sicherheitskonzept zu erarbeiten. Eines der Ziele des Konzeptes war es, eine Lösung zu finden, die ein höchstes Maß an Sicherheit gegenüber Angriffen aus dem Internet, gleichzeitig möglichst wenig Einschränkungen für die Benutzer und wenig administrativen Aufwand im Betrieb bietet. Die gefundene Lösung beruht auf einem gemeinsamen Router der Firma CISCO, der alle Göttinger Max-Planck-Institute miteinander und mit der GWDG verbindet, dem Betreiber des gemeinsamen Zugangs der Göttinger Max-Planck-Institute und der Universität Göttingen zum deutschen Wissenschaftsnetz (G-WIN). Der Router, der nur noch einen strikt geregelter Zugang aus dem Internet zu ausgewählten Institutsrechnern zulässt, wurde im Oktober 2000 installiert und läuft seitdem ohne Probleme. Ein Nebeneffekt dieser Maßnahme war die Erhöhung der Bandbreite für unser Institut von bisher 155 Mbit/s auf 1 Gbit/s. Da gleichzeitig die Verbindungen Göttingen-Hannover und Hannover-USA ebenfalls auf 1 Gbit/s aufgestockt wurden, verfügt das Institut nun über eine hervorragen-

de Anbindung an das internationale Internet.

### *RAPID/CLUSTER-Webportal*

Die neuen Web-Technologien des Internets eröffnen auch ganz neue Möglichkeiten der Nutzung in der täglichen Arbeit der Wissenschaftler. Das Rechenzentrum hat für das Projekt RAPID auf CLUSTER im Berichtszeitraum ein Softwaresystem entwickelt, das es erlaubt, über jeden Web-Browser einen graphischen Zugang zu den aktuellen Daten zu erhalten, die die vier RAPID-Instrumente auf den Cluster-Satelliten liefern. Damit konnten die Wissenschaftler des internationalen RAPID-Konsortiums bereits während der *Commissioning*-Phase sich schnell einen Überblick über die Resultate der Messungen verschaffen. Die benutzerfreundliche Web-Oberfläche erlaubt es dem Benutzer, zwischen den rund 60 verschiedenen graphischen Darstellungen (Seiten) für jeden Tag (ab dem 1.9.2000) hin und her zu blättern (navigieren) (Fig. 86). Damit entfällt die Notwendigkeit, wie in der Vergangenheit Übersichtsplots in Papierform zu produzieren oder die Daten auf vielen verschiedenen Rechnern aktuell bereitzuhalten.

Diese Software baut auf den Erfahrungen der Vorjahre auf, bei denen viel einfachere Webdarstellungen für die bodengebundenen Projekte STARE und SOUSY erstellt wurden. Für dieses Projekt wurde die in unserem Institut erstellte Grafik-Bibliothek DISLIN wesentlich weiterentwickelt.

(M. Bruns, G. Kettmann, H. Michels und I. Pardowitz)

### *SUMER Image Database*

Eine wesentliche Weiterentwicklung stellt die *SUMER Image Database* dar. Das Instrument SUMER auf SOHO hat seit seinem Start 1996 bis heute rund 4 Millionen UV-Spektren aufgenommen. Diese konnten nur mit spezieller Software und nur auf Rechnern, auf denen die gesamten SUMER-Daten installiert waren, durch-

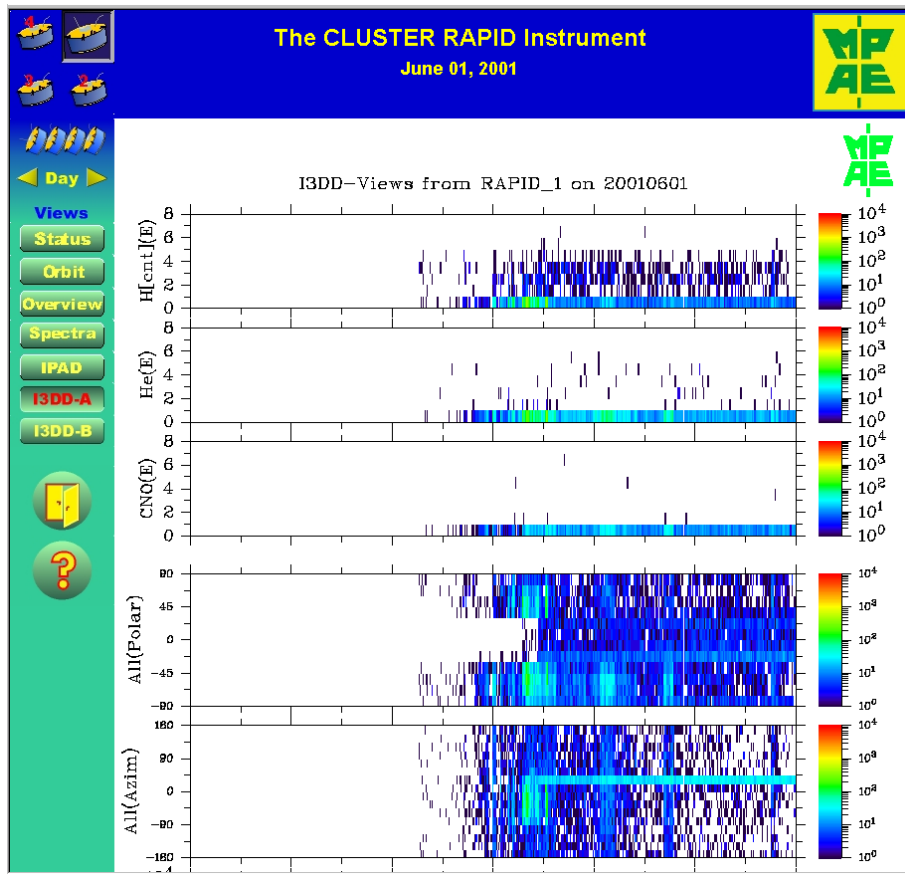


Abb. 86: Ansicht des Rapid-Data Viewing Systems/*Display of Rapid-Data Viewing System.*

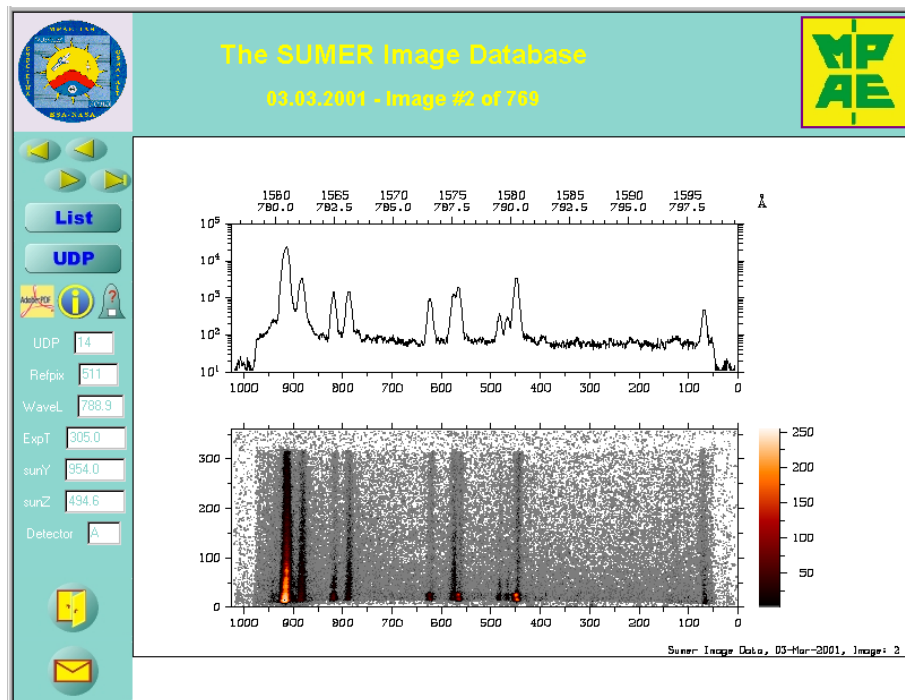


Abb. 87: Die Sumer Image Database im Internet/*Internet Sumer Image database.*



Abb. 88: Stand des MPAE in der Lokhalle Göttingen im Rahmen der EXPO 2000/MPAE exhibition stand in the „Lokhalle Göttingen“ during EXPO 2000.

gesehen werden. Nicht zuletzt auch wegen der Sicherheitsüberlegungen wurde diese Software-Neuentwicklung durch Mitarbeiter des Rechenzentrum notwendig. Das webbasierte Navigationssystem stellt nun jedem Internetbenutzer verschiedene Zugangspfade zu jedem der 4 Mio. Spektren sowie zu einer Fülle weiterer Zusatzinformationen zur Verfügung (Fig. 87).

Das Besondere an diesem System ist die dynamische Erstellung der Graphiken (.png und .pdf) direkt im Webserver, also ohne jede Zwischenspeicherung. In Verbindung mit einem speziellen sehr effektiven Indexsystem zum raschen Zugriff auf die Bilddaten und der hohen Internet-Bandbreite erreichen wir dadurch sehr kurze Zugriffszeiten und einen sehr hohen Durchsatz. Seitdem diese Web-Adresse freigegeben und in der Sonnenforschungs-Gemeinschaft bekannt gemacht wurde, ist sie zu einer der am häufigsten zugegriffenen Seiten des Instituts geworden. Die Nutzung dieses Informationsdienstes durch institutsfremde Wissenschaftler, meist aus dem Ausland, hat inzwischen die durch Institutswissenschaftler überholt.

Wegen seiner einfachen Handhabung und der Möglichkeit, sehr grundlegende physikalische Prinzipien (wie z.B. Bohrsches Atommodell,

Doppler-Effekt) anhand von aktuellen Forschungsdaten zu demonstrieren, wurde dieses System inzwischen auch dazu verwendet, Schülerpraktikanten an aktuelle Themen der Forschung unseres Institutes heranzuführen.

(M. Bruns, D. Germerott, H. Michels, I. Pardowitz)

#### EXPO-2000

Das Rechenzentrum war maßgeblich an den Planungen, der technischen Realisierung und Betreuung des Standes des Institutes auf dem Göttinger EXPO-2000-Projekt in der Göttinger Lokhalle beteiligt. Für diesen Stand hat das Rechenzentrum eine endlos ablaufende Präsentation von Ergebnissen der SOHO-Mission auf einer Rückprojektionsscheibe sowie ein *Touchscreen* basiertes Benutzerinformations-System mit Informationen zum Institut und seinen Forschungsschwerpunkten erstellt. Beides hat wesentlich zur hohen Aufmerksamkeit der Besucher für unsere Forschung beigetragen (Fig. 88).

(G. Monecke, I. Pardowitz, B. Wand)

#### Ausstattung und Dienstleistungen

Die Server-Ausstattung des Rechenzentrums ist wie in den letzten Jahren weiter ausgebaut worden.

Insbesondere ist mit der Neuanschaffung zweier DS20-Rechner der Firma COMPAQ und dem Ausbau der SUN-Server die zur Verfügung stehende arithmetische Leistung verdoppelt worden.

Die Erneuerung der Windows-NT-Server und die Migration zu Windows 2000 ist durch Inbetriebnahme eines neuen File-Servers, eines neuen Mail-Servers und eines neuen Terminal-Servers wesentlich vorangebracht worden.

Die personellen Dienstleistungen für die wissenschaftlichen Projekte spielen, wie in der Vergangenheit auch, neben dem Betrieb der Infrastruktur (Rechner, Netze, Peripherie) eine wichtige Rolle.

Für die Projekte STARE, WIND, CELIAS, ULYSSES, CRRES, GEOTAIL und inzwischen auch RAPID und CIS/CLUSTER werden regelmäßig die eingehenden Daten aufbereitet und für die weitere wissenschaftliche Analyse bereitgestellt.

(M. Bruns, C. Ludwig, H. Michels)

## Elektroniklabor/Electronic Laboratory

(H. Zapf und Mitarbeiter)

### *Funktion – Aufgaben*

Elektrotechnische Lösungen zur Umsetzung von wissenschaftlichen Konzepten und Projekten.

Das Labor setzt sich zur Zeit (Stand Januar 2002) aus folgenden Mitarbeitern zusammen:

### *Festangestellte Mitarbeiter:*

- 12 Diplom-Ingenieure für Hardware und Software, TU/TH/FH
- 15 Staatlich geprüfte Techniker
- 5 Elektro-Facharbeiter  
sowie
- 9 zeitlich befristete Ingenieure und Techniker

Ausbildungswerkstatt mit einem Meister, der 3-4 Auszubildende zum Facharbeiterabschluss –Industrieelektroniker– führt.

In der Summe sind durchschnittlich ca. 45 Mitarbeiter an unterschiedlichen Projekten beschäftigt. Diese Mitarbeiter werden ihren Aufgaben entsprechend geschult, weitergebildet und qualifiziert.

Die Mitarbeiter werden nach ihren Qualifikationen/Funktionen und Aufgaben einzeln bzw. in Gruppen, Projekten und Ressourcen orientiert eingesetzt.

### *Generelle Aufgaben*

Bereithaltung und Anpassung der Thermal-/Vakuum-Einrichtungen und des Vibrationsstandes. Pflege und Erweiterung des Messdatenaufzeichnungssystems zum Zweck der Dokumentation und zum Leistungsnachweis von Experimenten und elektronischen Komponenten. Damit erfolgt eine Überprüfung der geforderten Leistungsmerkmale von den erarbeiteten Lösungen. Ein besonderes Augenmerk gilt diesen Leistungsgrenzen der Prüflinge, da die Experimente den schwierigsten Bedingungen im Weltraum ausgesetzt sind und unter diesen Voraussetzungen gesichert ihre Funktionen ausführen müssen.

### *Projektarbeit*

Zur Zeit im Elektronik-Labor bearbeitete Projekte:

ROSETTA, bestehend aus den Teilprojekten OSIRIS, CONSERT, COSAC, RTOF (Teil von ROSINA), MIRO und RoLand.

Zusätzliche Projekte sind HIFI/FIRST, STEREO, ASPERA-3 und SIR.

Weitere Projekte befinden sich in der Startphase.

### *Technische Bereiche/Ausrüstung:*

*Qualitätssicherung:* Eingangs- und Ausgangsinspektion gemäß ESA/NASA-Spezifikationen.

*Produktsicherung:* komplette Material- und Eigenschaftstests der (int./ext.) Komponenten.

*Dokumentation:* Aufzeichnung der QS-Dokumente (Text, Video, Photo).

### *Programmierbare Logik:*

Programmiert werden können vielfältige Memory-Bausteine wie Eeproms, EEPROMs sowie Bausteine wie PAL/GAL, ASICs, FPGA, (*Field Programmable Gate Array*) und Microcontroller der 8051er und 62xx Familien. PIC-Microcontroller werden auch programmiert.

### *CAD/Software:*

Elektronik-Design-Simulation mit P-SPICE®/PROTEL®. Schalt- und Layout-Planerstellung mit den Werkzeugen PROTEL®/ORCAD®.

### *Hardware/Software:*

Elektronik-Aufbau mit vielfachen Bauteilen (High-rel Komponenten) wie IC (Integrated Circuit), MC (Microcontroller) und DSP (Digital Signal Prozessor). Austesten der Hardwarefunktionen sowie Erstellen von Software mit den



Abb. 89: Multifunktionslaser/*Multi function laser*.

Funktionen in Verbindung zu den logischen Verknüpfungen der Hardware.

*PC-Arbeitsplätze:*

Ausgerüstet mit Software steuerbaren Standard-Messeinrichtungen wie Analog/Digital-Scope, Netzteilen, Funktionsgenerator, u.a. (IEEE/CAN-Bus gesteuert). Dabei sind Möglichkeiten zur direkten Online-Dokumentation bei Tests und Funktionsüberprüfungen gegeben.

*Löt-Arbeitsplätze/Inspektionstechnik:*

Alle Löttechniken für ein Elektronik-Design in SMT/SMD (*surface mounting technic-device*) sind durchführbar. Die Arbeitsplätze sind mit ESD (Elektronik-Statik-Schutz) ausgerüstet für

die Erstellung von Space-Hardware nach ESA- und NASA-Qualitäts-Spezifikationen.

*Inspektionstechnik:*

Lötergebnisse können mit den adaptierten CCD-Kameras an den Löt-Inspektionsmikroskopen sofort überprüft und in die Dokumentation eingebracht werden. Das Arbeitshandling lässt sich vollständig dokumentieren. Mit einem Spezial-Mikroskop können auch Lötergebnisse unterhalb der Bauteile dargestellt und dokumentiert werden.

*Spezial-Einrichtungen:*

EMC/EMV: HF-(Hoch-Frequenz) Schirmkabine bis 3 GHz mit Messempfängern und Spektrumanalysen bis 21 GHz für die Ermittlung von Störabstrahlungen bei elektronischen Schaltungen.

*Transportüberwachung:* Zur Überwachung der Grenzwerte, die bei einem Gerätetransport von *space equipment* zu kontrollieren sind, stehen insgesamt 4 Datenlogger zur Verfügung. Dabei werden kleinste Veränderungen der Transportbedingungen aufgezeichnet.

*Schweißlaser:* Zur Erstellung von Präzisionsventilen und Spezialverbindungen.

*Laser:* Multifunktionslaser zur Spezial-Bearbeitung von Keramik, Metallen und Leiterplatten-Materialien. Dabei sind bis zu 40  $\mu\text{m}$  feine Strukturen für sehr große Hybrid-Integrationen möglich (Fig. 89).

## 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 15 Mitarbeitern wurden eine Vielzahl von Einzelaufträgen für die im Institut laufenden Projekte, für Laborexperimente, für Testreihen, für die Unterhaltung der Messlabore sowie für Reparatur- und Instandsetzungsarbeiten durchgeführt. Für 2000 und 2001 sind in den einzelnen Werkstätten folgende Hauptarbeiten zu nennen:

### Feinmechanik

In der Feinmechanik-Werkstatt wurde in den Jahren 2000 und 2001 hauptsächlich an folgenden Projekten gearbeitet: ROSETTA-Lander, Landing Gear, COSAC, ROMAP, CONSERT sowie OSIRIS, RTOF, MIRO und SIR, außer-

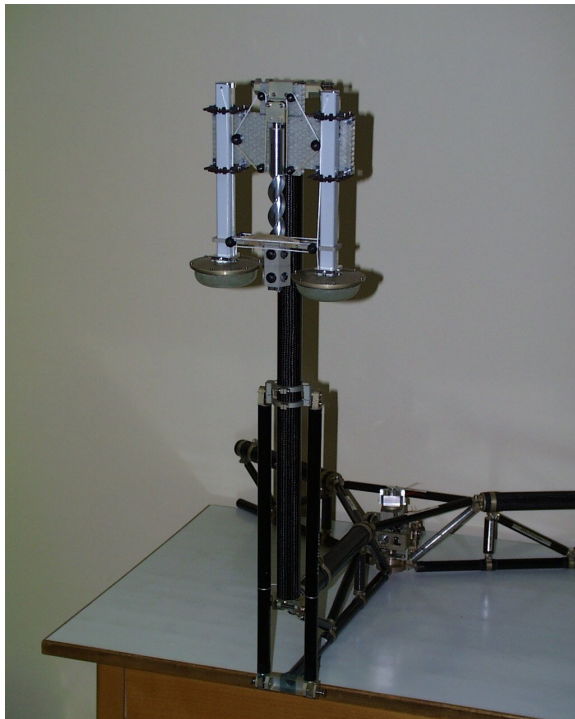


Abb. 90: Teil vom Landegestell mit Eisbohrer/  
*Part of landing gear with ice-drill.*

dem Einzelteilanfertigungen für die Bodenbeobachtungen von Kometen. Testvorrichtungen wurden für Thermal-, Vakuum- und Vibrationstests hergestellt. Umfangreiche feinmechanische Arbeiten wurden für die Lander durchgeführt, darunter fallen: Verriegelungssystem zur Aufnahme der Kräfte beim Start; das Dämpfungssystem, das die kinetische Energie während der Landung herausdämpft; die Beinstruktur, ein Fachwerk aus Kohlenfaserstäben, das der Standsicherheit dient; der Eisbohrer, der zur Verankerung des Landers am Boden dient (Abb. 90); das Kardangeln zur Anpassung an die Bodenunebenheiten (Abb. 91). Hauptarbeiten für das Projekt OSIRIS waren: die

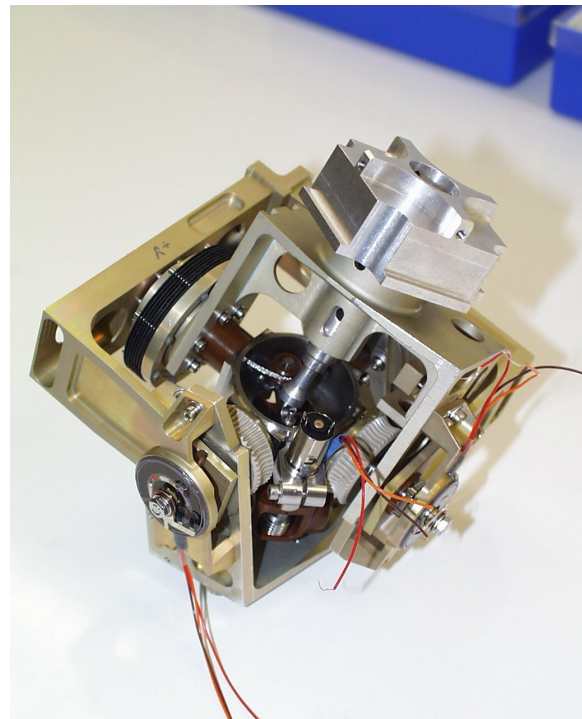


Abb. 91: Kardangeln/  
*Cardanic joint.*

Detektoreinheit 28x28mm, an die hohe Anforderungen bezüglich thermischer- und mechanischer Festigkeit sowie an die Strahlungsfestigkeit gestellt wurden. Bei der Bearbeitung sind eine Reihe von nicht alltäglichen Materialien verwendet worden. Zum Einsatz kamen Wolfram- und Titanlegierungen, Invar, glasfaserverstärkte Kunststoffe und Vespel.

### 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 wurden Kühlkörper aus Kupfer angefertigt und die Kühlschlangen hart eingelötet, sowie Versorgungsleitungen für Synthetische Luft und Stickstoff zum CCD-Labor verlegt. Für das Projekt BEAGLE2 wurde eine Abdeckhaube aus Aluminium für Tieftemperatur-Tests gefertigt. In Bad Lauterberg wurde die SOUSY-Antennenanlage abgebaut und für den Transport nach Peru vorbereitet. Für anstehende Änderungsarbeiten an der RIO-IMAGER-Antenne in Tromsø wurden Ersatzteile angefertigt und das Montagematerial zusammengestellt. In der Schlosserei wird ein Metallbauer, Fachrichtung Konstruktionstechnik, ausgebildet.

#### 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 jeweilige Legierung abgestimmt werden müssen. Gefordert werden Oberflächen, die je nach Anwendungsfall gut leitfähig, isolierend, glänzend, matt oder lichtabsorbierend sein müssen. Die hauptsächlichsten Verfahren sind dabei Gelbchromatisieren, Vergolden, Verkupfern, Vernickeln und Eloxieren. Kleinere Strukturen wie Blenden, Ablenk-

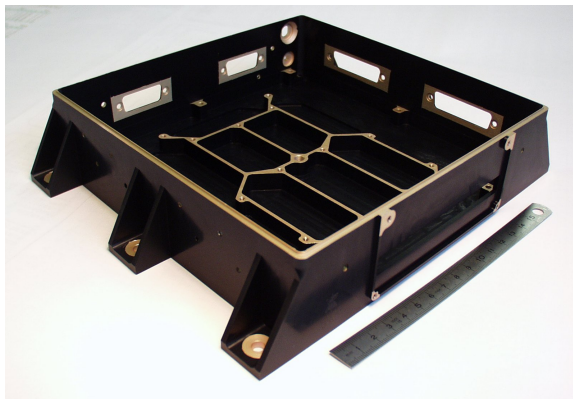


Abb. 92: Elektronik-Gehäuse mit selektiver Beschichtung/*Electronic box with selective coating.*

gitter 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. In den letzten 2 Jahren wurde mit erheblichem Aufwand bei den Gehäuserahmen für die Projekte

Rosetta-Mission, OSIRIS, MIRO und RTOF eine selektive Beschichtung mit Gelbchromatisierung (Iridite 14-2) und matt-schwarzer Eloxalschicht vorgenommen (Abb. 92). Für die Abdeckarbeiten der jeweiligen Schutzschicht wurde eine Ex-geschützte Schadstoff-Ejektor-Absaugung installiert. Weiterhin wurden galvanische Arbeiten für die Projekte ROLAND-LANDER, ROLAND-COSAC, IR-Spektrometer SIR und CONSERT durchgeführt. Für ganz spezielle Oberflächenbehandlungen, die nicht in unserer Galvanik ausgeführt werden können, bestehen gute Kontakte zur Industrie und zu Galvanikfachfirmen.

#### Siebdruck

Im Berichtszeitraum wurde hauptsächlich das Beschichten von verschiedenen Materialien mit Gold, Silber, Aluminium, Kupfer, Chrom und Nickel durchgeführt, für diese Arbeiten wurde die Aufdampf- und die Sputteranlage eingesetzt. Außerdem wurden beidseitig Mehrlagen-Dickschichtschaltungsdrucke mit Durchkontaktierung hergestellt, Laserschweißungen durchgeführt und mit Diamantwerkzeugen Formschliffe sowie Schneid- und Bohrarbeiten ausgeführt. Diese Arbeiten fielen überwiegend bei folgenden Projekten an: RTOF, CONSERT, ROLAND und OSIRIS.

#### Ausbildung

In den Lehrwerkstätten wurden 2000 und 2001 bis zu 28 Auszubildende beschäftigt, die in den Berufen Industrieelektroniker (Fachrichtung Gerätetechnik), Industriemechaniker (Fachrichtung Geräte- und Feinwerktechnik), Metallbauer (Fachrichtung Konstruktionstechnik), Elektroinstallateur und Kaufmann/-frau für Bürokommunikation ausgebildet wurden. Außerdem haben 24 Schülerpraktikanten und 18 Hochschulpraktikanten in verschiedenen Abteilungen ein Praktikum absolviert. In der Elektro-Lehrwerkstatt, wo 9 Auszubildende arbeiten, wurde neben ausbildungsbezogenen Arbeiten auch an verschiedenen Projekten mitgearbeitet. Diese Arbeiten beinhalten in der Regel das Bestücken von elektrischen Leiterplatten, das Einbauen und Verdrahten elektromechanischer Bauteile sowie im Anschluß das Prüfen auf Funktion und evtl. Fehlersuche. Zu den in der Lehrwerkstatt hergestellten elektronischen Geräten gehört u.a. ein im Schaltbetrieb arbeitender bidirektionaler Stromregler  $\pm 14V/7A$  für die Versorgung eines Peltier-Elements und 3 steuerbare elektronische Lastschalter, die das Einschalten stark induktiver Verbraucher am Netz mit verminderten Spannungsspitzen ermöglichen. Über eine mit Opto-Kopplern isolierte Schnittstelle können

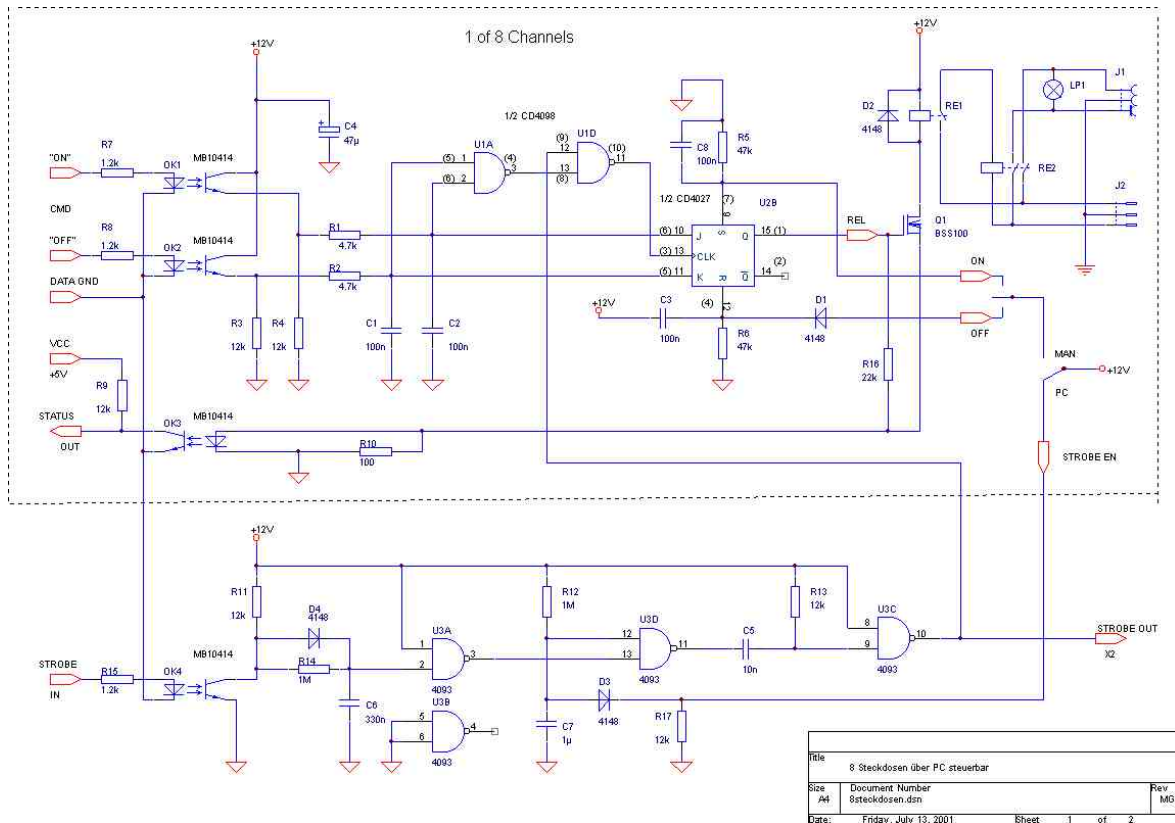


Abb. 93: Schaltbild für Steckdosensteuerung/Circuit diagram for wall-socket control.

an einem PC bis zu 8 verschiedene Netzverbraucher ein- und ausgeschaltet werden, wobei die Schaltzustände der 8 Kanäle am Ausgang ebenfalls über Opto-Koppler an den PC zurückgemeldet werden (Abb. 93).

In der Feinmechanik-Lehrwerkstatt werden neben den Grundfertigkeiten auch intensiv Grundkenntnisse über das Programmieren von CNC-Fräs- und Drehmaschinen sowie den Aufbau von Pneumatik-Schaltungen vermittelt. Entsprechend ihren Ausbildungsstand werden die Lehrlinge auch für Arbeiten der im Haus laufenden Projekte eingesetzt, wobei überwiegend Einzelteilerfertigungen für die Projekte ROLAND, OSIRIS, RIO-IMAGER, SIR und MIRO durchzuführen waren. Für projektbezogene Arbeiten wurden 2000 und 2001 von den Auszubildenden zusammen 6.800 Stunden geleistet.

tet.

Vor der Industrie- und Handelskammer bzw. Handwerkskammer haben folgende Mitarbeiterinnen und Mitarbeiter ihre Facharbeiterprüfung erfolgreich bestanden:

*Industrieelektroniker:* Hendrick Jakob, Mario Kücking, Hendrik Meierkord, Christopher Geile, Thilo Kröning, Tobias Regenhardt;

*Industriemechaniker:* Rainer Jünemann, Ron Lienemann, Thorsten Meyer, Karsten Ropte, Vitalij Mass, Sören Mende, Janet Nickel-Rilling, Sebastian Schettler;

*Metallbauer:* Ralf Triller;

*Elektroinstallateur:* Dennis Ziemann und

*Kaufmann/-frau für Bürokommunikation:* Sandra Hillebrecht, Axel Gloth.

## V. Personelle Gliederung/Personnel

### Kollegium, wissenschaftliche Mitglieder/Board of directors, scientific members

**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. Walter Dieminger*  
(† 29.09.2000)  
*Prof. Dr. Tor Hagfors*

### Auswärtige wissenschaftliche Mitglieder/External scientific members:

*Prof. Dr. Jules A. Fejer, University of California, La Jolla*  
*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*

**Geschäftsführer/Manager:** Dr. Peter Czechowsky

### Wissenschaftliche und wissenschaftlich-technische Mitarbeiter/ Scientific staff

Dipl.-Ing. Lothar Bemmann	Dr. Jürgen Klostermeyer
Dr. Reinhard Borchers	Dr. Andreas Kopp
Peter Börner	Dr. Axel Korth
Dr. Peter Barthol	Dr. Michael Kosch
Dr. Thomas Blümchen	Dr. Jörg-Rainer Kramm
Dr. Volker Bothmer	Dr. Norbert Krupp
Dr. Jörg Büchner	Dr. Andreas Lagg
Dr. Werner Curdt	Dipl.-Phys. Hans Lauche
Dr. Patrick W. Daly	Dr. Stefano Livi (beurlaubt)
Dipl.-Math. Ingolf Dammasch	Dr. Urs Mall
Dipl.-Ing. Rainer Enge	Dr. Ingrid Mann
Dr. Markus Fränz	Dr. Wojcieck Markiewicz
Dr. Fred Goesmann	Dr. Davina Markiewicz-Innes
Dr. Björn Grieger	Prof. Dr. Eckart Marsch
Dipl.-Phys. Heiner Grünwaldt	Prof. Dr. James F. McKenzie
Dr. Gerd K. Hartmann	Dipl.Math. Helmut Michels
Dr. Paul Hartogh	Dipl.-Ing. Reinhard Müller
Dipl.-Phys. Hermann Hartwig	Dipl.-Phys. Andreas Nathues
Dr. Martin Hilchenbach	Dr. Erling Nielsen
Dr. Nico Hoekzema	Dr. Bernd Nikutowski
Dr. Stubbe Hviid	Dr. Iancu Pardowitz
Dr. Bernd Inhester	Dipl.-Ing. Borut Podlipnik
Dr. Wing-Huen Ip (beurlaubt)	Dipl.-Ing. Ralf Pogadl
Dr. Christopher Jarchow	Dr. Fabrice Portier-Fozzani
Prof. Dr. Klaus Jockers	Dr. Michael Richards
Dr. habil. Horst Uwe Keller	Dr. Arne K. Richter
Dr. Georg Kettmann	Dr. Klaus Richter

Dr. Michael Rietveld	Dr. Dietrich Stratmann
Dr. habil. Jürgen Röttger	Prof. Dr. Peter Stubbe
Dr. Reinhard Roll	Dipl.-Ing. Istvan Szemerey
Dr. Rüdiger Rüster	Dr. Nicolas Thomas
Prof. Dr. Konrad Sauer	Dr. Hellmuth Timpl
Prof. Dr. Kristian Schlegel	Dr. Dimitri Titov
Dr. Gerhard Schmidt	Dipl.-Ing. Georg Tomasch
Dr. Dieter Schmitt	Dr. Stefan Werner
Dr. Udo Schühle	Dr. Thomas Wiegelmann
Prof. Dr. M. Schüssler	Dr. Klaus Wilhelm
Prof. Dr. Rainer Schwenn	Dr. Manfred Witte
Dipl.-Phys. Ilse Sebastian	Dr. Bernd Wöbke
Dr. Holger Sierks	Dr. Joachim Woch
Dipl.-Ing. Li Song	Dr. Helmut Zapf
Dr. Axel Steinhof	

**Abteilung EDV/Computing department (Leitung/Management: Dr. Iancu Pardowitz)**

Jürgen Baur	Herbert Lindner
Michael Bruns	Christine Ludwig
Peter Fahlbusch	Helmut Michels
Dietmar Germerott	Godehard Monecke
Lothar Graf	Adolf Piepenbrink
Terrence Ho	Jürgen Wallbrecht
Dr. Georg Kettmann	Bernhard Wand

**Laboratorien/Laboratories (Leitung/Management: Dr. Helmut Zapf)**

Sekretariat/Secretariat: Marlies Ott, Christiane Heise

Günther Auckthun (abgeordnet vom MPI für Strömungsforschung)	Markus Monecke
Walter Böker	Oliver Küchemann
Waltherus Boogaerts	Wolfgang Neumann
Dipl.-Ing. Irene Büttner	Jürgen Nitsch
Eberhard-Michael Clement	Dipl.-Ing. Henry Perplies
Dipl.-Ing. Arne Dannenberg	Borut Podlipnik
Werner Deutsch (abgeordnet vom MPI für Strömungsforschung)	Klaus-Dieter Preschel
Dipl.-Ing. Martin Döscher	Waltraut Reich
Klaus-Dieter Eulig	Dipl.-Ing. Claudius Römer
Andreas Fischer	Rolf Schäfer
Dipl.-Ing. Henning Fischer	Helmut Schild
Klaus Fischer	Gustav-Adolf Schlemm
Klaus-Dieter Gräbig	Dipl.-Ing. Jan Carsten Schröder
Bernhard Gräve	Helmut Schüddekopf
Wolfgang Güttler	Matthias Schwarz (abgeordnet vom MPI für Strömungsforschung)
Dipl.-Ing. Klaus Heerlein	Dipl.-Ing. Hartmut Sommer
Peter Hemmerich	Michael Sperling
Jakob Hendrick	Dipl.-Phys. Christoph Steinmetz
Heinz Günter Kellner	Dipl.-Ing. Eckhard Steinmetz
Axel Kühn	Ulrich Strohmeyer
Wolfgang Kühn (abgeordnet vom MPI für Strömungsforschung)	Werner Tappert
Wolfgang Kühne	Markus Thiele
Dipl.-Ing. Alexander Loose	Dipl.-Ing. Jörg Trautner
Olaf Matuscheck	Thomas Tzscheetzsch
Dipl.-Ing. Reinhard Meller	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, Bastian Kamphenkel, Roland Mende, Norbert Meyer, Thorsten Meyer, Egon Pinnecke, Walter Schmidt, Werner Steinberg

*Schlosserei:* Hans-Joachim Heinemeier

*Galvanik-Siebdruck:* Hans-Adolf Heinrichs, Joachim Weiß, Walter Wächter

**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:* Sylvia Aue, Dagmar Bönighausen, Ilona Brandt, Monika Doucet-Hitscher, Oxana Dunkel, Cornelia Fahlbusch, Sinaida Großkopf, Jennifer Hagemann, Dagmar Haarmann, Ilona Hisgen, Nana Heine, Astrid Karl, Monika Link, Anna Macke, Beate Meyer, Rita Pfeiff, Gudrun Müller, Maria Müller, Birgit Podritzki, Rosemarie Poppe, Inge Reuter, Lucia Ristau, Claudia Rudolph, Edeltraud Rümke, Manuela Schmidt, Margarete Schmidt, Maria Schmidt, Danuta Waßmann, Heidemarie Weber, Irmtraut Wolf

*Küche:* Johannes Kohlrantz, Marlis Borghold, Lilli Dargel, Monika Hale, Beate Meyer

**Ausbildung/Training:**

*Feinmechanik:* Roland Mende, Walter Schmidt, Norbert Meyer

*Elektrotechnik:* Manfred Güll

*Auszubildende:* Christian Biermann, Albert Dargel, David Enge, Julian Fellmann, Florian Frydetzki Christopher Geile, Simon Geile, Axel Gloth, Marcel Gruschka, Marius Hellmold, Torben Hillebrand, Daniel Hoffmann, Hendrick Jakob, Rainer Jünemann, Stephan Kellner, Thomas Kerl, Sebastian Kliemand, Martin Koch, Alexander Kornehl, Sven Krenauer, Till Kremser, Thilo Kröning, Mario Kücking, Ron Lieneemann, Henning Lohrengel, Artur Mass, Vitalij Mass, Sören Mende, Christian Menge, Hendrick Meierkord, Thorsten Meyer, Fiete Paul Miegwitz, Sebastian Neumann, Janet Nickel-Rilling, Sebastian Poppe, Tobias Regenhardt, Karsten Ropte, Christian Rust, Sebastian Schettler, Markus Thiele, Ralf Triller, Dennis Weber, Dennis Ziemann, Christian Zinke.

**Dokumentation, Konstruktion**/Documentation, construction:

Leitung: Wolfgang Engelhardt  
 Anita Brandt, Bernd Chares, Bernhard Goll, Marianne Krause,  
 Jürgen Wedekind

**Bibliothek**/Library:

Prof. Dr. Klaus Jockers (wissenschaftlicher Bibliotheksbeauftragter)  
 Marianne Hartmann, Inge Kraeter, Renate Meusel

**Öffentlichkeitsarbeit**/Public relations: Prof. Dr. Kristian Schlegel, Dr. Bernd Wöbke**Redaktion der Instituts-Informationen**/Editor of the institute newsletter:

Dr. Reinhard Borchers

**Sekretariate der Direktoren**/Secretariats of the directors:

Sabine Deutsch, Susanne Kaufmann, Rosemarie Röttger, Barbara Wieser

**Sekretariate**/Secretariats:

Anja Behrens, Gerlinde Bierwirth, Marianne Ebbighausen, Petra Fahlbusch, Ingeborg Güttler, Elke Hartmann, Karin Kellner, Andrea Macke, Maria Mühlhaus, Helga Oberländer, Karin Peschke, Helga Reuter, Ingrid Schrader, Sibylla Siebert-Rust, Ute Spilker, Margit Steinmetz, Sabine Stelzer, Andrea Vogt, Marita Wassermeyer

**Verwaltung**/

## Administration:

Andreas Poprawa (Verwaltungsleiter)  
 Jürgen Bethe, Bernhard Bleckert, Roswitha Komossa, Andrea Macke, Dorothee Schreiber

*Auszubildende*/Apprentices:

Axel Gloth, Sandra Hillebrecht, Nadine Senger, Martina Schlemme,  
 Nadine Teichmann

*Personalbüro*/Personell office:

Edith Deisel, Christiane Neu

*Einkauf*/Goods received:

Klaus-Dieter Hagen, Monika Majunke, Ilse Schwarz, Christina Thomitzek, Bernhard Vogt

*Buchhaltung*/Book-keeping:

Martina Heinemeier, Inge Kurtoglu, Andrea Werner

*Sonstige Dienste*/Other services:

Helga Haupt, Renate Heitkamp, Inge Reuter, Robert Uhde

**Doktoranden**/Ph.D. students

*Doktoranden, die in den Jahren 2000 und 2001 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 2000 and 2001; Higschool, supervisor at highschool and at MPAE, start and title of thesis in brackets.*

Dipl.-Phys. *Michael Bantin* (Universität Göttingen, Institut für Geophysik, Prof. Dr. K. Bahr – Prof. Dr. K. Schlegel; 15. Juni 1997 – 23. Oktober 2000. Schwerewellen und Gezeiten der polaren Hochatmosphäre).

Dipl.-Phys. *Juan Manuel Borrero-Santiago* (Universität Göttingen, Prof. F. Kneer – Prof. S.K. Solanki; 3. September 2001. Inversion of the stokes profile).

Dipl.-Phys. *Antonio Casares*, (Universität Gießen, Prof. H. Wollnik – Dr. H. Rosenbauer; 1. September 1999 – 30. Juni 2001. Aufbau und Inbetriebnahme des Multi-Reflexions-Massenspektrometers für das COSAC-Experiment im Rahmen der Rosetta-Mission).

Dipl.-Phys. *Kerstin Cierpka*, (Universität Göttingen, Institut für Geophysik, Prof. Dr. U. Christensen – Prof. Dr. K. Schlegel; 20. März 1999. Auswertung und Interpretation von Fabry-Perot- und EISCAT-Daten).

Dipl.-Phys. *Suiyan Fu* (Technische Universität Braunschweig, Institut für Geophysik und Meteorologie, Prof. Dr. K.-H. Glaßmeier – Dr. B. Wilken; 1. Dezember 1997. Ion composition in the inner magnetosphere and relation to geomagnetic activity).

Dipl.-Phys. *Michael Heuer* (Universität Göttingen, Prof. F. Kneer – Prof. 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 and SOHO observations).

Dipl.-Phys. *Tra-Mi Ho* (Universität Göttingen, Prof. F. Kneer – Dr. N. Thomas, Prof. K. Jockers; 1. Februar 2001. 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. *Thomas Horvath* (Universität Gießen, Prof. H. Wollnik – Dr. S. Livi; 1. Mai 1998 – 28. Februar 2001. Ausbau der statischen und gepulsten Versorgungsgeräte eines Flugzeitspektrometers für einen Weltraumeinsatz auf dem Gebiet Projekt RTOF/ROSETTA).

Dipl.-Phys. *Huixin Liu* (Wuhan University, Wuchang, China, Prof. S. Ma – Prof. Dr. K. Schlegel; 1. Oktober 1998 – 18. Mai 2001. EISCAT observations and solar terrestrial relations).

Dipl.-Phys. *Guillermo Munoz-Caro* (Universität Leiden, Niederlande, Prof. M. Greenberg – Dr. H. Rosenbauer; 1. Oktober 1998. From photoprocessing of interstellar ice to amino acids and other organics).

Dipl.-Phys. *Oliver Preuß* (Universität Bielefeld, Prof. Dr. B. Peterson – Prof. Dr. S.K. Solanki; 1. Dezember 1999. Astronomische Tests von Gravitationstheorien).

Dipl.-Phys. *Matthias Rempel* (Universität Göttingen, Universitätssternwarte, Priv.Do. Dr. D. Schmitt, Prof. Dr. F. Kneer – Prof. Dr. M. Schüssler; 1. Januar 2000 – 26. Juni 2001. Erzeugung von Magnetfeldern am Boden der Konvektionszone).

Dipl.-Phys. *Santo Valentin Salinas Cortijo* (Universität Göttingen, Prof. F. Kneer – Dr. H.U. Keller, 27. April 2000. Multidimensional radiative transfer modelling of Titan's atmosphere).

Dipl.-Phys. *Sergiy Shelyag* (Universität Göttingen, Prof. Dr. F. Kneer – Prof. Dr. S.K. Solanki, Prof. M. Schüssler; 1. August 2001. Simulations of solar magnetoconvection and their interpretation).

Dipl.-Phys. *Ilya Silin* (Technische Universität Braunschweig, Prof. U. Motschmann – Dr. J. Büchner; 1. Oktober 2001. Theory and simulation of kinetic plasma instabilities).

Dipl.-Phys. *Guillermo Stenborg* (Universität Göttingen, Prof. F. Kneer – Prof. Dr. R. Schwenn; 1. Juli 1999 – 21. Juni 2000. Beobachtung schneller dynamischer Vorgänge in der inneren Sonnenkorona).

Dipl.-Ing. *Geronimo Villanueva* (Universität Clausthal-Zellerfeld, Prof. U. Konigorski – Dr. P. Hartogh; 17. März 2001. CTS-chirp transform spectrometer for SOFIA, the stratospheric observatory for infrared astronomy).

Dipl.-Phys. *Christian Vocks* (Universität Braunschweig, Prof. Glaßmeier – Prof. E. Marsch; 1. März 1998 – 7. Februar 2001. Nichtgleichgewichtsprozesse in koronaler Plasmakopplung von Wellen, Teilchen und Strahlung).

Dipl.-Phys. *Alexander Vögler* (Universität Göttingen, Universitätssternwarte, Prof. Dr. F. Kneer – Prof. Dr. M. Schüssler; 1. Februar 2000. 3D-Simulation von solarer Magnetokonvektion).

Dipl.-Phys. *Peter Vollmöller* (Universität Göttingen, Universitätssternwarte, Prof. Dr. F. Kneer – Prof. Dr. M. Schüssler; 1. Februar 2000. 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. MHD and particle processes for the acceleration of the solar wind by observations of SUMER/SOHO).



## VI. 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, der DFG und Honorar-  
empfänger/  
Stipend holders of the MPG and the DFG)

*Laura Balmaceda*, University of San Juan, Argentinien, 12. November – 18. Dezember 2000. Zusammenarbeit mit Prof. R. Schwenn, B. Podlipnik, Dr. G. Stenborg.

*Dr. M. Banaszkiwicz*, Space Research Centre, Polish Academy of Sciences, Warschau, Polen, 15. August – 30. September 2001. Zusammenarbeit mit Dr. M. Witte.

*Dr. Janos Bogdany*, KFKI, Institute for Particle and Nuclear Physics, Budapest, Ungarn, 9. Januar – 31. Dezember 2000. Zusammenarbeit mit Dr. H. Rosenbauer.

*Dr. Vladimir I. Bogillo*, Laboratory of Antarctic Ecology, Institute of Geological Sciences, National Academy of Sciences, Kiev, Ukraine, 1. – 31. August 2001. Zusammenarbeit mit Dr. R. Borchers.

*Dr. Tanyu Bonev*, Institute of Astronomy, Bulgarian Academy of Sciences, Sofia, Bulgarien, 26. Februar – 10. Juni 2001 und 1. September – 17. November 2001. Farbe des Staubes von Komet C/1999 S4 (LINEAR). Zusammenarbeit mit Prof. Dr. K. Jockers.

*Dr. Nikolai D. Borissov*, IZMIRAN, Troitsk, Moscow Region, Russland, 4. Juli – 30. September 2001. Zusammenarbeit mit Prof. T. Hagfors und Dr. U. Mall.

*Dr. Tamara Breus*, Space Research Institute, Russian Academy of Sciences, Moskau, Russland, 6. November 1999 – 4. März 2000, 3. Juli – 5. August 2000, 18. Dezember 2000 – 1. Februar 2001, 31. Juli – 17. Dezember 2001. Solar wind interaction with Mars – effects on topside ionosphere; historical project. Zusammenarbeit mit Prof. W.I.

Axford.

*Dr. Jin Chang*, Purple Mountain Observatory, Nanjing, VR China, 11. Juni 2000 – 28. August 2001. Zusammenarbeit mit Dr. W.K.H. Schmidt.

*Dr. Zuyin Chen*, University of Peking, Beijing, China, 20. Juli 1998 – 30. Juni 2000. Zusammenarbeit mit Dr. A. Korth.

*Jorge Costa*, Vitry sur Seine, Frankreich, 11. Februar 2000 – 28. Februar 2001. Zusammenarbeit mit Dr. H.U. Keller.

*Dr. Andrzej Czechowski*, Space Research Centre, Polish Academy of Sciences, Warschau, Polen, 28. Juli – 8. September 2000, 2. November – 2. Dezember 2000, 1. – 31. Mai 2001, 2. August – 9. Oktober 2001. Propagation and acceleration of cosmic rays in the outer heliosphere and the interstellar medium; acceleration of cosmic rays by shocks. Zusammenarbeit mit Prof. J.F. McKenzie.

*Alisson Dallago*, INPE Sao José dos Campos, Brasilien, 1. Oktober 2000 – 31. März 2001. Zusammenarbeit mit Prof. R. Schwenn, B. Podlipnik und G. Stenborg.

*Prof. Terry B. Doyle*, School of Pure and Applied Physics, University of Natal, Durban, Südafrika, 18. Juli – 1. September 2001. Theoretical investigation of the structure of solitons in a magnetized plasma. Zusammenarbeit mit Prof. J.F. McKenzie.

*Dr. Eduard Dubinin*, Space Research Institute, Russian Academy of Sciences, Moskau, Russland, 26. Juni – 30. September 2000, 1. Januar 2001 – 31. Dezember 2001. Physik von Multi-Ionen-Plasmen. Zusammenarbeit mit Prof. K. Sauer

*Dr. Bhola N. Dwivedi*, Department of Applied Physics, Institute of Technology, Banaras Hindu University, Varanasi, India, Juni 2000. Zusammenarbeit mit Dr. K. Wilhelm und Dr. W. Curdt.

*Dr. Stephane Espinosa*, Space and Atmospheric Physics, Blackett Laboratory, Imperial College, London, UK, 9. Mai – 8. November 2001. Zusammenarbeit mit Dr. N. Krupp.

*Dr. A. Ferriz-Mas*, Facultad de Ciencias, Orense, Spanien, 23. Oktober – 12. November 2000 und 4. – 12. Dezember 2000. Zusammenarbeit mit Prof. M. Schüssler.

*Dr. F. Frutos-Alfaro*, Universidad de Costa Rica, Escuela de Física, San Pedro, Costa Rica, 15. März 2000 – März 2003. Zusammenarbeit mit Dr. A. Korth.

*Suiyan Fu*, Department of Geophysics, Peking University, Beijing, China, 1. Dezember 1997 – 30. November 2000; 19. Januar 2001 – 30. April 2001. Zusammenarbeit mit Dr. B. Wilken.

*Dr. O.S. Gadun*, Main Astronomical Observatory, National Academy of Sciences of Ukraine, Kiev, Ukraine, 1. März – 30. April 2000. Simulations of MHD granulation. Zusammenarbeit mit Prof. M. Schüssler und Prof. S.K. Solanki.

*Dr. Savely Grach*, Scientific and Research Radiophysical Institute (NIRFI), Nizhny Novgorod, Russland, 20. September – 20. Dezember 2001. Zusammenarbeit mit Prof. P. Stubbe.

*Prof. Christos Haldoupis*, Department of Physics, University of Crete, Iraklion, Crete, Griechenland, 16. Juni – 30. August 2001. E-region plasma instabilities. Zusammenarbeit mit Prof. K. Schlegel.

*Dr. Petr Heinzl*, Astronomical Institute, Ondrejow, Tschechien, Juli 2000, Oktober 2001. Zusammenarbeit mit Dr. W. Curdt.

*Dr. Stubbe Hviid*, Universität Kopenhagen, Dänemark, 7. Juni 1999 – 7. Juni 2001. Zusammenarbeit mit Dr. H.U. Keller.

*Ai Inada*, Kobe University, Japan, 1. Juni 2000 – 30. November 2001. Zusammenarbeit mit Dr. W.J. Markiewicz und Dr. H.U. Keller.

*Alexandre Kholomeev*, Universität Gießen, 2. März 1999 – 30. April 2001. Zusammenarbeit mit Dr. H. Rosenbauer.

*Dr. Hiroshi Kimura*, Dept. of Physics, University of Kobe, Kobe, Japan, 1. April 1996 – 31. Dezember 2000. Zusammenarbeit mit Dr. I. Mann.

*Dr. Nikolaj N. Kiselev*, Astronomical Observatory, Kharkiv State University, Kharkiv, Ukraine, 1. Oktober – 30. November 2001. Interpretation von Polarisationsmessungen von Kometenstaub. Zusammenarbeit mit Prof. Dr. K. Jockers.

*Dr. Konrad Kossacki*, Warsaw University, Polen, 7. Juli – 30. September 2001. Zusammenarbeit mit Dr. W. Markiewicz.

*Thijs Krijger*, Sterrekundig Instituut, Utrecht, Niederlande, Juli 2000, Oktober 2001. Zusammenarbeit mit Dr. W. Curdt.

*Dr. Alexander Krivov*, Astronomical Institute, St. Petersburg University, St. Petersburg, Russland, 1. August 1999 – 31. Juli 2000. Zusammenarbeit mit Dr. I. Mann.

*Dr. Natalia Krivova*, Astronomical Institute, St. Petersburg University, St. Petersburg, Russland, seit 1. August 1999. Zusammenarbeit mit Dr. P. Hartogh, Dr. I. Mann und Prof. S.K. Solanki.

*Koji Kubo*, (Stipendiat der Japan Society for the Promotion of Research) Radio Science Center for Space and Atmosphere, Kyoto University, Japan, September 2000 – Juni 2001. Zusammenarbeit mit Dr. J. Röttger.

*Irina Kulyk*, Main Astronomical Observatory, National Academy of Sciences, Goloseevo bei Kiew, Ukraine, 7. Juni – 20. Juli 2001. Photometrie der inneren Jupitermonde. Zusammenarbeit mit Prof. Dr. K. Jockers.

*Dr. Enrico Landi*, Department di Astronomia e Scienza Dello Spazio, Universität Florenz, Italien, 29. Juni 1999 – 30. Juni 2002. Zusammenarbeit mit Prof. S. Solanki und Dr. K. Wilhelm.

*Prof. Dr. Alexander Lipatov*, Dialogue Science Computing Center, Russian Academy of Sciences, Moskau, Russland, 1. Juli – 31. Oktober 2000. 2D-Hybridcode-Simulationen für Mars und Kometen. Zusammenarbeit mit Prof. K. Sauer; 8. September – 31. Oktober 2001. Zusammenarbeit mit Dr. J. Büchner.

*Prof. Shaoliang Liu*, Department of Earth and Space Sciences, University of Science and Technology of China, Heifei, Anhui, VR China, 1. November 2000 – 31. Januar 2001. Zusammenarbeit mit Dr. B. Wilken.

*Dr. Shibu K. Mathew*, Indian Institute of Astrophysics, Bangalore, Indien, 1. September 2000 – 31. August 2002. Solar optical instrumentation. Zusammenarbeit mit Dr. U. Schühle und Prof. R. Schwenn.

*Prof. Andrei Mikhailov*, IZMIRAN, Troitsk, Moscow Region, Russland, 1. – 31. Oktober 2000. Ionosphere-thermosphere interaction. Zusammenarbeit mit Prof. K. Schlegel.

*Rumi Ohgaito*, Kobe University, Nada Kobe, Japan, 9. August 1999 – 31. Juli 2000. Zusammenarbeit mit Dr. I. Mann.

*Dr. Elena V. Petrova*, Space Research Institute, Russian Academy of Sciences, Moskau, Russland, 1. Mai – 31. August 2000, 1. Februar – 15. April 2001. Streuung von Sonnenlicht an kometa- ren Staubteilchen. Zusammenarbeit mit Prof. Dr. K. Jockers und Dr. W. Markiewicz.

*Dr. S.R.O. Ploner*, Institut für Astronomie, ETH Zürich, Schweiz, 1. Januar 2000 – 30. November 2001. Solare Magnetohydrodynamik. Zusammen- arbeit mit Prof. M. Schüssler und Prof. S.K. So- lanki.

*Dr. Romana Ratkiewicz*, Space Research Centre, Polish Academy of Sciences, Warschau, Polen, 3. – 28. April 2000, 6. November – 5. Dezember 2000, 2. Mai – 30. Juli 2001. Origin of the solar wind: plumes. Zusammenarbeit mit Prof. J.F. McKen- zie.

*Dr. Anatoli Remizov*, Space Research Institute, Russian Academy of Sciences, Moskau, Russland, 20. März – 30. Juni 2000. Zusammenarbeit mit Dr. H. Rosenbauer.

*Dr. Susumu Saito*, Solar-Terrestrial Environment Laboratory (STEL), Nagoya University, Japan, Juni 2001. EISCAT. Zusammenarbeit mit Prof. T. Hagfors.

*Dr. V.A. Sheminova*, Main Astronomical Obser- vatory, National Academy of Sciences of Ukraine, Kiev, Ukraine. 1. März – 30. April 2000. Simulati- ons of Stokes profiles with MHD models. Zusam- menarbeit mit Prof. M. Schüssler und Prof. S.K. Solanki.

*Dr. Yuri Skorov*, Department of Planetary Phy- sics, Keldysh Institute of Applied Mathematics, Moskau, Russland, 16. Juni 2001 – 31. Mai 2002. Zusammenarbeit mit Dr. H.U. Keller.

*Dr. Nandita Srivastava*, Udaipur Solar Observa- tory, Udaipur, Indin, 1. September 1999 – 29. Februar 2000. Zusammenarbeit mit Prof. Dr. R. Schwenn.

*Dr. Guillermo Stenborg*, IAFE University, Buenos Aires, Argentinien, 1. Juli 2000 – 31. Dezember 2002. Zusammenarbeit mit Prof. R. Schwenn.

*Dr. Galina Sukhorukova*, IZMIRAN, Troitsk, Moskau Region, Russland, 6. April 1994 – 31. März 2000. Zusammenarbeit mit Prof. Sir Ian Axford, Prof. T. Hagfors, Dr. G. Hartmann, Dr. P. Hartogh, Dr. W. Markiewicz, und Dr. J.F. McKenzie.

*Dr. Karlheinz J. Trattner*, Lockheed Martin ATC, Palo Alto, CA, USA, 24. September – 20. Dezem-

ber 2001. Zusammenarbeit mit Dr. A. Korth.

*Prof. C.-Y. Tu*, Peking University, Beijing, Chi- na, 1. Oktober 2000 – 31. Januar 2001: Auswer- tung von Daten des EUV-Spektrometers SUMER auf SOHO. Auswertung der Plasmadaten der He- liosmission und Analyse von Plasmastabilitäten. Theoretische Arbeiten zur Koronaheizung und zur Beschleunigung des Sonnenwindes. 1. August – 31. Oktober 2001: Analyse der Pitchwinkelstreuung von Protonen im Sonnenwind. Zusammenarbeit mit Prof. E. Marsch.

*Dr. Hiroko O. Ueda*, Department of Urban Envi- ronment and Systems, Chiba University, Chiba, Japan, 21. Juni 1999 – 13. Januar 2000. Ionos- pheric plasma instabilities. Zusammenarbeit mit Prof. K. Schlegel.

*Prof. Jingsong Wang*, Department of Geophysics, Peking University, Beijing, China, 21. Februar 2001 – 31. Dezember 2002. Zusammenarbeit mit Dr. E. Nielsen.

*Dr. Tongjiang Wang*, National Astronomical Ob- servatories, Beijing, VR China, 5. Juni 2001 – 5. Juni 2003. SUMER-Datenanalyse. Zusammen- arbeit mit Prof. S.K. Solanki und Dr. K. Wilhelm.

*Dr. Thomas Wiegmann*, Universität Bochum, 15. November 1998 – 30. September 2000; 8. Januar – 2. Februar 2001. Zusammenarbeit mit Dr. J. Büchner. 10. Dezember 2001 – 18. Januar 2002. SECCHI/STEREO-Projekt. Zusammen- arbeit mit Dr. B. Inhester.

*Prof. L.M. Zelenyi*, Space Research Institute of the Russian Academy of Sciences, Moscow, Russ- land, 15. Oktober – 22. Dezember 2000. Zusam- menarbeit mit Dr. J. Büchner und Dr. B. Niku- towski.

*Dr. Jun Zhang*, National Astronomical Observa- tories, Beijing, VR China, 19. Juni 2001 – 19. Juni 2003. Solare Magnetfelder und ihre koronale Ma- nifestation. Zusammenarbeit mit Prof. S.K. So- lanki und Dr. K. Wilhelm.

*Prof. Min-yun Zi und Dr. Chang-shou Shen*, De- partment of Geophysics, Peking University, Bei- jing, China, 2. April – 3. August 2001. High- latitude convection. Zusammenarbeit mit Dr. H. Rosenbauer und Prof. K. Schlegel.

*Q.-G. Zong*, Center for Space and Physics, Boston University, Boston, MA, USA, 18. Dezember 1996 – 30. Juni 2001. Zusammenarbeit mit Dr. P.W. Daly und Dr. A. Korth.

**Wissenschaftler, die als Gäste nur kurzzeitig am MPAE tätig waren/**  
Scientific guests with short-term visits to MPAE

*Dr. Hermann Böhnhardt*, VLT Paranal Observatory, ESO, Chile, 28. Februar – 3. März 2001. Zusammenarbeit mit Prof. S.K. Solanki.

*Dr. José Castro*, University of San Juan, Argentinien, 19. November – 9. Dezember 2001. Zusammenarbeit mit Prof. R. Schwenn, B. Podlipnik und Dr. G. Stenborg.

*Prof. Fausto Cattaneo*, University of Chicago, USA, 30. August – 6. September 2001. Zusammenarbeit mit Prof. M. Schüssler.

*Dr. Thierry Emonet*, University of Chicago, USA, 30. August – 6. September 2001. Zusammenarbeit mit Prof. M. Schüssler.

*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, 27. – 31. August 2001. Zusammenarbeit mit Prof. Dr. V.M. Vasyliunas.

*Matthias Frische*, GEOMAR Forschungszentrum für marine Geowissenschaften, Abt. Vulkanologie und Petrologie, Universität Kiel, mehrere Kurzbesuche in 2001. Zusammenarbeit mit Dr. R. Borchers.

*Laurent Gizon*, Hansen Experimental Physics Laboratory, Stanford University, Stanford, CA, USA, 28. Mai – 25. Juni 2001. Asteroseismologie. Zusammenarbeit mit Prof. S.K. Solanki.

*Dr. Glenn C. Hussey*, Institute of Space and Atmospheric Studies, Department of Physics and Engineering Physics, University of Saskatchewan, Saskatoon, Kanada, 18. – 30. Juni 2001. Zusammenarbeit mit Prof. K. Schlegel.

*Emilia Huttunen*, Finnish Meteorological Institute Helsinki, Finnland, 20. Mai – 10. Juni 2001 und 11. – 30. November 2001. Zusammenarbeit mit Prof. R. Schwenn, B. Podlipnik, Dr. G. Stenborg.

*Frank Keppler*, Institut für Umwelt-Geochemie, Universität Heidelberg, mehrere Kurzbesuche in 2001. Zusammenarbeit mit Dr. R. Borchers.

*Elena Khomenko*, Main Astronomical Observatory, Kiev, Ukraine, 28. Januar – 24. Februar, 18. November – 16. Dezember 2001. Zusammenarbeit mit Prof. S.K. Solanki.

*Prof. Wlodek Kofman*, Batiment D de Physique, Laboratoire de Planetologie de Grenoble, Saint Martin d'Hères Cedex, Frankreich, 6. – 12. August 2000. MARSIS, Consert. Zusammenarbeit mit Prof. T. Hagfors.

*Dr. Konrad Kossacki*, Warsaw University, Polen, 27. März – 21. April 2000, 17. – 24. September 2000. Zusammenarbeit mit Dr. W. Markiewicz.

*Dr. Pieter Kotzè*, Hermanus Magnetic Observatory, Hermanus, SA, 20. November – 17. Dezember 2000. Zusammenarbeit mit Dr. J. Büchner.

*Dr. Kostas Kourtidis*, Laboratory of Atmospheric Physics, Physics Department, Aristotle University of Thessaloniki, Thessaloniki, Griechenland, 31. Juli – 4. August 2001. Zusammenarbeit mit Dr. R. Borchers.

*Dr. Vjatcheslav Kunitsyn*, Physics Department, Moscow State University, Russland, 27. – 28. Juni 2000. MARSIS, Consert. Zusammenarbeit mit Prof. T. Hagfors.

*Dr. Richard Lieu*, Dept. of Physics, University of Alabama, Huntsville, AL, USA, 28. Juli – 5. August 2000, 3. – 20. August 2001. Micro-relativity (the Lorentz transformation of Planck time scale uncertainties). Zusammenarbeit mit Prof. W.I. Axford.

*Maria Loukitcheva*, Astronomical Institute, State University, Sankt Petersburg, Russland, 7. – 29. Februar 2000, 5. – 30. November 2000. Struktur der Sonnenchromosphäre. Zusammenarbeit mit Prof. S.K. Solanki.

*Dr. G. Mann*, Astrophysikalisches Institut Potsdam, Observatorium für solare Radioastronomie, 17. – 21. Januar 2000, 5. – 8. November 2001. Zusammenarbeit mit Prof. E. Marsch.

*Dr. G. Mann und Dr. C. Claßen*, Astrophysikalisches Institut, Potsdam, 2000. Zusammenarbeit mit Dr. E. Keppler.

*Prof. Donald R. Moorcroft*, Department of Physics, University of Western Ontario, London, Ontario, Kanada, 10. – 12. Oktober 2000. Zusammenarbeit mit Prof. K. Schlegel.

*Prof. Dr. F. Moreno Inertis*, Instituto de Astrofísica de Canarias, Teneriffa, Spanien, 28. Oktober – 7. November 2001. Zusammenarbeit mit Prof. S.K. Solanki.

*Dr. Yasushi Muraki*, Solar-Terrestrial Environment Laboratory (STEL), Nagoya University, Japan, 29. Januar – 1. Februar 2001. Cosmic ray

origin and gamma ray sources. Zusammenarbeit mit Prof. W.I. Axford.

*Coralie Neiner*, Observatoire de Meudon, Paris, Frankreich, 19. August – 1. September 2001. Zusammenarbeit mit Prof. S.K. Solanki.

*Katariina Nykiri*, University of Alaska, Fairbanks, Kanada, 4. November – 8. Dezember 2001. Zusammenarbeit mit Dr. J. Büchner.

*Prof. K.-I. Nishikawa*, University of New Jersey, USA, 20. November - 4. Dezember 2000. Zusammenarbeit mit Dr. J. Büchner.

*Dr. Stanislav Perov*, Central Aerological Observatory, Moscow Region, Russland, 26. – 28. Februar 2001. Zusammenarbeit mit Dr. R. Borchers.

*Dr. Alexander Sadowski*, Space Research Institute, Moscow, Russland, 11. – 25. Dezember 2001. Zusammenarbeit mit Dr. J. Büchner.

*Dr. S. Savin*, Space Research Institute, Moscow, Russland, 15. Juni – 12. August 2001. Zusammenarbeit mit Dr. J. Büchner.

*Prof. Dr. Dayal T. Wickramasinghe*, Australian National University, Canberra, Australien, 11. – 15. August 2001. Zusammenarbeit mit Prof. S.K. Solanki.

**Wissenschaftler, die als Gäste am MPAE vom Deutschen Akademischen Austauschdienst (DAAD) gefördert worden sind/Scientific guests at MPAE sponsored by the DAAD**

*Huixin Liu*, Department of Space Physics, Wuhan University, Wuhan, China, 1. Oktober 1998 – 31. Dezember 2000. Doktorandin im Sandwich-Programm, Betreuer: Prof. K. Schlegel.

*Dr. Yaroslav Ilyushin*, Physics Department, Moscow State University, Russland, 1. Februar – 30. April 2000. Consort. Zusammenarbeit mit Prof. T. Hagfors.

*Dr. Nikolaj N. Kiselev*, Astronomical Observatory, Kharkiv State University, Kharkiv, Ukraine, 5. August – 30. September 2001. Properties of dust of unique comet C/1999 S4 (LINEAR) before and after break-up. Zusammenarbeit mit Prof. Dr. K. Jockers.

*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**

*Prof. C.H. Barrow*, Observatoire de Meudon, France, 24. – 29. April, 19. Juni – 11. Juli 2000, 17. – 31. Januar 2001. Zusammenarbeit mit Dr. A. Lecacheux (Ulysses/URAP) und Dr. P. Zarka (INTAS).

*Prof. Tor Hagfors*, Physics Institute, University of Tromsø, Norwegen, 14. März – 17. April 2000; Solar-Terrestrial Environment Laboratory (STEL), Nagoya University, Japan, 1. November 2000 – 3. Februar 2001; Dept. of Communication Systems, Lancaster University, UK, 1. Oktober – 13. November 2001.

*Prof. Dr. Klaus Jockers*, Pik Terskol Observatorium (Nordkaukasus), Internationales Zentrum für Astronomische und Medizinisch-Ökologische Forschung (Goloseevo bei Kiew), 7. – 28. Juli 2000, 28. Oktober – 2. Dezember 2000. Beobachtungen des Kometen C/1999 S4 (Linear), des Io-Torus, der inneren Jupitermonde, des Merkur und des mit AB Aurigae assoziierten Reflexionsnebels, mit dem 2m-Zeiss-RCC-Teleskop und dem Zweikanal-Fokalreduktor des MPAE, 8. November – 11. Dezember 2001.

*Dr. M. Kosch*, University of Lancaster, Lancaster, England, 18. August – 29. September 2000. Arbeiten an DASI- und IRIS-Daten (Imaging Riometer for Ionospheric Studies) zwecks Weitwinkel-Energiebilder von einfallenden Teilchen.

*Dr. Jürgen Röttger*, 3 Wochen im Oktober 2000: National Central University, Chung-Li, Taiwan; 1,5 Wochen im Juni 2001: Radio Science Center for Space and Atmosphere, Kyoto University, Japan; September-Oktober (6 Wochen) 2001: Professor adjunct, Institute of Space Science, National Central University, Chung-Li, Taiwan.

*Santo Salinas*, Jet Propulsion Laboratory, Pasadena, USA, 7. November 2000 – 7. Februar 2001.

*Dr. W.K.H. Schmidt*, Purple Mountain Observatory, Nanjing, VR China, 29. April – 18. Mai 2001.

*Prof. Dr. V.M. Vasyliūnas*, Center for Atmospheric Research, University of Massachusetts, Lowell, USA, 20. – 27. März 2001.

*K. Wilhelm, W. Curdt, D. Germerott, D.E. Innes, E. Landi, U. Schühle*, Goddard Space Flight Center, Greenbelt, MD, USA und MEDOC, Or-

say, Frankreich, 2000, 2001 wiederholt zum Betrieb des SUMER-Spektrometers auf SOHO.

Alexander Vögler, University of Chicago, USA, 6 Monate in 2001.

**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.*

**ATIC: Advanced Thin Ionization Calorimeter.-**

The ATIC Collaboration, Principal Investigator is J.-P. Wefel, J. Adams Jr. (2), J. Ampe (2), G. Bashindzhagyan (4), P. Boberg (2), G. Case (1), J. Chang (7), S. Ellison (1), A. Fazely (5), O. Ganel (3), R. Gould (1), D. Granger (1), R. Gunasingha (5), T.G. Guzik (1), J. Isbert (1), L. Khein (4), M. Kher (1), D. Khettry (1), H.J. Kim (6), K.C. Kim (3), S.K. Kim (6), I.M. Koo (6), Y. Kwon (6), L. Kommajasyula (1), R. Kroeger (2), R. Lockwood (1), R. Mohan (1), M. Panasyuk (4), B. Price (1), G.A. Samsonov (4), W.K.H. Schmidt (7), C. Schwarz (2), M. Sen (1), E.S. Seo (3), R. Sina (3), M. Stewart (1), A. Voronin (4), D. Wagner (2), J.Z. Wang (3), J.P. Wefel (1), J. Wu (3), V. Zatsepin (4)

(1): Louisiana State University, Baton Rouge, LA, USA; (2): Naval Research Laboratory, Washington, D.C. USA; (3): University of Maryland, College Park, MD, USA; (4): Moscow State University, Moscow, Russland; (5): Southern University, Baton Rouge, LA, USA; (6): Seoul National University, Seoul, Südkorea; (7): Max-Planck-Institut für Aeronomie.

**ATLAS-MAS-DAT (Nicht hierarchische Dokumentation und vertieftere, interaktive Validation von Zeitreihendaten der Erdatmosphäre: Eine Pilotstudie unter Verwendung der ATLAS-MAS-Daten).-** G.K. Hartmann und M.L. Richards, MPAE, in Zusammenarbeit mit G. Schneppe, DARA (Management) und R. Kruse, Universität Magdeburg; P. Behr, Science Softline, Frankfurt; A. Noelle, Science SoftCon, Maintal; M. Skorsky,

NAVICON, Frankfurt; G. Kirchengast, Universität Graz, Österreich; J.J. Olivero, Embry Riddle University, Daytona Beach, FL, USA; R. Bevilacqua, M. Daehler, Naval Research Laboratory, Washington, DC, USA; M. Abbas, NASA MSFC, Huntsville, AL, USA; G. Thomas, Colorado University, Boulder, CO, USA; H. Kroehl, WDC-A-STP, Boulder, CO, USA; E. Puliafito, Universität Mendoza, Argentinien; E. Amthauer, Universität Concepcion, Chile; A. Ebel, Institut für Geophysik und Meteorologie der Universität zu Köln; M. Bittner, DFD-DLR, Oberpfaffenhofen; K. E. Wolff, Fachhochschule Darmstadt; K. H. Weber, Fachinformationszentrum Karlsruhe; Dr. L. Weißflog, Umweltforschungszentrum Leipzig-Halle GmbH.

**CARIBIC (Civil Aircraft for Remote Sensing and In-Situ Measurement of Troposphere and Lower Stratosphere Based on the Instrument Container).-** Projekt des Max-Planck-Institutes für Chemie, Mainz. R. Borchers in Zusammenarbeit mit C. Brenninkmeijer (MPICH).

**CASSINI-Mission MIMI Magnetospheric Imaging Instrument (MIMI) on the Cassini Mission to Saturn/Titan.-** Principal Investigator: ..... S.M. Krimigis (JHUAPL), D.G. Mitchell (JHUAPL), D.C. Hamilton (U.M.), S. Livi (JHUAPL), J. Dandouras (CESR), S. Jaskulek (JHUAPL), T.P. Armstrong (UKANS), J.D. Boldt (JHUAPL), A.F. Cheng (JHUAPL), G. Gloeckler (U.M.), J.R. Hayes (JHUAPL), K.C. Hsieh (U.A.), W.-H. Ip (MPAE), E.P. Keath (JHUAPL), E. Kirsch (MPAE), N. Krupp (MPAE), L.J. Lanzerotti (BELL LABS), R. Lundgren (U.M.), B.H. Mauk (JHUAPL), R.W. McEntire (JHUAPL), E.C. Roelof (JHUAPL), C.E. Schlemm (JHUAPL), B.E. Tossman (JHUAPL), B. Wilken (MPAE), D.J. Williams (JHUAPL).

**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, M.J. Rietveld.

**CONCERT auf ROSETTA.**— E. Nielsen, T. Hagfors in Zusammenarbeit mit CEPHAG/CNRS, Grenoble, Frankreich; NDRE, Norwegen; Universität Rom, Italien; Ruhr-Universität Bochum; CNRS-SA, Frankreich; JPL, Los Angeles, USA; ESA/SSD, Niederlande.

**Continuum contrast and thermal structure of faculae.**— S.K. Solanki in Zusammenarbeit mit M. Fligge, T. Wenzler, ETH Zürich, Schweiz; A. Ortiz, University Barcelona, Spanien.

**Coronal holes studied with SUMER and CDS.**— U. Schühle, S.K. Solanki in Zusammenarbeit mit K. Stucki, ETH Zürich, Schweiz.

**Deep Space Mission 1 – PEPE.**— K. Sauer, Co-Investigator.

**Digital All Sky Imager (DASI):** M.J. Kosch in Zusammenarbeit mit der Universität Tromsø, Norwegen.

**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.J. Rietveld, J. Röttger, K. Schlegel.

**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.

**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.

**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.

**EUV variations in the quiet Sun: short-term.**— S.K. Solanki in Zusammenarbeit mit A. Brkovic, H. Peter, Kiepenheuer Institut für Sonnenphysik, Freiburg and I. Rüedi, PMOD-WRC, Davos, Schweiz.

**Fabry-Perot-Interferometer (FPI).**— M.J. Kosch in Zusammenarbeit mit der Universität Trömsø, Norwegen.

**Feinstruktur und Wellen in der Stratosphäre und Troposphäre mit FDI/SDI-Methoden.**— J. Röttger in Zusammenarbeit mit dem Radio Science Center for Space and Atmosphere (RASC) Kyoto University, Japan und Center for Space and Remote Sensing Research (CSRSR) und Institute of Space Science, National Central University, Chung Li, Taiwan.

**Galileo-EPD (Energetic Particles Detector).**— Datenauswertung. N. Krupp, A. Lagg, J. Woch in Zusammenarbeit mit D. Williams, APL, USA.

**Galileo-PLS,** V.M. Vasyliūnas in Zusammenarbeit mit der Universität Iowa, Iowa City, IA, USA.

**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.

**GPS-Atmosphere Sounding.**— Projekt der Helmholtz-Gemeinschaft Deutscher Forschungszentren, beteiligt: K. Schlegel.

**Helio-and asteroseismology, with applications to extrasolar planets.**— S.K. Solanki in Zusammenarbeit mit M. Fligge, ETH Zürich, Schweiz; L. Gizon, Stanford University, USA und IAC, Tenerife, Spanien.

**HIFI-WBS (Heterodyne Instrument for FIRST – Wideband Spectrometer).**- 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 (Omni-sys, Göteborg, Schweden), S. Torchinsky (Chalmers, Göteborg, Schweden), M. Larsson (Universität Stockholm, Schweden), C. Rosolen (Arpeges, Observatoire de Paris, Meudon, Frankreich), M. Salez, (LRM-DEMIRM, 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, Alcalá, 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 (John 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) in Zusammenarbeit mit P. Hartogh, P. Börner, C. Jarchow.

**INTAS project for the investigation by ground-based observations of Mercury.**- N. Thomas in Zusammenarbeit mit L. Ksanfomality, Space Research Institute, Moscow, Russland.

**INTAS-Programm mit ESA.**- Coupling processes between the solar wind and Martian atmosphere/ionosphere. K. Sauer (Koordinator) in Zusammenarbeit mit CETP, Frankreich, IKI, Russland und LCSRI, Ukraine.

**INTAS-Programm.**- Quantitative description of magnetospheric dynamics based on multisatellite and ground observations (1999-2002).

J. Büchner in Zusammenarbeit mit Jean-Andre Sauvaud (Koordinator), CESR, Toulouse, Frankreich.

**INTERBALL Satellit: Relikt-2-INTERBALL-3-Mission.- ESA-Mission Cluster 2 (Nachbau Cluster 1).**- *Experiment RAPID* J. Büchner in Zusammenarbeit mit CESR Toulouse, Frankreich (federführend), MPI Garching, University of New Hampshire, Washington, Seattle, Berkeley, USA, IFSI/CNR, Frascati, Italien, Lockheed, Palo Alto, USA, SISP, Kiruna, Schweden: Plasma- und Teilchensimulationen.

**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.

**Mars-Express Experiment ASPERA-3.**- (Analyzer of Space Plasmas and Energetic Atoms) Entwicklung und Bau des Experimentes. J. Woch, N. Krupp in Zusammenarbeit mit dem IRF Kiruna, Schweden (federführend) und weiteren europäischen und amerikanischen Institutionen.

**MARSIS auf MARS-EXPRESS.**- T. Hagfors in Zusammenarbeit mit INFO-COM Dept., University of Rome, Italien; Jet Propulsion Laboratory, Pasadena, USA; Institute of Radio Engineering and Electronics, Russian Academy of Sciences, Moskau, Russland.

**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. Makiewicz, S.F. Hviid, D.T. Titov.

**MIRO (Microwave Instrument for the ROSETTA-Orbiter).**- 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), P. Hartogh, W. Ip, I. Mann (MPAE), 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 Astronomia y Fisica del Espacio, Buenos Aires, Argentinien).

**Molecular Zeeman effect.**- S.K. Solanki in Zusammenarbeit mit S. Berdyugina, University Oulu, Finland and C. Frutiger, ETH Zürich, Schweiz.

**NASA STEREO-Mission – SECCHI.**- 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.

**NASA STEREO-Mission – IMPACT.**- Bauer Flugzeit-Elektronik für das SIT-Instrument. 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.

**Netzwerk der European Science Foundation, Straßburg: Space weather and terrestri-**

**al weather:** K. Schlegel.

**NIXT/TXI (Normal Incidence X-ray Telescope/Tuneable X-ray Imager).**- W.K.H. Schmidt, A. Dannenberg, B. Inhester und D. Innes in Zusammenarbeit mit Dr. L. Golub (PI), Smithsonian Astrophysical Observatory, Center for Astrophysics, Cambridge, MA, 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.

**Polar Atmosphere Research by Radar.**- J. Röttger in Zusammenarbeit mit University Courses on Svalbard (UNIS), Norwegen. Kampagnen im Oktober 2000 und November 2001.

**Ramanspektroskopie.**- M. Hilchenbach in Zusammenarbeit mit J. Popp, Universität Würzburg, und T. Stuffer, Kayser-Threde, München.

**RAPID auf CLUSTER II.**- Das Teilchenspektrometer RAPID. Principle Investigator: B. Wilken, in 2001 P.W. Daly; Co-Investigators: P.W. Daly, U. Mall, J. Büchner, A. Korth, S. Livi, J. Woch, W.I. Axford, V.M. Vasyliunas (MPAE, Lindau); J.B. Blake, J.F. Fennell (AC, Los Angeles); Z.Y. Pu (Beijing University, Beijing); T.A. Fritz (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 (RAL, Chilton); S. McKenna-Lawlor (SPC, Maynooth); F. Søråas, K. Aarsnes (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).

**RAPID auf Double Star.**- Principle Investigator: B. Wilken in Zusammenarbeit mit Q.G. Zong und dem CSSAR, Beijing, VR China.

**Raumsonde Ulysses – KEP (EPAC) Energetic Particle Composition Experiment.**- E. Keppler 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), N. Krupp (MPAE), J. Woch (MPAE).

**Raumsonde Ulysses.-** *KEP (GAS):* Interstellar Neutral GAS Experiment. H. Rosenbauer, M. Witte und E. Keppler zusammen mit H. Fahr, Universität Bonn und M. Banaszekiewicz, SRC, Warschau, Polen.

**Raumsonde Ulysses.-** *KET:* Kieler Elektronenteleskop in der ULYSSES-COSPIN-Investigation. Datenauswertung. M. Witte in Zusammenarbeit mit H. Kunow, G. Wibberenz, Universität Kiel.

**Raumsonde Ulysses.-** *SWICS: Solar Wind Ion Composition Spectrometer.* Datenauswertung. J. Woch in Zusammenarbeit mit Universität Bern, Schweiz und University of Maryland, USA.

**ROSINA: Rosetta Orbiter Spectrometer for Ion and Neutral Analysis.-** *Entwicklung und Bau des Massenspektrometers R-TOF für das ROSINA-Experiment.-* A. Korth, H. Lauche, S. Livi, B. Wilken, J. Woch in Zusammenarbeit mit H. Balsiger (PI), Physikalisches Institut, Universität Bern, Bern, Schweiz, CESR, Toulouse, Frankreich, Physik Institut, Universität Gießen, Technische Universität, Braunschweig, Lockheed Palo Alto Research Laboratory, Palo Alto, CA, USA, Southwest Research Institute, San Antonio, TX, USA, University of Michigan, Space Physics Research Laboratory, Ann Arbor, MI, USA, BIRA, Bruxelles, Belgien.

**Secular evolution of the Sun's magnetic field.-** M. Schüssler, S.K. Solanki in Zusammenarbeit mit M. Fligge, ETH Zürich, Schweiz; I. Usoskin, University Oulu, Finnland.

**SESCAT (Sporadic-E Scatter Experiment).-** Radar-Anlage zur Untersuchung von kohärenten Echos aus sporadischen E-Schichten in mittleren Breiten. K. Schlegel zusammen mit Dr. C. Haldoupis, University of Crete, Iraklion, Griechenland.

**SIR – SMART-1 Near IR Spectrometer.-** Technical Investigator: H.U. Keller, W.J. Markiewicz, A. Nathues, U. Mall; P. Huber, Tec5, Steinbach (Taunus).

**Skibotn CCD All Sky Imager (SCASI).-** M.J. Kosch in Zusammenarbeit mit der Universität Tromsø, Norwegen.

**SOFIA-GREAT (SOFIA - German Receiver for Astronomy at THz frequencies).-** R.

Guesten, K. Menten, P. v. d. Wal (MPI für Radioastronomie, Bonn), R. Schieder, J. Stutzki (Universität Köln), A. Krabbe, P. Röser (DLR-Berlin), P. Hartogh (MPAE).

**SOHO COSTEP-ERNE, Particle Analyser Collaboration (CEPAC).-** M. Witte in Zusammenarbeit mit H. Kunow (COSTEP-PI), Universität Kiel, und J. Torsti (ERNE-PI), Universität Turku, Finnland, sowie mit Kollegen von folgenden Instituten: ESTEC, Holland; St. Patrick's College, Irland; Universidad de Alcalá de Henares, Spanien; Bartol Research Institute, DE, USA.

**Solar and Heliospheric Observatory (SOHO).-** *Solar Ultraviolet Measurements of Emitted Radiation (SUMER)* Zusammenarbeit besonders mit P. Lemaire, A.H. Gabriel, J.-C. Vial (IAS, Orsay, Frankreich); A.I. Poland (GSFC, Greenbelt, USA); M.C.E. Huber (SSD, ESTEC, Noordwijk, Niederlande); 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); K. Stucki (ETH Zürich, Schweiz); A. Pauluhn (ISSI Bern, Schweiz). W. Curdt, I.E. Dammasch, D.E. Innes, E. Marsch, U. Schühle, S.K. Solanki.

**Solar-Terrestrische Beziehungen und Schumann Resonanzen.-** K. Schlegel in Zusammenarbeit mit Dr. M. Füllekrug, Universität Frankfurt/Main.

**Structure of the solar chromosphere.-** S.K. Solanki in Zusammenarbeit mit M. Loukitcheva, University St. Petersburg, Ukraine, und M. Carlsson, University Oslo, Norwegen.

**SUNRISE: Ballongetragenes 1-m-Sonnenteleskop für hochauflösende spektro-polarimetrische Beobachtungen der Sonnenatmosphäre.-** S.K. Solanki, M. Schüssler, W. Curdt in Zusammenarbeit mit dem Kiepenheuer-Institut für Sonnenphysik, Freiburg, Instituto de Astrofísica de Canarias, Teneriffa, Spanien, High Altitude Observatory, NCAR, Boulder, USA, Lockheed Martin Solar and Astrophysical Lab, Palo Alto, USA.

**Spurengasmessungen in mittleren Breiten und in den Tropen.-** R. Borchers in Zusammenarbeit mit P. Fabian, Universität München.

**STARE.-** E. Nielsen in Zusammenarbeit mit FMI, Finnland.

**Studies of Polar Mesosphere Summer Echoes.-** J. Röttger in Zusammenarbeit mit University of Tromsø, Norwegen und Leibniz-Institut für Atmosphärenphysik, Universität Rostock.

**SUMER-Bildatlas.-** I.E. Dammasch in Zusammenarbeit mit U. Feldman, NRL, Washington, USA.

**Temporal variations of atmospheric organic halides as revealed by Antarctic ice probes.-** (Analyse antarktischer Eisproben.) R. Borchers in Zusammenarbeit mit Dr. Vladimir I. Bogillo, Laboratory of Antarctic Ecology, Institute of Geological Sciences, National Academy of Sciences, Kiev, Ukraine.

**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.

**Vertrag über gemeinsame Nutzung des Zweikanal-Fokalreduktors des MPAE am 2-m-RCC-Zeiss-Teleskop des Internationalen Zentrums für Astronomische und Medizinisch-Ökologische Forschung (Golosevo bei Kiev, Ukraine) vom 1. Januar 1998 – 31. Dezember 2002.-** Im Rahmen dieses Vertrages werden auch wissenschaftliche Projekte gemeinsam mit ukrainischen Astronomen durchgeführt, z. B. Astrometrie und Photometrie ausgewählter Satelliten von Jupiter und Saturn. K. Jockers gemeinsam mit I. Kulyk, Hauptobservatorium der nationalen Akademie der Wissenschaften, Kiev, Ukraine.

**Volatiles and Fluids in Subduction Zones.-** Projekt des SFB 574, Universität Kiel. Am MPAE: Analyse vulkanischer Gasproben. R. Borchers in Zusammenarbeit mit Matthias Frische (SFB).

**WASPAM.-** P. Hartogh, C. Jarchow, L. Song in Zusammenarbeit mit G. Hansen (NILU, Tromsø, Norwegen), U.P. Hoppe (FFI, Kjeller, Schweden), Werner Eriksen (ALOMAR, Andenes, Norwegen), U. v. Zahn, F.J. Lübken, G. v. Cossart (IAP Kühlungsborn), Gerald Nedoluha (NRL,

Washington, USA).

**WAVE (Water Vapour Distribution Inside and Outside the Polar Vortex during Theseo).-** P. Hartogh, C. Jarchow, L. Song in Zusammenarbeit mit J. de La Noe, N. Lautie, P. Ricaud, J. Urban (Observatoire de Bordeaux), J. Ovarlez, H. Ovarlez (CNRS-LMD, Palaiseau), C. Schiller (FZ Jülich), D.G. Feist, L. Zalesak, N. Kampefer (IAP, Bern), M. Ridal, D. Murtagh (Universität Stockholm-MI), K. Lindner, U. Klein, K. Künzi (IUP, Bremen), P. Forkmann, A. Winnberg (Onsala Space Observatory), A. Engel (Universität Frankfurt-IMG).

**Projektförderungen durch das Bundesministerium für Bildung und Forschung (BMBF) und ESA/Project grants provided by BMBF and ESA**

**DLR:** ULYSSES, Ulysses-Kep., GALILEO, SWICS/ Ulysses, IDS (bis 31.8.01), NIXT, ROLAND, Sumer-Op., LASCO, RELICT-2, COSAC, MIRO, OSIRIS, MIMI, EQUATOR-S (bis 31.8.01), R-TOF, CASSINI-DAT., CASSINI-INMS (bis 31.8.01), MECA, ASPERA-3, HIFI WBS, SCHWARM, MARSIS, RAPID, STEREO IMPACT, STEREO SECCHI, Mars Express, STEREO Corona, Datenausw. CIS, Sunrise, Entwicklung tragbarer Gaschromatograph, Subsystem für den Rosetta Lander.

**ESA:** ESA CLUSTER CIS, ESA CLUSTER-RAPID, 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 2000/2001: Astroplasmas Introduction  
SS 2001: Astroplasmas Simulation  
WS 2001/2002: Astroplasmas Visualization

**Prof. Dr. K. Jockers**

WS 1999/2000: Planetenatmosphären  
SS 2000: Lichtstreuung an kosmischem Staub  
WS 2000/2001: Staub im interstellaren Medium und in Kometen  
SS 2001: Physik der Kometen

**Prof. Dr. E. Marsch**

WS 2000/2001: Weltraumplasmaphysik  
SS 2001: Physik der Heliosphäre  
WS 2001/2002: Sonnenkorona und Sonnenwind

**Prof. Dr. K. Schlegel:**

WS 2000/2001: Leuchterscheinungen in der Atmosphäre.  
WS 2001/2002: Elektrodynamik der Erdatmosphäre

**Dr. D. Schmitt/Prof. M. Schüssler**

WS 2000/2001: Hydrodynamik

**Prof. Dr. R. Schwenn**

SS 2000: Physik der Sonnenkorona I  
SS 2001: Einwirkungen der Sonne auf das System Erde  
WS 2001/2002: Physik der Heliosphäre I

**The University Courses on Svalbard (UNIS), Longyearbyen, Svalbard/Norwegen**

**Prof. T. Hagfors**

7.-19. Februar 2000.

**Dr. J. Röttger**

23.-27. Oktober 2000, 12.-23. November 2001:  
Middle and lower atmosphere observations with the SOUSY Svalbard radar.

**Autumn College on Plasma Physics, Abdus Salam International Center for Theoretical Physics (ICTP), Triest, Italien**

**Prof. Dr. E. Marsch:**

Three lectures:  
I. The Sun's corona and wind – structure, evolution and dynamics.  
II. Ions and electrons – velocity distributions and kinetics.  
III. Waves and turbulence – excitation, transport and dissipation.  
9.-11. Oktober 2001.

**Institute of Space Science, National Central University, Chung Li, Taiwan**

**Dr. J. Röttger**

17. September - 20. Oktober 2001: Radar design and methods, Part I.

**Max-Planck-Institut für Plasmaphysik und der Ernst Moritz Arndt Universität Greifswald**

**Prof. Dr. K. Schlegel**

Gastvorlesung im Rahmen der Max-Planck Research School "Bounded Plasmas".  
10-stündige Vorlesung, 25.-29. Juni 2001: Ionospheric plasma physics.

**First El Leoncito Summerschool of Solar Physics, El Leoncito, San Juan, Argentina**

**Prof. Dr. R. Schwenn**

Februar 2000: Introduction into the physics of the heliosphere  
Oktober 2001: Introduction into the physics of the heliosphere

**Eidgenössische Technische Hochschule Zürich, Schweiz**

**Prof. Dr. S.K. Solanki**

SS 2000:  
Sternatmosphären (zusammen mit Dr. W. Schmutz)  
SS 2001:  
Galaxien (zusammen mit Dr. W. Schmutz)

**Weitere Lehrtätigkeiten oder Kurse/Other lectures or courses**

**XLAB (Göttinger Experimentallabor für Junge Leute e.V.)**

Spurengase in der Atmosphäre (Spurengase, Luftverschmutzung, Treibhauseffekt) **Dr. R. Borchers und Prof. K. Schlegel:**  
3 Veranstaltungen am MPAE.

Die Sonne — der unruhige Stern nebenan

**Dr. S. Ploner, Prof. R. Schwenn, Prof. M. Schüssler:**

Einige Veranstaltungen im XLAB Göttingen.

Die Heliosphäre: Was wissen wir über unser Zuhause in der Galaxis?

**Dr. N. Krupp:**

Vortrag in der Freien Waldorfschule im Rahmen einer XLAB-Veranstaltung, Göttingen, 15. September 2001.

**Mitgliedschaften in wissenschaftlichen Gremien/Memberships in scientific councils**

*Bothmer V.:* Leiter (Secretary) des Bereichs Sonnenphysik für die European Geophysical Society in der Sektion Solar-Terrestrial Sciences; Mitglied

der ESA "Space Weather Euro News Group"; Auswahlgremium für die IMPRS Doktoranden.

*Büchner J.:* Board of the International Plasma-Astrophysics School, Vorstandsmitglied Arbeitsgemeinschaft extraterrestrische Forschung.

*Daly P.W.:* Cluster Science Data System, Implementation Working Group.

*Curdt W.:* JOSO (Joint Organisation of Solar Observatories).

*Hagfors T.:* EISCAT Council; Alomar Proposal Review Committee; MPG-Komitee zur Direktorenfindung für Arbeitsbereiche am MPI für Bio-geochemie.

*Hartogh P.:* ALOMAR Scientific Advisory Committee, SPARC-WAVAS, COST-712.

*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).

*Keller H.U.:* International Astronomical Union (IAU); Chairman der Commission 15 (IAU) Working Group on Comets; Division of Planetary Science (DPS); Arbeitsgemeinschaft Planetenforschung der DFG; European Astronomical Society (EAS); Astronomische Gesellschaft; European Geophysical Society (EGS); Panel Chairman of the ISO Observing Time Allocation Committee (OTAC) der ESA; International Academy of Astronautics (IAA); ROSETTA Science Working Group (ESA).

*Keppler E.:* DPG; AGU, EGS; „Forum für Zukunftsenternien“, Mitglied im Vorstandsrat der DPG, Vorsitzender Arbeitskreis Energie der DPG.

*Klostermeyer J.:* Bewertungsgruppe "Institut für Atmosphärenphysik (IAP)" des Wissenschaftsrats; ALOMAR Science Advisory Committee, Andøya Rocket Range, Norway; ALOMAR Research Infrastructures, User Selection Panel, Andøya Rocket Range, Norway; Mitglied der URSI-Kommission G in der Bundesrepublik Deutschland

*Kosch M.:* URSI Kommission G in Deutschland.

*Markiewicz W.J.:* EGS, AGU, AAS-Division of Planetary Sciences.

*Marsch E.:* Solar Science Planning Group (SSPG) der ESA (2000), Solar Physics Section Board der

European Physical Society (2000, 2001), Gutachterausschuss Extraterrestrik des DLR (ab 2001), Solar System Working Group (SSWG) der ESA (ab 2001).

*Nielsen E.:* American Geophysical Union (AGU); European Geophysical Society (EGS); URSI-Kommission G in der Bundesrepublik Deutschland.

*Rietveld M.:* URSI-Kommission G in der Bundesrepublik Deutschland, European Geophysical Society (EGS), Royal Astronomical Society (RAS).

*Röttger J.:* American Geophysical Union; Royal Astronomical Society; URSI-Kommission G in der Bundesrepublik Deutschland; Wissenschaftlicher Beirat, Leibniz Institut für Atmosphärenphysik an der Universität Rostock; Advisory Board member (atmospheric/ionosphere radar) of the Center for Space and Remote Sensing Research (CSRSR), National Central University, Chung-Li, Taiwan, R.O.C.

*Rüster R.:* URSI-Kommission G in der Bundesrepublik Deutschland.

*Sauer K.:* American Geophysical Union (AGU).

*Schlegel K.:* Vicepresident of URSI (International Union of Radio Sciences, seit August 1999); Mitglied der URSI Kommission G in Deutschland; ständiger Gastprofessor der Wuhan Universität, China.

*Schwenn R.:* Solar System Working Group der ESA, bis Ende 2000, 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.

*Thomas N.:* Chairman of COSPAR commission B1 "Small bodies in the Solar System", 1998-2002. Science Advisory Group for BepiColombo, Science Advisory Group for MASTER proposal to ESA.

*Wilhem K.:* DGG, DPG, AGU, AEF, COSPAR Associate, SOHO Science Working Team, URSI Commission H.

*Woch J.:* Chemisch-Physikalisch-Technische Sektion der MPG, Berufungskommission MPI für Extraterrestrische Physik, Beratender Ausschuss für Informationsversorgung in der MPG.

## 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 2000 und 2001 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, W. Curdt, T. Hagfors, B. Inhester, D. Innes, K. Jockers, E. Keppler, J. Klostermeyer, A. Korth, W.J. Markiewicz, E. Marsch, E. Nielsen, M.T. Rietveld, J. Röttger, R. Rüster, K. Sauer, K. Schlegel, R. Schwenn, S.K. Solanki, P. Stubbe, N. Thomas, V.M. Vasyliūnas, K. Wilhelm, M. Witte, J. Woch.

*Zeitschriften/Journals:* Advances in Polar Upper Atmosphere Research (2), Advances in Space Research (11), Annales Geophysicae (24), Astronomy and Astrophysics (14), Astrophysical Journal (3), Astrophysical Journal Letters (1), Astrophysics and Space Science (1), Contributions to Plasma Physics (1), Earth, Planets and Space (2), ESA-SP (1), ESLAB Symposium Proceedings (1), Geophysical Research Letters (32), Icarus (1), Journal of Atmospheric and Oceanic Technology (1), Journal of Atmospheric and Solar-Terrestrial Physics (11), Journal of Atmospheric and Terrestrial Physics (1), Journal of Electromagnetic Waves and Applications (2), Journal of Geophysical Research (41), Journal of Geophysical Research – Space Physics (2), Journal of Plasma Physics (1) National Science Foundation, USA (2), Nature (1), Natural Hazards and Earth System Science (1), Nonlinear Processes in Geophysics (4), Physics and Chemistry of the Earth (2), Physical Review Letters (1), Physical Letters A (1) Planetary and Space Science (13), Proceedings of the COSPAR Colloquium on Space Weather (1), Radio Science (7), Science (2), Solar Physics (2), Space Science Reviews (1), Zeitschrift für Flugwissenschaften und Weltraumforschung (2).

### *Gutachtertätigkeiten anderer Art/Other types of reviews:*

*Hagfors T.:* Evaluation of professor competence of two candidates, University of Tromsø; Dissertation “Demagnetization of electrons in the presence of turbulence in the polar ionospheric E region” by

Susumu Saito, University of Nagoya, Japan; Europe Orbital Ice Radar: modelling and interpretation, Academy of Finland; PPARC Research Grant Application: Studies in Solar-Terrestrial Physics; PPARC Research Grant Application: Research in Solar System Plasmas and Atmospheric Physics at the University of Leicester 2002-2006.

*Hagfors T.:* Gutachten Einzelpersonen betreffend: 8.

*Jockers K.:* Humboldt-Stiftung (1), 1 Gutachten für Indian Institute of Astrophysics, Bangalore, 1 Gutachten Habilitationsverfahren an der Georg-August-Universität Göttingen, Cospar (1).

*Klostermeyer J.:* Fonds zur Förderung der Wissenschaftlichen Forschung, Wien, Österreich: 2 Gutachten; NASA, Geospace Program: 2 Gutachten.

*Marsch E.:* 1 Gutachten für Research Proposals für (PPARC) Particle Physics and Astronomy Research Council, U.K.; 1 Gutachten für Cambridge University Press über ein Buchvorhaben; 1 Gutachten (vergleichendes) für die Mathematisch-Naturwissenschaftliche Fakultät der Christian-Albrechts-Universität zu Kiel.

*Röttger J.:* Projektvorschläge: Canada Council of Arts, Canada, National Science Foundation, USA (2x). Personen: National Center for Atmospheric Research, USA (2x); Cornell University, USA (2x); University of Nebraska, USA; University of Colorado, USA; Umea University, Sweden. Doktorarbeiten: Sri Venkatesvara University, India (3x); COSPAR Colloquium (1x); Memoirs of NIPR (1x).

*Schüssler M.:* Fachgutachter der DFG für Astronomie/Astrophysik.

*Schwenn R.:* Gutachten für den Schweizerischen Nationalfonds zur Förderung der wissenschaftlichen Forschung über ein Forschungsvorhaben, Gutachten für die Katholieke Universiteit Leuven (Belgien) über ein Forschungsprojekt, Gutachter im Peer Review Panel der NASA über LWS Projekte (2000), Gutachten über eine Doktorarbeit an der Universität von Paris.

*Solanki S.K.:* Gutachten für National Science Foundation, USA (3), für die Deutsche Forschungsgemeinschaft (2).

*Thomas N.:* Gutachter für DFG.

*Vasyliūnas V.M.:* je ein Gutachten über die wissenschaftliche Qualifikation von zwei Einzelpersonen an Forschungsinstituten.

*Wilhelm K.:* American Institute of Physics (3).

*Woch J.:* Gutachten für NASA-Research Proposals.

### **Tätigkeiten als Convener bei wissenschaftlichen Tagungen/Convenerships during scientific meetings**

*Barrow C.H.:* XXV General Assembly of the European Geophysical Society, Nizza, Frankreich, 24.-29. April 2000, 25.-30. März 2001, Session PS8.01: Joint session on radiophysics: Solar System Radiophysics.

*Büchner J.:* XXV General Assembly of the European Geophysical Society, Nizza, Frankreich, 24.-29. April 2000, Session: Theory and Simulation of Solar System Plasmas; 25.-30. März 2001, Session: Theory and Simulation of Solar System Plasmas. August 2000: COSPAR General Assembly, Warsaw, symposium "Comparative reconnection at sun and in magnetospheres"; September 2001: 6th International Conference on Space Plasma Simulation, Garching.

*Dubin E.:* Co-Convener, European Geophysical Society XXIII General Assembly, Nizza, Frankreich, 25.-29. April 2000, PS1.05 International Mars exploration: Mars ionosphere and its coupling to the solar wind: new results of current and former missions. 25.-30. März 2001, PS2.04 Comparative planetology of terrestrial planets: Ionospheric and exospheric processes on Mars and other terrestrial planets.

*Bothmer V.:* Joint SOHO-ACE Workshop 2001 Solar and Galactic Composition, Bern, Schweiz, Chair Working Group 3: Galactic Abundances, 6.-9. März 2001; XXIV General Assembly of the European Geophysical Society, Nizza, Frankreich, 25.-30. März 2001; Co-Convener Session ST5. Open session on solar and heliospheric physics; Co-Convener Session ST18.01. The science of space weather: Observational results; Co-Convener Session ST21.02. The solar atmosphere: Coupling coronal activity with the interplanetary medium; Convener: European Union INTAS/ESA Project Meeting "Geoeffective interplanetary structures: their origins on the Sun and in the solar wind".

*Daly P.W.:* German Cluster Workshop, Max-Planck-Institut für Aeronomie, Katlenburg-Lindau, 15.-16. November 2001.

*Hagfors T.:* Session "Techniques in Active Radio Observations of Surfaces and Atmospheres",

PIERS 2000, Cambridge, MA/USA, 5.-14. Juli 2000.

*Hilchenbach M.:* XXVI General Assembly of the European Geophysical Society, Nizza, Frankreich, 24.-29. April 2000, 25.-30. März 2001, Session: Solar Atmosphere and the solar wind.

*Markiewicz W.J.:* XXVI General Assembly of the European Geophysical Society, Nizza, Frankreich, 24.-29. April 2000, co-convener, International Mars exploration: Mars atmosphere: new results of current and former missions. 25.-30. März 2001, co-convener, Comparative planetology of terrestrial planets: Atmospheres of Mars and Venus.

*Marsch E.:* 33rd COSPAR Scientific Assembly, Session E2.4: Current and Future High Resolution In-situ and Remote Sensing Solar Physics Missions, Warschau, Polen, 16.-23. Juli 2000. COSPAR Colloquium "The Outer Heliosphere: The Next Frontiers", Potsdam, 24.-28. Juli 2000. IAGA-IASPEI Joint Scientific Assembly, Hanoi, Vietnam, Session G4.04: The 3-D Corona and Solar Wind, 19.-31. August 2001.

*Sauer K.:* European Geophysical Society XXIII General Assembly, Nizza, Frankreich, 25.-29. April 2000, PS1.05 International Mars exploration: Mars ionosphere and its coupling to the solar wind: new results of current and former missions. European Geophysical Society XXIII General Assembly, Nizza, Frankreich, 25.-30. März 2001, PS2.04 Comparative planetology of terrestrial planets: Ionospheric and exospheric processes on Mars and other terrestrial planets Co-Convener, XXIII General Assembly European Geophysical Society, Nizza, Frankreich, 25.-30. März 2001, PS4 Magnetic fields of solar system planets, moons and asteroids.

*Schlegel K.:* 10th International EISCAT-Workshop, Tokyo, Japan, 23.-27. Juli 2001. Asia-Pacific Radio Science Conference, Tokyo, Japan, 1.-4. August 2001.

*Schüssler M.:* Scientific Organizing Committee "Magnetic Fields Across the Hertzsprung-Russell Diagram", Santiago, Chile, Januar 2001, Scientific Organizing Committee "6th International Symposium for Space Plasma Simulation", Garching, September 2001.

*Wilhelm K.:* Scientific Program Committee: SOHO/ACE Workshop, Bern, Switzerland, 6.-9. März 2001.

## Organisation von Workshops/ Workshop organisation

*Büchner J.*: V1th International Space Plasma Simulation Conference (together with C. Dum and M. Scholer), September 2001, Garching.

*Grünwaldt H. mit M. Hilchenbach*: SOHO/ CELIAS Workshop, Quedlinburg, März 2001.

*Marsch E.*: Chair of the Scientific Organizing Committee für den Solar Orbiter Workshop in Teneriffe, Spanien, 14.-18. Mai 2001.

*Röttger J.*: Chairman International Steering Group and Programme Committee of the 9th Workshop on Technical and Scientific Aspects of MST Radar, März 2000, Toulouse, Frankreich. Scientific organizing committee: COSPAR Colloquium "Multipoint techniques in Space Weather" September 2000, Wan Li, Taiwan.

*Sauer K.*: ISSI (International Space Science Institute), Mars Workshop, Bern, Schweiz, 22.-26. Oktober 2001.

*Schlegel K.*: Workshop der European Science Foundation (ESF) "Space Processes and Electrical Changes Influencing Atmospheric Layers" (SPECIAL), Max-Planck-Institut für Aeronomie, Katlenburg-Lindau, 8.-11. November 2000.

*Schüssler M.*: SUNRISE Science & Technology Workshop, Katlenburg-Lindau, Oktober 2001.

*Schwenn R.*: Consortium meeting für LASCO, im Mai 2000 in Teistungenburg.

## Öffentlichkeitsarbeit/Public relations

Prof. Dr. K. Schlegel (Pressesprecher des MPAE), Dr. B. Wöbke, Dr. P. Czechowsky.

## Pressemitteilungen/Press releases

Im Berichtszeitraum wurden die folgenden Pressemitteilungen herausgegeben:

- MPAE beteiligt sich an 3. Göttinger Jugendwoche. 19. Mai 2000.
- Zehnter Vortrag der Erich-Regener Vortragsreihe: Luftverschmutzung und Klima. 20. Mai 2000.
- „Abenteuer Sonnensystem“ in der Göttinger Lokhalle. 30. Mai 2000.
- MPAE-Photometer auf „IMAG“ arbeiten erfolgreich. 5. Juni 2000.
- Start von Cluster II steht bevor/MPAE mit Hardware beteiligt. 19. Juni 2000.
- Aufbruch zu den Sternen. 18. Juli 2000
- Cluster II: Start der beiden ersten Satelliten geglückt. 19. Juli 2000.
- Zweiter Start von Cluster II gelungen/MPAE-Mitarbeiter sind glücklich. 9. August 2000.
- Elfter Vortrag der Erich-Regener Vortragsreihe: Weltraumwetter. 22. August 2000.
- Cluster-Satelliten in der Testphase. 5. September 2000.
- Zwölfter Vortrag der Erich-Regener Vortragsreihe: Die eisigen Monde der äußeren Planeten. 4. Oktober 2000.
- Wieder ein Asteroid nach MPAE-Mitarbeiter benannt. 27. Oktober 2000.
- Workshop über Auswirkungen des Weltraumwetters. 7. November 2000.
- Wirkt die Sonne auf das Erdklima? 23. November 2000.
- Dreizehnter Vortrag der Erich-Regener-Vortragsreihe: Jesuiten und Naturwissenschaften heute. 30. November 2000.
- Raumsonde Cassini passiert Jupiter. 20. Dezember 2000.
- Professor Sir Ian Axford tritt in den Ruhestand. 23. Januar 2001.
- Vierzehnter Vortrag der Erich-Regener-Vortragsreihe: Energieverbrauch und Klimaentwicklung. 12. Februar 2001.
- Fünfzehnter Vortrag der Erich-Regener-Vortragsreihe: Weltraummüll. 27. März 2001.
- Fünf Jahre SOHO / Sun-Earth Days. 24. April 2001.
- Achter Vortrag der Erich-Regener Vortragsreihe: Experimente in der Ionosphäre. 7. Januar 2000
- Neunter Vortrag der Erich-Regener Vortragsreihe: Die frühe Erdatmosphäre. 17. April 2000.
- Sonnenforscher treffen sich in Teistungenburg. 10. Mai 2000

- Neues Auswärtiges Wissenschaftliches Mitglied am MPAE. 10. Mai 2001.
- Sechzehnter Vortrag der Erich-Regener-Vortragsreihe: Die Sonne – der Stern, von dem wir leben. 22. Mai 2001.
- Dr. Rosenbauer wird 65. 31. Mai 2001.
- Siebzehnter Vortrag der Erich-Regener-Vortragsreihe: Weltraumforschung – Ein Rückblick. 21. August 2001.
- Sonnenposter „Anatomie eines koronalen Loches“ vom MPAE. 21. August 2001.
- Achtzehnter Vortrag der Erich-Regener-Vortragsreihe: Reise zum Mittelpunkt der Erde. 28. September 2001.
- Neunzehnter Vortrag der Erich-Regener-Vortragsreihe: Der Stern von Bethlehem. 5. Dezember 2001.
- Braunschweig (DLR), Tag der Raumfahrt, 21. September 2001.
- Buxtehude (Halepaghen-Schule), Astrobux 2001, 8. – 11. Oktober 2001.
- Göttingen (IWF Wissen und Medien), Bilder aus der Physik, 9. – 11. November 2001.

**Forschungs-Infos des MPAE/Research brochures of the MPAE**  
(Discontinued due to planned change of institute's name)

Wegen der bevorstehenden Namensänderung des Instituts wurde diese Serie beendet. Seit Ende 1998 wurden insgesamt 7 verschiedene Titel herausgegeben und bei Institutsveranstaltungen kostenlos an Interessenten abgegeben

Ionosphärenforschung (8/98)

Weltraumwetter (9/98)

Spurenstoffe in der Stratosphäre (11/98)

Struktur und Dynamik der Troposphäre (1/99)

Sonnenatmosphäre, Sonnenwind, Sonnenaktivität (7/99)

Polarlicht (8/99)

Die Magnetosphäre der Erde (Okt. 2001)

#### **Ausstellungsstand/Exhibition stand**

Der mobile Ausstellungsstand, mit dessen Hilfe die wissenschaftliche Arbeit am Institut der Öffentlichkeit in verständlicher Form vorgestellt wird, wurde bei folgenden Anlässen ausgestellt:

- Berlin (Urania), Jahr der Physik, 17. – 21. Januar 2000.
- 22. Informationsmarkt zur Berufsfindung. Es wurden die im Institut ausgebildeten Berufe vorgestellt: Industrieelektroniker, Industriemechaniker, Metallbauer, Elektroinstallateur, Kaufmann für Bürokommunikation, Schützenselt am Mühlenanger, Northeim, 23.-24. Mai 2000.
- Göttingen (Lokhalle), EXPO 2000 – Forum für Wissenschaft und Technik, 3. Juni – 29. Oktober 2000.
- Göttingen (MPI für experimentelle Medizin), Tage der Forschung, 10. – 11. Februar 2001.
- Dortmund (Westfalenhallen), HobbyTronic, 14. – 18. Februar 2001.
- Hamburg (Planetarium), Tage der Sonne und der Erde, 19. – 29. April 2001.
- 23. Informationsmarkt zur Berufsfindung. Berufsbildende Schulen II, Northeim, 23.-24. Mai 2001.
- Greifswald (MPI für Plasmaphysik), ESA 2000, 18. – 28. Juni 2001.

#### **Institutsführungen und Anfragen/Institute tours and information**

Im Berichtszeitraum wurden ferner 52 Institutsführungen mit insgesamt 1240 Personen durchgeführt und zahlreiche Anfragen beantwortet.

#### **Erich-Regener-Vortragsreihe/Erich-Regener lecture series**

*Vorträge dieser Reihe wenden sich an in der Region wohnende Laien.*

27. Januar 2000

Dr. Michael Rietveld (Max-Planck-Institut für Aeronomie, Katlenburg-Lindau): Experimente in der Ionosphäre. Heating und HAARP.

27. April 2000

Dr. Mario Trieloff (Mineralogisches Institut der Universität Heidelberg): Entstehung und Entwicklung der frühen Erdatmosphäre.

5. Juni 2000

Prof. Dr. Peter Fabian (Lehrstuhl für Bioklimatologie und Immissionsforschung der Ludwig-Maximilians-Universität München): Luftverschmutzung und Klima. Abgase unserer

Zivilisation – Ursache globaler Umweltveränderungen.

31. August 2000

Prof. Dr. Kristian Schlegel (Max-Planck-Institut für Aeronomie, Katlenburg-Lindau): Weltraumwetter.

12. Oktober 2000

Prof. Dr. Klaus Jockers (Max-Planck-Institut für Aeronomie, Katlenburg-Lindau): Die eisigen Monde der äusseren Planeten.

7. Dezember 2000

Prof. Dr. Otto Schärpf S.J. (München): Jesuiten und Naturwissenschaften heute.

22. Februar 2001

Dr. Erhard Keppler (Max-Planck-Institut für Aeronomie, Katlenburg-Lindau): Klima und Energieverbrauch.

3. April 2001

Dr. Jörg Bendisch (Institut für Flugmechanik und Raumfahrttechnik, Technische Universität Braunschweig): Weltraummüll.

29. Mai 2001

Prof. Dr. Sami K. Solanki (Max-Planck-Institut für Aeronomie, Katlenburg-Lindau): Die Sonne – der Stern, von dem wir leben.

30. August 2001

Prof. Sir Ian Axford (Max-Planck-Institut für Aeronomie, Katlenburg-Lindau): Weltraumforschung. Ein Rückblick auf mein Arbeitsleben.

4. Oktober 2001

Prof. Dr. Ulrich Christensen (Institut für Geophysik der Georg-August-Universität Göttingen): Reise zum Mittelpunkt der Erde.

13. Dezember 2001

Dr. Ralf Bülow (Berlin): Der Stern von Bethlehem.

#### Öffentliche Vorträge/Public presentations

*Bothmer V.*: Sonne und Erde – Eine stürmische Beziehung. Planetarium Hamburg, 4. April 2001.

*Bothmer V.*: Expertenchat (Webchat) für [www.wissen.de](http://www.wissen.de), 27. April 2001.

*Bothmer V. und T.W. Kraupe*: Sonderevent aus Anlass des 5. Jahrestages der Mission SOHO, 27.-29. April 2001.

*Büchner J.*: Der Weg der Killerelektronen, URANIA Berlin, April 2001.

*Curdt W.*: ESA Science News Press Release: SOHO's guidebook to the Sun's extreme ultraviolet light, 30. Juli 2001.

SOHO Hotshot: The Solar Genom (<http://sohowww.nasa.gov/hotshots/20030>). Juli 2001.

*Schühle U.*: Die dynamische Sonne, Max-Born-Gymnasium, Germering, Schulvortrag anlässlich der Hauptversammlung der Max-Planck-Gesellschaft in München, 8. März 2000; 5 Jahre SOHO, Archenholt Planetarium, Berlin, 27. April 2001;

Sonnenobservatorium SOHO: Erforschung der dynamischen Sonne, Auto- und Technik Museum, IMAX-Theater, Sinsheim, 22. Mai 2001.

*Schüssler M.*: Öffentliche Vorträge an/bei Wilhelm-Foerster-Sternwarte, Berlin, Planetarium Recklinghausen, AstroBux Buxtehude, Förderverein Planetarium Göttingen, XLAB Göttingen, VHS Soest, Planetarium Stuttgart, Planetarium Mannheim.

*Wilhelm K.*: 5 Jahre SOHO, Olbers-Gesellschaft, Bremen, 27. April 2001.

#### Verschiedenes/Miscellaneous

*Dr. P.W. Daly*: Betreuung der Online-Veröffentlichungsliste.

*Dr. Andreas Nathues*: Der Asteroid mit der vorläufigen Bezeichnung 1997 QV3 erhielt im Oktober 2000 offiziell den Namen "(10210) Nathues". Nathues ist damit der vierte Mitarbeiter des MPAAE, der auf diese Weise geehrt wurde.

#### Anerkennung der Referententätigkeit

*Prof. Dr. V.M. Vasylunas* erhielt vom Herausgeber des Journals of Geophysical Research eine ausdrückliche Anerkennung für seine hervorragende Tätigkeit als Referent (Editor's Citation for Excellence in Refereeing, 2000).

*K. Wilhelm*: Beiträge zur Sonderausgabe einer CD-ROM "Solar Pysics", Band 200, 2001, SUMER-Beobachtungen.

#### Ernennung/Appointment

*Prof. Dr. S.K. Solanki*  
Verleihung des Professorentitels durch die ETH Zürich (2001).

**Herausgebertätigkeit/Editorships**

*Marsch E., R. Schwenn et al.:* Solar Orbiter – A High-Resolution Mission to the Sun and Inner Heliosphere. Assessment Study Report, ESA-SCI(2000)6, Juli 2000.

*Marsch E. et al.:* Proceedings of the first Solar Orbiter Workshop “Solar Encounter”, Puerto de la Cruz, Tenerife, 14-18 May 2001, ESA-SP 493, September 2001.

*Mathys G., S.K. Solanki, D.T. Wickramasinghe:* Magnetic Fields Across the Hertzsprung-Russell Diagram. Astron. Soc. Pacific Conf. Ser., Vol. 248, pp. 687 (2001).

*Scherer K., H. Fichtner, H.-J. Fahr, and E. Marsch:* The Outer Heliosphere: The Next Frontiers. COSPAR Colloquia Series, Volume 11, Pergamon (An Imprint of Elsevier Science), ISBN 0-444-50909-7, 2001.

*Scherer K., H. Fichtner, and E. Marsch:* The Outer Heliosphere: Beyond the Planets, Copernicus Gesellschaft, Katlenburg-Lindau, ISBN 3-9804862-3-0, Mai 2000.

*Röttger J.:* Guest Editor Annales Geophysicae (special issue MST Radar Workshop)

**Direktionsbeirat des MPAE/**

„Direktionsbeirat“ at MPAE

Am 15. Dezember 1999 wurden in den Direktionsbeirat des MPAE für die Amtszeit 2000 gewählt: *Dr. Bernd Inhester, Prof. Dr. Eckart Marsch, Prof. Dr. Rainer Schwenn*, als Stellvertreter *Dr. Iancu Pardowitz, Herr Reinhard Meller, Herr Dietmar Germerott, Herr Hartmut Sommer*.

Am 6. Dezember 2000 wurden in den Direktionsbeirat des MPAE für die Amtszeit 2001 gewählt: *Herr Dietmar Germerott, Dr. Norbert Krupp, Herr Henry Perplies*, als Stellvertreter *Dr. Helmut Zapf, Prof. Dr. Manfred Schüssler*.

Am 7. Dezember 2001 wurden in den Direktionsbeirat des MPAE für die Amtszeit 2002 gewählt: *Dr. Iancu Pardowitz, Prof. Dr. Manfred Schüssler, Herr Eckard Steinmetz*, als Stellvertreter *Dr. Andreas Lagg*.

**25 Jahre in der MPG/25 years at MPG**

- Marlis Borghold (13. Januar 2000)
- Terrance Ho (16. Januar 2000)
- Peter Hemmerich (1. April 2000)
- Arne Richter (1. September 2000)
- Anita Brandt (20. Oktober 2000)
- Dr. Erling Nielsen (1. Januar 2001)
- Prof. Dr. Eckart Marsch (1. August 2001)
- Olaf Matuschek (1. August 2001)



## VII. 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-015-00-01

*Gerd K. Hartmann*

Wissenschaftliche Daten im Spannungsfeld zwischen notwendiger qualifizierender Filterung, unerwünschtem, technischen Vergessen und betrügerischer Manipulation.

MPAE-W-813-00-02

*Markus Fränz and Norbert Krupp*

ULYSSES EPAC experiment: Spherical harmonic expansion of three-dimensional particle distributions.

MPAE-L-015-00-03

*Gerd K. Hartmann*

Computer responsibility: A challenge for Bildung and science. (For Prof. Dr. S.K. Solanki on his assumption of the directorship of the Max-Planck-Institut für Aeronomie)

MPAE-L-015-00-04

*Gerd K. Hartmann*

Filtered, Fiddled, Forgotten – Scientific data between screening imperatives, oblivion and fraud. (For Prof. Dr. Reinhart Leitinger on his 60th birthday)

MPAE-W-085-00-05

*Ingrid Mann*

Dust in the solar system and in other planetary systems.

MPAE-W-004-00-06

*Erling Nielsen, C. Del Pozo, and P.J.S. Williams*  
VHF coherent radar signals from the E region ionosphere and the relationship to electron drift velocity and ion acoustic velocity.

MPAE-W-100-01-01

*Günter Lichtenberg*

Massenbilanz und Energiehaushalt des Io-Plasma-Torus: Modell und Beobachtung. Dissertation, Universität Göttingen. (ISBN 3-89744-153-5)

MPAE-W-100-01-02

*Suiyan Fu*

Energetic ion behaviour in the inner magnetosphere during geomagnetic activity observations of the MICS instrument onboard CRRES. Dissertation, Technische Universität Braunschweig.

MPAE-W-04-01-03

*Erling Nielsen*

Mars' ionosphere and the solar wind.

MPAE-W-03-01-04

*Erling Nielsen*

Antenna system for a high resolution imaging riometer.

MPAE-L-853-01-05

*Gerd K. Hartmann*

Gedanken und Fragen zur Globalisierung.  
- Dr. Andreas Nürnberger zur Promotion gewidmet -  
Beitrag zu den 'Gföhler Maitagen' 2001

MPAE-L-853-01-06

*Gerd K. Hartmann*

Auf der Suche nach einer allgemeinen Ordnung der Information.

MPAE-L-853-01-07

*Gerd K. Hartmann*

Teamarbeit bedeutet Gemeinsamkeit und Arbeitsteilung.

### Experimentvorschläge/Proposals

**HiRISE: A high-resolution imaging system for NASA's 2005 Mars Reconnaissance Orbiter mission.** (PI: A. McEwen, University of Arizona, USA), Proposal to NASA, selected October 2001, MPAE: N. Thomas.

**APEX: Atacama Pathfinder Experiment.**

(PI: P. Hartogh), Proposal to BMBF, DESY-HS, September 2001, nicht genehmigt.

**GAME: Ground-Based Atmospheric Measurements of Water Vapour over Europe.** (Co-PI: P. Hartogh) Proposal to EU, Oktober 2001.

**MAOAM: The Martian Atmosphere: Observation and Modeling.** (PI: P. Hartogh) Proposal to DFG, März 2001, genehmigt Dezember 2001.

**EUV Solar Spectroscopic Explorer (ESSEX).** (W. Curdt, I.E. Dammasch, D.E. Innes, E. Marsch, U. Schühle, D.M. Hassler et al.) Proposal für eine NASA MIDEX Mission (AO 01-OSS-03) (Oktober 2001).

**IS: In-situ Investigation of the Sun.** (PI: D. McComas, SWRI, USA; E. Marsch), Vorschlag für die Solar Probe Mission der NASA, 6. Juli 2000.

**ISIS: Integrated Solar Probe Imaging Suite: A Remote Sensing Instrument Package for Solar Probe.** (PI: D. Hassler, SWRI, USA; V. Bothmer, W. Curdt, U. Schühle, M. Schüssler, S.K. Solanki, E. Marsch), Proposal für die NASA Solar Probe Mission (AO 99-OSS-04), 6. Juli 2000.

**Investigation of the production and composition of Martian soils and dust and their effect upon the Martian atmosphere.** (S.F. Hviid), Proposal submitted to NASA for the Mars Exploration Rover programme.

**RADEX (FACET) experiment for ESA's Exobiology facility.** (PI: Gerda Horneck, DLR, Koeln; N. Thomas), Proposal to ESA. Mission cancelled.

**Solar Orbiter.** Proposal Coordinator: E. Marsch), Vorschlag an die ESA für F3 Mission von Horizon 2000 plus.

**Sunrise, A lightweight telescope for spectro-polarimetric high-resolution observations of the Sun.** (PIs: S. K. Solanki and W. Schmidt), submitted to DLR on February 16, 2000.

**SUNRISE: Ballongetragenes 1-m Sonnentelerskop für hochauflösende spektropolarimetrische Beobachtungen der Sonnenatmosphäre.** (S.K. Solanki, W. Curdt, M. Schüssler). Projektvorschlag DLR Kleinmission, 2000.

**Technology development for instruments on Solar Orbiter.** (PI: S.K. Solanki and E.

Marsch, U. Schühle, W. Curdt, S. K. Mathew), November 2001.

**VENNIS and VENUS-Express – Contributions to the VENSIS Radar.** (E. Nielsen), Proposal for the ESA VENUS EXPRESS Mission.

**SCHWARM-Phase A Study, IRAS on MMS, ROY with Russia.** (J. Büchner)

### Dissertationen/Dissertations

*Michael Bantin* Untersuchung des Ausbreitungsverhaltens wandernder ionosphärischer Störungen in der Hochatmosphäre der Polkappe. Universität Göttingen, 23. Oktober 2000.

*Antonio Casares:* Ein Multireflexions-Flugzeit-Massenspektrometer für in-situ Messung auf einem Kometenkern. Universität Gießen, 27. April 2001.

*Suiyan Fu:* Energetic ion behaviour in the inner magnetosphere during geomagnetic activity observations of the MICS instrument onboard CRRES. Technische Universität Braunschweig, 18. Januar 2001.

*Thomas Horvath:* Ausbau der statischen und gepulsten Versorgungsgeräte eines Flugzeitmassenspektrometers für einen Weltraumeinsatz. Universität Gießen, 28. Februar 2001.

*Huixin Liu:* High-latitude ionosphere and its response to magnetic storms. University of Wuhan, China, 18. Mai 2001.

*Matthias Rempel:* Struktur und Ursprung starker Magnetfelder am Boden der solaren Konvektionszone, Universität Göttingen, 25. Juni 2001.

*Guillermo Stenborg:* Interpretation and analysis on various time scales of narrow-band coronal observations obtained with a new coronagraph system, Universität Göttingen, 21. Juni 2000.

*Christian Vocks:* Ein kinetisches Modell der Ionen in koronalen Löchern mit Welle-Teilchen-Wechselwirkung und Coulomb-Stößen, Universität Göttingen, 7. Februar 2001.

### Tee-Seminare/Tea seminars

**Leitung: Dr. P.W. Daly, Dr. B. Inhester und Dr. J. Woch**

*In den Tee-Seminaren wird von Wissenschaftlern des MPAE, aber auch von Gästen in unregelmäßi-*

gen Zeitabständen über laufende Arbeiten vorge-tragen.

MPAE scientists as well as guests to the institute report on their current work in the informal seminars.

Dr. Klaus Scherer, dat-hex, Katlenburg-Lindau: The heliosphere, cosmic rays, and climate. 13. Januar 2000.

Jorge Costa, Service d'Aeronomie du CNRS, Verrieres le Buisson, France: Heliospheric interstellar hydrogen velocity and temperature from SOHO/-SWAN H cell data. 14. Januar 2000.

Dr. E. Wiehr, Sternwarte der Universität Göttingen: Protuberanzen-Physik ohne Spektrograph. 24. Januar 2000.

Wolfgang Dröge, Bartol Research Institute, University of Delaware, Newark, USA: What do we know about acceleration and transport of solar energetic particles? 27. Januar 2000.

Dr. P. Ehrenfreund, University of Leiden, Niederlande: Ices and organics: from dark clouds to early earth. 27. Januar 2000.

Prof. N.O. Weiss, University of Cambridge, Großbritannien: Modelling photospheric magnetoconvection. 11. Februar 2000.

Manolo Collados, Instituto de Astrofisica de Canarias, La Laguna, Tenerife: Near-infrared solar spectropolarimetry using TIP. 24. Februar 2000.

Dr. Carsten Dominik, Sterrenkundig Instituut 'Anton Pannekoek', Amsterdam, Niederlande: Heavy bombardment in nearby stellar systems? 28. Februar 2000.

Dr. Thomas Heinemann, Freie Universität Berlin, Institut für Weltraumwissenschaften: Remote sensing of aerosols in the Earth's troposphere with spaceborne ocean colour sensors. 3. März 2000.

H. Hartwig, MPAE: Aktuelle Entwicklungstendenzen bei wissenschaftlichen Satelliten und ihre Auswirkungen auf die Auswahl zukünftiger Beteiligungen. 7. März 2000.

Prof. Kristian Schlegel, MPAE: Die stärksten geomagnetischen Stürme des vergangenen Jahrhunderts. 8. März 2000.

Dr. Patrick Chaizy, Rutherford Appleton Laboratory, Großbritannien: Theoretical and observational multi-spacecraft analysis of  $E > 30$  keV solar event electrons at 1 AU; general concept of cross-IMF gradients. 9. März 2000.

C. Frutiger, Astrophysikalisches Institut der ETH, Zürich, Schweiz: Inversion of solar and stellar line profiles. 16. März 2000.

Dr. J. Birn, Los Alamos National Laboratory, USA: Simulations of three dimensional reconnection in low and high  $\beta$  space plasmas. 20. März 2000.

Prof. J. L. Kohl, Harvard-Smithsonian Center for Astrophysics, Cambridge, USA: The advanced solar coronal explorer mission. 24. März 2000.

Dr. Michael Küppers, Physikalisches Institut der Universität Bern, Schweiz: A model of the evolution of planetary and asteroidal regolith and implications for remote sensing. 27. März 2000.

Dr. U. Ziegler, Astrophysikalisches Institut, Potsdam: Numerical evolution of diffuse and intermittent magnetic fields in rotating, stratified atmospheres. 28. März 2000.

Dr. R. Ratkiewicz, Space Research Center of the Polish Academy of Sciences, Warsaw, Polen: News from the edge of the heliosphere. 12. April 2000.

Prof. T. Hada, Kyushu University, Japan: Particle diffusion and transport: Stepping beyond the quasilinear approach. 5. Mai 2000.

Dr. Nick Hoeckzema, Utrecht Obs. Sterrenkundig Instituut and Kiepenheuer-Institut für Sonnenphysik, Freiburg: UV radiation in the lower atmosphere: Simulating sources and observations. 11. Mai 2000.

Dr. I. Pardowitz, MPAE: Präsentationstechniken: Grundlagen, Vorüberlegungen, Technik. 12. Mai 2000.

Dr. Russ Howard, Naval Research Laboratory, Washington, DC, USA: SECCHI – The optical imaging package for the STEREO mission. 18. Mai 2000.

Dr. I. Pardowitz, MPAE: Präsentationstechniken: Die graphische Bearbeitung mit der COREL-Suite. 19. Mai 2000.

Prof. R. Schwenn, MPAE: Präsentationstechniken: Vorträge mit MS-Powerpoint. 26. Mai 2000.

Dr. Steve Spangler, University of Iowa, USA: Radioastronomical tests of coronal heating mechanisms. 26. Mai 2000.

E. Huttunen, FMI Helsinki, Finnland: Geoefficiency of CMEs during 1996-1998. 29. Mai 2000.

Priv.-Doz. Dr. Björn Grieger, Universität Bremen: Paleoclimate modelling. 29. Mai 2000.

- Prof. M.B. Kallenrode*, Universität Lüneburg: Particle observations at IP shock waves and modelling efforts. 15. June 2000.
- Dr. V. Kunitsyn*, Moscow State University, Russland: Investigation of the ionosphere and near space environment by satellite radiotomography. 27. June 2000.
- Dr. Mark Haugen*, Purdue University, Lafayette, Indiana, USA: Testing the fundamental principles of gravitation physics. 6. Juli 2000.
- Prof. Ted A. Fritz*, Boston University, MA, USA: Energetic particles and the magnetospheric cusps. 22. August 2000.
- Prof. Ted A. Fritz*, Boston University, MA, USA: Energetic particles in the equatorial magnetosphere – New insights. 23 August 2000.
- Dr. M. Hellberg*, Univ. of Natal, Durban, Südafrika: Wave propagation in non-Maxwellian plasmas. 18. September 2000.
- Dr. Tetsuya Tokano*, Institut für Geophysik und Meteorologie, Universität zu Köln: Simulation of Titan's atmospheric methane cycle by a general circulation model. 31. Oktober 2000.
- Dr. Maarit J. Korpi*, University of Oulu, Finland: Numerical models of supernova regulated flows. 2. November 2000.
- Dr. Reiner Friedel*, Los Alamos National Lab., NM, USA: On relativistic electrons during magnetic storms: Analysis with Salammbô code, comparison to in situ data and superposed epoch. 13. November 2000.
- Harald Frey*, Space Sciences Lab, Berkeley, CA, USA: The electron and proton aurora as seen by the FUV instrument on IMAGE. 20. November 2000.
- Prof. Lev Zelenyi*, Space Research Institute (IKI), Russian Academy of Sciences, Moscow, Russland: Structure of thin current sheets in a collisionless plasma. 24. November 2000.
- Dr. Y. Voytenko*, Centre for Plasma Astrophysics, Leuven, Belgien: Nonlinear wave dynamics and coronal Alfvén waves in the ion cyclotron range. 28. November 2000.
- Dr. V. Martinez-Pillet*, Instituto de Astrofísica des Canarias, Teneriffe: Magnetic field structuring of sunspot penumbrae. 29. November 2000.
- Prof. K. Nishikawa*, Rutgers University, NJ, USA: Global particle simulations of magnetic substorms. 30. November 2000.
- Prof. V. Kunitsyn*, Moscow State University, Russland: Tomography of natural objects with a limited number of projections. 8. Dezember 2000.
- PD Dr. Ralf Greve*, Technische Universität Darmstadt: Ice flow, isostasy and gravity anomaly of the north polar layered deposits of Mars. 11. Dezember 2000.
- Prof. Dr. G. Rüdiger*, Astrophysikalisches Institut, Potsdam: Differential rotation, meridional flow and dynamo theory for the Sun and solar-type stars. 13. Dezember 2000.
- Dr. Alexander Kokhanovsky*, Institute of Physics, National Academy of Sciences of Belarus: Radiative and polarization characteristics of water clouds. 20. Dezember 2000.
- Dr. Alexander Rodin*, Space Research Institute (IKI), Moscow, Russland: A compact microphysical model for the aerosols on Mars and Titan. 15. Januar 2001.
- Dr. F. Portier-Fozzani*, MPAE: From SOHO to STEREO: 3D observations of the solar corona. 31. Januar 2001.
- Dr. Marcus Bruggen*, Institute of Astronomy, Cambridge, UK: Tomography of the Sun. 6. Februar 2001.
- Dr. Alexander Rodin*, Space Research Institute (IKI), Moscow, Russland: Water ice clouds and seasonal climate cycle on Mars. 13. Februar 2001.
- Dr. Hardi Peter*, Kiepenheuer-Institut, Freiburg: Struktur der Übergangsregion von der Chromosphäre zur Korona. 26. Februar 2001.
- Dr. N. Schuch*, INPE, Sao Paulo, Brasil: Recent facilities for space research in Brasil. 3. April 2001.
- Dr. W. Gonzales*, INPE, Sao Paulo, Brasil: Interplanetary origin of geomagnetic storms. 3. April 2001.
- Dr. H. Spruit*, MPI für Astrophysik, Garching: Magnetic fields and the rotation of the Sun's core. 6. April 2001.
- Dr. R. Schlichenmaier*, Kiepenheuer-Institut, Freiburg: The sunspot Penumbra: an interplay of theory and observation. 11. April 2001.
- Dr. Stefan Werner*, Institut für Astrophysik und Extraterrestrische Forschung, Universität Bonn: On the origin of positive ionospheric storms. 1. Juni 2001.
- Dr. Laurent Gizon*, Stanford University, USA: Recent results in local-area helioseismology. 11. Juni

2001.

*Dr. Axel vom Endt*, Siemens, Erlangen: Magnetic resonance imaging (MRI) or what a ionospheric physicist ended up doing. 19. Juni 2001.

*Dr. S. Saito*, Nagoya University, Japan: Demagnetization of electrons in the presence of turbulence in the polar ionospheric E region. 20. Juni 2001.

*Prof. Franz Kneer*, Universitäts-Sternwarte Göttingen: High resolution solar physics from the ground. 12. Juli 2001.

*Dr. L.H. Lyu*, Institute of Space Science, National Central University, Chung-Li, Taiwan: A theoretical model for cross-scale simulation of collisionless plasmas in space. 1. August 2001.

*Dr. L.H. Lyu*, Institute of Space Science, National Central University, Chung-Li, Taiwan: A unified model for explosive thinning and onset of a substorm. 2. August 2001.

*Dr. Richard Lieu*, University of Alabama, Huntsville, USA: Microrelativity. 13. August 2001.

*Prof. D.T. Wickramasinghe*, Australian National University, Canberra, Australien: Magnetic fields in white dwarfs. 14. August 2001.

*Dr. C. Neiner*, Observatoire de Meudon, Frankreich und Astronomical Institute of Amsterdam, Niederlande: Non-radial pulsations, magnetic fields, activity and wind modulation in early B stars. 22. August 2001.

*Dr. Thorsten Carroll*, Astrophysikalisches Institut, Potsdam: Stokes profile inversion with artificial neural networks. 29. August 2001.

*Prof. F. Cattaneo*, University of Chicago, USA: Numerical simulations of self-excited dynamos. 4. September 2001.

*Prof. Dr. Jorge Paez*, University of Costa Rica, Institute of Astrophysics; z. Zt. Astrophysikalisches Institut, Potsdam: Criteria of geoeffectiveness of CME's during the years 1994 to 1997. 4. September 2001.

*Dr. M. DelBo*, DLR Institut für Weltraumsensorik, Berlin: Asteroid thermal models and the problem of their application to near Earth asteroids. 5. September 2001.

*Dr. Th. Emonet*, University of Chicago, USA: Interaction between convection and magnetic field. 5. September 2001.

*Dr. W. Kalkofen*, Harvard-Smithsonian Center for Astrophysics: The structure and dynamics of the

quiet chromosphere. 17. September 2001.

*Prof. G. Rüdiger*, Astrophysikalisches Institut, Potsdam: Two types of stellar dynamos. 16. Oktober 2001.

*Dr. J. Segsneider*, INGV, Bologna, Frankreich: Use of satellite-observed sea-level data to improve coupled seasonal climate forecasts. 20. November 2001.

*Prof. Hongqi Zhang*, Chinese National Astronomical Observatories, Beijing: The study of observational solar magnetic field. 23. November 2001.

*Prof. A. Tilgner*, Institut für Geophysik, Universität Göttingen: The Karlsruhe-Dynamo-Experiment. 5. Dezember 2001.

*Dr. E. Khomenko*, Main Astronomical Observatory NASU, Kiev, Ukraine: Magnetoacoustic waves in a stratified magnetic atmosphere. 6. Dezember 2001.

## Mitarbeiter-Seminar Heliosphäre/ Staff seminar of the Heliosphere

*Das Seminar wird von Diplomanden und Doktoranden des MPAE gestaltet, und es behandelt die Heliosphäre im weitesten Sinne. Eingeladen sind insbesondere die Diplomanden, die Doktoranden und deren Betreuer, aber auch interessierte Mitarbeiter und Gäste. Das Seminar findet wöchentlich und in Anlehnung an die Universitätssemester statt.*

*Berichtet wird sowohl aus laufenden als auch aus abgeschlossenen Arbeiten. Die Themen erfassen das gesamte Sonnensystem und streuen von Sonnenatmosphäre über Korona, Sonnenwind, Planeten und Monde, Kometen, Staub und kosmischer Strahlung bis hin zur Atmosphäre der Erde. Seltener gibt es auch Vorträge über abgeschlossene Arbeiten aus anderen Gebieten.*

*This seminar is organized by the MSc and PhD students of MPAE, and covers the heliosphere in its widest sense. However, all interested staff members and guests are invited. The seminar takes place weekly, in accordance with the university semesters.*

*Reports and talks are on current as well as finished works. The topics cover the whole solar system and vary from the sun's atmosphere through corona, solar wind, planets and moons, comets, dust and cosmic radiation to earth's atmosphere. Less frequent are talks on other fields of work.*

- Christian Vocks:* Nichtgleichgewichtsprozesse im koronalen Plasma – Kopplung von Wellen und Teilchen. 13. Januar 2000.
- Thomas Wiegmann:* Kinetische Simulationen von Weltraumplasmen. 27. Januar 2000.
- Nandita Srivastava:* Gradual coronal mass ejections as observed by LASCO. 3. Februar 2000.
- Bernd Heber:* Charge sign dependent recurrent modulation of galactic cosmic ray electrons and protons: Implications from Ulysses. 10. Februar 2000.
- Eckart Marsch:* Der Ursprung des schnellen Sonnenwindes in koronalen Trichtern. 17. Februar 2000.
- Lidong Xia:* Numerical simulation on merging interaction of transient shocks in the inner Heliosphere. 2. März 2000.
- Peter Vollmöller:* Strahlungstransport für MHD auf unstrukturierten Gittern. 13. April 2000.
- Matthias Rempel:* Speicherung toroidaler Magnetfelder am Boden der Konvektionszone. 20. April 2000.
- Alexander Vögler:* Magnetfelder in Galaxien mit Gezeitenwechselwirkung. 4. Mai 2000.
- Rainer Schwenn:* Generation of shock waves in the corona: CMEs and other drivers.
- Joachim Woch:* Substorms at Jupiter? 11. Mai 2000.
- Konrad Sauer:* Waves and nonlinear structures in bi-ion plasmas with relevance to comets and Mars. 18. Mai 2000.
- Bernd Heber:* The influence of the solar magnetic reconfiguration on galactic cosmic rays: Ulysses COSPIN/KET observations. 24. Mai 2000.
- Volkmar Holzwarth:* Dynamik magnetischer Flussröhren in Riesen- und Doppelsternen. 31. Mai 2000.
- Till Credner:* Optische Photometrie des Staubes im Kometen Hale-Bopp. 8. Juni 2000.
- Thomas Wiegmann:* Entwicklung eines Vlasov-Codes. 15. Juni 2000.
- Christian Vocks:* Ein kinetisches Modell der Welle – Teilchen – Wechselwirkung im koronalen Plasma. 6. Juli 2000.
- Kristian Schlegel:* From Aristotle to Atmospheric Explorer – Highlights from 2400 years of atmospheric research. 19. Oktober 2000.
- Antonio Ferriz-Mas:* Mechanisms producing long-term changes in solar and stellar activity. 2. November 2000.
- Francisco Frutos:* Visualization of gravitational lenses. 16. November 2000.
- Rainer Schwenn:* Comments on a strange metamorphosis between sun and earth, or: how to turn a CME into a menace. 23. November 2000.
- Konrad Sauer:* New type of bi-ion solitons (wavytons) and Phobos/Deimos plasma torus effects. 7. Dezember 2000.
- Allison Dal Lago:* Increasing the accuracy on halo CME's speed measurements. 14. Dezember 2000.
- Lidong Xia:* SUMER observations of coronal holes on the solar disc. 11. Januar 2001.
- Andreas Lagg:* Energetic particle measurements during the Earth swing-by of the CASSINI spacecraft in August 1999. 18. Januar 2001.
- Norbert Krupp:* Cassini and Galileo combined energetic particle measurements in the vicinity of Jupiter. 1. Februar 2001.
- Manfred Schüssler:* Solar magneto-convection. 15. Februar 2001.
- Bernd Inhester:* Stereoscopy and tomography of solar observations. 26. April 2001.
- Tanyu Bonev:* Colour and polarization of the dust in comet C/1999 S4 during its disintegration. 3. Mai 2001.
- Ilya Silin:* 2D simulations of thin current sheet instabilities using a Vlasov code. 10. Mai 2001.
- Geronimo Villanueva:* Object programming (Visual Basic) and micro-controllers (PIC). 17. Mai 2001.
- Oliver Preuß:* New astronomical tests of the Einstein equivalence principle: Progress report.
- Stephane Espinosa:* Spin-periodic perturbations in Saturn's magnetic field: Evidence for a magnetic anomaly? 31. Mai 2001.
- Shibu K. Mathew:* Solar observations with Fabry-Perot Etalons. 7. Juni 2001.
- Manfred Schüssler:* Variability of the solar magnetic field. 21. Juni 2001.
- Björn Grieger:* Inverse radiation modeling of Titan's atmosphere to assimilate Huygens DISR data (Appendix with summary of Huygens recovery task force results). 28. Juni 2001.

*Irina Kulyk*: Ground-based observations of the inner satellites of Jupiter. 5. Juli 2001.

*Michael Heuer*: Ein Einblick in die algebraische Quantenfeldtheorie. 12. Juli 2001.

*Matthias Rempel*: Explosion of magnetic flux tubes. 11. Oktober 2001.

*Tongjiang Wang*: The large-scale coronal field structure and source region features for a halo CME. 18. Oktober 2001.

*Antonius Otto*: Reconnection triggered by Kelvin-Helmholtz instability. 06. November 2001.

*Tongjiang Wang*: Evidence for kink instability to cause the collapse of a Delta-spot active region. 15. November 2001.

*Dieter Schmitt*: The geodynamo as a bistable oscillator. 22. November 2001.

*Katariina Nykyri*: Signatures of Kelvin-Helmholtz instabilities in simulations and CLUSTER observations. 29. November 2001.

*Davina Innes*: Explosive events. 13. Dezember 2001.

*Andrei Sadovski*: The acceleration of Solar wind by the dissipation of Alfvén waves. 20. Dezember 2001.

für die SOLAR PROBE.  
17. März 2000

*U. Schühle*: EUV Spectroscopic Explorer (ESSEX) – Proposal für die NASA/SMEX Mission. 6. April 2000

*R. Schwenn und B. Inhester*: Das SECCHI Instrument für die STEREO Mission – Ziele, Durchführung und Beiträge des MPAE.

*J. Woch*: Bericht von der letzten Sektionsitzung. 25. Mai 2000

*M. Schüssler und S. Solanki*: SUNRISE: Ein ballongetragenes Experiment zur Sonnenbeobachtung. 1. August 2000

*P. Hartogh*: Entwicklung eines hochauflösenden Chirp Transform Spektrometers für das Atacama Pathfinder Experiment (APEX). 28. September 2001

*D.V. Titov*: Venus Express – A proposed European mission to Venus in 2005.

*W. Markiewicz*: Venus monitoring camera (VMC)  
*J. Woch, N. Krupp*: Neutral Particle Imaging – Solar Wind – Atmosphere interaction (Aspera).

*P. Hartogh*: Microwave sounder.

*H.U. Keller*: CCD electronics development and applications. 21. November 2001

## 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.*

*K. Jockers*: Die Bibliothek geht on-line. Informationen und Diskussion. 14. Januar 2000

*N. Thomas*: ESA's Mercury Orbiter Cornerstone (BepiColombo). 26. Januar 2000

*E. Marsch*: Übersicht über die SOLAR PROBE Mission.

*S. Livi*: In-situ Teichenmessungen für die SOLAR PROBE.

*S.K. Solanki*: Vorschläge für optische Experimente

## 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. Dr. K. Menten*, MPI für Radioastronomie, Bonn: Das Atacama Large Millimeter Array und dessen Bedeutung für die Erforschung des Sonnensystems. 11. April 2000.

*Prof. Fred Taylor*, Oxford University: Extraterrestrial life as a problem in physics. 17. Oktober 2000.

*Prof. Ulrich Christensen*, Institut für Geophysik, Universität Göttingen: Warum Jupiter Streifen hat. 10. Januar 2001.

*Dr. Hermann Boehnhardt*, VLT Paranal Observatory, ESO, Chile: The Transneptunian region: ves-

tibule and backyard of the solar system. 1. März 2001.  
2001.

*Prof. Willy Benz*, Physikalisches Institut der Uni-  
versität Bern: The formation of planets. 26. April

*Prof. Franz Kneer*, Universitäts-Sternwarte  
Göttingen: High resolution solar physics from the  
ground. 12. Juli 2001.

## Vorträge 2000/Talks 2000

*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.*

**Alpatov V.**, M. Kosch, A. Matveev, and A. Steen: Investigation of atmospheric processes and objects with the use of their dynamic characteristics and self-organising neutral networks on ground-based multi-position optical observations. 27. Annual European Meeting on Atmospheric Studies by Optical Methods, Stockholm, Schweden, 21.-25. August 2000.

**Amm O.**, K. Kauristie, A. Panjunpaa, N. Partamies, U. Brandstrom, and M. J. Kosch: The signature of bursty bulk flows and vortices in the ionosphere.\* EGS XXV General Assembly, Nizza, Frankreich, 25.-29. April 2000.

**Aruliah A.L.**, I.C.F. Mueller-Wodarg, A.D. Aylward, J. Ruxton, M.J. Kosch, and M. Lester: The flywheel effect: Consequences of neutral wind inertia on the ionosphere-thermosphere system after a geomagnetic storm. Magnetosphere, ionosphere and solar-terrestrial (MIST), Imperial College, London, England, 11.-13. April, 2000.

**Axford W.I.:** Major achievements since the birth of space physics.\* OBS2000 Meeting on Physics of Space: Growth Points and Problems, Observatoire de Paris-Meudon, Frankreich, 10.-14. Januar 2000.

— Connection and reconnection of magnetic fields.\* 33rd COSPAR Scientific Assembly, Warschau, Polen, 16.-23. Juli 2000.

— Magnetic fields in the heliosphere: introductory remarks.\* COSPAR Colloquium on The Outer Heliosphere: The Next Frontiers, Potsdam, 24.-28. Juli 2000.

— Future of interplanetary missions.\* Topical International Workshop LSUN-EARTH-MAN (dedicated to the 60th Anniversary of IZMIRAN), Troitsk, Moskau-Region, Russland, 20.-22. August 2000.

— The solar wind. Seminar, ECE Dept., UCSD, La Jolla, CA, USA, 27. September 2000.

— Origin of cosmic rays. Astrophysics Seminar, UCSD, La Jolla, CA, USA, 10. Oktober 2000.

— The origin of solar wind. Colloquium, University of Maryland, College Park, MD, USA, 20. November 2000.

— The origin of solar wind. Colloquium, UCSD, La Jolla, CA, USA, 29. November 2000.

— The high speed solar wind and coronal holes.\* Parker Lecture, AGU 2000 Fall Meeting, San Franzisko, CA, USA, 15.-19. Dezember 2000.

**Axford W.I.** and J.F. McKenzie: Coronal heating.\* 33rd COSPAR Scientific Assembly, Warschau, Polen, 16.-23. Juli 2000.

**Bamert K.**, R. Schaerer, R.F. Wimmer-Schweingruber, R. Kallenbach, M. Hilchenbach, B. Klecker, and A. Bogdanov: Elemental and ionic composition of suprathermal ions in the May 2-3, 1998 CME, Jahrestagung der Schweizerischen Physikalischen Gesellschaft, Montreux, Schweiz, 16.-17. März 2000.

**Bantin M.** and K. Schlegel: Observations of AGW induced TIDs in the polar cap region. EGS XXV General Assembly, Nizza, Frankreich, 25.-29. April 2000.

**Barrow C.H.**, A. Lecacheux, and R.J. Macdowell: Jovicentric latitude effect on the bKOM radio emission observed by Ulysses. EGS XXV General Assembly, Nizza, Frankreich, 25.-29. April 2000.

**Basilevsky A.T.**, N. Thomas, S.F. Hviid, and H.U. Keller: Colours of the APXS-analyzed rocks at the Mars Pathfinder site. EGS XXV General Assembly, Nizza, Frankreich, 25.-29. April 2000.

**Basilevsky A.T.**, O. Yakovlev, A. Fisenko, L. Semjonova, N. Zinovieva, L. Moroz, C. Pieters, H. Keller, A. Semenova, L. Barsukova, I. Roshchina, A. Galuzinskaya, and I. Stroganov: Simulation of impact melting of Martian regolith. EGS XXV General Assembly, Nizza, Frankreich, 25.-29. April 2000.

**Belikov Yu.E.**, M.J. Kosch, and K.B. Moseyenko: The influence of large-scale artificial and natural ejection of aerosol particles on the ozone content in the stratosphere. 27. Annual European Meeting on Atmospheric Studies by Optical Methods, Stockholm, Schweden, 21.-25. August 2000.

**Blagoveshchenskaya N.F.**, V.A. Kornienko, T.D. Borisova, R.Yu. Lu'yanova, B. Thide, M.J. Kosch, M. Rietveld, and E.V. Mishin:

- Triggering of local substorm activation by powerful HF radio waves. Fifth International Conference on Substorms (ICS-5), St. Petersburg, Russland, 16.-20. Mai 2000.
- Bogdanov A.T.**, B. Klecker, E. Möbius, M. Hilchenbach, L.M. Kistler, M.A. Popecki, D. Hovestadt, J. Weygand: Energy dependence of ion charge states in CME related S-solar energetic particle events observed with ACE/SEPICA and SOHO/STOF, Acceleration and transport of energetic particles observed in the heliosphere. ACE-2000 Symposium, Indian Wells, CA, USA, 5.-8. Januar 2000.
- Bogdanov, A.T.**, B. Klecker, E. Möbius, M. Hilchenbach, L.M. Kistler, M.A. Popecki and D. Hovestadt: Messungen der Energieabhängigkeit der Ladungszustände solarer energetischer Teilchen in CME-getriebenen Ereignissen. Deutsche Physikalische Gesellschaft, Frühjahrstagung Bremen, 21.-24. März 2000.
- Bogdanov A.T.**, B. Klecker, E. Moebius, M. Hilchenbach, M.A. Popecki, L.M. Kistler, D. Morris and D. Hovestadt: Heavy ion charge states as function of energy in CME initiated solar energetic particle events. EGS XXV General Assembly, Nizza, Frankreich, 25.-29. April 2000.
- Bogdanov A.T.**, B. Klecker, E. Moebius, M. Hilchenbach, M.A. Popecki, L.M. Kistler, D. Morris and D. Hovestadt: Observations of heavy ion charge spectra in CME driven gradual solar energetic particle events. 33rd COSPAR Scientific Assembly, Warschau, Polen, 16.-23. Juli 2000.
- Bonev T.**, K. Jockers, P. Korsun, N. Karpov, and S. Sergeev:  $\text{H}_2\text{O}^+$  and  $\text{CO}^+$  in comet C/1999J3 (Linear). EGS XXV General Assembly, Nizza, Frankreich, 25.-29. April 2000.
- Borchers R.** and P. Fabian: Buildup of CFC replacement substances: first measurements of new hydro-halocarbons in the tropical and midlatitude stratosphere. Quadrennial Ozone Symposium, Sapporo, Japan, 3.-8. Juli 2000.
- Brynildsen N.**, P. Maltby, O. Kjeldseth-Moe, and K. Wilhelm: Plumes and oscillations in the sunspot transition region. EGS XXV General Assembly, Nizza, Frankreich, 25.-29. April 2000.
- Büchner J.:** Kinetic reconnection: Simulations and satellite observations. Fachbeirat MPAE, Februar 2000.
- 3D effects of kinetic reconnection. Magnetic Reconnection 2000, Tokio, Japan, 2. März 2000.
- Numerische Plasmasimulationen und Multi-Satelliten Messungen. DPG-Frühjahrstagung, AG Extraterrestrische Physik, Bremen, 22. März 2000.
- Physical mechanisms of solar wind entry: Satellite observations and simulations.\* EGS XXV General Assembly, Nizza, Frankreich, 25.-29. April 2000.
- Multiscale structure formation in the course of kinetic reconnection. 33rd COSPAR Scientific Assembly, Symposium D3.5 Multiscale Structures in Dynamic Regions in Critical Regions, Warschau, Polen, 20. Juli 2000.
- Future of multispacecraft experiments. Boston University, USA, 27. Juli 2000.
- Helicity evolution and structure formation in kinetic reconnection. Princeton University, Princeton Plasma Physics Laboratory, Princeton, NJ, USA, 2. August 2000.
- Coupling of small and large scale processes at boundaries and multispacecraft experiments. NASA Goddard Space Flight Center, Greenbelt, Maryland, USA, 4. August 2000.
- Helicity and structure formation in kinetic reconnection - simulations and observations. UCLA, IGPP, Los Angeles, USA, 8. August 2000.
- Helicity and multiscale structure formation in kinetic reconnection - simulations and observations. University of California, Berkeley, USA, 11. August 2000.
- 2D and 3D kinetic reconnection: Structure formation and helicity evolution to be studied in a schwarm multispacecraft project. University of California San Diego, USA, 14. August 2000.
- Kinetic Reconnection: Structure formation and helicity evolution in 2D and 3D. University of Iowa, Iowa City, USA, 17. August 2000.
- Kinetic simulation of thin current sheet boundaries. The First S-Ramp Conference, Symposium S14: Wave-Particle Interactions at Shocks and Boundary Layers. Sapporo, Japan, 2. October 2000.

- Kinetics of three-dimensional magnetic reconnection. Symposium S10: Magnetic Reconnection: Theory and Simulations. The First S-Ramp Conference, Sapporo, Japan, 3. Oktober 2000.
  - Magnetosphäre im Weltraumwetter. Nationaler Workshop zum Weltraumwetter, DLR/IKN, Aussenstelle Neustrelitz, 26.-27. Oktober 2000.
  - Multispacecraft investigations after CLUSTER-II. AGU Fall meeting, session SM04 "New space missions: Science and technology", San Franzisko, USA, 15. Dezember 2000.
- Büchner J.**, B. Nikutowski, V. Vasyliunas, J. Woch, K.H. Glaßmeier, M. Scholer, R. Treumann, and L.M. Zelenyi: Schwarm for Roy: a fleet of small spacecraft to study plasma turbulence and magnetic field annihilation. Workshop "Future Missions", ISAS, Tokio, Japan, 8. März 2000.
- Büchner J.**, B. Nikutowski, and T. Wiegelmann: Observation and kinetic simulations of Hall-generated magnetic fields. EGS XXV General Assembly, Nizza, Frankreich, 25.-29. April 2000.
- Büchner J.**, B. Nikutowski, and T. Wiegelmann: Magnetic Helicity Evolution in Kinetic Reconnection: Plasma Simulations and s/c Observations. 33rd COSPAR Scientific Assembly, Symposium D0.1/E3.1 on Comparative Reconnection Studies at Sun and in Magnetospheres, Warschau, Polen, 20. Juli 2000.
- Büchner J.**, B. Nikutowski, T. Wiegelmann, T. Ogino, and A. Otto: Rapid on Cluster: Simulations for observations in the tail and at the magnetopause. Rapid-team meeting, Katlenburg-Lindau, 2. Mai 2000.
- Büchner J.**, B. Nikutowski, V. Vasyliunas, J. Woch, K.-H. Glaßmeier, M. Scholer, and R. Treumann: Scientific Goals of Schwarm Kickoff-meeting. Kayser-Threde, Katlenburg-Lindau, 14. Juni 2000.
- Büchner J.** and B. Nikutowski: Kinetic simulations of multiscale turbulence and structure formation in a plasma sheet. Symposium S11: Cross-Scale Coupling: Observations and Theories. The First S-Ramp Conference, Sapporo, Japan, 5. Oktober 2000.
- Generation of multi-scale power law spectra in the course of magnetic reconnection – an indication of SOC? AGU Fall meeting, session SM02 "Multi-and cross-scale processes in space plasmas", San Franzisko, USA, 15. Dezember, 2000.
- Büchner J.** and T. Wiegelmann: Helicity evolution in two- and three- dimensional reconnection. AGU Fall meeting, session SH04 "A 3-D view of the sun and heliosphere". San Franzisko, USA, 15. Dezember 2000.
- Chilson P.B.**, R.D. Palmer, A. Muschinski, D.A. Hooper, G. Schmidt, and H. Steinhagen: SOMARE-99: A demonstrational field campaign for ultra-high resolution VHF atmospheric profiling using frequency diversity. 9th International workshop on Technical and Scientific Aspects of MST Radar- MST9 combined with COST-76 final profiler workshop, Toulouse, Frankreich, 13.-18. März 2000.
- Chilson P.B., E. Belova, **M.T. Rietveld**, S. Kirkwood, and U-P. Hoppe: First artificially induced modulation of PMSE using the EISCAT heating facility. Proceedings of the Ninth International Workshop on Technical and Scientific Aspects of MST Radar, combined with COST76 Final Profiler Workshop, Toulouse, Frankreich, 13.-18. März 2000.
- Chiu W.-T.**, A. Kopp, and W.-H. Ip: Titan's ionospheric outflow. EGS XXV General Assembly, Nizza, Frankreich, 25.-29. April 2000.
- Curdt W.**, E. Landi, U. Feldman, D.E. Innes, B.N. Dwivedi, and K. Wilhelm: Spectroscopic features in the EUV emission of a M8 flare observed by SUMER. IAU Symp. 203: Recent Insights into the Physics of the Sun an Heliosphere - Highlights from SOHO and Other Space Missions, Manchester, Großbritannien, 7.-11. August 2000.
- Czechowski A.**, S. Grzedzielski, H. Fichtner, M. Hilchenbach, K.C. Hsieh: Anomalous cosmic rays outside of the termination shock. COSPAR Colloquium on The Outer Heliosphere: The Next Frontiers, Potsdam, 24.-28. Juli 2000.
- Daly P. W.**, U. Mall, and B. Wilken: First observations of energetic ions on the plasma-sheet by the RAPID experiment on board Cluster. AGU Fall Meeting, San Franzisko, CA, USA, 15.-19. Dezember 2000.
- Dandouras I.**, A. Amsif, S.M. Krimigis, D.G. Mitchel, E.C. Roelof, B.H. Mauk, D.C. Hamilton, S. Livi, and N. Krupp: Analysis of

- ENA observations by MIMI/INCA during the Cassini Venus-2 and earth flybys. EGS XXV General Assembly, Nizza, Frankreich, 25.-29. April 2000.
- Dammasch I.E.** and K. Wilhelm: SUMER observations of solar transition region structures and dynamics. 33rd COSPAR Scientific Assembly, Warschau, Polen, 16.-23. Juli 2000.
- Dammasch I.E.**, W. Curdt, B.N. Dwivedi, B. Kliem, and K. Wilhelm: Spectroscopic signatures of a flare observed in a SUMER time series. IAU Symp. 203: Recent insights into the physics of the sun and heliosphere – highlights from SOHO and other space missions, Manchester, Großbritannien, 7.-11. August 2000.
- de Graauw T.**, N.D. Whyborn, H. van de Stadt, H.J. Aarts, D.A. Beintema, P. Cais, E. Caux, R. Cerrulli, A. Cros, A. Emrich, N.R. Erickson, T.C. Gaier, J.D. Gallego-Puyol, J. Gao, R. Güsten, P. Hartogh, C.H. Honingh, H. Jacobs, K. Jacobs, W. Jellema, R. Kruijsinga, W. Luinge, W.R. McGrath, V. Natale, R. Orfei, J.C. Pearson, T.G. Phillips, P.R. Roelfsema, C. Rosolen, M. Salez, R. Schieder, K. Schuster, K. Smorenburg, J. Stutzki, X. Tielens, S. Torchinsky, B. van Leeuwen, H. Visser, H. Wang, K.J. Wildeman, P. Zimmermann, and J. Zmuidzinas: Heterodyne instrument for FIRST (HIFI): design and development status. SPIE International Symposium on Astronomical Telescopes and Instrumentation 2000, München, 27.-31. März 2000.
- de La Noe J.**, J. Ovarlez, H. Ovarlez, C. Schiller, N. Lauutie, P. Ricaud, J. Urban, D.G. Feist, L. Zalesak, N. Kämpfer, M. Ridal, D. Murtagh, K. Lindner, U. Klein, K. Künzi, P. Forkman, A. Winnberg, P. Hartogh, and A. Engel: Water vapour distribution inside and outside the polar vortex during THESEO. EGS XXV General Assembly, Nizza, Frankreich, 25.-29. April 2000.
- Djuth F., B. Isham, **M.T. Rietveld**, J. Elder, T. Hagfors, and C. La Hoz: The first one hundred milliseconds of HF modification at Tromsø. High Power RF Ionospheric Interaction Workshop, Santa Fe, New Mexico, USA, April 2000.
- Dubinin E.**, K. Sauer, and K. Schwingenschuh: 3-D magnetic field configurations in the solar wind/Mars interaction. EGS XXV General Assembly, Nizza, Frankreich, 25.-29. April 2000.
- Dziembowski W., C. Fröhlich, and **S.K. Solanki**: How are irradiance variations during the onset of cycle 23 explained? 33rd COSPAR Scientific Assembly, Warschau, Polen, 16.-23. Juli 2000.
- Fabian P.** and R. Borchers: Growth of halocarbon abundances in the stratosphere between 1977 and 1999. Quadrennial Ozone Symposium, Sapporo, Japan, 3.-8. Juli 2000.
- Fedorov A.**, E. Budnik, A. Grigoriev, A. Skalsky, E. Dubinin, and J.-A. Sauvaud: Exterior cusp structure by INTERBALL-Tail observations. An attempt to create regular pattern under very irregular solar wind conditions. EGS XXV General Assembly, Nizza, Frankreich, 25.-29. April 2000.
- Foing B.H.**, G. Racca, A. Marini, M. Grande, H.U. Keller, K.L. Josset, L. Iess, and H. Laakso: SMART-1 science/technology preparation for future missions to Mercury. EGS XXV General Assembly, Nizza, Frankreich, 25.-29. April 2000.
- Fredvik T., O. Kjeldseth-Moe, S.V.H. Haugan, P. Brekke, J.B. Gurman, and **K. Wilhelm**: Variability and dynamic state of active region loops. 33rd COSPAR Scientific Assembly, Warschau, Polen, 16.-23. Juli 2000.
- Goldspiel J.M.**, F. Giovane, J.F. Seely, J.L. Hill, C. Boyer, S.W. Squyres, H.U. Keller, and G. Strazzulla: A subsurface probe suitable for deployment from a Mars Rover. 32th Annual Meeting of the Division for Planetary Sciences, Pasadena, California, USA, 23.-27. Oktober 2000.
- Grande M.**, R. Browning, N. Waltham, B. Kent, B. Kellett, C.H. Perry, B. Phillips, K. Swinyard, J. Huovenin, N. Thomas, S. Livi, U. Mall, D. Hughes, H. Alleyne, M. Lundin, R. Grady, S. Barabash, D. Baker, C. D. Murray, J. Guest, S.K. Dunkin, I. Maurice, S. Casanova, and B. Foing: Lunar elemental composition and investigations with D-CIXS X-Ray Mapping Spectrometer on Smart-1. 31st Annual Lunar and Planetary Science Conference, Houston, Texas, 13.-17. März 2000, abstract no. 1442
- Grande M.**, C. Perry, T. Zurbuchen, G. Gloeckler, J.F. Fennell, T. Fritz, B. Wilken, and S. Hefti: Tracing solar wind entry to the magnetosphere. EGS XXV General Assembly, Nizza, Frankreich, 25.-29. April 2000.

- za, Frankreich, 25.-29. April 2000.
- Güsten R.**, F. Schäfer, P. Van der Wal, R. Stark, R. Schieder, U. Graf, J. Stutzki, H. Röser, H. Hübers, and P. Hartogh: GREAT: the first-generation German heterodyne receiver for SOFIA. SPIE International Symposium on Astronomical Telescopes and Instrumentation 2000, München, 27.-31. März 2000.
- Hackenberg P.**, G. Mann, and E. Marsch: On the origin of the fast solar wind in polar coronal funnels. EGS XXV General Assembly, Nizza, Frankreich, 25.-29. April 2000.
- Hagfors T.:** On the pre-history of Heating at Tromsø and Arecibo. 20th Anniversary Symposium on Ionospheric Interactions in Tromsø, Ramfjordmoen, Norwegen, 10.-11. Oktober 2000.
- Can ESR observations contribute to the study of decametric-sized structure in the auroral ionosphere? 10th International EISCAT Workshop, NIPR, Tokio, Japan, 8. Dezember 2000.
- Hartmann G.K.:** Measuring methods for tropospheric water vapor. ECCA Workshop, IMG, Universität Graz, Österreich, 3. Januar 1999.
- Hartmann G. K.**, A. Nölle, M. L. Richards, and R. Leitinger (Eds.): DUST-2: An interactive graphic linkage of texts and data, applied to ozone, water vapour and other selected data of the Earth's atmosphere. EGS-Tagung, Nizza, Frankreich, 25.-29. April 2000.
- Hartmann G. K.:** More effective use of human resource for innovative processes. Internationaler Kongress für Innovations-Technologie, Mendoza, Argentinien, 1.-3. November 2000.
- DUST-2 (CD-ROM): Tools and history. IEMA-UM, Universität Mendoza, Argentinien, 7. November 2000.
- New MAS ozone results with the Formal Concept Analysis (FCA) on DUST-2 (CD-ROM). IEMA-UM, Universität Mendoza, Argentinien, 10. November 2000.
- New MAS ozone results with the Formal Concept Analysis (FCA) on DUST-2 (CD-ROM). Universidad de Concepcion, PMPR, Concepcion, Chile, 13. November 2000.
- Auf dem Weg zum maß-gerechten unternehmerischen Wirtschaften. Universidad de Concepcion, Concepcion, Chile, 14. November 2000.
- Ersticken wir im Unrat? (Nos ahogamos en los desperdicios?). Santiago de Chile, Chile, 16. November 2000.
- Hartogh P.:** Chirp transform spectrometer for the exploration of the Mars atmosphere. Symposium on Concepts and Approaches for Mars Exploration, Lunar and Planetary Institute, Houston, Texas, USA, 18.-20. Juli 2000.
- Hybrid spectrometers and the platforming problem. Steward Observatory, Tucson, Arizona, USA, 11. August 2000.
- Microwave remote sensing techniques and their application.\* 27th Annual European Meeting on Atmospheric Studies by Optical Methods, Stockholm, Schweden, 21.-25. August 2000.
- Hartogh P.** C. Jarchow, C. Seele, and L. Song: Microwave measurements of water vapour at ALOMAR: Latest results. 6th WAVE meeting, CNES, Paris, Frankreich, 15.-16. Mai 2000.
- Hartogh P.** and R. Schieder: New concept for a HIFI backend subsystem. HIFI Consortium Meeting, ESRIN, Frascati, Italien, 10.-12. September 2000.
- Haugan S.V.H.**, P. Brekke, T. Fredvik, O. Kjeldseth-Moe, K. Wilhelm, and J.B. Gurman: Observed variability and dynamics of active region loops. American Astronomical Society, Solar Physics Division, 32nd Annual Meeting, Lake Tahoe, Nevada, USA, 19.-22. Juni 2000.
- Hilchenbach M.:** Rosetta - Neues von dem Schnee von gestern, Tag der Raumfahrt, DLR Göttingen, 24. Oktober 2000.
- Hilchenbach M.**, K. C. Hsieh, and A. Czechowski: Doppler shifted photon emission expected due to reactions of energetic protons with the LISM atoms in the heliosphere. COSPAR Colloquium on The Outer Heliosphere: The Next Frontiers, Potsdam, 24.-28. Juli 2000.
- Hilchenbach M.**, K. C. Hsieh, D. Hovestadt, R.Kallenbach, A. Czechowski, E. Möbius, and P. Bochsler: Energetic neutral hydrogen of heliospheric origin observed with SOHO/CELIAS at 1 AU. COSPAR Colloquium

- on The Outer Heliosphere: The Next Frontiers, Potsdam, 24.-28. Juli 2000.
- Hilchenbach M.** and H. Kochar: Sample acquisition systems in space applications. EGS XXV General Assembly, Nizza, Frankreich, 25.-29. April 2000.
- Hilchenbach M.** and H. Rosenbauer: Future observations of the outer heliosphere. COSPAR Colloquium on The Outer Heliosphere: The Next Frontiers, Potsdam, 24.-28. Juli 2000.
- Hocking W.K.** and J. Röttger: The internal structure of turbulence as revealed by radar and diagnostic studies. 9th International Workshop on Technical and Scientific Aspects of MST Radar- MST9 combined with COST-76 Final Profiler Workshop, Toulouse, Frankreich, 13.-18. März 2000.
- Holzwarth V.** and M. Schüssler: Dynamics of magnetic flux tubes in close binary stars. IAU-Symposium No 200: The formation of binary stars, Potsdam, 10.-15. April 2000.
- Holzwarth V.:** Buried flux tubes in the coronal graveyard. 3. MHD-Tag, Astrophysikalisches Institut Potsdam, 11.-12. September 2000.
- Hsieh K. C.,** A. Czechowski, and M. Hilchenbach: Imaging the global distribution of anomalous cosmic rays. Acceleration and Transport of Energetic Particles Observed in the Heliosphere, ACE-2000 Symposium, Indian Wells, CA, USA, 5.-8. Januar 2000.
- Huttunen K.E.J.,** H.E.J. Koskinen, R. Schwenn, and O.C. St.Cyr: Geoefficiency of coronal mass ejections during a rising solar cycle. First S-RAMP Conference, Sapporo, Japan, 2.-6. Oktober 2000.
- Hviid S.F.** and W. Markiewicz: Optimised geometric camera model of the Imager for Mars Pathfinder. 32th Annual Meeting of the Division for Planetary Sciences, Pasadena, California, USA, 23.-27. Oktober 2000.
- Inhester B.:** Stereoscopy and tomography for the STEREO mission. DPG-Jahrestagung der Arbeitsgemeinschaft Extraterrestrische Physik (AEF), Bremen, 21.-24. März 2000.
- Beyond SOHO: an outlook to the STEREO mission. LASCO/EIT Consortium Meeting, Teistungenburg, 15.-17. Mai 2000.
- MPAE contributions to the SECCHI 3D reconstruction software package. SECCHI Consortium meeting, Easton, MD, USA, 6.-9. November 2000.
- Innes D.E.:** Evidence for explosive start of CME. LASCO/EIT Consortium Meeting, Teistungenburg, 15.-17. Mai 2000.
- SUMER observations of high Fe XX Doppler shifts in the solar corona during the initial phase of a flare and CME. 33rd COSPAR Scientific Assembly, Warschau, Polen, 16.-23. Juli 2000.
- Observational signatures of magnetic reconnection in the solar network. 33rd COSPAR Scientific Assembly, Warschau, Polen, 16.-23. Juli 2000.
- Innes D.E.,** W. Curdt, G. Stenborg, R. Schwenn, and D.E. McKenzie: Flare and CME onset: UV spectra show fast 3-D flow. IAU Symp. 203: Recent Insights into the Physics of the Sun and Heliosphere - Highlights from SOHO and Other Space Missions, Manchester, Großbritannien, 7.-11. August 2000.
- Ipavich F.M.,** J.A. Paquette, P. Bochsler, S.E. Lasley, P. Wurz, H. Grunwaldt, M. Hilchenbach, G. Gloeckler, J. Geiss, and D. Hovestadt: The abundance of iron isotopes in the solar wind: Results from SOHO/CELIAS/MTOF. AGU Spring Conference, Washington, DC, USA, 30. Mai - 3. Juni 2000.
- Isham B., F.T. Djuth, **M.T. Rietveld,** C. La Hoz, H. Kohl, K.M. Groves, R. C. Livingston, and T. Hagfors: Simultaneous incoherent scatter radar and stimulated electromagnetic emission observations of high latitude pump-induced Langmuir turbulence. AGU Fall Meeting, San Franzisko, CA, USA, 15.-19. Dezember 2000.
- Jockers K.:** Die eisigen Monde der äußeren Planeten. Erich-Regener-Vortrag am MPI für Aeronomie, Katlenburg-Lindau, 12. Oktober 2000.
- Jockers K.,** I. Kulyk, and N. Karpov: Ground-based imaging of S<sup>+</sup> and S<sup>++</sup> in the Io plasma torus in support of the Galileo Mission. EGS XXV General Assembly, Nizza, Frankreich, 25.-29. April 2000.
- Jockers K.,** T. Credner, T. Bonev, N. Kiselev, P. Korsun, I. Kulyk, V. Rosenbush, A. Andrenko, N. Karpov, A. Sergeev, and V. Tarady:

- Exploration of the solar system with the two-channel focal reducer at the 2m-RCC telescope of Pik Terskol Observatory. Astronomy in Ukraine, 2000 and beyond, Kiev-Goloseevo, Ukraine, 5.-8. Juni 2000.
- Jockers K.**, T. Bonev, P. Korsun, N. Karpov, A. Sergeev, and V. Tarady: Water production of comets derived from observations of [OI] (6300 Å) and H<sub>2</sub>O<sup>+</sup> (6150 Å): Comets C/1998 U5 (Linear) and C/1999 J3 (Linear). Astronomy in Ukraine, 2000 and beyond, Kiev-Goloseevo, Ukraine, 5.-8. Juni 2000.
- Jordan A.**, J. Harnisch, R. Borchers, F. Le Guern, and H. Shinohara: Volcanogenic emission of halogenated hydrocarbons. Quadrennial Ozone Symposium, Sapporo, Japan, 3.-8. Juli 2000.
- Jordan A.**, J. Harnisch, M. Frische, and R. Borchers: Halogenierte Spurengase aus geologischen Quellen. HydroGeoEvent 2000 Wasser-Gesteins-Wechselwirkungen, 152. Hauptversammlung Deutsche Geologische Gesellschaft zugleich Fachtagung Fachsektion Hydrogeologie in der Deutschen Geologischen Gesellschaft, Heidelberg, 29. September - 4. Oktober 2000.
- Keller H.U. (and the OSIRIS Consortium):** OSIRIS - The scientific imaging system for the Rosetta orbiter. Rosetta payload review, ESTEC, Noordwijk, Niederlande, 18. Januar 2000.
- Keller H.U.:** Space-borne remote sensing: From cold comets to hot Mercury. Fachbeiratssitzung, MPAE, 31. Januar 2000.
- Keller H.U.:** Mars, der rote Schleier wird gelüftet. Förderkreis Planetarium Göttingen, Göttingen, 7. März 2000.
- Keller H.U.**, Y.V. Skorov and H. Rickman: Kinetic non-equilibrium gas-dust in the innermost coma and its influence on the macroscopic characteristics of the inner coma. IAU Colloquium No. 181, Dust in the Solar System and Other Planetary Systems, Canterbury, Großbritannien, 10.-14. April 2000.
- Keller H.U.**, Y.V. Skorov, and H. Rickman: Heterogeneous gas-dust flow in the innermost coma. Kinetic approaches. IAU Colloquium No. 181, Dust in the Solar System and Other Planetary Systems, Canterbury, Großbritannien, 10.-14. April 2000.
- Keller H.U.**, et al.: Lunar mineralogy and SIR compact infrared spectrometer on SMART-1. EGS XXV General Assembly, Nizza, Frankreich, 25.-29. April 2000.
- Keller H.U.:** The Descent Imager/Spectral Radiometer (DISR) aboard Huygens. Titan Workshop, Lissabon, Portugal, 22.-26. Juni 2000.
- Keller H.U.** and J. Jorda: Cometary nucleus structure and morphology: Observations, models, and plans. 33rd COSPAR Scientific Assembly, Warschau, Polen, 16.-23. Juli 2000.
- Keller H.U.**, T.P. Meloy, J. Marshall, W.J. Markiewicz, and M. Hecht: The Mars Environmental Compatibility Assessment (MECA). 33rd COSPAR Scientific Assembly, Warschau, Polen, 16.-23. Juli 2000.
- Keller H.U.**, Y.V. Skorov, W.J. Markiewicz, and A.T. Basilevsky: Stability of water ice beneath porous dust layers of the martian south polar terrain. Second International Conference on Mars Polar Science and Exploration, Reykjavik, Island, 18.-27. August 2000.
- Keller H.U.**, L. Jorda, H. Rickman, and N. Thomas: A model of comet nucleus rotation. 32th Annual Meeting of the Division for Planetary Sciences, Pasadena, California, USA, 23.-27. Oktober 2000.
- Keller H.U.**, U. Mall, and A. Nathues: Mapping the moon with SIR, an infrared spectrometer for SMART-1. Conference "Earth-Moon Relationships", Padua, Italien, 8.-10. November 2000.
- Kiselev N.N.**, K. Jockers, and V.K. Rosenbush: Organic matter in dust particles of comet 21P/Giacobini-Zinner and the Draconid meteoroids. Astronomy in Ukraine, 2000 and beyond, Kiev-Goloseevo, Ukraine, 5.-8. Juni 2000.
- Klecker B.**, A.T. Bogdanov, M. Hilchenbach, A.T. Galvin, F.M. Ipavich, D. Hovestadt E. Moebius, and P. Bochsler: On the variability of He<sup>+</sup> abundances in energetic particle events. 8th CELIAS Workshop, Charlston, USA, 16.-18. März 2000.
- Klecker B.**, A.T. Bogdanov, M. Hilchenbach, A.T. Galvin, E. Möbius, F. M. Ipavich, and P. Bochsler: On the variability of suprathermal pickup He at 1 AU. COSPAR Colloquium on The Outer Heliosphere: The Next Frontiers, Potsdam, 24.-28. Juli 2000.

- Klostermeyer J.:** Generation and effects of ice particles at the polar summer mesopause. Fachbeiratssitzung, Katlenburg-Lindau, 31. Januar - 2. Februar 2000.
- Kopp A.** and W.-H. Ip: Asymmetric mass loading effect at Titan's ionosphere. EGS XXV General Assembly, Nizza, Frankreich, 25.-29. April 2000.
- Kopp A.,** W.-H. Ip, and A. Schoerer: Comparative MHD simulations of the interaction of the Galilean satellites with the Jovian magnetosphere. EGS XXV General Assembly, Nizza, Frankreich, 25.-29. April 2000.
- Korsun P.P.** and K. Jockers: CN and NH<sub>2</sub> atmospheres of comet C/1999 J3 (Linear). Astronomy in Ukraine, 2000 and beyond, Kiev-Goloseevo, Ukraine, 5.-8. Juni 2000.
- Korth A.:** Geomagnetische Stürme und Weltraumwetter. DPG-Jahrestagung der Arbeitsgemeinschaft Extraterrestrische Forschung (AEF), Bremen, 21.-24. März 2000.
- Observations of the ring current during magnetic storms. Seminar i Romfysikk, Universität Bergen, Bergen, Norwegen, 2. Juni 2000.
  - Weltraumwetter: Sturmwarnung aus dem All? Wissenschaftler-Pressekonferenz, Bonn-Bad Godesberg, 19. September 2000.
  - Erdmagnetische Stürme – Das Weltraumwetter. Lehrerfortbildung, Tagung der Astronomischen Gesellschaft - 2000, Bremen, 23. September 2000.
- Korth A.,** R. Friedel, C. Mouikis, Q. Zong, and F. Frutos-Alfaro: Storm-substorm signatures in the outer radiation belt. NATO Advanced Study Institute on Space Storms and Space Weather Hazards, Kreta, Griechenland, 19.-29. Juni 2000.
- Korth A.,** R.H.W. Friedel, F. Frutos-Alfaro, C. Mouikis, and Q. Zong: Are magnetic storms qualitatively different from magnetospheric substorms? The First S-Ramp Conference, Sapporo, Japan, 2.-6. Oktober 2000.
- Kosch M.J.,** K. Cierpka, M. Rietveld, T. Hagfors, and K. Schlegel: Thermospheric ion-drag time constants using EISCAT and a Fabry-Perot interferometer. Conference on Magnetosphere, Ionosphere, and Solar-Terrestrial (MIST), Imperial College, London, Großbritannien, 11.-13. April 2000.
- Kosch M.J.,** M.T. Rietveld, F. Honary, T.B. Leyser, and T. Hagfors: Observations of HF induced airglow by DASI and CUTLASS. Magnetosphere, Ionosphere, and Solar-Terrestrial (MIST), Imperial College, London, Großbritannien, 11.-13. April 2000.
- Kosch M.J.,** K. Cierpka, M.T. Rietveld, T. Hagfors, and K. Schlegel: Thermospheric ion-drag time constants from ground-based measurements. 33rd COSPAR Scientific Assembly, Warschau, Polen, 16.-23. Juli 2000.
- Kosch M.J.** and E. Nielsen: Coherent radar estimates of high latitude field-aligned currents. 33rd COSPAR Scientific Assembly, Warschau, Polen, 16.-23. Juli 2000.
- Kosch M.J., **M.T. Rietveld,** T.B. Leyser, F. Honary, J.W. Wright, and T. Hagfors: HF induced airglow from the EISCAT heating facility. 33rd COSPAR Scientific Assembly, Warschau, Polen, 16.-23. Juli 2000.
- Kosch M.J.,** M.W.J. Scourfield, and O. Amm: The importance of conductivity gradients in ground-based field-aligned current studies. 33rd COSPAR Scientific Assembly, Warschau, Polen, 16.-23. Juli 2000.
- Krimigis S.M.,** D.G. Mitchell, D.C. Hamilton, S. Livi, T.P. Armstrong, A.F. Cheng, J. Dandouras, G. Gloeckler, K.C. Hsieh, W.-H. Ip, E.P. Keath, E. Kirsch, N. Krupp, L.J. Lanzerotti, B.H. Mauk, R.W. McEntire, E.C. Roelof, and B. Wilken: In-flight performance and first observations at Venus and Earth of Magnetospheric Imaging Instrument (MIMI) on Cassini/Huygens.\* EGS XXV General Assembly, Nizza, Frankreich, 25.-29. April 2000.
- Krupp N.:** Plasmakonvektion in der Jupitermagnetosphäre. Jupiter-Workshop, Universität Köln, Köln, 6.-7. Juli 2000.
- Krupp N.,** A. Lagg, J. Woch, E.C. Roelof, and D.J. Williams: Bewegung energiereicher Ionen in der Jupitermagnetosphäre. Deutsche Physikalische Gesellschaft, Frühjahrstagung AEF, Bremen, 21.-24. März 2000.
- Krupp N.,** S. Livi, A. Lagg, and S.M. Krimigis: MIMI/LEMMS energetic particle measurements during the Cassini Earth swing-by. Cassini Earth Swing-By Workshop, Leicester University, Leicester, Großbritannien, 14.-16. Februar 2000.

- Krupp N.**, J. Woch, A. Lagg, B. Wilken, S. Livi, E.C. Roelof, and D.J. Williams: Flows of energetic particles in Jupiter's equatorial plane. EGS XXV General Assembly, Nizza, Frankreich, 25.-29. April 2000.
- Krupp N.**, Roelof, E.C., D.J. Williams, A. Lagg, and J. Woch: Energetic ion convection velocities at Jupiter. EGS XXV General Assembly, Nizza, Frankreich, 25.-29. April 2000.
- Krupp N.**, S. Livi, A. Lagg, S.M. Krimigis, D.G. Mitchell, T.P. Armstrong, I. Dandouras, and D.C. Hamilton: First results of the energetic particle detector MIMI/LEMMS onboard CASSINI during Earth flyby. EGS XXV General Assembly, Nizza, Frankreich, 25.-29. April 2000.
- Krupp N.**, A. Lagg, J. Woch, S. Livi, S.M. Krimigis, and D.J. Williams: Cassini and Galileo combined energetic particle measurements in the vicinity of Jupiter. AGU Fall Meeting, San Franzisko, CA, USA, 15.-19. Dezember 2000.
- Kulyk I.**, K. Jockers, N. Karpov, and A. Sergeev: Near-infrared photometric observations of the inner Jovian satellites. Astronomy in Ukraine, 2000 and beyond, Kiew-Goloseevo, Ukraine, 5.-8. Juni 2000.
- Lagg A.**, N. Krupp, and J. Woch: Ion pitch angle distributions in the Io plasma torus.\* EGS XXV General Assembly, Nizza, Frankreich, 25.-29. April 2000.
- La Hoz C., **M.T. Rietveld**, T. Grydeland, and B. Isham: Observations of anomalous ion line spectra associated with enhanced plasma lines during auroral precipitation. AGU Fall Meeting, San Franzisko, CA, USA, 15.-19. Dezember 2000.
- Latteck R.**, R. Rüster, W. Singer, J. Röttger, P.B. Chilson, and V. Barabash: Comparison of polar mesosphere summer echoes observed with the Alwin MST Radar at 69° and the SOUSY Svalbard Radar at 78° in summer 1999. 9th International Workshop on Technical and Scientific Aspects of MST Radar-MST9 combined with COST-76 Final Profiler Workshop, Toulouse, Frankreich, 13.-18. März 2000.
- Lemaire P.**, K. Wilhelm, W. Curdt, and U. Schühle: The FUV/EUV SUMER Solar Spectrometer on SOHO: From ground to flight performances. EGS XXV General Assembly, Nizza, Frankreich, 25.-29. April 2000.
- Lemaire P.**, J.-C. Vial, G. Artzner, W. Curdt, U. Schühle and K. Wilhelm: Transition region quiet Sun velocity field evolution. 33rd COSPAR Scientific Assembly, Warschau, Polen, 16.-23. Juli 2000.
- Liu H.**, K. Schlegel, and S.Y. Ma: Comparison of storm effects in the auroral oval and the polar cap. EGS XXV General Assembly, Nizza, Frankreich, 25.-29. April 2000.
- Ma S.Y.**, P. Liu, and K. Schlegel: High-latitude ionisation troughs and associated solar-terrestrial coupling processes. EGS XXV General Assembly, Nizza, Frankreich, 25.-29. April 2000.
- Mall U.**, M. Banaszekiewicz, and S. Verani: Investigating the lunar exosphere by in-situ mass spectrometry. EGS XXV General Assembly, Nizza, Frankreich, 25.-29. April 2000.
- Mall U.**, P. Daly, E. Kirsch, J. Woch, S. Christon and G. Gloeckler: Energetic O<sup>+</sup>, N<sup>+</sup> and O<sub>2</sub><sup>+</sup> composition observations in the night-side magnetosphere. AGU Spring Meeting 2000, Washington DC, USA, 30. Mai - 3. Juni 2000.
- Mall U.** and N. Borisov: Electric fields and plasma perturbations in the vicinity of the Moon. Fourth International Conference on the Exploration and Utilisaton of the Moon, ESTEC, Nordwijk, Niederlande, 10.-14. Juli 2000.
- Mall U.**, M. Banaszekiewicz, and S. Verani: Investigating planetary exospheres by in-situ mass spectrometry: The lunar case. Fourth International Conference on the Exploration and Utilisaton of the Moon, ESTEC, Nordwijk, Niederlande, 10.-14. Juli 2000.
- Markiewicz W.J.**: Martian atmosphere – results from the Imager for Mars Pathfinder HRSC on Mars Express. Co-Investigator Team Meeting, Berlin, 24.-25. Januar 2000.
- Markiewicz W.J.**, H.U. Keller, N. Thomas, and D. Titov: Optical properties of the Martian aerosols. EGS XXV General Assembly, Nizza, Frankreich, 25.-29. April 2000.
- Markiewicz W.J.**, H.U. Keller, N. Thomas, and D. Titov: Optical Properties of the Martian Aerosols. 33rd COSPAR Scientific Assembly, Warschau, Polen, 16.-23. Juli 2000.

- Markiewicz W.J.**, K.J. Kossacki, and H.U. Keller: Effect of surface roughness on ice distribution in the south subpolar region of Mars. Second International Conference on Mars Polar Science and Exploration, Reykjavik, Island, 18.-27. August 2000.
- Markiewicz W.J.**, E.V. Petrova, and H.U. Keller: On the problem of light scattering by planetary regolith. 32th Annual Meeting of the Division for Planetary Sciences, Pasadena, CA, USA, 23.-27. Oktober 2000.
- Marsch E.:** Solar Orbiter.\* Presentation to the Solar System Working Group, ESA Headquarters, Paris, Frankreich, Februar 2000.
- Solar Orbiter.\* Presentation, NASA Workshop “LIVING WITH A STAR” (LWS) Programms, GSFC, Greenbelt, Maryland, USA, 11. Mai 2000.
- Solar Orbiter – High resolution mission to the Sun and inner heliosphere.\* 33rd COSPAR Scientific Assembly, Warschau, Polen, 16.-23. Juli 2000.
- Observations and models of the fast and slow solar wind.\* 24th General Assembly IAU, Manchester, England, 7.-18. August 2000.
- The solar wind.\* Kolloquium, Kiepenheuer-Institut für Sonnenphysik, Freiburg, 16. November 2000.
- Marsch E.**, B. Fleck, and R. Schwenn: Solar Orbiter – A high resolution mission to the Sun and inner heliosphere. COSPAR Colloquium, Potsdam, 24.-28. Juli 2000.
- Marsch E.**, R. Harrison, and O. Pace: Solar Orbiter – An orbiter for solar observations at very high spatial resolution.\* Presentation of Assessment Study Results, UNESCO Building (ESA Headquarters), Paris, Frankreich, 12. September 2000.
- Marsch E.**, J.F. McKenzie and W.I. Axford: The solar wind.\* 34th ESLAB Symposium on The 3-D Heliosphere at Solar Maximum, ESTEC, Noordwijk, Niederlande, 3.-6. Oktober 2000.
- Marsch E.**, R. Schwenn, E. Antonucci, P. Bochsler, J.-L. Bougeret, B. Fleck, R. Harrison, R. Marsden, and J.-C. Vial: Solar Orbiter – High resolution mission to the Sun and inner heliosphere. 24th General Assembly IAU, Manchester, England, 7.-18. August 2000.
- Marsch E.** and C.-Y. Tu: Heizung und Beschleunigung von Ionen durch Zyklotron- und Landau-Resonanz mit Plasmawellen. DPG-Jahrestagung der Arbeitsgemeinschaft Extraterrestrische Physik (AEF), Bremen, 21.-24. März 2000.
- Heating and acceleration of ions by cyclotron- and Landau-resonances. COSPAR Colloquium, Potsdam, 24.-28. Juli 2000.
- Marsch E.**, K. Wilhelm, I. E. Dammasch, and D. M. Hassler: Die Entstehung des schnellen Sonnenwindes in polaren koronalen Löchern. DPG-Jahrestagung der Arbeitsgemeinschaft Extraterrestrische Physik (AEF), Bremen, 21.-24. März 2000.
- Mazelle C.**, M.H. Acuna, K. Sauer, and E. Dubinin: Low frequency waves around Mars in the light of Mars global surveyor.\* EGS XXV General Assembly, Nizza, Frankreich, 25.-29. April 2000.
- McKenzie J.F.**, K. Sauer, and E. Dubinin: Bion soliton structures perpendicular to the magnetic field. Workshop on Waves in Dusty, Solar and Space Plasmas, Katholieke Universiteit Leuven, Belgien, 22.-26. Mai 2000.
- McKenzie J.F.:** Compressive instability driven by ion-cyclotron dissipation in the solar wind. AGU 2000 Fall Meeting, San Franzisko, USA, 15.-19. Dezember 2000.
- Mikhailov A.V.** and K. Schlegel: A self-consistent estimate of  $O^+ + N_2$  rate coefficient and total EUV solar flux with  $\lambda < 105$  nm using EISCAT observations. EGS XXV General Assembly, Nizza, Frankreich, 25.-29. April 2000.
- Mouikis C.G.**, L. Kistler, B. Klecker, W. Baumjohann, and A. Korth: Equator-S observations of  $He^+$  energisation by EMIC waves in the equatorial magnetosphere. EGS XXV General Assembly, Nizza, Frankreich, 25.-29. April 2000.
- Muñoz Caro G. M.:** Last results on the analysis of UV photolysis products of interstellar ice analogs. Expanding your Universe 2000, London, England, 5. März 2000.
- Muñoz Caro G. M.:** UV photolysis of hydrocarbons under simulated dense and diffuse cloud conditions. International School of Space Chemistry, Erice, Italien, 5.-16. Juni 2000.

- Muschinski A.**, P.B. Chilson, R.D. Palmer, D.A. Hooper, G.Schmidt, and H. Steinhagen: SOMARE-99: Boundary-Layer convection and diurnal variation of vertical-velocity characteristics in the free troposphere. 9th International workshop on Technical and Scientific Aspects of MST Radar- MST9 combined with COST-76 final profiler workshop, Toulouse, Frankreich, 13.-18. März 2000.
- Nathues A.**, U. Mall, H.U. Keller, W.J. Markiewicz, and N. Thomas: SIR, a NIR spectrometer on SMART-1. EGS XXV General Assembly, Nizza, Frankreich, 25.-29. April 2000.
- Nathues A.**, U. Mall, and H.U. Keller: Near infrared spectrometry with SIR on SMART-1; Exploration and Utilisation of the Moon, Proceedings of the fourth international conference, ESTEC, Noordwijk, Niederlande, 10.-15. Juli 2000.
- Nathues A.**, U. Mall, and H.U. Keller: Near Infrared Spectrometry with SIR on SMART-1. 4th International Conference on Exploration and Utilisation of the Moon, ICEUM 4, abstract and formal report, ESTEC, Noordwijk, Niederlande 10.-15. Juli 2000.
- Nikutowski B.**, J. Büchner, A. Otto, W. Baumjohann, G. Haerendel, U. Auster, K.-H. Fornacon, and E. Georgescu: Equator-S observations and simulation of Kelvin-Helmholtz waves at the magnetopause. Session ST1, EGS XXV General Assembly, Nizza, Frankreich, April 2000.
- Nikutowski B.**, J. Büchner, A. Korth, and A. Otto: Observations and simulations of reconnection coupled to Kelvin-Helmholtz-unstable surface waves. 33rd COSPAR Scientific Assembly, Symposium D0.1/E3.1 on Comparative Reconnection Studies at Sun and in Magnetospheres, Warschau, Polen, 20. Juli 2000.
- Nykyri K.**, A. Otto, J. Büchner, and B. Nikutowski: Simulations of magnetic reconnection in Kelvin-Helmholtz vortices and comparison with Equator-S observations. AGU Fall meeting, session SM61 "Tail magnetopause and boundary layers", San Franzisko, 14. Dezember 2000.
- Palmer R.D.**, P.B. Chilson, A. Muschinski, G. Schmidt, T.-Y. Yu, and H. Steinhagen: Range imaging using frequency diversity: Theory and application. 9th International Workshop on Technical and Scientific Aspects of MST Radar-MST9 combined with COST-76 Final Profiler Workshop, Toulouse, Frankreich, 13.-18. März 2000.
- Pauluhn A.**, S.K. Solanki, U. Schühle, K. Wilhelm, J. Lang, W.T. Thompson, I. Rüedi, J. Hollandt, and M.C.E. Huber: Comparison of quiet Sun radiances measured by CDS and SUMER on SOHO. 34th ESLAB Symposium, The 3-D Heliosphere at Solar Maximum, ESTEC, Noordwijk, Niederlande, 3.-6. Oktober, 2000.
- Perry C.**, M. Grande, T. Zurbuchen, G. Gloeckler, J. Fennell, T. Fritz, B. Wilken, and S. Hefti: Use of Fe charge state changes as a tracer for solar wind entry to the magnetosphere. EGS XXV General Assembly, Nizza, Frankreich, 25.-29. April 2000.
- Petrova E.V.**, K. Jockers, and N.N. Kiselev: Light scattering by aggregates and a negative branch of polarization of comets and small celestial bodies. EGS XXV General Assembly, Nizza, Frankreich, 25.-29. April 2000.
- Petrova E.V.** and W.J. Markiewicz: A method for retrieval of aerosol properties with co-analysis of the SSI and lidar data (Mars Polar Lander). EGS XXV General Assembly, Nizza, Frankreich, 25.-29. April 2000.
- Ploner, S.R.O.**, M. Schüssler, S.K. Solanki, and A.S. Gadun: An example of reconnection and magnetic flux recycling near the solar surface. Advanced Solar Polarimetry – Theory, Observation, and Instrumentation, 20th Sacramento Peak Summer Workshop, Sunspot, USA, 11.-15. September 2000.
- Ploner, S.R.O.**, M. Schüssler, S.K. Solanki, V.A. Sheminova, and A.S. Gadun: The formation of one-lobed Stokes V profiles in an inhomogeneous atmosphere. Advanced Solar Polarimetry – Theory, Observation, and Instrumentation, 20th Sacramento Peak Summer Workshop, Sunspot, USA, 11.-15. September 2000.
- Portier-Foazzani F.**, and the STEREO team at MPAE: From EIT to Secchi: 3D observation methods. STEREO/SECCHI Meeting, Easton, MD, USA, November 2000.
- Portier-Foazzani F.** and Inhester B.: 3D Coronal structures and their evolutions measured by stereoscopy, consequences for space weather and the STEREO mission. 34th ESLAB Symposium "The 3-D Heliosphere at Solar

- Maximum”, ESTEC, Noordwijk, Niederlande, 3.-6. Oktober 2000.
- Pryor W.**, J. Ajello, and M. Witte: Remote sensing of H and He from Ulysses and Galileo. 34th ESLAB Symposium “The 3-D Heliosphere at Solar Maximum”, ESTEC, Noordwijk, Niederlande, 3.-6. Oktober 2000.
- Rempel M.:** Storage of magnetic field in the solar overshoot region. 3. MHD-Tag, Astrophysikalisches Institut Potsdam, 11.-12. September 2000.
- Storage of strong magnetic field in spherical geometry. High Altitude Observatory, Boulder, CO, USA, 20. September 2000.
- Rietveld M.T., **B. Isham**, C. La Hoz, T. Grydeland, F. Honary, T.B. Leyser, H. Ueda, M.J. Kosch, and T. Hagfors: HF-enhanced F-region electron temperatures and E-region plasma lines from the nighttime auroral ionosphere. 33rd COSPAR Scientific Assembly, Warschau, Polen, 16.-23. Juli 2000.
- Roelof E.C.**, D.J. Williams, N. Krupp, A. Lagg, and J. Woch: Energetic ion convection velocities at Jupiter. EGS XXV General Assembly, Nizza, Frankreich, 25.-29. April 2000.
- Romstedt J.**, M.A. Barucci, A. Balogh, C. Carr, A. Coradini, M.C. De Sanctis, F. Ferri, M. Grande, C. Lagerkvist, M. Pätzold, E. Perozzi, N. Thomas, and M. Novara: MASTER - Mars + ASTERoid: An ESA flexible mission connecting different worlds. American Astronomical Society, Division for Planetary Sciences, Pasadena, Kalifornien, USA, 23.-27. Oktober 2000.
- Rosenbush V.K.**, N.N. Kiselev, K. Jockers, V.V. Korokhin, N.M. Shakhovskoy, and Yu.S. Efimov: Optical polarimetry of the Galilean satellites, Iapetus, and 64 Angelina near opposition. Astronomy in Ukraine, 2000 and beyond, Kiew-Goloseevo, Ukraine, 5.-8. Juni 2000.
- Röttger J.:** Observations of the Arctic troposphere and lower stratosphere with the SOUSY Svalbard Radar. Second International Symposium on Environmental Research in the Arctic and Fifth Ny-Ålesund Scientific Seminar, Tokio, Japan, 23.-25. Februar 2000.
- Observations of the Arctic mesosphere and D-region with the EISCAT Svalbard Radar and the SOUSY Svalbard Radar. Second International Symposium on Environmental Research in the Arctic and Fifth Ny-Ålesund Scientific Seminar, Tokio, Japan, 23.-25. Februar 2000.
  - Polar mesosphere summer echoes and the structure and dynamics of the lower atmosphere over Svalbard observed with the EISCAT Svalbard Radar and the SOUSY Svalbard Radar. Seminar, Radio Atmospheric Science Centre, Kyoto University, Kyoto, Japan, 7. Juni 2000.
  - Observations of the lower and middle atmosphere with the SOUSY Svalbard Radar and the EISCAT Svalbard Radar. Seminar, Institute of Space Science, National Central University, Chung Li, Taiwan, 14. Juni 2000.
  - Orographically generated atmospheric waves investigated by VHF Radar. Seminar, Institute of Space Science, National Central University, Chung Li, Taiwan, 16. Juni 2000.
  - A general introduction of ST radar wind profilers. Workshop on the Development of a Troposphere Profiling Network on Taiwan, National Central University, Chung-Li, Taiwan, 16. September 2000.
  - Scientific reasoning of a network of ST radar wind profilers on Taiwan. Workshop on the Development of a Troposphere Profiling Network on Taiwan, National Central University, Chung-Li, Taiwan, 16. September 2000.
  - System requirements for ST radar wind profilers. Workshop on the Development of a Troposphere Profiling Network on Taiwan, National Central University, Chung-Li, Taiwan, 16. September 2000.
  - The application of high-latitude ionospheric radars for space weather research. COSPAR Colloquium Space Weather Study Using Multi-point Techniques and COSMIC International Workshop, Pacific Green Bay, Wanli, Taipei, Taiwan, 27.-29. September 2000.
  - Troposphere layer structure and development observed by the SOUSY Svalbard Radar. First ASTAR Workshop, Kawaguchiko, Japan, 3.-5. Oktober 2000.
  - Radar studies of the middle and lower atmosphere in: The middle polar atmosphere (Course AGF-210). UNIS (University Courses on Svalbard), Longyearbyen, Norwegen, 23.-27. Oktober 2000.
  - A brief history and an overview of radars for

- studies of the atmosphere and ionosphere (together with S. Fukao). Physics of Mesosphere-Stratosphere-Troposphere Interactions with Special Emphasis on MST Radar Techniques (Course SMR-1247), The Abdus Salam International Centre for Theoretical Physics, Trieste, Italien, 13.-24. November 2000.
- Radar modulation schemes, data acquisition and analysis techniques. Physics of Mesosphere-Stratosphere-Troposphere Interactions with Special Emphasis on MST Radar Techniques (Course SMR-1247), The Abdus Salam International Centre for Theoretical Physics, Trieste, Italien, 13.-24. November 2000.
  - Spaced antenna method and interferometry: multiple receiver and multi-frequency techniques. Physics of Mesosphere-Stratosphere-Troposphere Interactions with Special Emphasis on MST Radar Techniques (Course SMR-1247), The Abdus Salam International Centre for Theoretical Physics, Trieste, Italien, 13.-24. November 2000.
  - Synoptic-scale disturbances and cyclones: frontal systems, tropopause foldings and typhoons. Physics of Mesosphere-Stratosphere-Troposphere Interactions with Special Emphasis on MST Radar Techniques (Course SMR-1247), The Abdus Salam International Centre for Theoretical Physics, Trieste, Italien, 13.-24. November 2000.
  - Basics of coherent and incoherent scatter from the middle atmosphere. Physics of Mesosphere-Stratosphere-Troposphere Interactions with Special Emphasis on MST Radar Techniques (Course SMR-1247), The Abdus Salam International Centre for Theoretical Physics, Trieste, Italien, 13.-24. November 2000.
  - The mesosphere and lower thermosphere in polar latitudes. Physics of Mesosphere-Stratosphere-Troposphere Interactions with Special Emphasis on MST Radar Techniques (Course SMR-1247), The Abdus Salam International Centre for Theoretical Physics, Trieste, Italien, 13.-24. November 2000.
  - Interpretation of Polar Mesosphere Summer Echoes observed with the EISCAT Svalbard Radar and the SOUSY Svalbard Radar.\* Internal EISCAT Workshop, National Institute of Polar Research, Tokio, Japan, 8. Dezember 2000.
- Röttger J.,** C. Hall and J. Markkannen: First D-Region incoherent scatter and PMSE observations with the EISCAT Svalbard Radar (500 MHz) and comparison with collocated observations of PMSE with the SOUSY-Svalbard-Radar (53.5 MHz). 9th International Workshop on Technical and Scientific Aspects of MST Radar- MST9 combined with COST-76 Final Profiler Workshop, Toulouse, Frankreich, 13.-18. März 2000.
- Röttger J.,** C.M. Hall and J. Markkannen: First observations of polar mesospheric summer echoes using the EISCAT Svalbard Radar. Planetary Scale Mesopause Observing System PSMOS-2000 Workshop, Toronto, Kanada, 23.-26. Mai 2000.
- Röttger J.,** H. Luce, M. Yamamoto, and S. Fukao: Combined high-time resolution SDI-FDI experiments with the MU Radar. 9th International Workshop on Technical and Scientific Aspects of MST Radar- MST9 combined with COST-76 Final Profiler Workshop, Toulouse, Frankreich, 13.-18. März 2000.
- Röttger J.,** G. Schmidt, R. Rüster, P. Czechowsky, J. Klostermeyer, J. Trautner, K. Meyer, K.D. Preschel, and H. Becker: An update on the SOUSY-Svalbard-Radar: Observations of PMSE, meteors and the arctic stratosphere and troposphere. 9th International Workshop on Technical and Scientific Aspects of MST Radar- MST9 combined with COST-76 Final Profiler Workshop, Toulouse, Frankreich, 13.-18. März 2000.
- Röttger J.,** S.Y. Su, C.J. Pan, C.H. Liu, and J. Wu: SDI-FDI detection of lightning echoes with the Chung-Li VHF Radar: Three-dimensional interferometry. 9th International Workshop on Technical and Scientific Aspects of MST Radar-MST9 combined with COST-76 Final Profiler Workshop, Toulouse, Frankreich, 13.-18. März 2000.
- Röttger J.** and J. Trautner: Synoptic and meso-scale disturbances observed in the arctic troposphere and lower stratosphere with the SOUSY-Svalbard-Radar. 9th International Workshop on Technical and Scientific Aspects of MST Radar- MST9 combined with COST-76 Final Profiler Workshop, Toulouse, Frankreich, 13.-18. März 2000.
- Rüster R.,** J. Röttger, G. Schmidt, P. Czechowsky, and J. Klostermeyer: Small and large scale processes observed in the sum-

- mer mesopause region. Fachbeiratssitzung, Katlenburg-Lindau, 31. Januar - 2. Februar 2000.
- Rüster R.**, J. Röttger, G. Schmidt, P. Czechowsky, and J. Klostermeyer: First results from observations in the summer polar mesosphere using the SOUSY-Svalbard-Radar (78 N, 16 E). EGS XXV General Assembly, Nizza, Frankreich, 25.-29. April 2000.
- Sauer K.:** Looking for Phobos/Deimos events in the MAG/ER data of MGS. University of California, Space Science Laboratory, Berkeley, CA, USA, 24. Februar 2000.
- The magnetic pile-up boundary at Mars. Jet Propulsion Laboratory, Pasadena, CA, USA, 1. März 2000.
  - Plasma-Satelliten-Wechselwirkung: Erkenntnisse aus der Mars- und Kometenforschung. Jupiter-Workshop, Köln, 6.-7. Juli 2000.
  - Bi-ion solitons related to solar wind mass loading at comets and Mars. CETP, Velizy, Frankreich, 11. November 2000.
  - Solar wind – Mars interaction: New theoretical concepts. Centre d'Etude Spatiale des Rayonnements (CESR), Toulouse, Frankreich, 19. November 2000.
- Sauer K.**, E. Dubinin, and J.F. McKenzie: Wellen und nichtlineare Plasmastrukturen in der Marsmagnetosphäre. DPG-Jahrestagung, Arbeitsgemeinschaft Extraterrestrische Forschung (AEF), Bremen, 21.-24. März 2000.
- Sauer K.**, E. Dubinin, and J.F. McKenzie: Stationary bi-ion structures (solitons) related to the physics of the martian magnetic pile-up boundary/protonpause. EGS XXV General Assembly, Nizza, Frankreich, 25.-29. April 2000.
- Sauer K.**, J.F. McKenzie, and E. Dubinin: Waves and non-linear stationary structures in bi-ion plasmas.\* Workshop on Waves in Dusty, Solar and Space Plasmas, Katholieke Universiteit Leuven, Belgien, 22.-26. Mai 2000.
- Sauer K.**, J.F. McKenzie, and E. Dubinin: Magnetised plasma-dust solitons. AGU Spring Meeting, Washington, DC, USA, 30. Mai - 3. Juni 2000.
- Sauer K.**, E. Dubinin, and J.F. McKenzie: The physics of the magnetic pile-up boundary at Mars and comets. AGU Spring Meeting, Washington, DC, USA, 30. Mai - 03. Juni 2000.
- Sauer K.**, J.F. McKenzie, and E. Dubinin: Bi-ion solitons and related LH wave emission. AGU Spring Meeting, Washington, DC, USA, 30. Mai - 3. Juni 2000.
- Sauer K., **J.F. McKenzie**, and E. Dubinin: Structure of oblique Bi-ion solitons. AGU Fall Meeting, San Franzisko, CA, USA, 15.-19. Dezember 2000.
- Sauer K.**, J.F. McKenzie and E. Dubinin: Are long magnetic holes in the solar wind related to bi-ion solitons? AGU 2000 Fall Meeting, San Franzisko, U.S.A., 15.-19. Dezember 2000.
- Savin S.**, J. Büchner, B. Nikutowski, N. Maynard, G. Wilson, W. White, G. Siscoe, H. Kawano, I. Sandahl, C.T. Russell, J. Safrankova, Z. Nemecek, L. Zelenyi, Y. Yermolaev, and V. Romanov: Multi point IACG Campaign 2 observations versus simulations of the plasma processes at magnetospheric boundaries. EGS XXV General Assembly, Nizza, Frankreich, 25.-29. April 2000.
- Savin S.**, L. Zelenyi, S. Romanov, A. Skalsky, E. Budnik, S. Klimov, E. Dubinin, Y. Yermolaev, V. Romanov, J. Büchner, B. Nikutowski, I. Sandahl, A. Pedersen, C.T. Russell, N. Maynard, J. Pickett, J. Scudder, J. Safrankova, Z. Nemecek, J.A. Sauvaud, J. Blecki, and J.-L. Rauch: Intermittent reconnection as a primary mechanism for the entry of the plasma into magnetosphere. EGS XXV General Assembly, Nizza, Frankreich, 25.-29. April 2000.
- Savin S.**, L. Zelenyi, J. Büchner, B. Nikutowski et al.: Multi-scale interactions of magnetosheath flow with high latitude magnetopause. Symposium S11: Cross-Scale Coupling: Observations and Theories. The First S-Ramp Conference, Sapporo, Japan, 5. Oktober 2000.
- Scherer K.**, E. Marsch, R. Schwenn, and H. Rosenbauer: Long-term variations of the flow direction and angular momentum of the solar wind observed by Helios. DPG-Jahrestagung der Arbeitsgemeinschaft Extraterrestrische Physik (AEF), Bremen, 21.-24. März 2000.
- Schieder R.**, O. Siebertz, F. Schlöder, C. Gal, J. Stutzki, P. Hartogh, and V. Natale: Wide-band spectrometer for HIFI-FIRST. SPIE International Symposium on Astronomical Telescopes and Instrumentation 2000, München, 27.-31. März 2000.

- Schlegel K.:** From Aristotle to Atmospheric Explorer – Highlights from 2400 years of atmospheric research.\* EGS XXV General Assembly, Nizza, Frankreich, 25.-29. April 2000.
- Leuchterscheinungen in der Atmosphäre. Schulvortrag, Gymnasium Einbeck, 3. Juli 2000.
  - Die stärksten geomagnetischen Stürme des vergangenen Jahrhunderts. Nationaler Workshop zum Weltraumwetter, Neustrelitz, 26.-27. Oktober 2000.
  - Einfluss des Weltraumwetters auf Mesosphäre, Stratosphäre, Troposphäre. Nationaler Workshop zum Weltraumwetter, Neustrelitz, 26.-27. Oktober 2000.
  - Solar and geomagnetic data and data sources for SPECIAL investigations.\* SPECIAL-Workshop (Space Processes and Electrical Changes Influencing Atmospheric Layers) of the European Science Foundation (ESF), Max-Planck-Institut für Aeronomie, Katlenburg-Lindau, 8.-11. November 2000.
  - Solar activity and lightning. SPECIAL-Workshop (Space Processes and Electrical Changes Influencing Atmospheric Layers) of the European Science Foundation (ESF), Max-Planck-Institut für Aeronomie, Katlenburg-Lindau, 8.-11. November 2000.
  - Leuchterscheinungen in der Atmosphäre. Planetarium Recklinghausen, 29. November 2000.
  - Solar activity control of lightning. Seminar, University of Leicester, Ionospheric Physics Group, Leicester, England, 5. Dezember 2000.
- Schlegel K.** and M. Füllekrug: Tides and planetary waves in Schumann resonances. EGS XXV General Assembly, Nizza, Frankreich, 25.-29. April 2000.
- Schühle U., J. Hollandt, A. Pauluhn, and K. Wilhelm:** Variations of the quiet Sun radiance at ultraviolet and extreme-ultraviolet wavelengths. 33rd COSPAR Scientific Assembly, Warschau, Polen, 16.-23. Juli 2000.
- Schühle U., A. Pauluhn, J. Hollandt, and K. Wilhelm:** Radiance variations of quiet solar transition region and coronal lines. IAU Symp. 203: Recent Insights into the Physics of the Sun and Heliosphere – Highlights from SOHO and Other Space Missions, Manchester, Großbritannien, 7.-11. August 2000.
- Schühle U., J. Hollandt, A. Pauluhn, and K. Wilhelm:** Mid-term radiance variations of far-ultraviolet emission lines from quiet-Sun areas. Euroconference: “The Solar Cycle and Terrestrial Climate”, Teneriffa, Spanien, 25.-29. September 2000.
- Schüssler M.:** Numerical simulation of magneto-convection. Advanced solar polarimetry – theory, observation, and instrumentation, 20th Sacramento Peak Summer Workshop, Sunspot, USA, 11-15 September 2000.
- Schwenn R.:** What have we learned on the Solar Wind in the last decade? Physics of Space: Growth points and problems, Observatoire de Paris-Meudon, France, 10.-14. Januar 2000.
- Strukturen und Dynamik der Sonnenkorona aus der Sicht von SOHO. Universität Bern, Schweiz, 4. Februar 2000.
  - Massenauswürfe und magnetische Aktivität der Sonnenkorona. Arbeitsgemeinschaft Extraterrestrische Forschung AEF/DPG Tagung, Bremen, 21.-24. März 2000.
  - Generation of shock waves in the corona: CMEs and others drivers.\* EGS XXV General Assembly, Nizza, Frankreich, 25.-29. April 2000.
  - Ein neues Bild der Sonne – das Weltraumobservatorium SOHO macht’s möglich. Im Rahmen der 3. Göttinger Woche Wissenschaft & Jugend, Arnoldschule, Göttingen, 21. Juni 2000.
  - The solar wind and the interplanetary magnetic field. Summer School on Sun Earth Connection and Space Weather, L’Aquila, Italien, 30. August - 8. September 2000.
  - Coronal mass ejections and their propagation through interplanetary space. Summer School on Sun Earth Connection and Space Weather, L’Aquila, Italien, 30. August - 8. September 2000.
  - Unser Stern, die Sonne – Neue Erkenntnisse durch das Weltraumobservatorium SOHO. Sternwarte Essen, 20. September 2000.
  - Geoeffectiveness of CMEs. First S-RAMP Conference, Sapporo, Japan, 2.-6. Oktober 2000.

- Comments on a strange metamorphosis between Sun and Earth, or: how to turn a CME into a menace. First S-RAMP Conference, Sapporo, Japan, 2.-6. Oktober 2000.
  - Unruhen im Sonnensystem – neue Ergebnisse aus einem turbulenten Plasmalabor. Institutskolloquium des Max-Planck-Instituts für Plasmaphysik, Garching, 27. November 2000.
  - Ein neues Bild der Sonne – das Weltraumobservatorium SOHO macht's möglich. Im Rahmen der 3. Göttinger Woche Wissenschaft & Jugend, 21. Juni 2000 in der Arnoldschule in Göttingen.
  - The solar wind and the interplanetary magnetic field. Summer School on Sun Earth Connection and Space Weather, L'Aquila, Italien, 30. August - 8. September 2000.
  - Coronal mass ejections and their propagation through interplanetary space. Summer School on Sun Earth Connection and Space Weather, L'Aquila, Italien, 30. August - 8. September 2000.
  - Unser Stern, die Sonne – Neue Erkenntnisse durch das Weltraumobservatorium SOHO. Sternwarte Essen, 20. September 2000.
  - Geoeffectiveness of CMEs. First S-RAMP Conference in Sapporo, Japan, 2.-6. Oktober 2000.
  - Comments on a strange metamorphosis between Sun and Earth, or: how to turn a CME into a menace. First S-RAMP Conference in Sapporo, Japan, 2.-6. Oktober 2000.
  - Unruhen im Sonnensystem – neue Ergebnisse aus einem turbulenten Plasmalabor. Institutskolloquium des Max-Planck-Instituts für Plasmaphysik, Garching, 27. November 2000.
- Shaw A.,** K. C. Hsieh, M. Hilchenbach, M. A. Czechowski, D. Hovestadt, B. Klecker, R. Kallenbach, E. Möbius, and P. Bochler: Energetic neutral helium of heliospheric origin at 1 AU. COSPAR Colloquium on The Outer Heliosphere: The Next Frontiers, Potsdam, 24.-28. Juli 2000.
- Silin I.,** J. Büchner, Yu. Galperin, V. Kunitsin, M. Veselov, T. Wiegmann, and L.M. Zelenyi: Development of tomographic methods of space plasma diagnostics. Session ST1, EGS XXV General Assembly, Nizza, Frankreich, April 2000.
- Solanki S.K.:** Die Sonne und das radikale Element kosmischer Unruhe.\* Physikalisches Kolloquium, Universität Göttingen, 17. Januar 2000.
- Die Sonne und ihr Einfluss auf das Wetter.\* Vereinsversammlung der Astronomischen Gesellschaft Luzern, Luzern, Schweiz, 7. Februar 2000.
  - The Sun: From core to corona.\* Frühjahrstagung der Deutschen Physikalischen Gesellschaft, Dresden, 20.-24. März 2000.
  - Solar physics in the new millennium: where are we heading? EGS XXV General Assembly, Nizza, Frankreich, 25.-29. April 2000.
  - Assessment of NASA and ESA roadmaps in heliosphere and Sun: European perspective.\* International Hearing on Collaboration in Space Science, European Science Foundation, Nizza, Frankreich, 27.-28. April 2000.
  - Beeinflusst die Sonne das Erdklima?\* Institut für Geophysik, Universität Göttingen, 9. Mai 2000.
  - Solar variability and climate.\* NATO Advanced Study Institute "Space Storms and Space Weather Hazards", Kreta, Griechenland, 19.-29. Juni 2000.
  - Was hat das Magnetfeld der Sonne mit Einstein und dem Erdklima zu tun? Kolloquium Max-Planck-Institut für Kernphysik, Heidelberg, 29. Juni 2000.
  - How much of solar irradiance variability can be explained by the direct influence of magnetic fields? 33rd COSPAR Scientific Assembly, Warschau, Polen, 16.-23. Juli 2000.
  - Spectral irradiance variations.\* 24th General Assembly International Astronomical Union, Manchester, Großbritannien, 7.-18. August 2000.
  - Long-term changes in solar irradiance.\* Euroconference "The Solar Cycle and Terrestrial Climate", Santa Cruz de Tenerife, Spanien, 25.-30. September 2000.
  - Solar activity, its origin and evolution.\* 34th ESLAB Symposium on "The 3-D Heliosphere at Solar Maximum", ESTEC, Noordwijk, Niederlande, 3.-6. Oktober 2000.
  - What has the Sun's magnetic field got to do with Einstein and our climate? Seminar Big

- Bear Observatory, Kalifornien, USA, 6. Dezember 2000.
- Srivastava N.** and R. Schwenn: Kinematics of gradual CMEs observed by LASCO. EGS XXV General Assembly, Nizza, Frankreich, 25.-29. April 2000.
- Kinematics of gradual coronal mass ejections by LASCO. 6th WAVE meeting, CNES, Paris, Frankreich, 15.-16. Mai 2000.
- Stenborg G.:** "LASCO and EIT". MICA and HASTA as complements of 6th WAVE meeting, CNES, Paris, Frankreich, 15.-16. Mai 2000.
- Stenborg G.,** D.E. Innes, and R. Schwenn: Solar flare observations from SOHO, MICA and YOHKOH in relation with a coronal shock wave. Arbeitsgemeinschaft Extraterrestrische Forschung, AEF/DPG Tagung, Bremen, 21.-24. März 2000.
- Stubbe P.:** Modification experiments at Tromsø: Scientific highlights 1980 to 1992. 20th Anniversary Symposium of Ionospheric Interactions in Tromsø, Ramfjordmoen, Norwegen, 10.-11. Oktober 2000.
- Thomas N.,** M. Scotto, and G. Lichtenberg: Spectra of the Io plasma torus in 1997 and immediately after Galileo I24 in 1999. COSPAR, Warschau, Polen, 20. Juli 2000.
- Titov D.V.,** W.J. Markiewicz, N. Thomas, and H.U. Keller: Optical studies of the atmospheric water vapour from the surface of Mars. EGS XXV General Assembly, Nizza, Frankreich, 25.-29. April 2000.
- Tsurutani B.T.,** X.-Y. Zhou, J.K. Arballo, W.D. Gonzalez, G.S. Lakhina, and V.M. Vasyliunas: Interplanetary shock triggering of planetary auroras.\* EGS XXV General Assembly, Nizza, Frankreich, 25.-29. April 2000.
- Tu C.-Y. and **E. Marsch:** Modellrechnungen zur zyklotron-resonanten Heizung und Beschleunigung von Ionen durch Wellen in der Sonnenkorona. DPG-Jahrestagung der Arbeitsgemeinschaft Extraterrestrische Physik (AEF), Bremen, 21.-24. März 2000.
- Ion-cyclotron resonance heating and acceleration of solar wind ions in coronal holes. EGS XXV General Assembly, Nizza, Frankreich, 25.-29. April 2000.
- Ulamiec S.,** J.P. Bibring, D. Moura, R. Mugnolo, and H. Rosenbauer: Landing on comet Wirtanen - Rosetta Lander. EGS XXV General Assembly, Nizza, Frankreich, 25.-29. April 2000.
- van Eyken A.P.,** A. Brekke, R. Fujii, T. Hagfors, and H. Opgenoorth: Future scientific developments in the study of the high-latitude ionosphere. EGS XXV General Assembly, Nizza, Frankreich, 25.-29. April 2000.
- Vasyliunas V.M.:** Physik der Jupitermagnetosphäre – Übersicht. Jupiter-Workshop 2000, Universität Köln, Köln, 6.-7. Juli 2000.
- The energy budget of the magnetosphere: Implications for spaceweather.\* COSPAR Colloquium: Space weather study using multipoint techniques, Taipei, Taiwan, 27.-29. September 2000.
- Fast magnetospheric convection and its ionosphere coupling and magnetic reconnection – Introductory lecture.\* First S-RAMP Conference, Sapporo, Japan, 2.-6. Oktober 2000.
- Magnetospheric boundaries: Can the free-surface method be applied to the open magnetosphere? AGU Fall Meeting, San Francisco, CA, USA, 15.-19. Dezember 2000.
- Vocks C.,** and E. Marsch: Nonequilibrium processes in coronal plasma – Coupling between particles and waves. EGS XXV General Assembly, Nizza, Frankreich, 25.-29. April 2000.
- Wiegelmann T.** and J. Büchner: Numerical simulations regarding the coupling of current instabilities and magnetic reconnection. EGS XXV General Assembly, Nizza, Frankreich, 25.-29. April 2000.
- Wilhelm K., **E. Marsch,** I.E. Dammasch, and D.M. Hassler: On the source regions of the fast solar wind in polar coronal holes. XXV General Assembly, Nizza, Frankreich, 25.-29. April 2000.
- Wilhelm K.,** and B. Inhester: The low solar corona seen by SUMER and LASCO-C1: Electron temperatures and densities.\* LASCO/EIT Consortium Meeting, Teistungenburg, 15.-17. Mai 2000.
- Wilhelm K.:** Selected topics concerning SUMER observations and results.\* CEPAC-EPAC-KET Consortium Meeting, Katlenburg-Lindau, 15. Juni 2000.
- Solar spicules and macrospicules observed by SUMER on SOHO. Western Pacific Geophysics Meeting, Tokio, Japan, 27.-30. Juni 2000.

- Solar spicules and macrospicules observed by SUMER on SOHO. 33rd COSPAR Scientific Assembly, Warschau, Polen, 16.- 23. Juli 2000.
- Wilhelm K.**, I.E. Dammasch, and L. Xia: Observations of ultraviolet emission lines in solar coronal holes with SUMER on SOHO. 33rd COSPAR Scientific Assembly, Warschau, Polen, 16.-23. Juli 2000.
- Wilhelm K.**, I.E. Dammasch, and D.M. Hassler: A small plasma jet in the solar atmosphere. AGU 2000 Fall Meeting, San Franzisko, CA, USA, 15.-19. Dezember 2000.
- Wilken B.**, P. W. Daly, and U. Mall: The energetic particle detector RAPID on the ESA fleet of CLUSTER spacecraft - initial results. AGU Fall Meeting, San Franzisko, CA, USA, 15.-19. Dezember 2000.
- Witte M.:** Temporal variations of Ly- $\alpha$  intensities, backscattered from interstellar hydrogen atoms upstream of the Sun: ULYSSES-GAS observations. COSPAR Colloquium on The Outer Heliosphere: The Next Frontiers, Potsdam, 24.-28. Juli 2000.
- Woch J.**, N. Krupp, A. Lagg, S. Livi, B. Wilken, and D.J. Williams: Dynamics of the Jovian magnetosphere – substorms at Jupiter? \* EGS XXV General Assembly, Nizza, Frankreich, 25.-29. April 2000.
- Zecha M.**, J. Röttger, W. Singer, P. Hoffmann, and D. Keuer: Scattering properties of PMSE irregularities after Doppler beam and spaced antenna observations. 9th International Workshop on Technical and Scientific Aspects of MST Radar-MST9 combined with COST-76 Final Profiler Workshop, Toulouse, Frankreich, 13.-18. März 2000.
- Zecha M.**, W. Singer, P. Hoffmann, D. Keuer, and J. Röttger: Simultaneous spaced antenna and Doppler beam observations of the polar summer mesosphere. 9th International Workshop on Technical and Scientific Aspects of MST Radars – MST9 combined with COST-76 Final Profiler Workshop, Toulouse, Frankreich, 13.-18. März 2000.
- Zong Q.-G.**, B. Wilken, S.-Y. Fu, N. Hasebe, and D.J. Williams: Ring current oxygen ions escaping into the magnetosheath. EGS XXV General Assembly, Nizza, Frankreich, 25.-29. April 2000.

**Vorträge 2001/Talks 2001**

- Axford W.I.:** Looking back at the heliosphere.\* The Interstellar Environment of the Heliosphere, COSPAR Colloquium in Honour of Stanislaw Grzedzielski (leaving Executive Director of COSPAR), Institut de France, Paris, Frankreich, 23. Januar 2001.
- Diffusion, convection and shock acceleration of cosmic rays. Solar Terrestrial Environment Laboratory, Nagoya University, Nagoya, Japan, 26. Februar 2001.
- The origin of cosmic rays. Solar Terrestrial Environment Laboratory, Nagoya University, Nagoya, Japan, 14. März 2001.
- The origin of cosmic rays.\* Physical Society of Japan, Tokio, Japan, 28. März 2001.
- The origin of cosmic rays. The Institute of Space and Astronautical Science (ISAS), Tokio, Japan, 10. April 2001.
- The origin of the solar wind. Solar/Astrophysics Group, Kyoto University, Kyoto, Japan, 26. April 2001.
- The origin of the solar wind. Space Physics Dept., National Central University, Chung-Li, Taiwan, 2. Mai 2001.
- Origins of cosmic rays. Kolloquium, Academia Sinica, Taipeh, Taiwan, 4. Mai 2001.
- The solar wind. Solar Terrestrial Environment Laboratory, Nagoya University, Nagoya, Japan, 11. Mai 2001.
- Origins of cosmic rays.\* Physics Department, University of Alabama, Huntsville, USA, 25. September 2001.
- Baker D. N.**, J. L. Burch, P. W. Daly, R. E. Ergun, R. Friedel, T. A. Fritz, J. M. Jahn, D. G. Mitchell, and G. E. Reeves: A telescopic and microscopic view of a magnetospheric substorm on 31 March 2001: New CLUSTER observations of the near magnetotail. AGU Fall Meeting, San Franzisko, CA, USA, 10.-14. Dezember 2001.
- Baker D. N.**, J. L. Burch, P. W. Daly, R. E. Ergun, R. Friedel, T. A. Fritz, J. M. Jahn, D. G. Mitchell, and G. E. Reeves: The magnetospheric response to solar wind forcing on 31 March 2001: SOHO, ACE, CLUSTER, IMAGE, FAST, SAMPEX, and GEO observations of a Major Geomagnetic Storm. AGU

- Fall Meeting, San Franzisko, CA, USA, 10.-14. Dezember 2001.
- Bamert K.**, R.F. Wimmer-Schweingruber, R. Kallenbach, M. Hilchenbach, and B. Klecker: The particle storm on July 14-15, 2000 observed with SOHO/CELIAS/(H)STOF: First results. EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- 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, AGU Fall Meeting, San Franzisko, USA, 10.-14. Dezember 2001.
- Barabash S.**, A. Grigoriev, J. Gimholt, R. Lundin, A. Fedorov, E. Budnik, P. Wurz, P. Bochsler, M. Grande, C. Curtis, B. Snadel, K.H. Hsieh, J. Woch, N. Krupp, S. Livi, and S. Orsini: Neutral particle detector (NPD) for the Mars Express mission: A novel instrumentation for detection of low energy (0.1-10 keV) neutral atoms. EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- Barrow C.H.**, A. Lecacheux, and R. J. Macdowall: Ulysses/URAP observations of the jovian bKOM and HOM radio emissions. EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- Barrow C.H.**, A. Lecacheux, and R. J. Macdowall: Polarization and beaming of the jovian bKOM and HOM observed by Ulysses at 5 AU from Jupiter. 5th International Workshop on Planetary and Solar Radio Emissions (PRE 5), Graz, Österreich, 2.-4. April 2001.
- Barucci M. A.**, H. Boehnhardt, A.C. Delsanti, L. Barrera, C. de Bergh, K. Birkle, J. Davies, A. Doressoundiram, E. Dotto, O.R. Hainaut, M. Lazzarin, K.J. Meech, J.L. Ortiz, J. Romon, P. Rousselot, T. Sekiguchi, N. Thomas, G.P. Tozzi, J.I. Watanabe, and R. West: ESO large program for TNOs: Presentation and first results. American Astronomical Society, Division for Planetary Sciences, 33rd Annual Meeting, New Orleans, LA, USA, 27. November - 1. Dezember 2001.
- Basilevsky A. T.**, N. Thomas, S. F. Hviid, and H. U. Keller: Color Ratios of the APXS Analyzed Rocks at the Mars Pathfinder Landing Site. Abstract no.1099, 32nd Annual Lunar and Planetary Science Conference, Houston, Texas, USA, 12.-16. März 2001.
- Bavassano-Cattaneo M.-B.**, E. Amata, M.F. Marcucci, R. Bruno, A.M. DiLellis, G. Pallochia, V. Formisano, H. Rème, J.M. Bosqued, I. Dandouras, J.-A. Sauvaud, L.M. Kistler, E. Moebius, B. Klecker, C.W. Carlson, J.P. McFadden, G.K. Parks, M. McCarthy, A. Korth, and R. Lundin: Multipoint observations of the duskside magnetopause: Cluster preliminary results. EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- Belikovich V.V.**, N.V. Bakhmet'eva, A.V. Tolmacheva, M.T. Rietveld, and E. Turunen: The Artificial Periodic Inhomogeneities (API) technique to study the mesosphere and the lower thermosphere: outlook for joint research using EISCAT and SURA heating facilities. 10th International EISCAT Workshop, NIPR, Tokio, Japan, 23.-27. Juli 2001.
- Blagoveshchenskaya N.F.**, V. A. Kornienko, M. T. Rietveld, and B. Thide: HF pump wave impact on the modification of the ionosphere-magnetosphere coupling\*. 10th International EISCAT Workshop, NIPR, Tokio, Japan, 23.-27. Juli 2001.
- Blagoveshchenskaya N.F.**, T. D. Borisova, I. V. Moskvina, B. Thide, M.T. Rietveld, and M.J. Kosch: Doppler shift simulation of scattered HF signals during Tromsø HF pumping experiment on February 16, 1996. 10th International EISCAT Workshop, NIPR, Tokio, Japan, 23.-27. Juli 2001.
- Bogdanova Y.V.**, B. Klecker, G. Paschmann, L.M. Kistler, E. Moebius, H. Rème, J. Bosqued, I. Dandouras, J. Sauvaud, A. Korth, M. Bavassano-Cattaneo, C.W. Carlson, G.K. Parks, M. McCarthy, and R. Lundin: Multi-spacecraft observations of oxygen beams from the southern polar region by CIS onboard Cluster. AGU Fall Meeting, San Franzisko, CA, USA, 10.-14. Dezember 2001.
- Boice D.C.**, D.T. Britt, B.R. Sandel, L.A. Soderblom, N. Thomas, and R.V. Yelle: The circumnuclear environment of comet 19P/Borrelly observed during the Deep Space One encounter. American Astronomical Society, Division for Planetary Sciences, 33rd Annual Meeting, New Orleans, LA, USA, 27. November - 1. Dezember 2001.
- Bonev T., **K. Jockers**, N. Kiselev, and E.V. Petrova: Properties of the dust in comet LL-NEAR during its disintegration, derived from

- narrow band imaging of its color and polarization. Workshop on Polarization 2001 with Emphasis on Cometary Observations, Paris, Frankreich, 10.-12. April 2001.
- Bonev T.**, N. Kiselev, K. Jockers, F. Velichko, S. Velichko, G. Borisov, and A. Ivanova: Properties of the dust in comet C/1999 S4 (Linear) from narrow-band imaging and polarization. EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- Borchers R.**, C.A.M. Brenninkmeijer, A. Jordan, and A. Zahn: Latitudinal distribution of halocarbons in the northern hemisphere derived from aircraft measurements with the project CARIBIC. EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- Bosqued J.M.**, H. Rème, I. Dandouras, J.-A. Sauvaud, L.M. Kistler, E. Moebius, C. Mouikis, B. Klecker, H. Kucharek, C. Carlson, J.P. McFadden, G.K. Parks, V. Formisano, E. Amata, M.-B. Bavassano-Cattaneo, A.M. DiLellis, M. McCarthy, A. Korth, L. Eliasson, R. Lundin, P. Escoubet, and FGM co-authors: Structure and dynamics of ion populations in the plasma sheet boundary layers: Initial multi-spacecraft Cluster/Ion SP. EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- Bothmer V.:** From solar activity minimum to maximum: A summary of SOHO observations.\* EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- The NASA STEREO Mission: A milestone for the science of space weather.\* EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
  - Sonne und Erde – Eine stürmische Beziehung. Planetarium Hamburg, 4. April 2001.
  - Interplanetare Evolution und solarer Ursprung koronaler Materieausstöße. Institutskolloquium IEAP, Universität Kiel, 14. Juni 2001.
  - Solar magnetic field processes determining the field configurations of coronal mass ejections.\* COSPAR Colloquium on Solar-Terrestrial Magnetic Activity and Space Environment, Beijing, China, 10.-12. September 2001.
  - Sonne und Erde – eine stürmische Beziehung. Kiepenheuer-Institut für Sonnenphysik, Freiburg, 15. November 2001.
- Bothmer V.**, P. Cargill, E. Romashets, I. Veselovsky, and A. Dmitriev: Heliospheric dynamical processes responsible for geomagnetic disturbances in the rising phase of solar cycle. EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- Bothmer V.**, P. Cargill, E. Romashets, and I. Veselovsky: Solar origins of geoeffective heliospheric disturbances in the rising phase of solar cycle. EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- Bothmer V.**, H. Sierks, E. Böhm, and H. Kunow: <sup>3</sup>He-enrichments in solar energetic particle events: SOHO/COSTEP observations. Joint SOHO-ACE Workshop Solar and Galactic Composition, Bern, Schweiz, 6.-9. März 2001.
- Bothmer V.**, H. Sierks, E. Böhm, and H. Kunow: MeV He3/He4 isotope abundances in solar energetic particle events: SOHO/COSTEP observations. 27th International Cosmic Ray Conference, Hamburg, 7.-15. August 2001.
- Britt, D. T.**, D. C. Boice, R. M. Nelson, L. A. Soderblom, and N. Thomas: The geology of Comet 19P/Borrelly. American Astronomical Society, Division for Planetary Sciences, 33rd Annual Meeting, New Orleans, LA, USA, 27. November - 1. Dezember 2001.
- Brynildsen N., P. Maltby, O. Kjeldseth-Moe, and **K. Wilhelm**: Temporal variations in the sunspot atmosphere. EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- Buchert S.C.**, S. Saito, R. Fujii, and T. Hagfors: Effect of electrojet irregularities on DC current flow and on absorption in riometer observations.\* 10th International EISCAT Workshop, Tokio, Japan, 23.-27. Juli 2001.
- Büchner, J.:** Magnetische Rekonnexion im Weltall wie auf Erden? Physikalisches Kolloquium der Universität Kiel, 24. April 2001.
- Unwetter im Weltraum: Der Weg der Killer-Elektronen. URANIA Berlin, 30. April 2001.
  - Magnetic reconnection and helicity evolution at sun and in astrophysical plasmas. Rutgers University, N.J., USA, 24. Juli 2001.
  - Ein SCHWARM von Kleinsatelliten zur Erforschung stoßfreier Turbulenz und magnetischer Rekonnexion – Ergebnisse einer Pha-

- se A Studie. DLR Bonn-Oberkochen, 31. August 2001.
- Satelliten SCHWARM zur Untersuchung kleinskaliger Prozesse im Weltraum – Antrag zur Brückenphase B. DLR Bonn-Oberkochen, 19. Oktober 2001.
- Büchner J.** and B. Nikutowski: Consequences of 3D kinetic reconnection. Frühjahrstagung der Deutschen Physikalischen Gesellschaft, Hamburg, 20.-22. März 2001.
- Büchner J.**, B. Nikutowski, P. Daly, U. Mall, A. Balogh, K.-H. Glassmeier, H.-U. Auster, and K.-H. Fornacon: Dynamics of thin current sheets during substorms: Comparison with simulation results. IAGA-IASPEI Joint Scientific Assembly section G3.08, Hanoi, Vietnam, 19.-31. August 2001.
- Büchner J.**, B. Nikutowski, P. Daly, U. Mall, A. Balogh, K.-H. Glassmeier, H.-U. Auster, and K.-H. Fornacon: German CLUSTER workshop. Lindau, 16. November 2001.
- Büchner, J.**, B. Nikutowski, P. Daly, U. Mall, A. Balogh, K.-H. Glassmeier, H.-U. Auster, and K.-H. Fornacon: Kinetic simulations of thin current sheets: Prediction and comparison with CLUSTER observations. Fall Meeting, San Franzisko, CA, USA 17. Dezember 2001.
- Büchner J.**, B. Nikutowski and the RAPID team: Reconnection at the Earth's magnetopause. CLUSTER SWT Meeting, ESTEC, Noordwijk, Niederlande, 7. Juni 2001.
- Büchner J.**, B. Nikutowski, I. Silin, P. Daly, U. Mall, A. Balogh, K.-H. Glassmeier, K.-H. Fornacon and the FGM-Team, H. Rème, J.-A. Sauvaud, L. Kistler, A. Korth, and the CIS Team: Kinetic simulations of thin current sheets: Predictions and comparison with CLUSTER observations. AGU Fall Meeting, San Franzisko, CA, USA, 10.-14. Dezember 2001.
- Buratti, B. J.**, L. A. Soderblom, D. T. Britt, M. D. Hicks, N. Thomas, J. Oberst, R. H. Brown, R. M. Nelson, J. A. Mosher, and J. K. Hillier: Photometry and surface physical properties of comet 19P/Borrelly American Astronomical Society, Division for Planetary Sciences, 33rd Annual Meeting, New Orleans, LA, USA, 27. November - 1. Dezember 2001.
- Chang J.**, and W.K.H. Schmidt: High energy electron and gamma-ray detection with ATIC. 27th ICRC, Hamburg, 7.-15. August 2001.
- Chilson P.B., E. Belova, **M.T. Rietveld**, and S. Kirkwood: Artificially induced modulation of PMSE using the EISCAT heating facility. URSI meeting, University of Colorado, Boulder, CO, USA, 8.-11. Januar 2001.
- Christon S.P.**, U. Mall, T.E. Eastman, G. Gloeckler, A.T. Lui, R.W. McEntire, and E.C. Roelof: Outer ring current energetic N+1 and O+1: Solar cycle and geomagnetic variations and relation to topside ionosphere ion densities. AGU Fall Meeting, San Franzisko, CA, USA, 10.-14. Dezember 2001.
- Combi M. R.**, T.-M. Ho, and N. Thomas: Axisymmetric dusty gas-kinetic models for comet 46P/Wirtanen. American Astronomical Society, Division for Planetary Sciences, 33rd Annual Meeting, New Orleans, LA, USA, 27. November - 1. Dezember 2001.
- Crews S.**, K.-I. Nishikawa, J. Büchner, and P. Kotze: Particle simulation of collisionless magnetic reconnection in the Harris model. 6th International Conference on Space Plasma Simulation ISSS-6, Garching, 3.-7. September 2001.
- Curdt W., P. Brekke, U. Feldman, **K. Wilhelm**, B.N. Dwivedi, U. Schühle, and P. Lemaire: The SUMER spectral atlas of solar-disk features. Joint SOHO-ACE Workshop on "Solar and Galactic Composition", Bern, Schweiz, 6.-9. März 2001.
- Curdt W.**, P. Brekke, and K. Wilhelm: The SUMER spectral atlas of solar-disk features. 12th Cambridge Workshop on Cool Stars, Stellar Systems, and the Sun, Boulder, CO, USA, 30. Juli - 3. August 2001.
- Curdt W.**, D.E. Innes, E. Landi, E., and I.E. Dammasch: SUMER measurements of doppler flows during flare onset. EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- Czechowski A.**, M. Hilchenbach and K.C. Hsieh: Deriving ACR shock spectrum from observations of the energetic neutral atoms. 27th International Cosmic Ray Conference, Hamburg, 7.-15. August 2001.
- Daly P. W.:** Results from the Cluster RAPID experiment. Royal Astronomical Society, London, England, 9. November 2001.

- Daly P. W.**, U. Mall, B. Wilken, and the RAPID-team. First results from the RAPID particle spectrometer on board Cluster. EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- Daly P. W.**, U. Mall, B. Nikutowski, J. F. Fennell, and C. H. Perry: Plasmasheet motions in the distant magnetotail determined by 4-point ion measurements: RAPID/Cluster. AGU Fall Meeting, San Franzisko, CA, USA, 10.-14. Dezember 2001.
- Dammasch I.E.**, U. Feldman, and K. Wilhelm: The morphology of the solar transition region as seen by SUMER on SOHO. EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- Dandouras I.**, J.M. Bosqued, L. Lavraud, H. Rème, J.-A. Sauvaud, L.M. Kistler, E. Moebius, C. Mouikis, B. Klecker, H. Kucharek, G. Paschmann, E. Amata, M.-B. Bavassano-Cattaneo, V. Formisano, C. Carlson, J.P. McFadden, G.K. Parks, M. McCarthy, A. Korth, L. Eliasson, R. Lundin, K. Torkar, P. Escoubet, and P. Chaizy: In-flight performance and first results of the CIS ion spectrometer onboard Cluster during the interference campaign. EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- Dubin E.:** Ion dynamics in the Martian plasma environment. Team Workshop: Mars Magnetism, and its Interaction with the Solar Wind, ISSI, Bern, Schweiz, 22.-26. Oktober 2001.
- Role of mass loading and foreshock phenomena upstream from the Martian box shock. Team Workshop: Mars Magnetism, and its Interaction with the Solar Wind, ISSI, Bern, Schweiz, 22.-26. Oktober 2001.
- Eliasson L.**, R. Lundin, J. Bosqued, B. Lavraud, J. Sauvaud, H. Rème, A. Balogh, A. Korth, L.M. Kistler, E. Moebius, B. Klecker, C.W. Carlson, G.K. Parks, and M.B. Bavassano-Cattaneo: Cusp and dayside boundary layer dynamics during various IMF conditions. AGU Fall Meeting, San Franzisko, CA, USA, 10.-14. Dezember 2001.
- Espinosa S.**, N. Krupp, J. Woch, M. K. Dougherty, S. Livi, D.J. Williams, and S.M. Krimigis: Periodicities in particle intensities onboard Cassini and Galileo during the Cassini Jupiter flyby. Conference on Jupiter – Planet, Satellites & Magnetosphere, LASP, University of Colorado, Boulder, CO, USA, 25.-30. Juni 2001.
- Eviatar A.**, V.M. Vasyliunas, N. Krupp, D.J. Williams, B.H. Mauk, W.S. Kurth, and D.A. Gurnett: Trapped energetic electrons at Ganymede revisited. AGU Fall Meeting, San Franzisko, CA, USA, 10.-14. Dezember 2001.
- Fleck B., **R. Marsden**, E. Marsch, R. Schwenn, E. Antonucci, P. Bochsler, J.-L. Bougeret, R. Harrison, and J.-C. Vial: Solar Orbiter – A high resolution mission to the Sun and inner heliosphere. EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- Forme F.**, B. Isham, and M.T. Rietveld: Parametric decay of beam generated Langmuir waves in the upper ionosphere. EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- Fraser B.J.**, Y.D. Hu, A. Korth, H.J. Singer, and D.A. Hardy: Pc5 hydromagnetic waves in the middle magnetosphere: modulation of Pc1 ion cyclotron waves and the role of medium energy ions. ISEC, Radiation Belt Science and Technology, Queenstown, Neuseeland, 23.-27. Juli, 2001.
- Fraser B.J.**, Y.D. Hu, A. Korth, H.J. Singer, D.A. Hardy, and R.R. Anderson: Stormtime Pc5 hydromagnetic waves in the middle magnetosphere: Modulation of Pc1 ion cyclotron waves and the role of medium energy ions. AGU Fall Meeting, San Franzisko, CA, USA, 10.-14. Dezember 2001.
- Friedel R. H.**, G. D. Reeves, M. G. Henderson, D. N. Baker, P. W. Daly, T. A. Fritz, and R. D. Belian: Investigation of the detailed energetic electron trapping boundary structure using CLUSTER II RAPID data. AGU Fall Meeting, San Franzisko, CA, USA, 10.-14. Dezember 2001.
- Grande M.**, M. K. Carter, C. H. Perry, B. Wilken, P. W. Daly, U. Mall, J. F. Fennell, J. L. Roeder, F. Søråas, and T. Fritz: Investigation of energetic electrons in the geotail using Cluster RAPID IES. AGU Fall Meeting, San Franzisko, CA, USA, 10.-14. Dezember 2001.
- Grieger B.:** Inverse radiation modeling of Titan's atmosphere to assimilate Huygens DISR data. EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- Inverse radiation modeling of Titan's atmosphere to assimilate Huygens DISR data. Huy-

- gens Science Working Team Meeting, Milton Keynes, Großbritannien, 15. Juni 2001.
- Inverse radiation modeling of Titan's atmosphere to assimilate Huygens DISR data. DISR Science Team Meeting, Oxford, Großbritannien, 16. Juni 2001.
  - Inverse radiation modeling of Titan's atmosphere to assimilate Huygens DISR data. Seminar am Institut für Fernerkundung, Universität Bremen, 20. Juli 2001.
  - Assimilation of data from the solar aureole imager and the visible spectrometer onboard the Huygens probe into a radiative transfer model of Titan's atmosphere. Division of Planetary Science Meeting, New Orleans, LA, USA, 1. Dezember 2001.
- Godunova V.,** V. Tarady, A. Sergeev, N. Karpov, B. Zhylyaev, and K. Jockers: International research projects at the Peak Terskol Observatory: Current results and perspectives. Joint European and National Meeting JENAM 2001 of the European Astronomical Society and the Astronomische Gesellschaft, München, 10.-15. September 2001.
- Grydeland T.,** C. La Hoz, and T. Hagfors: EISCAT Svalbard Radar dual antennas in an interferometer mode to detect small spatial structures in the ionosphere. National Radio Science Meeting, University of Colorado, Boulder, CO, USA, Januar 2001.
- Gustavsson B.,** U. Brändström, T. Sergienko, T. B. Leyser, F. Honary, A. Steen, M.T. Rietveld, and T. Aso: Three dimensional distribution of HF enhanced airglow. EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- Gustavsson B.,** A. Steen, U. Broendstroem, T. Aso, T. Sergienko, M.T. Rietveld, and F. Honary: Simultaneous EISCAT and ALIS observations of artificial airglow and their implications. 10th International EISCAT Workshop, NIPR, Tokio, Japan, 23.-27. Juli 2001.
- Hagfors T.:** The Arecibo Observatory: From incoherent scatter to the world's most sensitive radio/radar astronomy instrument. Kolloquium, Solar-Terrestrial Environmental Laboratory, Nagoya University, Nagoya, Japan, 15. Januar 2001.
- Some recent heating experiments with EISCAT, and some experiments in need to be done to better understand what is going on.
- Kolloquium, Solar-Terrestrial Environmental Laboratory, Nagoya University, Nagoya, Japan, 22. Januar 2001.
- Long wavelength radar on Mars Express: A divining rod in the search for water. Kolloquium, Imperial College, London, Großbritannien, 12. September 2001.
  - Position in space of the HF-excited ion acoustic and Langmuir waves with the Tromsø heater EISCAT combination. Kolloquium, University of Leicester, Leicester, Großbritannien, 31. Oktober 2001.
  - On the comparison of performance of cross correlation and filled aperture imaging riometers. Kolloquium, University of Lancaster, Lancaster, Großbritannien, November 2001.
- Hagfors T.,** C. La Hoz, and T. Grydeland: A search for small scale plasma structure using the EISCAT Svalbard Radar dual antenna in an interferometer mode.\* EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- Hagfors T.,** M.T. Rietveld, B. Isham, C. LaHoz, and W. Kofman: Determination of the position in space of the HF excited ion acoustic and Langmuir waves with the Tromsø Heater/EISCAT combination. 4th International workshop on nonlinear waves and chaos in space plasmas, Tromsø, Norwegen, 17.-21. Juni 2001.
- Hagfors T., **M.T. Rietveld,** B. Isham, C. La Hoz, and W. Kofman: Position in space of the HF-excited ion acoustic and Langmuir waves with the Tromsø Heater EISCAT combination. Workshop on Nonlinear Waves and Chaos in Space Plasma, Tromsø, Norwegen, 17.-22. Juni 2001.
- Hagfors T.,** S.C. Buchert, S. Saito, and R. Fujii: Effect of electro-jet irregularities on DC current flow. AGU Fall Meeting, San Franzisko, CA, USA, 10.-14. Dezember 2001.
- Hartmann, G.K. :** In Memoriam Walter Die-minger: 07.07.1907 – 29.09.2000.\* URSI Tagung, Kleinheubach, 25. September 2001.
- Philosophy of Science: The European origin and crisis of empirical science. Seminar talk at the International Institute of Islamic Thought (IIIT), Herndon, VA, USA, 6. November 2001.
  - The DUST-2 CD ROM: Background and pro-

- gress towards interactive ADLATUS interfaces atmosphere and drinking water. Seminar talk at NOAA/NGDC STP, Boulder, CO, USA, 9. November 2001.
- The DUST-2 CD ROM: Background and progress towards interactive ADLATUS interfaces atmosphere and drinking water. Seminar talk at Institute of Soft Computing (BISC), University Berkely, 14. November 2001.
  - WWW.SURE-TEC.COM: Creating self-sustaining, cross-generational communities in desert regions: Pilot project proposal. Seminar at “El Bajio”, Mexico, 17. November 2001.
- Hartmann G. K.**, M. G. Ritter, E. Schircks, K.-C. Hsieh, and H.-G. Flepp: WWW.SURE-TEC.COM: Creating self-sustaining, cross-generational communities in desert regions: pilot project proposal. Seminar at College of Agriculture Dept. of Educational Communications and Technology (ECAT), University of Tucson, AZ, USA, 16. November 2001.
- Hartogh P.:** 22 GHz Wasserdampfmessungen über Alomar: Ergebnisse der letzten 2 Jahre.\* Leibniz-Institut für Atmosphärenphysik, Kühlungsborn, 18. Januar 2001.
- MPAE capabilities for mm and submm experiments. Workshop Bepi Colombo/Mars, DLR, Bonn, 15. Februar 2001.
  - Microwave investigation of water vapour transport during a stratospheric warming. EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
  - Microwave spectrometers for remote sounding of comets and planets. EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
  - WASPAM: Newest results. ASAC-Meeting, Oslo, Norwegen, 31. März - 2. April 2001.
  - Microwave instrument on Mars Express. Mars Express 2 Meeting, DLR-Adlershof, 25. April 2001.
  - Characterization of the CTS frequency and amplitude stability. MIRO-Science Meeting, JPL, Pasadena, CA, USA, 24.-26. Juni 2001.
  - Mikrowellenfernerkundung am MPAE. Perspektiven für die Planetenforschung. DLR, Bonn, 9. Juli 2001.
  - Spaceborne microwave sounding of planetary atmospheres: Mars and Venus.\* IAMAS 2001, Innsbruck, Österreich, 10.-18. Juli 2001.
  - MPAE Beitrag. Deutsches HIFI Science Koordinationsmeeting, Universität Köln, 19. August 2001.
  - Requirements for future microwave real-time spectrometers. Acadimia Sinica, Institute for Acoustics, Peking, China, 14. September 2001.
  - Microwave Limb sounder for Venus’s atmosphere.\* International Venus Workshop, ISAS, Tokio, Japan, 15.-17. Oktober 2001.
  - Microwave Limb sounding of planetary atmospheres.\* Communications Research Laboratory, Tokio, Japan, 18. Oktober 2001.
  - Semiannual mesospheric ozone variation observed by WASPAM. National Institute for Environmental Studies (NIES), Tsukuba, Japan, 19. Oktober 2001.
  - Heritage of the Chirp transform spectrometer and its possible application for mesospheric research as part of SMILES.\* National Space Development Agency of Japan (NASDA), Tsukuba, Japan, 19. Oktober 2001.
  - The MPAE science contribution. HIFI Planetary Science Meeting, Sterrewacht Leiden, Niederlande, 19. November 2001.
  - The CTS specs. MAMBO-Meeting, LMD, Paris, Frankreich, 13. Dezember 2001.
- Hartogh P.**, C. Jarchow, and L. Song: Annual and interannual variations of polar upper stratospheric and mesospheric water vapour.\* NDSC 2001 Symposium, Arcachon, Frankreich, 24.-27. September 2001.
- Hartogh P.**, L. Song, and C. Jarchow: Annual and interannual variation of polar mesospheric and upper stratospheric water vapour. EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- Hilchenbach M.:** Heliospherische energetische Wasserstoffatome. AEF-Tagung, Hamburg, 20.-22. März 2001.
- Neutral particle sensor: goals, objectives and complications, First Solar Orbiter Workshop, Puerto de la Cruz, Teneriffa, Spanien, 14.-18. Mai 2001.
  - Mission Rosetta - Kometen oder Neues vom Schnee von gestern. Astrobox, Buxtehude, 8.-11. Oktober 2001.

- Hilchenbach M.**, F. Goesmann, and R. Roll: "In-situ" instrumentation for elemental and isotopic mercurian soil abundancy measurements. DLR, Bonn, 15.-16. Februar 2001.
- Hilchenbach M.**, F. Goesmann, and R. Roll: Instrumentation for elemental and isotopic mercurian soil abundancy measurements. EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- Hilchenbach M.**, K.C. Hsieh, and A. Czechowski: Heliospheric energetic neutral hydrogen. IAGA, Hanoi, Vietnam, 19.-31. August 2001.
- Hilchenbach M.**, H. Sierks, H. Grünwaldt, R. Kallenbach: Solar energetic particle events. EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- Hilchenbach M.**, H. Sierks, B. Klecker, K. Bamert, and R. Kallenbach: Solar energetic particle events observed by SOHO/CELIAS/STOF, 27th International Cosmic Ray Conference, Hamburg, 7.-15. August 2001.
- Hoekzema N.M.**, W.J. Markiewicz, and H.U. Keller: Methods to estimate optical depth of the Martian atmosphere from orbiter images. 33th Annual Meeting of the Division for Planetary Sciences, New Orleans, USA, 27. November - 1. Dezember 2001.
- Holter O.**, P. Galopeau, A. Roux, S. Perraut, A. Korth, A. Pedersen, T. Bössinger, and N. Leprovost: Two satellite study of substorm current disruption. EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- Holzwarth V.:** Dynamics of magnetic flux tubes in giant stars and close binary stars. Dept. of Astronomy, University of St. Andrews, Schottland, 19. Juni 2001.
- Holzwarth V.** and M. Schüssler: Preferred longitudes of starspots on magnetically active stars. International Inter-Institutional Workshop "Magnetic Fields across the Hertzsprung-Russell Diagram", Santiago, Chile, 15.-19. Januar 2001.
- Holzwarth V.**, M. Schüssler, and S.K. Solanki: A model for the decline of coronal X-ray emission of cool giant stars. International Inter-Institutional Workshop "Magnetic Fields across the Hertzsprung-Russell Diagram", Santiago, Chile, 15.-19. Januar 2001.
- Holzwarth V.**, M. Schüssler, and S.K. Solanki: A model for the decline of coronal X-ray emission of cool giant stars. International Inter-Institutional Workshop on Magnetic Fields Across the Hertzsprung-Russell Diagram, Santiago, Chile, 15.-19. Januar 2001. Poster
- Honary F.**, M. J. Kosch, M. Rietveld, T. Yeoman, and V. Howells: Recent Heater-induced aurora observations at Tromsø. 10th International EISCAT Workshop, Tokio, Japan, 23.-27. Juli 2001.
- Honary F.**, M.J. Kosch, M.T. Rietveld, and T. K. Yeoman: Heater-induced airglow emission. Jorvik MIST (Magnetosphere Ionosphere and Solar-Terrestrial) Meeting, University of York, England, 9.-11. April 2001.
- Hviid S.F.**, N. Thomas, H.U. Keller, W.J. Markiewicz, T. Blümchen, P. Smith, R. Tanner, R. Reynolds, C. Oquest, J. Josset, S. Whitehead, C. Pillinger, and B. Hofmann: The Beagle2 Optical Microscope. 32nd Annual Lunar and Planetary Science Conference, Houston, Texas, USA, 12.-16. März 2001.
- Inada A.**, Y. Yokota, N. Noda, A.M. Nakamura, W.J. Markiewicz, and T. Mukai: Absolute sensitivity of Mars Imaging Camera (MIC) onboard NOZOMI: Inflight calibration with the Moon Images. EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- Inada A.** and W.J. Markiewicz: Numerical simulations of diurnal variation in Martian surface fogs. 33th Annual Meeting of the Division for Planetary Sciences, New Orleans, USA, 27. November - 1. Dezember 2001.
- Inhester B.:** 3D reconstruction from observations of the Sun and the heliosphere. EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- Problems of applying tomography to coronal observations. Universität Nizza, Frankreich, 28. März 2001.
- Innes D.E:** Explosive events in the solar transition region. Dept of Physics, University of Alabama, Huntsville, USA, 1. November 2001.
- The science is in the spectra. Part of the undergraduate course 'Frontiers of Science', Dept. of Physics, University of Alabama, Huntsville, USA, 5. November 2001.
- Coronal mass ejection: Insight from recent

- spectroscopic observations. NASA, Marshall Space Flight Center, Huntsville, Alabama, USA, 6. November 2001.
- Explosive events. The quiet Sun: Transient events and coronal heating. Medoc, Paris, Frankreich, 3.-5. Dezember 2001.
- Isham B.**, C. LaHoz, T. Hagfors, M.T. Rietveld, M. Kosch, and B. Khudukon: Large effects of the magnetic field on Langmuir and ion acoustic waves, on transmission through the ionosphere, on artificial aurorae and a search for related SEE effects in the HF heating experiments. 10th International EISCAT Workshop, Tokio, Japan, 23.-27. Juli 2001.
- Jockers K.**, T. Bonev, M. Delva, and N. Kiselev: The disintegration of Comet/C1999 S4: Properties of cometary dust derived from narrow-band images of its color and polarization. Joint European and National Meeting JENAM 2001 of the European Astronomical Society and the Astronomische Gesellschaft, München, 10.-15. September 2001.
- Jockers K.**, I. Kulyk, N. Karpov, and A. Sergeev: Narrow band imaging of the Io torus in the light of singly and doubly ionized sulfur. Conference on Jupiter: Planet, Satellites and Magnetosphere, Boulder, Colorado, USA, 25.-30. Juni 2001.
- Jockers K., I. Kulyk, N. Karpov, A. Sergeev, and **T. Bonev**: Narrow band imaging of the Io torus in the light of singly and doubly ionized sulfur. EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- Keller H.U.:** Mars, der rote Schleier wird gelüftet. Astronomischer Arbeitskreis Ingolstadt e.V., Ingolstadt, 18. Januar 2001.
- Instruments and potential scientific objectives of the Mars Express cameras and spectrometers. International Mars Imaging Camera (MIC) Science Meeting, Kobe, Japan, 22.-26. Januar 2001.
  - Mars planetary atmospheric explorer. Workshop Bepi Colombo/Mars, DLR, Bonn-Oberkassel, 15. Februar 2001.
  - The Halley Multicolour Camera (HMC). GIOTTO: An historical perspective. The Science Museum, London, 29.-30. März 2001.
  - Are inactive comets asteroids? ASTEROIDS 2001: From Piazzi to the 3rd Millennium, Palermo, Italien, 11.-16. Juni 2001.
  - Cometary nucleus morphology and evolution. Sixth Course of Space Chemistry, Erice, Italien, 17.-25. Juni 2001.
  - Imaging the atmosphere and surface of Venus with a CCD camera from Orbit. International Venus Workshop, Sagamihara, Japan, 15.-17. Oktober 2001.
  - The scientific imaging system for the Rosetta Orbiter. 9th ROSETTA Science Working Team Meeting, ESTEC, Noordwijk, Niederlande, 5.-6. Dezember 2001.
- Keller H.U.**, N.M. Hoekzema, and W.J. Markiewicz: Optical depth of the Martian atmosphere from orbiter stereo images. 33th Annual Meeting of the Division for Planetary Sciences, New Orleans, USA, 27. November - 1. Dezember 2001.
- Keller H.U.** and R. Kramm: CCD electronics development and applications. Institutsseminar, MPAE Katlenburg-Lindau, 21. November 2001.
- Keller H.U.**, and the OSIRIS consortium: OSIRIS – The scientific imaging system for the Rosetta Orbiter. 8th ROSETTA Science Working Team Meeting, ESTEC, Noordwijk, Niederlande, 16.-17. Mai 2001.
- Keller H.U.**, and the OSIRIS consortium: OSIRIS – The scientific imaging system for the Rosetta Orbiter. Besuch von Prof. Southwood (ESA) am MPAE, MPAE Katlenburg-Lindau, 5. Juli 2001.
- Kirsch E.**, and U. Mall: Suprathermal proton and alpha-particle spikes ( $E/e = 6.5-225$  keV/e) observed by the WIND-SMS experiment near the libration point L1. 27th International Cosmic Ray Conference, Hamburg, 7.-15. August 2001.
- Kiselev N.N.**, K. Jockers, and V.K. Rosenbush: Polarimetric properties of the dust in disintegrating comets. NATO Advanced Research Workshop on the Optics of Cosmic Dust, Bratislava, Bulgarien, 16.-19. November 2001.
- Kikuchi T.**, H. Lühr, K. Schlegel, and T. Kitamura: Penetration of magnetospheric electric fields to the global ionosphere during substorm. 2001 Asia-Pacific Radio Science Conference, Chuo University, Tokio, Japan, 1.-4. August 2001.
- Kiselev N., **K. Jockers**, V.K. Rosenbush, and P.P. Korsun: Analysis of polarimetric, pho-

- tometric and spectral observations of comet C/1996 Q1 (Tabur). Workshop on Polarization 2001 with Emphasis on Cometary Observations, Paris, Frankreich, 10.-12. April 2001.
- Kistler L.M.,** H.U. Frey, E. Moebius, C. Mouikis, B. Klecker, H. Rème, J.M. Bosqued, I. Dandouras, J.A. Sauvaud, C. Carlson, J.P. McFadden, G.K. Parks, M. McCarthy, A. Korth, V. Formisano, M.B. Bavassano-Cattaneo, M.F. Marcucci, R. Lundin, H. Balsiger, A. Balogh, and M.A. Popecki: A comparison of the motion of auroral ion outflow regions with the motion of auroral arcs. AGU Fall Meeting, San Franzisko, CA, USA, 10.-14. Dezember 2001.
- Klassen A.,** V. Bothmer, G. Mann, M. Reiner, S. Krucker, A. Vourlidas, and H. Kunow: Solar energetic particle events and coronal shocks. EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- Klecker B.,** A. T. Bogdanov, A. T. Galvin, F. M. Ipavich, M. Hilchenbach, E. Moebius, and P. Bochsler: On the variability of suprathermal He<sup>+</sup> ions at 1 AU. 27th International Cosmic Ray Conference, Hamburg, 7.-15. August 2001.
- Klecker B.,** A.T. Bogdanov, M. Hilchenbach, A. B. Galvin, E. Möbius, F. M. Ipavich, J. T. Steinberg, and P. Bochsler: On the acceleration of pickup He at 1 AU. AGU Fall Meeting, San Franzisko, CA, USA, 10.-14. Dezember 2001.
- Kliem B.,** I.E. Dammasch, W. Curdt, and K. Wilhelm: Multi-Temperatur Plasmadynamik in einem solaren Flare, beobachtet von SUMER auf SOHO. Arbeitsgemeinschaft Extraterrestrische Forschung, AEF-Tagung, Hamburg, 20.-22. März 2001.
- Klostermeyer J.:** Effect of tidal variability on the diurnal variation of noctilucent clouds. EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- Knaack R., M. Fligge, **S.K. Solanki,** and Y.C. Unruh: Stellar irradiance variations caused by magnetic activity: The influence of an inclined rotation axis. International Inter-Institutional Workshop on Magnetic Fields Across the Hertzsprung-Russell Diagram, Santiago, Chile, 15.-19. Januar 2001.
- Kohl H., **M.T. Rietveld,** and C. LaHoz: The first few milliseconds of HF-induced plasma turbulence. 10th International EISCAT Workshop, NIPR, Tokio, Japan, 23.-27. Juli 2001.
- Korth A.,:** First results from the CLUSTER ion spectrometry (CIS) instrument on the four CLUSTER S/C. Los Alamos National Laboratory, Los Alamos, NM, USA, 5. Juli 2001.
- First results from the CLUSTER ion spectrometry (CIS) instrument on the four CLUSTER S/C. The Aerospace Corporation, El Segundo, CA, USA, 9. Juli 2001.
- Korth A.,** M. Fränz, F. Frutos, K.H. Trattner, L.M. Kistler, C.G. Mouikis, E. Möbius, H. Rème, I. Dandouras, J.A. Sauvaud, J.M. Bosqued, B. Klecker, E. Amata, M.B. Bavassano-Cattaneo, C. Carlson, J.P. McFadden, G.K. Parks, T. Phan, R. Lundin, L. Eliasson, I. Sandahl, M. McCarthy, P. Escoubet, K.-H. Glassmeier: Oxygen outflow during the large magnetic storms on March 31, 2001 and April 12, 2001. Measurements from the CLUSTER-CIS instrument. AGU Fall Meeting, San Franzisko, CA, USA, 10.-14. Dezember 2001.
- Korth A.,** R.H.W. Friedel, and F. Frutos-Alfaro: The ion composition of the ring current during quiet and disturbed periods. measurements from the CRRES spacecraft. ISEC 2001, Radiation Belt Science and Technology, Queenstown, Neuseeland, 23.-27. Juli 2001.
- Korth A. ,** R.H.W. Friedel, C.G. Mouikis, and F. Frutos-Alfaro: Storm-substorm relationship using spacecraft data.\* AGU Chapman Conference on Storm-Substorm Relationship, Lonavala, Indien, 12.-16. März 2001.
- Kosch M.J.,** K. Cierpka, A. Kohsiek, T. Hagfors, and K. Schlegel: How good are horizontal thermospheric wind measurements from ground-based Fabry-Perot interferometers? Jorvik MIST (Magnetosphere Ionosphere and Solar-Terrestrial) Meeting, University of York, England, 9.-11. April 2001.
- Kosch M.J.,** M.T. Rietveld, F. Honary, and T. Hagfors: HF-induced artificial airglow at high latitudes from the EISCAT facility.\* EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- Kosch M.J.,** M.T. Rietveld, F. Honary, and T. Hagfors: HF induced artificial airglow at high latitudes from the EISCAT facility.\* EGS XXVI General Assembly, Nizza, Frankreich,

- 25.-30. März 2001.
- Kotze P.**, K.-I. Nishikawa, and J. Büchner: Particle modeling of magnetic reconnection in collisionless plasmas. Annual Meeting, South African Institute of Physics, Durban, Südafrika, 4.-6. Juli 2001.
- Kotze P.**, K.-I. Nishikawa, and J. Büchner: Particle simulation of collisionless reconnection using the TRISTAN code. 6th International Conference on Space Plasma Simulation ISSS-6, Garching, 3.-7. September 2001.
- Kubo K.**, J. Röttger and S. Fukao: PMSE as potential indicators for a mesopause temperature increase during a solar proton event. EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- Kubo K.**, J. Röttger, and S. Fukao: PMSE as potential indicators of mesopause temperature and electron diffusion during the Bastille-II Solar-Proton Event. 10th International EISCAT Workshop, National Institute of Polar Research, Tokio, Japan, 23.-27. Juli 2001.
- Kulyk I., **K. Jockers**, N. Karpov, and A. Sergeev: Near-infrared ground-based photometric observations of the inner Jovian satellites Thebe, Amalthea and Metis. Conference on Jupiter: Planet, Satellites and Magnetosphere, Boulder, Colorado, USA, 25.-30. Juni 2001.
- Krimigis S.M.**, D.G. Mitchell, D.C. Hamilton, S. Livi, T.P. Armstrong, A.F. Cheng, J. Dandouras, G. Gloeckler, K.C. Hsieh, W.-H. Ip, E.P. Keath, E. Kirsch, N. Krupp, A. Lagg, L.J. Lanzerotti, B.H. Mauk, R.W. McEntire, E.C. Roelof, B. Wilken, and D.J. Williams: First results from observations of Jupiter's magnetosphere, October 2000 – March 2001 with the magnetospheric imaging instrument (Mimi) on Cassini/Huygens. EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- Krimigis S.M.**, D.G. Mitchell, D.C. Hamilton, S. Livi, T.P. Armstrong, A.F. Cheng, J. Dandouras, G. Gloeckler, K.C. Hsieh, W.-H. Ip, E.P. Keath, E. Kirsch, N. Krupp, A. Lagg, L.J. Lanzerotti, B.H. Mauk, R.W. McEntire, E.C. Roelof, B. Wilken, and D.J. Williams: Observations in Jupiter's vicinity with the Magnetospheric Imaging Instrument (MIMI) during Cassini/Huygens flyby (October 2000 – March 2001). AGU Spring Meeting, Boston, MA, USA, 29. Mai - 2. Juni 2001.
- Krimigis S.M.**, D.G. Mitchell, D.C. Hamilton, S. Livi, T.P. Armstrong, A.F. Cheng, J. Dandouras, G. Gloeckler, K.C. Hsieh, W.-H. Ip, E.P. Keath, E. Kirsch, N. Krupp, A. Lagg, L.J. Lanzerotti, B.H. Mauk, R.W. McEntire, E.C. Roelof, B. Wilken, and D.J. Williams: Jupiter's nebula and magnetosphere as viewed by Cassini/MIMI: ENA's, pickup ions and distant magnetotail. Conference on Jupiter – Planet, Satellites & Magnetosphere, LASP, University of Colorado, Boulder, CO, USA, 25.-30. Juni 2001.
- Krupp N.**, A. Lagg, J. Woch, S. Livi, S.M. Krimigis, and D.J. Williams: Cassini and Galileo combined energetic particle measurements in the vicinity of Jupiter (October 2000 – March 2001). EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- Krupp N.**, A. Lagg, and J. Woch: Energetic electrons in the Jovian magnetosphere: Galileo-EPD results. EGS XXVI General Assembly, Nizza, Frankreich, 26.-30. März 2001.
- Krupp N.**, A. Lagg, J. Woch, D.J. Williams, and S.M. Krimigis: Cassini and Galileo combined energetic particle measurements in the vicinity of Jupiter (October 2000 – March 2001). Conference on Jupiter – Planet, Satellites & Magnetosphere, LASP, University of Colorado, Boulder, CO, USA, 25.-30. Juni 2001.
- Krupp N.**, E.C. Roelof, A. Lagg, J. Woch, S. Livi, S.M. Krimigis, and D.J. Williams: Global configuration of the Jovian magnetosphere. Conference on Jupiter – Planet, Satellites & Magnetosphere, LASP, University of Colorado, Boulder, CO, USA, 25.-30. Juni 2001.
- Kucharek H.**, E. Moebius, B. Klecker, W. Li, M. Popecki, A. Galvin, M. Hilchenbach, and P. Bochsler: Abundance variations of energetic He<sup>+</sup> in CME related SEP events. AGU Fall Meeting, San Franzisko, CA, USA, 10.-14. Dezember 2001.
- Kulyk I., K. Jockers, N. Karpov, and **A. Sergeev**: Astrometric CCD observations of the inner Jovian satellites in 1999-2000. International Conference "AstroKazan-2001", Kazan State University, Kazan, Russland, 24.-29. September 2001.
- Kuska J.-P.** and J. Büchner: Visualization of simulations. 6th International Conference on

- Space Plasma simulation ISSS-6, Garching, 3.-7. September 2001.
- Lagg A.**, N. Krupp, J. Woch, and D. Williams: The average energetic particle environment in the inner Jovian magnetosphere. EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- LaHoz C.**, M.T. Rietveld, T. Grydeland, B. Is-ham, and F. Forme: Observations of a ty-pe of anomalous ion line spectra coincident with enhancements of electron Langmuir wa-ves and associated with auroral precipitation. 10th International EISCAT Workshop, NI-PR, Tokio, Japan, 23.-27. Juli 2001.
- Liu H.**, K. S.Y. Ma, and K. Schlegel: Diurnal, seasonal and geomagnetic variations of large field – aligned ion upflows in the high-latitude ionospheric F-region. 10th International EIS-CAT Workshop, National Institute of Polar Research, Tokio, Japan, 23.-27. Juli 2001.
- Lund E.J.**, C.J. Farrugia, H.J. Opgenoorth, C.G. Mouikis, L.M. Kistler, H. Kucharek, M.A. Popecki, B. Klecker, H. Rème, J.M. Bosqued, I. Dandouras, J.A. Sauvaud, C.W. Carlson, G.K. Parks, M. McCarthy, A. Korth, M.B. Bavassano-Cattaneo, L. Eliasson, and J. Watermann: Simultaneous Cluster/CIS and FAST observations of boundary layer plasmas. AGU Fall Meeting, San Franzisko, CA, USA, 10.-14. Dezember 2001.
- Ma S.Y.**, K. Schlegel, H.T. Cai, and H.X. Liu: Ionospheric O+ outflow and polar patch ob-served by EISCAT and ESR during magnetic storm of May 1997. 10th International EIS-CAT Workshop, National Institute of Polar Research, Tokio, Japan, 23.-27. Juli 2001.
- Macdowall R. J. and **C. H. Barrow**: A 3-D mo-del of Jovian HOM and bKOM radio emis-sions. EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- Mall U.**, M. Banaszekiewicz, and S. Verani: In-vestigating planetary exospheres by in-situ mass spectrometry. EGS XXVI General As-sembly, Nizza, Frankreich, 25.-30. März 2001.
- Mall U.** and N. Borisov: Electric potential distri-bution on the nightside of the Moon. Thirty-Second Lunar and Planetary Science Con-ference, Houston, Texas, USA, 12.-16. März 2001.
- Mall U.** and N. Borisov: Electric fields around the Moon. EGS XXVI General Assembly, Nizza, Frankreich, 26.-30. März 2001.
- Mall U.**, P.W. Daly, C. Perry, B. Nikutowski, and R. Friedel: Energetic particle observati-ons with RAPID/Cluster. AGU Fall Meeting, San Franzisko, CA, USA, 10.-14. Dezember 2001.
- Mall U.**, S. Christon, E. Kirsch, P. Daly, and G. Gloeckler: On the Solar Cycle dependence of atomic N and O in the Earth exosphere and its relation to N+ and O+ content in the ma-gnetosphere. AGU Fall Meeting, San Franzis-ko, CA, USA, 10.-14. Dezember 2001.
- Mann G.**, H. Aurass, H.-T. Classen, A. Klassen, and V. Bothmer: Formation and development of shock waves in the solar corona and near Sun interplanetary space. EGS XXVI Gene-ral Assembly, Nizza, Frankreich, 25.-30. März 2001.
- Markiewicz W.J.**, N.M. Hoekzema, and H.U. Keller: Methods to estimate the optical depth of the Martian atmosphere from Orbiter images. EGS XXVI General Assembly, Niz-za, Frankreich, 27.-30. März 2001.
- Markiewicz W.J.** and K.J. Kossacki: Martian seasonal CO<sub>2</sub> ice in Malea Planum polygo-nal features: Role of the permafrost. 33th An-nual Meeting of the Division for Planetary Sciences, New Orleans, USA, 27. November - 1. Dezember 2001.
- Marsch E.** : The solar corona and the solar wind.\* Kolloquium, Instituto de Astrofisica de Canarias, Tenerife, Spanien, 15. Februar 2001.
- On ion-cyclotron-resonance heating of coro-nal funnels and holes.\* Fourth International Workshop “On Nonlinear Waves and Chaos in Space Plasmas”, Tromsø, Norwegen, 17.-22. Juni 2001.
- The solar wind.\* 35th ESLAB Symposium “Stellar Corona in the Chandra and XMM–Newton Era”, ESTEC, Noordwijk, Niederlan-de, 25.-29. Juni 2001.
- Cyclotron wave resonance in the solar corona and the evolution of solar wind ion velocity distributions.\* IAGA–IASPEI, Joint Scienti-fic Assembly, Hanoi, Vietnam, 19.-31. August 2001.
- Solar Orbiter – ESA’s high-resolution missi-on to the Sun and inner heliosphere.\* JEN-AM 2001, 10th European and 75th Annu-

- al Assembly of Astronomische Gesellschaft, München, 10.-15. September 2001.
- The Sun's corona and wind – structure, evolution and dynamics.\* Autumn College on Plasma Physics, Abdus Salam International Center for Theoretical Physics (ICTP), Trieste, Italien, 9.-11. Oktober 2001.
  - Ions and electrons – velocity distributions and kinetics.\* Autumn College on Plasma Physics, Abdus Salam International Center for Theoretical Physics (ICTP), Trieste, Italien, 9.-11. Oktober 2001.
  - Waves and turbulence – excitation, transport and dissipation.\* Autumn College on Plasma Physics, Abdus Salam International Center for Theoretical Physics (ICTP), Trieste, Italien, 9.-11. Oktober 2001.
- Marsch E.**, R. Harrison, and G. Whitcomb: Solar orbiter – A high-resolution mission to the Sun and inner heliosphere.\* Solar Encounter: The First Solar Orbiter Workshop, Puerto de la Cruz, Tenerife, Spanien, 14.-18. Mai 2001.
- Marsch E.** and C.-Y. Tu: Heizung und Beschleunigung von Ionen durch Zyklotronwellen in der Sonnenkorona. DPG-Frühjahrstagung, Hamburg, 20.-22. März 2001.
- Pitch-Winkel-Diffusion von Ionen im Sonnenwind. DPG-Frühjahrstagung, Hamburg, 20.-22. März 2001.
  - Heating and acceleration of ions by cyclotron waves in the solar corona. Solar Encounter: The First Solar Orbiter Workshop, Puerto de la Cruz, Tenerife, Spanien, 14.-18. Mai 2001.
  - Pitch-angle diffusion of ions in the solar wind. Solar Encounter: The First Solar Orbiter Workshop, Puerto de la Cruz, Tenerife, Spanien, 14.-18. Mai 2001.
- Marsden R.**, B. Fleck, R. Schwenn, E. Marsch, E. Antonucci, P. Bochsler, J.-L. Bougeret, R. Harrison, and J.-C. Vial: Solar orbiter – a high resolution mission to the Sun and inner heliosphere. EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- Mathew S.K.:** Inversion of 1.5 micron spectral data of a sunspot. Probing the Sun with high resolution, Udaipur Solar Observatory, Udaipur, India, 16.-19. Oktober 2001.
- Fabry Perots. Solar Orbiter VIM workshop, Max-Planck-Institut für Aeronomie, Katlenburg-Lindau, 23.-24. Oktober 2001.
- Mathew S.K.**, A. Lagg, S.K. Solanki, M. Collados, S. Berdyugina, N. Krupp, J. Woch, and C. Frutiger: Inversion of 1.5  $\mu\text{m}$  spectral data of a sunspot. Probing the Sun with high resolution, a meeting to celebrate 25 years of USO, Udaipur, Indien, 16.-19. Oktober 2001.
- Mazelle C., **K. Sauer**, and M.H. Acuna: The Phobos/Deimos plasma torus really exists? New observations from Mars global surveyor.\* EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- McKenzie J.F.** and W.I. Axford: The origin of the fast solar wind. AGU Spring Meeting, Boston, MA, USA, 29. Mai - 2. Juni 2001.
- Meziane K.**, C. Mazelle, D. LeQueau, M. Wilber, H. Rème, J.A. Sauvaud, J.M. Bosqued, I. Dandouras, E. Penou, G.K. Parks, C.W. Carlson, M. McCarthy, E. Möbius, B. Klecker, A. Korth, V. Formisano, R. Lundin, A. Balogh, T. Horbury, and E. Lucek: Cluster-CIS observations of bow shock-reflected ions. AGU Fall Meeting, San Franzisko, CA, USA, 10.-14. Dezember 2001.
- Minami S.**, M. Nishino, and M.T. Rietveld: Plan to the artificial ionosphere stimulation by high power HF radio waves at EISCAT. 10th International EISCAT Workshop, NIPR, Tokio, Japan, 23.-27. Juli 2001.
- Moebius E.**, H. Kucharek, L. Kistler, C. Mouikis, B. Klecker, M. Scholer, E. Georgescu, G. Paschmann, H. Rème, J. Bosqued, I. Dandouras, J. Sauvaud, C. Carlson, J. McFadden, G. Parks, A. Korth, V. Formisano, M. Bavassano-Cattaneo, A. DiLellis, M. McCarthy, L. Eliasson, R. Lundin, and T. Horbury: On the evolution of ion distributions across quasi-perpendicular bow shocks: CIS multipoint observations. AGU Fall Meeting, San Franzisko, CA, USA, 10.-14. Dezember 2001.
- Moran T.G.**, N. Gopalswamy, I.E. Dammasch, and K. Wilhelm: An observational study of solar coronal-hole regions showing radio enhancements. AGU 2001 Spring Meeting, Boston, USA, 29. Mai - 2. Juni 2001.
- Mouikis C.G.**, L.M. Kistler, E. Moebius, M.A. Popecki, B. Klecker, G. Paschmann, H. Rème, J.M. Bosqued, I. Dandouris, J.-A. Sauvaud, C. Carlson, J.P. McFadden, G.K. Parks, M. McCarthy, A. Korth, V. Formisano, M.-B. Bavassano-Cattaneo, A.M. DiLellis, R. Lundin, H. Balsiger: Multi-spacecraft observations of the CPS/PSBL boundary

- using the CIS instruments on Cluster. EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- Mouikis C.**, L.M. Kistler, E. Moebius, H. Kucharek, M.A. Popecki, B. Klecker, A. Korth, H. Rème, I. Dandouras, J. Bosqued, J. Sauvaud, C. Carlson, J.P. McFadden, G.K. Parks, M. McCarthy, V. Formisano, M. Bavassano-Cattaneo, A. DiLellis, L. Eliasson, H. Balsiger, and M. Dunlop: Multi-spacecraft observations of the CPS and PS-BL using the CIS instruments on CLUSTER. AGU Fall Meeting, San Franzisko, CA, USA, 10.-14. Dezember 2001.
- Muñoz Caro G.M.:** Experimental simulations of ice processing in the interstellar medium. Open University, Milton Keynes, UK, 5. März 2001.
- Muñoz Caro G.M.:** Detection of prebiotic molecules in UV-photoprocessed interstellar ice analogs. 3rd NL-Gravity and Astrobiology Symposium, Amsterdam, Niederlande, 15.-16. Mai 2001.
- Nakamura R.**, W. Baumjohann, B. Klecker, G. Paschmann, A. Balogh, H. Rème, H. Noda, T. Zhang, H. Eichelberger, Y. Bogdanova, E. Georgescu, P. Puhl-Quinn, J.M. Bosqued, I. Dandouras, J.A. Sauvaud, L. Kistler, E. Moebius, J.M. Quinn, R.B. Tobert, L. Eliasson, G.K. Parks, C.W. Carlson, A. Korth, M. McCarthy, and V. Formisano: Substorm intensifications observed by Cluster. AGU Fall Meeting, San Franzisko, CA, USA, 10.-14. Dezember 2001.
- Nathues A.**, C.-I. Lagerkvist, M. Dahlgren, A. Erikson, O. Karlsson, and F. Lahulla: A study of Cybele Asteroids II: Optical spectra. Asteroids 2001 conference, Palermo, Sizilien, 11.-16. Juni 2001.
- Nielsen E.:** Mars Express and MARSIS.\* Workshop on Mars magnetism and its interaction with the solar wind, International Space Science Institute, Bern, Schweiz, 22.-26. Oktober 2001.
- Nielsen E.**, F. Honary, and T. Hagfors: Advanced Rio-Imaging experiment in Scandinavia (ARIES): System specification and scientific goals.\* 10th International EISCAT Workshop, National Institute of Polar Research, Tokio, Japan, 23.-27. Juli 2001.
- Nielsen E.**, et al.: Antenna for sounding of a cometary nucleus in the ROSETTA mission, IEE 11th International Conference on Antennas and Propagation, Manchester, Großbritannien, 17.-20. April 2001.
- Nikutowski B.** J. Büchner, P. Daly, U. Mall, and B. Wilken: Messungen der Teilchenbeschleunigung mit Rapid auf Cluster. Frühjahrstagung der Deutschen Physikalischen Gesellschaft, Hamburg, 20.-22. März 2001.
- Nikutowski B.**, P.W. Daly, U. Mall, J.F. Fennell, and C.H. Perry: Plasmasheet motions in the distant magnetotail determined by 4-point ion measurements: RAPID/Cluster. AGU Fall Meeting, San Franzisko, CA, USA, 10.-14. Dezember 2001.
- Perry C. H.**, M. K. Carter, M. Grande, P. J. Carter, P. W. Daly, A. N. Fazakerley, T. Fritz, U. Mall, S. Szita, P. Travnicek, G. Watson, and B. Wilken: Observations of dayside boundary crossings using Cluster RAPID and PEACE. EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- Petkaki P.**, N. Krupp, and M.K. Dougherty: Correlation between low frequency waves and particle observations in the middle Jovian magnetosphere. EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- Petrova E.V.**, K. Jockers, and N.N. Kiselev: Interpreting the light scattering by cometary and planetary regolith with an aggregate model of particles. Workshop on Polarization 2001 with Emphasis on Cometary Observations, Paris, Frankreich, 10.-12. April 2001.
- Petrova E.V.**, W.J. Markiewicz, and H.U. Keller: On the problem of light scattering by planetary regolith. EGS XXVI General Assembly, Nizza, Frankreich, 27.-30. März 2001.
- Phan T.D.**, C. Carlson, G.K. Parks, J.P. McFadden, H. Rème, J.M. Bosqued, I. Dandouras, J.-A. Sauvaud, C. Aoustin, L.M. Kistler, E. Moebius, C. Mouikis, B. Klecker, G. Paschmann, M. McCarthy, V. Formisano, M.-B. Bavassano-Cattaneo, A.M. DiLellis, A. Korth, and R. Lundin: Cluster-II multi-point observations of the flank magnetopause and low-latitude boundary layer. EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- Phan T.**, C. Carlson, G. Parks, C. Twitty, J. McFadden, H. Rème, A. Balogh, J.M. Bos-

- qued, I. Dandouras, J.A. Sauvaud, C. Aoustin, L. Kistler, E. Moebius, C. Moukikis, B. Klecker, G. Paschmann, M. McCarthy, V. Formisano, M. Bavassano-Cattaneo, D. Dilellis, A. Korth, and R. Lundin: Cluster-II multi-spacecraft observations of continuous reconnection at the dayside magnetopause under steady IMF conditions. AGU Fall Meeting, San Franzisko, CA, USA, 10.-14. Dezember 2001.
- Popp, J.,** J. Koster, R. Geßner, P. Rösch, W. Kiefer, N. Thomas, and M. Hilchenbach: Raman spectroscopy on model mineral materials. EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- Popp, J.,** N. Tarcae, W. Kiefer, M. Hilchenbach, N. Thomas, S. Hofer, and T. Stuffer: Investigations on Mars model minerals by in situ laser Raman spectroscopy. First European Workshop on Exo-/Astrobiology, Frascati, Italien, 21.-23. Mai 2001.
- Pryor W.,** D. McComas, J. Ajello, M. Witte, I. Stewart: H-atom lifetimes in the 3-D heliosphere: Solar maximum vs. solar minimum. EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- Pryor W.,** I. Stewart, L. Esposito, R. West, D. Shemansky, A. Jouchoux, N. Krupp, F. Crary, B. Kurth, C. Hansen, W. McClintock, and J. Ajello: Cassini UVIS at Jupiter: First results on aurora. EGS XXVI General Assembly, Nizza, Frankreich, 26.-30. März 2001.
- Pryor W.,** I. Stewart, L. Esposito, D. Shemansky, J. Ajello, R. West, A. Jouchoux, C. Hansen, W. McClintock, B. Tsurutani, N. Krupp, F. Crary, and J. Colwell: Cassini UVIS observations of Jupiter's auroral variability. Conference on Jupiter – Planet, Satellites & Magnetosphere, LASP, University of Colorado, Boulder, CO, USA, 25.-30. Juni 2001.
- Pryor W.,** Witte M., McComas D., and Ajello J.: H-Atom lifetimes at solar maximum. Voyager, Ulysses and ACE Joint Science Workshop, Oxnard, CA, USA, 15.-19. Oktober 2001.
- Rème H.,** and CLUSTER/CIS team: First small and medium scale multipoint ion measurements in and near the Earth's magnetosphere from CIS experiments.\* EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- Rempel M.:** Speicherung und Verstärkung von Magnetfeld am Boden der solaren Konvektionszone. Kiepenheuer Institut für Sonnenphysik, Freiburg, 22. März 2001.
- Magnetohydrodynamik in der solaren Konvektionszone – ein Überblick und spezielle Anwendungen. Institut für Angewandte Mathematik, Freiburg, 22. November 2001.
- Rempel M.** and M. Schüssler: Intensification of magnetic fields in stellar convection zones by conversion of potential energy. International Inter-Institutional Workshop "Magnetic Fields across the Hertzsprung-Russell Diagram", Santiago, Chile, 15.-19. Januar 2001.
- Rempel M.** and M. Schüssler: Intensification of magnetic field by conversion of potential energy. 4. MHD-day, Bochum, 1.-2. Oktober 2001.
- Rietveld M.T.:** HF ionospheric heating at Tromsø: Application to ELF/ULF wave generation. Resonance Project: Phase-A meeting, Orleans, Frankreich, 10.-11. April 2001.
- The status of present research using the EISCAT HF-facility and outlook for the future\*. 10th International EISCAT Workshop, NIPR, Tokio, Japan, 23.-27. Juli 2001.
- Plasma physics experiments using powerful HF waves injected into the ionosphere. Kleinheubacher Tagung, 24.-28. September 2001.
- Rietveld M.T.,** C. La Hoz, T. Grydeland, and B. Isham: Observations of anomalous ion line spectra associated with enhanced plasma lines during auroral precipitation. EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- Rietveld M.T.,** B. Isham, H. Kohl, C. La Hoz, and T. Hagfors: Height-separated radar observations of HF-induced Langmuir turbulence. 4th International workshop on nonlinear waves and chaos in space plasmas, Tromsø, Norwegen, 17.-21. Juni 2001.
- Rietveld M.T.,** E. Belova, P.B. Chilson, S. Kirkwood, and U.-P. Hoppe: The effect of HF-induced electron temperature increases on the PMSE strength detected by the EISCAT VHF radar. Kleinheubacher Tagung, 24.-28. September 2001.
- Rietveld M.T.,** J. Röttger, and T. Hagfors: Future directions in aeronomy using the EIS-

- CAT facilities in northern Scandinavia. AGU Fall Meeting, San Franzisko, CA, USA, 10.-14. Dezember 2001.
- Romashets E.,** V. Bothmer, P. Cargill, and I. Veselovsky: Application of a MHD-model describing the draping of the IMF in the plasmasheath of a CME's bow shock. EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- Röckmann T.,** J. Kaiser, C. A. M. Brenninkmeijer, J.N. Crowley, R. Borchers, W.A. Brand, and P.J. Crutzen: The isotopic enrichment of nitrous oxide ( $^{15}\text{N}^{14}\text{NO}$ ,  $^{14}\text{N}^{15}\text{NO}$ ,  $^{14}\text{N}^{14}\text{N}^{18}\text{O}$ ) in the stratosphere and in the laboratory, EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- Röttger J.:** EISCAT employed as polar middle and lower atmosphere observatory.\* EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- The MST radar technique.\* Third Winter School on Indian MST Radar, Sri Venkateswara University, Tirupati, Indien, 5.-9. März 2001.
  - The radar interferometry technique.\* Third Winter School on Indian MST Radar, Sri Venkateswara University, Tirupati, Indien, 5.-9. März 2001.
  - Earth – Space environment research, multidisciplinary science and education. Physical Society Meeting, Sri Venkateswara University, Tirupati, Indien, 14. März 2001.
  - Radar studies of convective systems and lightning events. Seminar, National MST Radar Facility, Gadanki, Indien, 15. März 2001.
  - Perspective of radar observations for global atmosphere research. Inauguration Equatorial Atmosphere Radar, Bukittinggi, Indonesien, 26. Juni 2001.
  - Bodengebundene Messungen der Dynamik in der oberen Atmosphäre. Physikalisches Kolloquium, Universität Rostock, 12. Juli 2001.
  - Magnetosphere-Ionosphere-Mesosphere coupling observed with the SOUSY and the EISCAT Svalbard Radars during the Solar-Proton-Event in July 2000 (Bastille II). Seminar, Institute of Space Science, National Central University, Chung-Li, Taiwan, 19. Juli 2001.
  - The interpretation of Polar Mesosphere Summer Echoes (PMSE) using observations with the EISCAT Svalbard Radar and the SOUSY Svalbard Radar. PIERS-2001, Progress in Electromagnetic Research Symposium, Osaka, Japan, 18.-22. Juli 2001.
  - Radar ground clutter removal using digital filter – a hardware or software approach. 10th International EISCAT Workshop, National Institute of Polar Research, Tokio, Japan, 23.-27. Juli 2001.
  - Scatter cross sections of polar mesosphere summer echoes measured with the SOUSY Svalbard Radar on 53.5 MHz and the EISCAT Svalbard Radar on 500 MHz – Inference on large ions and electron diffusion. 10th International EISCAT Workshop, National Institute of Polar Research, Tokio, Japan, 23.-27. Juli 2001.
  - Middle and lower atmosphere observations with EISCAT. 10th International EISCAT Workshop, National Institute of Polar Research, Tokio, Japan, 23.-27. Juli 2001.
- Saito S.,** S.C. Buchert, R. Fujii, and T. Hagfors: Demagnetization of electrons in the presence of turbulence in the polar ionospheric E-region. 10th International EISCAT Workshop, Tokio, Japan, 23.-27. Juli 2001.
- Saito S.,** A. Stromme, T. Grydeland, C. La Hoz, and T. Hagfors: Investigation of fine structures in the ionosphere by interferometry with the EISCAT Svalbard Radar. 10th International EISCAT Workshop, Tokio, Japan, 23.-27. Juli 2001.
- Sauer K.:** Coherent nonlinear structures in bi-ion plasmas. University of Oslo, Department of Physics, Oslo, Norwegen, 12. Juni 2001.
- Bi-ion solitons in space plasmas. Fourth International Workshop on Nonlinear Waves and Chaos in Space Plasmas, Tromsø, Norwegen, 17.-22. Juni 2001.
  - Bi-ion effects in space plasmas. University of Tromsø, Institute of Physics, Tromsø, Norwegen, 19. Juni 2001.
  - Physics of bi-ion plasmas. Institut für Theoretische Physik, Innsbruck, Österreich, 28. Juni 2001.
  - Coherent waves and structures in bi-ion plasmas.\* International Topical Conference

- on Plasma Physics: New Plasma Horizons, Faro, Portugal, 3.-7. September 2001.
- Phobos/Deimos events – Observations and simulations. Team Workshop: Mars Magnetism, and its Interaction with the Solar Wind, ISSI, Bern, Schweiz, 22.-26. Oktober 2001.
  - Mechanisms of proton cyclotron emission. Team Workshop: Mars Magnetism, and its Interaction with the Solar Wind, ISSI, Bern, Schweiz, 22.-26. Oktober 2001.
- Sauer K.** and E. Dubinin: Generation and observations of coherent waves in the magnetospheric data. Workshop on Analysis Techniques for Space Plasma Data, CNRS School, La Londe-Les Maures, Frankreich, 8.-13. Oktober 2001.
- Sauer K.**, E. Dubinin, K. Baumgärtel, C. Mazelle and M. Acuna: Phobos/Deimos-Effekte: Neue Ergebnisse von Mars Global Surveyor und Simulationen. Frühjahrstagung der Deutschen Physikalischen Gesellschaft, Hamburg, 20.-22. März 2001.
- Sauer K.**, E. Dubinin, K. Baumgärtel, C. Mazelle and M. Acuna: Magnetic field effects of small bodies in space. EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- Sauer K.**, E. Dubinin, C. Mazelle, K. Baumgärtel and M. Acuna: Mechanisms of proton cyclotron emission in mass loaded plasmas. EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- Sauer K.**, E. Dubinin and J.F. McKenzie: Wavytons: Ein neuer Typ solitärer Wellen in Bi-Ionen-Plasmen. Frühjahrstagung der Deutschen Physikalischen Gesellschaft, Hamburg, 20.-22. März 2001.
- Sauer K.**, E. Dubinin and J.F. McKenzie: “Oscillitons” – a new type of soliton in bi-ion plasmas. Fourth International Workshop on Nonlinear Waves and Chaos in Space Plasmas, Tromsø, Norwegen, 17.-22. Juni 2001.
- Sauer K.**, E. Dubinin and J.F. McKenzie: Kohärente nichtlineare Wellen: Whistler- und LH-Oszillitonen. German Cluster Workshop, MPAE Katlenburg-Lindau, 16. November 2001.
- Sauer K.**, C. Mazelle, E. Dubinin, K. Baumgärtel, A. Lipatov and M. Acuna: The Phobos/Deimos plasma torus effects: Observations and simulation. EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- Sauer K.**, J.F. McKenzie and E. Dubinin: Main signatures of bi-ion plasma flows: Theory and observations.\* EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- Sauvaud J.**, R. Lundin, H. Rème, J.P. McFadden, C.W. Carlson, G.K. Parks, E. Moebius, L.M. Kistler, B. Klecker, E. Amata, A.M. DiLellis, V. Formisano, J.M. Bosqued, I. Dandouras, P. Decreau, M. Dunlop, L. Eliasson, A. Korth, B. Lavraud, and M. McCarthy: Ionospheric thermal plasma acceleration linked to magnetopause motions: First cluster results. AGU Fall Meeting, San Franzisko, CA, USA, 10.-14. Dezember 2001.
- Sauvaud J.-A.**, H. Rème, J.-M. Bosqued, I. Dandouras, C. Aoustin, L.M. Kistler, E. Moebius, C. Mouikis, B. Klecker, H. Kucharek, E. Amata, M.-B. Bavassano-Cattaneo, V. Formisano, C. Carlson, J.P. McFadden, G.K. Parks, M. McCarthy, A. Korth, L. Eliasson, R. Lundin, and A. Balogh: Evidence for ionospheric H<sup>+</sup>, He<sup>+</sup>, and O<sup>+</sup> ions in the plasma sheet with mass square-root-like ratio of energies: Cluster. EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- Schlegel K.**: Plasmainstabilitäten in der Ionosphäre.\* Physikalisches Kolloquium, Universität Greifswald, 24. Januar 2001.
- Schauer und Stürme – das Weltraumwetter. Tage der Forschung, Max-Planck-Institut für experimentelle Medizin, Göttingen, 10.-11. Februar 2001.
  - Polarlicht. Arbeitskreis Amateurfunk und Telekommunikation in der Schule, Jahrestagung, Goslar, 9. März 2001.
  - Polarlicht – Ein sichtbares Zeichen des Weltraumwetters. Frühjahrstagung der Deutschen Physikalischen Gesellschaft, Didaktik der Physik, Bremen, 21.-23. März 2001.
  - E-region plasma irregularities, their investigation and use for ionospheric diagnostics – Contributions of T.B. Jones and his group. Festkolloquium anlässlich der Verabschiedung von Prof. Dr. Tudor Jones in den Ruhestand, University of Leicester, Leicester, England, 3. April 2001.
  - Gewitter, Blitze und Sonnenaktivität. Kolloquiumsvortrag am Institut für Meteorologie

- und Klimatologie, Universität Hannover, 17. Mai 2001.
- Solar activity and lightning. Institute of Space and Astronautical Science, Sagamihara, Japan, 30. Juli 2001.
  - The influence of solar activity on lightning. 2001 Asia-Pacific Radio Science Conference, Chuo University, Tokio, Japan, 1.-4. August 2001.
  - Polarlicht und Weltraumwetter. Fürst-Pückler-Gymnasium, Cottbus, 7. November 2001.
  - Das Incoherent-Scatter-Verfahren – Ein vielseitiges Werkzeug zur Erforschung der Ionosphäre und Thermosphäre. Meteorologisches Kolloquium, Universität Leipzig, 8. November 2001.
- Schlegel K.** and M. Füllekrug: A D-region conductivity model for Schumann-Resonance simulations. 10th International EISCAT Workshop, National Institute of Polar Research, Tokio, Japan, 23.-27. Juli 2001.
- Schmidt W.**, S.K. Solanki, M. Schüssler, W. Curdt, B.W. Lites, A.M. Title, and V. Martinez Pillet: High-resolution solar polarimetry with sunrise. AG/EAS – Joint European and National Astronomical Meeting, München, 10.-15. September 2001.
- Schüssler M.:** Magnetic variability of the Sun. EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- Magnetic variability of the Sun. Solar Cycle and Space Weather, ESA/SOLSPA Euroconference, Vico Equense, Italien, 25.-29. September 2001.
  - Entwicklung eines 3D-MHD-Codes für Anwendungen in der Sonnenphysik. Jahreskolloquium DFG-Schwerpunktprogramm “Analysis und Numerik von Erhaltungsgleichungen”, Magdeburg, 31. Januar - 2. Februar 2001.
- Schüssler M.** and M. Knölker: Magnetoconvection. International Inter-Institutional Workshop “Magnetic Fields across the Hertzsprung-Russell Diagram”, Santiago, Chile, 15.-19. Januar 2001.
- Schwenn R.:** Strukturen und Dynamik der Sonnenkorona aus der Sicht von SOHO. Kiepenheuer-Institut für Sonnenphysik, Freiburg, 1. Februar 2001.
- Coronal mass ejection initiation, development and interplanetary propagation. “G” Discussion Meeting, Royal Astronomical Society, London, England, 9. März 2001.
  - The Sun as the driver of space weather – new views from SOHO. “A” and “G” Joint Meeting, Royal Astronomical Society, London, England, 9. März 2001.
  - Unsere Sonne, der unruhige Stern – neue Erkenntnisse durch das Weltraumobservatorium SOHO. Anästhesiologisches Kolloquium, Universität Göttingen, April 2001.
  - Coronal mass ejections and space weather: New views from SOHO. Special Seminar des Space Environment Center in Boulder, CO, USA, 15. Juni 2001.
  - CME mythology: Do global CMEs or sympathetic CMEs exist? ISCS 2001 Symposium on Solar Variability, Climate and Space Weather, Longmont, Colorado, 13.-16. Juni 2001.
  - The solar origins of space weather. Tutorial reviews, STP-10/CEDAR 2001 Joint Meeting, Longmont, CO, USA, 22. Juni 2001.
  - The solar origins of space weather: New views from SOHO. VI. Latin American Conference on Space Geophysics (COLAGE), Concepcion, Chile, 5. Oktober 2001.
  - The solar origins of space weather. Seminar der Facultad de Ciencias y Matematicas, Universität Concepcion, Chile, 8. Oktober 2001.
  - The sun, our star: New views from SOHO. Seminar der Facultad de Ciencias y Matematicas, Universität Concepcion, Chile, 8. Oktober 2001.
  - Sun and heliosphere: New views from SOHO. Instituto para el Estudio del Medio Ambiente (IEMA), Universität Mendoza, Argentinien, 12. Oktober 2001.
  - Introduction to physics of the heliosphere. Vorlesungsreihe im Rahmen der 2nd EL Leoncito Summer School on Solar Physics, El Leoncito, Argentinien, 14. - 22. Oktober 2001.
  - Sun and heliosphere: new views from SOHO. Instituto Nacional de Pesquisas Espaciais (INPE), Santa Maria, Brasilien, 24. Oktober 2001.
  - The solar origins of space weather. INPE, Sao Jose do Campos, Brasilien, 26. Oktober

- 2001.
- Schwenn R., **F. Portier-Foazzani**, B. Inhester, A. Bijaoui, M. Aschwanden, R. Schwenn, and B. Podlipnik: From SOHO to STEREO: The solar corona in 3 dimensions. EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- Shaw A.**, K. Hsieh, M. Hilchenbach, A. Czechowski, D. Hovestadt, B. Klecker, R. Kallenbach, G. Gloeckler, E. Moebius, P. Bochler: Detection of energetic helium atoms of heliospheric origin at 1 AU. AGU Spring Meeting, Boston, MA, USA, 29. Mai - 2. Juni 2001.
- Silin I.** and J. Büchner: 2D kinetic simulations of the instability of current sheets and spontaneous magnetic reconnection using a Vlasov code. EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- Silin I.** J. Büchner, and T. Wiegmann: 2D kinetic simulations of current sheet instabilities using a Vlasov code. Frühjahrstagung der Deutschen Physikalischen Gesellschaft, Hamburg, 20.-22. März 2001.
- Silin I.**, J. Büchner, and L. Zelenyi: Linear theory and simulations of current sheet instabilities. 6th International Conference on Space Plasma Simulation ISSS-6, Garching, 3.-7. September 2001.
- Skorov Y.V.**, W.J. Markiewicz, H.U. Keller, and K. Muinonen: Acceleration of non-spherical dust particles in a cometary Knudsen layer. EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- Soderblom L. A.**, D.C. Boice, D.T. Britt, R.H. Brown, B.J. Buratti, M.D. Hicks, R.M. Nelson, J. Oberst, B.R. Sandel, S.A. Stern, N.Thomas, and R. V. Yelle: Observations of comet 19P/Borrelly from the Miniature Integrated Camera and Spectrometer (MICAS) aboard Deep Space 1 (DS1). American Astronomical Society, Division for Planetary Sciences, 33rd Annual Meeting, New Orleans, LA, USA, 27. November - 1. Dezember 2001.
- Solanki S.K.:** Small-scale structure of the sun's magnetic field: non-spot fields. International Inter-Institutional Workshop on Magnetic Fields Across the Hertzsprung-Russell Diagram, Santiago, Chile, 15.-19. Januar 2001.\*
- Globale Erwärmung der Erde: Ist die Sonne schuld? Tage der Forschung 2001, MPI für experimentelle Medizin/MPI für Aeronomie, Göttingen, 10.-11. Februar 2001.\*
- The lower polar atmosphere and the solar dynamo. Solar Encounter: The First Solar Orbiter Workshop, Puerto de la Cruz, Teneriffa, Spanien, 14.-18. Mai 2001.\*
- Die Sonne, der Stern von dem wir leben. Erich-Regener-Vortrag, Max-Planck-Institut für Aeronomie, Katlenburg-Lindau, 29. Mai 2001.\*
- How is the Sun's magnetic field related to Einstein and our climate? Seminar, Max-Planck-Institut für Quantenoptik, Garching, 10. Juli 2001.\*
- Magnetic field of the Sun, Einstein and climate. Kolloquiumsvortrag, Universität Beijing, China, 13. September 2001.\*
- Solar variability. ISSI Workshop on Radiometric Inter-Calibration of SOHO (II), Bern, Schweiz, 8.-12. Oktober 2001.\*
- Was hat das Magnetfeld der Sonne mit Einstein und dem Erdklima zu tun? Kolloquiumsvortrag, Astrophysikalisches Institut Potsdam, 17. Oktober 2001.\*
- Das Sonnensystem. Schulvortrag, Primarschule Affoltern, Schweiz, 12. November 2001.\*
- Was hat das Magnetfeld der Sonne mit Einstein und unserem Klima zu tun? Kolloquiumsvortrag, Universität Mainz, 13. November 2001.\*
- Song L.**, P. Hartogh, and C. Jarchow: Intercomparison of water vapour profiles derived from ground-based microwave measurements with HALOE data. EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- Stubbe P.:** Stimulierte Elektromagnetische Emission (SEE). Kleinheubacher Tagung, 24.- 28. September 2001.
- Thiel V.:** Der Start ins Berufsleben. Fortbildungsseminar für Ausbilder in metallverarbeitenden Berufen, MPG, Schloss Ringberg, Tegernsee, 22. November 2001.
- Thomas N.:** Towards understanding solar system evolution. Kolloquium, DLR, Köln, 13. April 2001.
- Remote sensing tools as probes of physical processes in the solar system. Physikalische

- Institut, Universität Bern, Schweiz, 22. Juni 2001.
- The Io plasma torus. International Conference on Jupiter, Boulder, CA, USA, 25.-30. Juni 2001.
- Thomas N.**, G. Lichtenberg, and M. Scotto: High resolution spectra of the Io plasma torus near the time of Galileo I24 Encounter. International Conference on Jupiter, Boulder, 25.-30. Juni, 2001.
- Thomas N.**, G. Lichtenberg, and M. Scotto: High resolution spectroscopy of the Io plasma torus during the Galileo mission. American Astronomical Society, Division for Planetary Sciences, AAAS, New Orleans, USA, 23.-27. Oktober 2001.
- Thomas N.**, M.F. A'Hearn, D.C. Boice, D.T. Britt, K.J. Meech, B.R. Sandel, L.A. Soderblom, and R.V. Yelle: Jet morphology in the inner coma of Comet 19P/Borrelly observed by the Deep Space One MICAS imaging system. Division for Planetary Sciences, AAAS, New Orleans, USA, 23.-27. Oktober 2001.
- Titov D.V.**, W.J. Markiewicz, N. Thomas and H.U. Keller: Spectroscopic sounding of the Martian Aerosol from the Orbit. EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- Tokarev Y.V.**, M.T. Rietveld, J.-L. Bougeret, M.L. Kaiser, P. Rodriguez, V.A. Alimov, G.P. Komrakov, and G.N. Boiko: The EISCAT-SURA-WIND experiments: ionospheric influence on a decameter superlong baseline interferometer. EGS XXVI General Assembly, Nizza, Frankreich, 26.-30. März 2001.
- Ulich T.**, N. Crosby, K. Schlegel, M. Füllekrug, J. Manninen, and M. Rycroft: SPECIAL – Space process and electrical changes influencing atmospheric layers. 10th International EISCAT Workshop, National Institute of Polar Research, Tokio, Japan, 23.-27. Juli 2001.
- van Eyken A.P.**, T. Hagfors, and H. Opge-noorth: The EISCAT radars in the new millennium.\* EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- Vasyliunas V.M.:** The energy budget of the magnetosphere. Seminar, Department of Environmental, Earth and Atmospheric Sciences, University of Massachusetts Lowell, Lowell, MA, USA, 20. März 2001.
- Transport of plasma from the Io torus to the outer magnetosphere. Conference on Jupiter: Planet, Satellites and Magnetosphere, Boulder, CO, USA, 25.-30. Juni 2001.
  - The puzzle of the magnetospheric substorm. Festkolloquium anlässlich der Emeritierung von Professor Dr. G. Haerendel, Garching, 9. August 2001.
  - Energetics of the magnetosphere during geomagnetic storms.\* VI Conferencia Latinoamericana de Geofisica Espacial, Puerto de Tomé, Chile, 1.-5. Oktober 2001.
  - The largest imaginable magnetic storm. Space Physics Seminar, Jet Propulsion Laboratory, Pasadena, CA, USA, 6. Dezember 2001.
  - The largest imaginable magnetic storm. AGU Fall Meeting, San Franzisko, CA, USA, 10.-14. Dezember 2001.
- Vocks C.** and E. Marsch: Ein kinetisches Modell der Ionen in koronalen Löchern mit Welle-Teilchen-Wechselwirkung und Coulomb-Stößen. DPG-Frühjahrstagung, Hamburg, 20.-22. März 2001.
- Voitenko Yu.**, M. Gossens, and E. Marsch: On the role of ion-cyclotron kinetic Alfvén waves in the solar wind: Results from Helios and expectations for Solar Orbiter. Solar Encounter: The First Solar Orbiter Workshop, Puerto de la Cruz, Tenerife, Spanien, 14.-18. Mai 2001.
- Wiegelmann T.** and J. Büchner: 2D Vlasov-code simulations of the evolution of magnetic helicity under kinetic reconnection. EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- Wiegelmann T.** J. Büchner, and I. Silin: A newly developed 2D Vlasov code for space plasma simulations. EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- Wiegelmann T.**, T. Neukirch, and J. Büchner: Tests and limits of Vlasov code simulations and its application to null-helicity and co-helicity reconnection. 6th International Conference on Space Plasma Simulation ISSS-6, Garching, 3.-7. September 2001.
- Wilber M.**, G.K. Parks, C.W. Carlson, S.D. Bale, J.P. McFadden, F. Mozer, H. Rème, I. Dandouras, J. Sauvaud, J. Bosqued, M. McCarthy, L.M. Kistler, E. Möbius, A. Balogh, C.P. Escoubet, B. Klecker, M.B. Bavassano-

- Cattaneo, and A. Korth: Cluster observations of particle structures on field lines mapping to active auroral regions. AGU Fall Meeting, San Franzisko, CA, USA, 10.-14. Dezember 2001.
- Wilber M.**, G.K. Parks, M. McCarthy, H. Rème, Y. Dandouras, J.M. Bosqued, J.A. Sauvaud, C. Aoustin, E. Moebius, L.M. Kistler, B. Klecker, C.W. Carlson, D.W. Curtis, J. McFadden, R.P. Lin, C. Ingraham, V. Formisano, M.-B. Bavassano-Cattaneo, E.G. Shelley, A. Korth, H. Rosenbauer, R. Lundin, and H. Balsiger: Initial results from the Cluster/CIS retarding potential analyser. EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- Wilhelm K.:** Beobachtungen von Spikulen im Ultravioletten.\* Kolloquium, Kiepenheuer-Institut für Sonnenphysik, Freiburg, 18. Januar 2001.
- Unsere Sonne auf dem Prüfstand.\* Tage der Forschung 2001, Göttingen, 10.-11. Februar 2001.
  - SUMER and its radiometric calibration status.\* ISSI Team Workshop on the "Radiometric Inter-Calibration of SOHO", Bern, Schweiz, 12.-16. Februar 2001.
  - Transition region and coronal plasma diagnostics – Instrumentation and spectral analysis.\* 10th UN/ESA Workshop on Basic Space Science, Reduit, Mauritius, 25.-29. Juni 2001.
  - The chromospheric network and the solar wind sources.\* IAGA – IASPEI Joint Scientific Assembly, Hanoi, Vietnam, 18.-30. August 2001.
  - Past and recent observations of the solar upper atmosphere in the far-ultraviolet light.\* IAGA – IASPEI Joint Scientific Assembly, Hanoi, Vietnam, 18.-30. August 2001.
  - Calibration and inter-calibration efforts for vacuum-ultraviolet instrumentation on the SOHO spacecraft.\* ISSI Workshop on SOHO Intercalibration, Bern, Schweiz, 8.-12. Oktober 2001.
- Wilhelm K.**, U. Schühle, W. Curdt, I.E. Dammasch, J. Hollandt, P. Lemaire, and M.C.E. Huber: Solar vacuum-ultraviolet radiometry with SUMER.\* ISSI Workshop on SOHO Intercalibration, Bern, Schweiz, 8.-12. Oktober 2001.
- Wilken B.**, P. Daly, T. A. Fritz, U. Mall, and Q.-G. Zong: Search for energetic oxygen ions in the dusk magnetosheath – first results from RAPID/Cluster. EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- Witte M.**, and Banaszekiewicz M.: Interstellar neutral He parameters during solar maximum: Ulysses/Gas observations. EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- Witte M.**, Banaszekiewicz M., and Rosenbauer H.: An update on the kinetic parameters of interstellar neutral He. Voyager, Ulysses and ACE Joint Science Workshop, Oxnard, CA, USA, 15.-19. Oktober 2001.
- Witte M.**, Banaszekiewicz M., and Rosenbauer H.: An update on the kinetic parameters of interstellar neutral helium: ULYSSES/GAS results. AGU 2001 Fall Meeting, San Franzisko, CA, USA, 10.-14. Dezember 2001.
- Woch J.**, N. Krupp, A. Lagg, D.J. and Williams: Dynamic processes in the Jovian magnetosphere – solar wind or internally driven? Conference on Jupiter – Planet, Satellites & Magnetosphere, LASP, University of Colorado, Boulder, CO, USA, 25.-30. Juni 2001.
- Xia L.-D.**, E. Marsch, I. E. Dammasch, and K. Wilhelm: SUMER observations of coronal holes on the disk. EGS XXVI General Assembly, Nizza, Frankreich, 25.-30. März 2001.
- Zong Q.-G.**, B. Wilken, T. Fritz, P. Daly, and S. Y. Fu: Initial results from the RAPID/Cluster instrument: composition variation in substorms. EGS XXVI General Assembly, Nizza, Frankreich, 26.-30. März 2001.
- Zong Q.**, T. A. Fritz, B. Wilken, and P. Daly: Energetic ions in the high latitude boundary layer of the magnetosphere – RAPID/CLUSTER observation. AGU Fall Meeting, San Franzisko, CA, USA, 10.-14. Dezember 2001.

## Veröffentlichungen 2000/ Publications 2000

### Betreuung der Online-Veröffentlichungsliste: P.W. Daly

*Belova, E., S. Kirkwood, E. Nielsen and H. Tammet:* The ground-level atmospheric current response to a magnetic substorm. In: Proc. 5th International Conference on Substorms, (Ed.) A. Wilson. ESA SP-433, ESTEC, ESA Publ. Div., Noordwijk 2000, 473–476.

*Berdugina, S.V., C. Frutiger, S.K. Solanki and W. Livingston:* Successful spectral synthesis of Zeeman-split molecular bands in sunspot spectra. *Astronomy & Astrophysics* **364**, L101–L104 (2000).

*Blagoveshchenskaya, N.F., V.A. Kornienko, T.D. Borisova, B. Thide, M.J. Kosch, M.T. Rietveld, E.V. Mishin, R.Y. Luk'yanova and O.A. Troshichev:* Triggering of local substorm activation by powerful HF radio waves. In: Proc. 5th International Conference on Substorms, (Ed.) A. Wilson. ESA SP-443, ESTEC, ESA Publ. Div., Noordwijk 2000, 477–480.

*Blum, J., G. Wurm, S. Kempf, T. Poppe, H. Klahr, T. Kozasa, M. Rott, T. Henning, J. Dorschner, R. Schraepler, H. U. Keller, W. J. Markiewicz, I. Mann, B. A. S. Gustafson, F. Giovani, D. Neuhaus, H. Fechtig, E. Gruen, B. Feuerbacher, H. Kochan, L. Ratke, A. E. Goresy, G. Morfill, S. J. Weidenschilling, G. Schwehm, K. Metzler and W.-H. Ip:* Growth and form of planetary seedlings: results from a microgravity aggregation experiment. *Physical Review Letters* **85**, 2426–2429 (2000).

*Bogdanov, A.T., B. Klecker, E. Möbius, M. Hilchenbach, L.M. Kistler, M.A. Popecki, D. Hovestadt and J. Weygand:* Energy dependence of ion charge states in CME related solar energetic particle events observed with ACE/SEPICA and SOHO/STOF. In: *Acceleration and Transport of Energetic Particles Observed in the Heliosphere*, AIP Conference Proceedings 528, (Eds.) R.A. Mewaldt, J.R. Jokipii, M.A. Lee, E. Möbius and T.H. Zurbuchen. American Institute of Physics, Melville, N.Y. 2000, 143–146.

*Borisov, N. and U. Mall:* Electric fields and plasma perturbations in the vicinity of the Moon. In: Proc. 4th International Conference on the Exploration and Utilisation of the Moon, (Eds.) B. H. Foing and M. Perry. ESA SP-462, ESTEC, ESA Publ. Div., Noordwijk 2000, 191–194.

— Plasma distribution and electric fields behind the Moon. *Physics Letters A* **265**, 369–376 (2000).

*Bösinger, T., T. Pashin, A. Kero, P. Pollari, P. Belyaev, M. Rietveld, T. Turunen and J. Kangas:* Generation of artificial magnetic pulsations in the Pc1 frequency range by periodic heating of the Earth's ionosphere: indications of Alfvén resonator effects. *Journal of Atmospheric and Solar-Terrestrial Physics* **62**, 277–297 (2000).

*Brekke, P., N. Brynildsen, O. Kjeldseth-Moe, P. Maltby and K. Wilhelm:* Signatures of magnetic reconnection and observed EUV emission line profiles in an active region. *Advances in Space Research* **26**, 457–460 (2000).

*Brkovic, A., I. Rüedi, S. K. Solanki, A. Fludra, R. A. Harrison, M. C. E. Huber, J. O. Stenflo and K. Stucki:* EUV brightness variations in the quiet Sun. *Astronomy & Astrophysics* **353**, 1083–1093 (2000).

*Brooks, D. H., G. A. Fischbacher, A. Fludra, R. A. Harrison, D. E. Innes, E. Landi, M. Landini, J. Lang, A. C. Lanzafame, S. D. Loch, R. W. P. McWhirter and H. P. Summers:* A study of opacity in SOHO-SUMER and SOHO-CDS spectral observations. I. Opacity deduction at the limb. *Astronomy & Astrophysics* **357**, 697–715 (2000).

*Brynildsen, N., P. Maltby, T. Leifsen, O. Kjeldseth-Moe and K. Wilhelm:* Observations of sunspot transition region oscillations. *Solar Physics* **191**, 129–159 (2000).

*Büchner, J.:* Collisionless astrophysical reconnection. In: *Plasmas in the Universe*, (Eds.) B. Coppi, A. Ferrari and E. Sindoni, IOS Press, Amsterdam, Tokyo, Washington DC, 2000, 287–302.

— Theory and Simulation of Solar System Plasmas. *Nonlinear Processes in Geophysics* **7**, 126–221 (2000).

— Time spent as a guest professor in Toyokawa. *STEL Newsletter* **20**, 8–9 (2000).

*Büchner, J., A. Korth and R. Schwenn:* Die Einkopplung solarer Energie über die Magnetosphäre. In: *Proceedings Nationaler Workshop zum Weltraumwetter*, (Eds.) D. Adrian, N. Jakowski and A. Wehrenpfennig. Institut für Kommunikation und Navigation, DLR, Neustrelitz 2000, 5–14.

*Büchner, J., B. Nikutowski, Y. Kamide, T. Ogino, A. Otto, P. Daly, A. Korth, U. Mall, V. Vasyliunas, B. Wilken and J. Woch:* Numerical simulations for CLUSTER tested with EQUATOR-S and GEOTAIL. In: *Cluster-II Workshop: Multiscale/Multipoint Plasma Measurements*, (Ed.) R. A. Harris. ESA SP-

449, ESTEC, ESA Publ. Div., Noordwijk 2000, 219–226.

*Burger, R. A., M. S. Potgieter and B. Heber:* Rigidity dependent of cosmic-ray proton latitudinal gradients measured by the Ulysses spacecraft: Implications for the diffusion tensor. *Journal of Geophysical Research* **105**, 27447–27455 (2000).

*Chae, J., H. Wang, P. R. Goode, A. Fludra and U. Schühle:* Comparison of Transient Network Brightenings and Explosive Events in the Solar Transition Region. *The Astrophysical Journal* **528**, L119–L122 (2000).

*Chae, J., H. Wang, J. Qiu, P. R. Goode and K. Wilhelm:* Active region loops observed with SUMER on board the Solar and Heliospheric Observatory. *The Astrophysical Journal* **533**, 535–545 (2000).

*Chen, Z. X., A. Korth, Z. Y. Pu and C. Moukis:* The pitch angle distribution transition of energetic particles at substorm onset observed by GEOS-2. *Geophysical Research Letters* **27**, 645–648 (2000).

*Chilson, P. B., E. Belova, M. T. Rietveld, S. Kirkwood and U.-P. Hoppe:* First artificially induced modulation of PMSE using the EISCAT heating facility. *Geophysical Research Letters* **27**, 3801–3804 (2000).

*Chilson, P. B., R. D. Palmer, A. Muschinski, D. A. Hooper, G. Schmidt and H. Steinhagen:* SOMARE-99: A Demonstrational field campaign for ultra-high resolution VHF atmospheric profiling using frequency diversity. In: *Proc. 9th Workshop on Technical and Scientific Aspects of MST Radar*, (Ed.) B. Edwards. SCOSTEP Secretariat, Boulder 2000, 39–42.

*Cierpka, K., M. J. Kosch, S. Nozawa, K. Schlegel and T. Hagfors:* Combined EISCAT and Fabry-Perot interferometer measurements of ionospheric-thermospheric coupling. *Physics and Chemistry of the Earth* **25**, 563–566 (2000).

*Cierpka, K., M. J. Kosch, M. Rietveld, K. Schlegel and T. Hagfors:* Ion-neutral coupling in the high-latitude F-layer from incoherent scatter and Fabry-Perot interferometer measurements. *Annales Geophysicae* **18**, 1145–1153 (2000).

*Cierpka, K., M. J. Kosch, M. T. Rietveld, K. Schlegel and T. Hagfors:* Direct calculation of F-region Joule heating from simultaneous ion and neutral measurements at high latitudes. *Physics and Chemistry of the Earth* **25**, 439–442 (2000).

*Crovisier, J., T. Y. Brooke, K. Leech, D. Bockelee-Morvan, E. Lellouch, M. S. Hanner, B. Altieri, H. U. Keller, T. Lim, T. Encrenaz, A. Salama, M. Griffith, T. de Graauw, E. van Dishoeck and R. F. Knacke:* The thermal infrared spectra of comets Hale-Bopp and 103P/Harley 2 observed with the Infrared Space Observatory. In: *Thermal Emission Spectroscopy and Analysis of Dust, Disks, and Regoliths*, ASP Conference Proceedings Series 196, (Eds.) M. L. Sitko, A. L. Sprague and D. K. Lynch. The Astronomical Society of the Pacific, San Francisco, CA 2000, 109–117.

*Crovisier, J., K. Leech, D. Bockelee-Morvan, E. Lellouch, T. Y. Brooke, M. S. Hanner, B. Altieri, H. U. Keller and T. Lim:* The spectrum of comet Hale-Bopp as seen by ISO. In: *The Universe as seen by ISO*, (Eds.) P. Cox and M. F. Kessler. ESA-SP 427, ESTEC, ESA Publ. Div., Noordwijk 2000, 137–140.

*Curd, W., B. N. Dwivedi and U. Feldman:* The EUV spectrum of sunspot plumes observed by SUMER on SOHO. *Journal of Astrophysics and Astronomy* **21**, 397–401 (2000).

*Curd, W., E. Landi, K. Wilhelm and U. Feldman:* Wavelength measurements of heliumlike  $1s2s\ ^3S_1 - 1s2p\ ^3P_{0,2}$  transitions in  $Ne^{8+}$ ,  $Na^{9+}$ ,  $Mg^{10+}$ , and  $Si^{12+}$  emitted by solar flare plasmas. *Physical Review A* **62**, 022502-1 – 022502-7 (2000).

*Daly, P. W. and U. Mall:* Remote sensing of plasma boundaries by finite ion gyroradius effects: applications for the RAPID instrument on Cluster. In: *Cluster-II Workshop: Multiscale/ Multipoint Plasma Measurements*, (Ed.) R. A. Harris. ESA SP-449, ESTEC, ESA Publ. Div., Noordwijk 2000, 315–318.

*Das, A. C. and W.-H. Ip:* Field aligned current and particle acceleration in the near-Io plasma torus. *Planetary Space Science* **48**, 127–131 (2000).

*de LaNoe, J., J. Ovarlez, H. Ovarlez, C. Schiller, N. Lautié, P. Ricaud, J. Urban, D. G. Feist, L. Zalesak, N. Kämpfer, M. Ridal, D. Murtagh, K. Lindner, U. Klein, K. Künzi, P. Forkman, A. Winnberg, P. Hartogh and A. Engel:* Water vapour distribution inside and outside the polar vortex during THESEO. In: *Stratospheric ozone 1999, Air Pollution Research Report 73*. (Eds.) N. R. P. Harris, M. Guirlet and G. T. Amanatidis. Saint Jean de Luz, France, 2000, 558–561.

*Dubinin, E., K. Sauer, M. Delva, R. Grard, S. Livi, R. Lundin, A. Skalsky, K. Schwingenschuh, K. Szegö and J.-G. Trotignon:* Multi-instrument study of the upstream region near Mars: Phobos-2 observations. *Journal of Geophysical Research* **105**, 7557–7571 (2000).

- Dubinín, E., K. Sauer, M. Delva, S. Livi, R. Lundin, A. Skalsky and K. Szego:* Deceleration of the solar wind upstream of the Martian bow shock. Mass-loading or foreshock features? *Advances in Space Research* **26**, 1627–1631 (2000).
- Dwivedi, B. N., A. Mohan and K. Wilhelm:* On the electron temperatures, densities and hot ions in coronal hole plasma observed by SUMER on SOHO. *Advances in Space Research* **25**, 1751–1756 (2000).
- Fedorov, A., E. Dubinín, P. Song, E. Budnick, P. Larson and J.-A. Sauvaud:* Plasma characteristics of high-altitude cusp for steady southward-dawnward. *Advances in Space Research* **25**, 1435–1444 (2000).
- Feist, D. G., C. P. Aellig, N. Kämpfer, P. M. Solomon, J. W. Barrett, S. Zoonematkermani, P. Hartogh, C. Jarchow and J. W. Waters:* Validation of stratospheric ClO measurements from the Millimeter-wave Atmospheric Sounder (MAS). *Journal of Geophysical Research* **105**, 9053–9062 (2000).
- Feldman, U., W. Curdt, E. Landi and K. Wilhelm:* Identification of spectral lines in the 500–1600 Å wavelength range of highly ionized Ne, Na, Ar, K, Ca, Ti, Cr, Mn, Fe, Co, and Ni emitted by flares ( $T_e > 3 \times 10^6$  K) and their potential use in plasma diagnostics. *The Astrophysical Journal* **544**, 508–521 (2000).
- Feldman, U., I. E. Dammasch and K. Wilhelm:* The morphology of the solar upper atmosphere during the sunspot minimum. *Space Science Review* **93**, 411–472 (2000).
- Feldstein, Y. I., L. A. Dremukhina, U. Mall and J. Woch:* On the two-phase decay of the Dst-variation. *Geophysical Research Letters* **27**, 2813–2816 (2000).
- Ferreira, S.E.S., M.S. Potgieter, R.A. Burger and B. Heber:* Modulation effects of anisotropic perpendicular diffusion on cosmic ray electron intensities in the heliosphere. *Journal of Geophysical Research* **105**, 18305–18314 (2000).
- Fligge, M. and S. K. Solanki:* Properties of flux tubes and the relation with solar irradiance variability. *Journal of Astrophysics and Astronomy* **21**, 275–282 (2000).
- The solar spectral irradiance since 1700. *Geophysical Research Letters* **27**, 2157–2160 (2000).
- Fligge, M., S. K. Solanki, N. Meunier and Y. C. Unruh:* Solar surface magnetism and the increase of solar irradiance between activity minimum and maximum. In: *Proc. 1st Solar & Space Weather Euroconference “The Solar Cycle and Terrestrial Climate”*, (Ed.) A. Wilson. ESA SP-463, ESTEC, ESA Publ. Div., Noordwijk 2000, 117–121.
- Fligge, M., S. K. Solanki and Y. Unruh:* Modelling irradiance variations from the surface distribution of the solar magnetic field. *Astronomy & Astrophysics* **353**, 380–388 (2000).
- Fligge, M., S. K. Solanki and Y. C. Unruh:* Modelling short-term spectral irradiance variations. *Space Science Review* **94**, 139–144 (2000).
- Foukal, P., S. K. Solanki and J. Zirker:* Sun: Surface magnetism and its tracers. In: *Allen's Astrophysical Quantities*, 4th Edition, (Ed.) A. N. Cox. AIP Springer Verlag, New York 2000, 364–367.
- Friedel, R. H. W., G. Reeves, D. Belian, T. Cayton, C. Moukikis, A. Korth, B. Blake, J. Fennell, R. Selesnick, D. Baker, T. Onsager and S. Kanekal:* A multi-spacecraft synthesis of relativistic electrons in the inner magnetosphere using LANL, GOES, GPS, SAMPEX, HEO, and POLAR. *Advances in Space Research* **26**, 93–98 (2000).
- Friis-Christensen, E., C. Fröhlich, J. Haigh, M. Schüssler and R. von Steiger* (Eds.): *Solar Variability and Climate*. Kluwer, Dordrecht 2000, 427 p.
- Frolov, V. L., E. N. Ermakova, L. M. Kagan, G. P. Komrakov, E. N. Sergeev and P. Stubbe:* Features of the broad upshifted structure in stimulated electromagnetic emission spectra. *Journal of Geophysical Research* **105**, 20919–20933 (2000).
- Frutiger, C., S. K. Solanki, M. Fligge and J. H. M. J. Bruls:* Properties of the solar granulation obtained from the inversion of low spatial resolution spectra. *Astronomy & Astrophysics* **358**, 1109–1121 (2000).
- Gadun, A. S., A. Hanslmeier, K. N. Pikalov, S. R. O. Ploner, K. G. Puschmann and S. K. Solanki:* Size-dependent properties of simulated 2-D solar granulation. *Astronomy & Astrophysics, Supplement Series* **146**, 267–291 (2000).
- Granzer, T., M. Schüssler, P. Caligari and K. G. Strassmeier:* Distribution of starspots on cool stars II. Pre-main-sequence and ZAMS stars between 0.4  $M_{\odot}$  and 1.7  $M_{\odot}$ . *Astronomy & Astrophysics* **355**, 1087–1097 (2000).
- Grossmann-Doerth, U., M. Schüssler, M. Sigwarth and O. Steiner:* Strong Stokes V asymmetries of photospheric spectral lines: What can they tell us about the magnetic field structure? *Astronomy & Astrophysics* **357**, 351–358 (2000).

- Grün, E., S. B. Peschke, M. Stickle, T. G. Müller, H. Krüger, H. Böhnhardt, T. Y. Brooke, H. Campins, J. Crovisier, M. S. Hanner, I. Heinrichsen, H. U. Keller, R. Knacke, P. Lamy, C. Leinert, D. Lemke, C. M. Lisse, M. Müller, D. J. Osip, M. Solc, M. Sykes, V. Vanysek and J. Zarnecki: ISOPHOT observations of comet Hale-Bopp: initial data reduction. In: The Universe as seen by ISO, (Eds.) P. Cox and M. F. Kessler. ESA-SP 427, ESTEC, ESA Publ. Div., Noordwijk 2000, 181–183.
- Güsten, R., P. Hartogh, H.-W. Hübers, U. Graf, H.-P. Röser, F. Schäfer, R. Schieder, R. Stark, J. Stutzki, P. van der Wal and A. Wunsch: GREAT: the first-generation German heterodyne receiver for SOFIA. In: Airborne Telescope Systems, Proc. SPIE 4014, (Eds.) R.K. Melugin, H.-P. Röser, Bellingham 2000, 23–30.
- Hackenberg, P., E. Marsch and G. Mann: On the origin of the fast solar wind in polar coronal funnels. *Astronomy & Astrophysics* **360**, 1139–1147 (2000).
- Haldoupis, C., A. Bourdillon, K. Schlegel, J. Delloue and G. C. Hussey: Radio backscatter studies in South Europe of the Midlatitude E Region Ionosphere. *The Radio Science Bulletin* **295**, 6–14 (2000).
- Haldoupis, C., K. Schlegel and G. Hussey: Auroral E-region electron density gradients measured with EISCAT. *Annales Geophysicae* **18**, 1172–1181 (2000).
- Harnisch, J., M. Frische, R. Borchers, A. Eisenhauer and A. Jordan: Natural fluorinated organics in fluorite and rocks. *Geophysical Research Letters* **27**, 1883–1886 (2000).
- Hartmann, G. K.: Scientific data between validation imperatives, oblivion and fraud. *Physics and Chemistry of the Earth* **25**, 613–618 (2000).
- The variability of H<sub>2</sub>O fluxes in the Earth's atmosphere. *Physics and Chemistry of the Earth* **25**, 189–194 (2000).
- Hartmann, G. K., G. Kirchengast, A. v. Engeln, M. L. Richards, J. Ramsauer and C. Jarchow: MAS-GRAS sensor combination and optimal estimation retrieval of temperature and H<sub>2</sub>O profiles. *Physics and Chemistry of the Earth* **25**, 625–628 (2000).
- Hartmann, G. K., A. Nölle, M. L. Richards and R. Leitinger: DUST-2: Towards a more efficient (interactive) documentation and validation of scientific information demonstrated with ozone, water vapour and other selected data of the Earth's atmosphere. *Physics and Chemistry of the Earth* **25**, 607–612 (2000).
- Hartogh, P.: The MPAE ground-based microwave spectrometer (WASPAM). In: Stratospheric Processes and their Role in Climate (A project of the WMO/ICSU/IOC World Climate Research Programme): SPARC Assessment of Upper Tropospheric and Stratospheric Water Vapour. (Eds.) D. Kley, J. M. R. III and C. Phillips. WCRP-113, SPARC Office, Verrières le Buisson Cedex, France 2000, 45–46.
- Haus, R. and D. V. Titov: Sensitivity of temperature retrieval in the Martian atmosphere to transmittance simulation accuracy and instrumental noise. *Planetary Space Science* **48**, 473–481 (2000).
- Heber, B., J. B. Blake, M. Fränz, E. Keppler and H.P. Kunow: Evolution of cosmic ray fluxes during the rising phase of solar cycle 23: ULYSSES EPAC and COSPIN/KET observations. In: Acceleration and Transport of Energetic Particles Observed in the Heliosphere, AIP Conference Proceedings 528, (Eds.) R. A. Mewaldt, J. R. Jocipii, M. A. Lee, E. Moebius and T. Zurbuchen, American Institute of Physics, Melville, N.Y. 2000, 349–352.
- Heber, B., J. B. Blake, C. Paizis, V. Bothmer, H. Kunow, R. Müller-Mellin, G. Wibberenz, R. A. Burger and M. S. Potgieter: Recurrent modulation of galactic cosmic ray electrons and protons: Ulysses COSPIN/KET observations. In: Acceleration and Transport of Energetic Particles Observed in the Heliosphere, AIP Conference Proceedings 528, (Eds.) R. A. Mewaldt, J. R. Jocipii, M. A. Lee, E. Moebius and T. Zurbuchen, American Institute of Physics, Melville, N.Y. 2000, 357–360.
- Heber, B. and M. S. Potgieter: Galactic cosmic ray observations at different heliospheric latitudes. *Advances in Space Research* **26**, 839–852 (2000).
- Hilchenbach, M., K. C. Hsieh and A. Czechowski: Energetic neutral atoms. In: The Outer Heliosphere: Beyond the Planets, (Eds.) K. Scherer, H. Fichtner and E. Marsch, Copernicus Gesellschaft e.V., Katlenburg-Lindau 2000, 235–250.
- Hilchenbach, M., O. Küchemann and H. Rosenbauer: Impact on a Comet: Rosetta Lander Simulations. *Planetary and Space Science* **48**, 361–370 (2000).
- Hocking, W. K. and J. Röttger: Radar contributions to understanding the structure of atmospheric – A brief history. In: Proc. 9th Workshop on Technical and Scientific Aspects of MST Radar, (Ed.) B. Edwards. SCOSTEP Secretariat, Boulder 2000, 157–170.

- Holzwarth, V. and M. Schüssler:* Stability of magnetic flux tubes in close binary stars. *Astronomische Nachrichten* **321**, 175-179 (2000).
- Howard, R. A., G. E. Brueckner, O. C. St. Cyr, D. A. Biesecker, K. P. Dere, M. J. Koomen, C. M. Korendyke, P. L. Lamy, A. Llebaria, M. V. Bout, D. J. Michels, J. D. Moses, S. E. Paswaters, S. P. Plunkett, R. Schwenn, G. M. Simnett, D. G. Socker, S. J. Tappin and D. Wang:* Observations of CMEs from SOHO/LASCO. In: *Coronal Mass Ejections, Geophysical Monograph 99*, (Ed.) N. Crooker, J. Feynman, J.A. Joselyn. American Geophysical Union, Washington, DC 1999, 17–26.
- Hsieh, K. C., A. Czechowski and M. Hilchenbach:* Imaging the global distribution of anomalous cosmic rays. In: *Acceleration and Transport of Energetic Particles Observed in the Heliosphere*, AIP Conference Proceedings 528, (Eds.) R. A. Mewaldt, J. R. Jokipii, M. A. Lee, E. Möbius and T. H. Zurbuchen. AIP Publishing Center, Melville, N.Y. 2000, 325-332.
- Huebner, W. F. and W. J. Markiewicz:* The temperature and bulk flow speed of a gas effusing or evaporating from a surface into a void after reestablishment of collisional equilibrium. *Icarus* **148**, 594–596 (2000).
- Ip, W.-H., A. Kopp, L. M. Lara and R. Rodrigo:* Pluto's ionospheric models and solar wind interaction. *Advances in Space Research* **26**, 1559-1563 (2000).
- Jahunen, P., A. Olsson, O. Amm and K. Kauristie:* Characteristics of a stable arc based on FAST and MIRALE observations. *Annales Geophysicae* **18**, 152–160 (2000).
- Jockers, K., T. Bonev, P. Korsun, N. Karpov, A. Sergeev and V. Tarady:* Water production of comets derived from observations of [OI] (6300 Å) and H<sub>2</sub>O<sup>+</sup> (6150 Å): comets C/1998 U5 (Linear) and C/1999 J3 (Linear). In: *Proceedings "Astronomy in Ukraine - 2000 and Beyond (Impact of International Cooperation)"*. Kinematics and Physics of Celestial Bodies, Supplement 3. (Ed.) Y. S. Yatskiv. Main Astronomical Observatory, National Academy of Sciences of Ukraine, Kyiv 2000, 262–265.
- Jockers, K., T. Credner, T. Bonev, N. Kiselev, P. Korsun, I. Kulyk, V. Rosenbush, A. Andrienko, N. Karpov, A. Sergeev and V. Tarady:* Exploration of the solar system with the two-channel focal reducer at the 2m-RCC telescope of Pik Terskol Observatory. In: *Proceedings "Astronomy in Ukraine – 2000 and Beyond (Impact of International Cooperation)"*. Kinematics and Physics of Celestial Bodies, Supplement 3. (Ed.) Y. S. Yatskiv. Main Astronomical Observatory, National Academy of Sciences of Ukraine, Kyiv 2000, 13–18.
- Jordan, A., J. Harnisch, R. Borchers, F. L. Guern and H. Shinohara:* Volcanogenic halocarbons. *Environmental Science & Technology* **34**, 1122–1124 (2000).
- Keller, H. U., Y. V. Skorov, W. J. Markiewicz and A. T. Basilevsky:* Stability of water ice beneath porous dust layers of the Martian south polar terrain. In: *The Second International Conference on Mars Polar Science and Exploration*, LPI Contribution No. 1057, (Eds.) H. Björnsson, S. Clifford, D. Paige and T. Thornsteinsson. Lunar and Planetary Institute, Houston, Texas 2000, 90-91.
- Keppens, R., S. K. Solanki and C. Charbonnel:* Spin and orbital angular momentum exchange in binary star systems. II. Ascending the giant branch: a new path to FK Comae stars. *Astronomy & Astrophysics* **359**, 552–562 (2000).
- Kero, A., T. Bösinger, P. Pollari, E. Turunen and M. Rietveld:* First EISCAT measurement of electron-gas temperature in the artificially heated D-region ionosphere. *Annales Geophysicae* **18**, 1210–1215 (2000).
- Kikuchi, T., H. Lühr, K. Schlegel, H. Tachihara, M. Shinohara and T.-I. Kitamura:* Penetration of auroral electric fields to the equator during a substorm. *Journal of Geophysical Research* **105**, 23251–23261 (2000).
- Kimura, H. and I. Mann:* Selection effects on interstellar dust in heliosphere. *Advances in Space Research* **25**, (2)299–(2)302 (2000).
- Kirsch, E., U. Mall, K. Cierpka, B. Wilken, G. Gloeckler and A. B. Galvin:* Composition of low energy solar particles (0.5 - 225 keV/e) measured by the WIND-S/C during impulsive and gradual flares. *Advances in Space Research* **26**, 833–837 (2000).
- Kiselev, N. N., K. Jockers and V. K. Rosenbush:* Negative wavelength gradient of polarization of Comet 21P/Giacobini-Zinner as an indicator of organic matter in its dust particles. In: *Proceedings "Astronomy in Ukraine - 2000 and Beyond (Impact of International Cooperation)"*. Kinematics and Physics of Celestial Bodies, Supplement 3. (Ed.) Y. S. Yatskiv. Main Astronomical Observatory, National Academy of Sciences of Ukraine, Kyiv 2000, 266.
- Organic matter in dust of comet 21P/Giacobini-Zinner and the Draconid meteoroids. *Earth, Moon and Planets* **82-83**, 141–148 (2000).

- Kiselev, N. N., K. Jockers, V. K. Rosenbush, F. P. Velichko, T. Bonev and N. Karpov:* Anomalous wavelength dependence of polarization of comet 21P/Giacobini-Zinner. *Planetary and Space Science* **48**, 1005–1009 (2000).
- Klose, A., A. Nürnberger, R. Kruse, G. K. Hartmann and M. L. Richards:* Interactive text retrieval based on document similarities. *Physics and Chemistry of the Earth* **25**, 649–654 (2000).
- Knaack, R., M. Fligge, S. K. Solanki and Y. C. Unruh:* The influence of an inclined rotation axis on solar irradiance variations. In: *Proceedings Workshop on "The Sun and Sun-like Stars"*. (Eds.) I. Jankovics, J. Kovács and I. J. Vincze. Gothard Astrophysical Observatory, Szombathely, Hungary, 2000, 45–52.
- Kollewe, W., M. Skorsky, G. K. Hartmann, A. Nölle and M. L. Richards:* TOSCANA applied to Thesaurus Research. *Physics and Chemistry of the Earth* **25**, 643–648 (2000).
- Korsun, P. P. and K. Jockers:* CN and NH<sub>2</sub> atmospheres of Comet C/1999 J3 (Linear). In: *Proceedings "Astronomy in Ukraine - 2000 and Beyond (Impact of International Cooperation)"*. Kinematics and Physics of Celestial Bodies, Supplement 3. (Ed.) Y. S. Yatskiv. Main Astronomical Observatory, National Academy of Sciences of Ukraine, Kyiv 2000, 267–268.
- Korth, A., R. H. W. Friedel, C. G. Moukikis, J. F. Fennell, J. R. Wygant and H. Korth:* Comprehensive particle and field observations of magnetic storms at different local times from the CRRES spacecraft. *Journal of Geophysical Research* **105**, 18729–18740 (2000).
- Korth, A. and K.-H. Glassmeier:* Cluster- Der kosmische Regen. Rumba, Salsa, Samba und Tango untersuchen die Erdmagnetosphäre in 3-D. *Raumfahrt Concret* **14**, 11–12 (2000).
- Kosch, M., M. T. Rietveld, T. Hagfors and T. B. Leyser:* High-latitude HF-induced airglow displaced equatorwards of the pump beam. *Geophysical Research Letters* **27**, 2817–2820 (2000).
- Kosch, M., M. T. Rietveld, Å. Steen and T. Hagfors:* HF Induced airglow: double patches! *Physics and Chemistry of the Earth* **25**, 475–481 (2000).
- Kosch, M. J.:* Editorial: Atmospheric Studies by Optical Methods. *Physics and Chemistry of the Earth* **25**, 407 (2000).
- Kosch, M. J., O. Amm and M. W. J. Scourfield:* A plasma vortex revisited: The importance of including conductivity measurements. *Journal of Geophysical Research* **105**, 24889–24898 (2000).
- Kosch, M. J., M. Ishii, A. Kohsiek, D. Rees, K. Schlegel, T. Hagfors and K. Cierpka:* A comparison of vertical thermospheric winds from Fabry-Perot interferometer measurements over a 50 km baseline. *Advances in Space Research* **26**, 985–988 (2000).
- Kosch, M. J., M. Ishii, S. Nozawa, D. Rees, K. Cierpka, A. Kohsiek, K. Schlegel, R. Fujii, T. Hagfors, T. J. Fuller-Rowell and C. Lathuillere:* A comparison of thermospheric winds and temperatures from Fabry-Perot interferometer and EISCAT radar measurements with models. *Advances in Space Research* **26**, 979–984 (2000).
- Kossacki, K. J., W. J. Markiewicz and H. U. Keller:* Small Scale Trench in the Martian Soil: Conditions for Condensation of Atmospheric Volatiles. *Icarus* **144**, 463–478 (2000).
- Kotikov, A. L., M. I. Pudovkin, A. B. Pashin, E. Y. Grazhdantseva, T. Böisinger and M. T. Rietveld:* Auroral electrojet dynamics in relation with the HF ionosphere heating. In: *Proc. 5th International Conference on Substorms*, (Ed.) A. Wilson. ESA SP-443, ESTEC, ESA Publ. Div., Noordwijk 2000, 507–510.
- Kramm, J. R. and H. U. Keller:* CCD's for the Rosetta Science Imaging System OSIRIS. In: *Optical Detectors for Astronomy II*, (Eds.) P. Amico and J. W. Beletic. Kluwer, Dordrecht 2000, 55–62.
- Krivov, A. V., I. Mann and N. A. Krivova:* Size distribution of dust in circumstellar debris disks. *Astronomy & Astrophysics* **362**, 1127–1137 (2000).
- Krivova, N. A. and V. B. Il'in:* Dust around Herbig Ae/Be Stars: Porous, Cometary-like Grains? *Icarus* **143**, 159–169 (2000).
- Krivova, N. A., N. V. Krivov and I. Mann:* The disk of beta Pictoris in the light of polarimetric data. *Astrophysical Journal* **539**, 424–434 (2000).
- Kučera, A., W. Curdt, A. Fludra, J. Rybák and H. Wöhl:* SOHO JOP 078 – Variability and properties of the quiet Sun, Supergranular network and internetwork. In: *JOSO Annual Report 1998*, (Eds.) A. Antalová, H. Balthasar and A. Kučera. Astronomical Institute, Tatranská Lomnica, Slowakei 1999, 149–150.
- Kučera, T. A., U. Feldman, K. G. Widing and W. Curdt:* Wavelengths of forbidden transitions arising

- from levels within the  $\text{Fe}^{+19} 2s^2 2p^3$  ground configuration. *Astrophysical Journal* **538**, 424–427 (2000).
- Kuhn, J. R., R. M. MacQueen, J. Streete, G. Tansey, I. Mann, P. Hillebrand, R. Coulter and H. Lin*: Probable detection of a bright infrared coronal emission line of SI IX near 3.93 microns. *Astrophysical Journal* **521**, 478–482 (1999).
- Kuhn, J. R. and M. Schüssler*: Physical causes of solar variability. *Space Science Review* **94**, 177–181 (2000).
- Kulyk, I., K. Jockers, N. Karpov and A. Sergeev*: Near-infrared photometric observations of the inner Jovian satellites. In: Proceedings “Astronomy in Ukraine - 2000 and Beyond (Impact of International Cooperation)”. Kinematics and Physics of Celestial Bodies, Supplement 3. (Ed.) Y. S. Yatskiv. Main Astronomical Observatory, National Academy of Sciences of Ukraine, Kyiv 2000, 231–233.
- Landi, E., H. E. Mason, P. Lemaire and M. Landini*: SUMER observations of transition region fine structure. *Astronomy & Astrophysics* **357**, 743–756 (2000).
- Latteck, R., R. Rüster, J. Röttger, P. B. Chilson and V. Barabash*: Comparison of polar mesosphere summer echoes observed with the Alwin radar at 69°N, the SOUSY-Svalbard-Radar at 78°N, and the ESRAD radar at 68°N in summer 1999. In: Proc. 9th Workshop on Technical and Scientific Aspects of MST Radar, (Ed.) B. Edwards. SCOSTEP Secretariat, Boulder 2000, 100–103.
- Lauche, H. and O. Widell*: Intercalibration of low light level sources. *Physics and Chemistry of the Earth* **25**, 483–484 (2000).
- Lazutin, L., T. Kozelova and A. Korth*: Fast changes of energetic particle intensity near the boundary between the magnetotail and trapped region during substorm activations. In: Proc. 5th International Conference on Substorms, (Ed.) A. Wilson. ESA SP-443, ESTEC, ESA Publ. Div., Noordwijk 2000, 515–518.
- Le Contel, O., S. Perraut, A. Roux, R. Pellat and A. Korth*: Substorms in the inner plasma sheet. *Advances in Space Research* **25**, 2395 (2000).
- Ledovskaya, I., K. Jockers, N. Karpov and A. Sergeev*: Astrometric CCD observations of Jovian inner satellites Thebe, Amalthea, and Saturnian satellite Phoebe in the 1998 opposition. *Kinematika i fizika nebesnykh tel* **15/6**, 483–485 (1999).
- Leech, K., J. Crovisier, D. Bockelee-Morvan, T. Y. Brooke, M. S. Hanner, B. Altieri, H. U. Keller, E. Lellouch and T. Lim*: The infrared spectrum of comet Hale-Bopp as seen by the Infrared Space Observatory. In: Thermal Emission Spectroscopy and Analysis of Dust, Disks, and Regoliths, ASP Conference Proceedings Series 196, (Eds.) M. L. Sitko, A. L. Sprague and D. K. Lynch. The Astronomical Society of the Pacific, San Francisco, CA 2000, 81–83.
- Leitinger, R., N. Jakowski, K. Davies, G. K. Hartmann and E. Feichter*: Ionospheric electron content and space weather: some examples. *Physics and Chemistry of the Earth* **25**, 629–634 (2000).
- Leyser, T. B., B. Gustavsson, B. U. E. Brändström, Å. Steen, F. Honary, M. T. Rietveld, T. Aso and M. Ejiri*: Simultaneous measurements of high-frequency pump-enhanced airglow and ionospheric temperatures at auroral latitudes. *Advances in Polar Upper Atmospheric Research* **14**, 1–11 (2000).
- Liu, H., S. Ma and K. Schlegel*: Magnetic storm effects in the auroral ionosphere observed with EISCAT radar - two case studies. *Wuhan University Journal of Natural Sciences* **5**, 181–186 (2000).
- Liu, H., K. Schlegel and S.-Y. Ma*: Combined ESR and EISCAT observations of the dayside polar cap and auroral oval during the May 15, 1997 storm. *Annales Geophysicae* **18**, 1067–1072 (2000).
- Liu, P., S. Ma and K. Schlegel*: EISCAT observations of main ionization troughs in the high-latitude ionosphere. *Wuhan University Journal of Natural Sciences* **5**, 187–193 (2000).
- Luce, H., J. Röttger, M. Crochet, M. Yamamoto and S. Fukao*: The scattering layer thickness and position estimated by radar frequency domain interferometry; Part II: Effects of the scattering layer and radar beam tilts. *Radio Science* **35**, 1109–1127 (2000).
- Luce, H., J. Röttger, M. Yamamoto and S. Fukao*: The scattering layer thickness and position estimated by radar frequency domain interferometry; Part I: Effects of the limited horizontal extent and advection of the scattering layers. *Radio Science* **35**, 119–131 (2000).
- Ma, S. Y., P. Liu and K. Schlegel*: EISCAT observations of a high latitude ionization trough associated with a reversed westward plasma flow. *Geophysical Research Letters* **27**, 3269–3272 (2000).
- Mai, H. and K. Jockers*: Fabry-Perot imaging of Jupiter's aurora at 2.1  $\mu\text{m}$ . *Icarus* **146**, 494–500 (2000).

- Maia, D., A. Vourlidas, M. Pick, R. Howard, R. Schwenn and P. Lamy:* Coronal mass ejections and large scale structure of the corona. *Advances in Space Research* **25**, 1843–1846 (2000).
- Mall, U.:* ‘Fremdionen’ in the solar wind. In: *The Outer Heliosphere: Beyond the Planets*, (Eds.) K. Scherer, H. Fichtner and E. Marsch, Copernicus Gesellschaft e.V., Katlenburg-Lindau, 2000, 137–164.
- Mall, U., M. Banaszkiewicz and S. Verani:* Investigating the lunar exosphere by in-situ mass spectrometry. In: *Proc. 4th International Conference on the Exploration and Utilisation of the Moon*, (Eds.) B. H. Foing and M. Perry. ESA SP-462, ESTEC, ESA Publ. Div., Noordwijk 2000, 195–198.
- Maltby, P., N. Brynildsen, T. Fredvik, O. Kjeldseth-Moe and K. Wilhelm:* On the sunspot transition region. *Solar Physics* **190**, 429–450 (2000).
- Mann, I. and H. Kimura:* Interstellar dust properties derived from mass density, mass distribution, and flux rates in the heliosphere. *Journal of Geophysical Research* **105**, 10317–10328 (2000).
- Mann, I., A. Krivov and H. Kimura:* Dust cloud near the sun. *Icarus* **146**, 568–582 (2000).
- Marcucci, M. F., M. B. B. Cattaneo, A. M. D. Lellis, P. I. Cerulli, L. M. Kistler, T.-D. Phan, G. Haerendel, B. Klecker, G. Paschmann, W. Baumjohann, E. Möbius, M. A. Popecki, J. A. Sauvaud, H. Rème, A. Korth, L. Eliasson, C. W. Carlson, M. McCarthy and G. K. Parks:* Evidence for interplanetary magnetic field  $B_y$  controlled large-scale reconnection at the dayside magnetopause. *Journal of Geophysical Research* **105**, 27497–27507 (2000).
- Markiewicz, W. J., K. J. Kossacki and H. U. Keller:* Effect of surface roughness on ice distribution in the south subpolar region of Mars. In: *The Second International Conference on Mars Polar Science and Exploration*, LPI Contribution No. 1057, (Eds.) H. Björnsson, S. Clifford, D. Paige and T. Thorsteinsson. Lunar and Planetary Institute, Houston 2000, 127–128.
- Marsch, E.:* Dissipation and wave-ion interaction in the solar wind—links between fluid and kinetic theory. *Nonlinear Processes in Geophysics* **6**, 149–160 (2000).
- Marsch, E., C.-Y. Tu and K. Wilhelm:* Hydrogen temperature gradient in the transition region of a solar coronal hole. *Astronomy & Astrophysics* **359**, 381–385 (2000).
- Mason, G. M., R. von Steiger, R. B. Decker, M. I. Desai, J. R. Dwyer, L. A. Fisk, G. Gloeckler, J. T. Gosling, M. Hilchenbach, R. Kallenbach, E. Keppler, B. Klecker, H. Kunow, G. Mann, I. G. Richardson, T. R. Sanderson, G. M. Simnett, Y.-M. Wang, R. F. Wimmer-Schweingruber, M. Fränz and J. E. Mazur:* Origin, injection, and acceleration of CIR particles: Observations. *Space Science Review* **89**, 327–367 (1999).
- McKenna-Lawlor, S. M. P., E. Kirsch and P. Daly:* Particle acceleration at comet related shock surfaces. *Astrophysical Space Science* **264**, 545–566 (1999).
- McKenzie, J. F. and W. I. Axford:* Can gravitational effects damp Alfvén waves? *Solar Physics* **193**, 153–159 (2000).
- Hydromagnetic gravity waves in the solar atmosphere. *Astrophysical Journal* **537**, 516–523 (2000).
- Mikhailov, A. V. and K. Schlegel:* A self-consistent estimate of  $O^+$ ,  $N_2$ -rate coefficient and total EUV flux with  $\lambda < 1050 \text{ \AA}$  using EISCAT observations. *Annales Geophysicae* **18**, 1164–1171 (2000).
- Mishin, E. V., H. C. Carlson and T. Hagfors:* On the electron distribution function in the F region and airglow enhancements during HF modification experiments. *Geophysical Research Letters* **27**, 2857–2860 (2000).
- Mohan, A., B. N. Dwivedi and E. Landi:* Electron density and temperature measurements, and abundance anomalies in the solar atmosphere. *Journal of Astrophysics and Astronomy* **21**, 407–411 (2000).
- Mohan, A., E. Landi and B. N. Dwivedi:* FIP effect measurements in the off-limb corona observed by SUMER on SOHO. *Astronomy and Astrophysics* **364**, 835–844 (2000).
- Moreno-Insertis, F. and S. K. Solanki:* Distribution of magnetic flux on the solar surface and low-degree p-modes. *Monthly Notices of the Royal Astronomical Society* **313**, 411–422 (2000).
- Muglach, K., B. Fleck, U. Schühle, F. Stolpe, B. H. Foing and K. Wilhelm:* Dynamics of chromospheric and transition region lines observed with SOHO/SUMER and the GCT/Tenerife. *Advances in Space Research* **25**, 1731–1734 (2000).
- Nathues, A., U. Mall and H. U. Keller:* Near infrared spectrometry with SIR on SMART-1. In: *Proc. 4th International Conference on the Exploration and Utilisation of the Moon*, (Eds.) B. H. Foing and M.

- Perry. ESA SP-462, ESTEC, ESA Publ. Div., Noordwijk 2000, 101–103.
- Nedoluha, G. E. and P. Hartogh*: Upper stratosphere comparisons (WVMS and WASPAM). In: Stratospheric Processes and their Role in Climate (A project of the WMO/ICSU/IOC World Climate Research Programme): SPARC Assessment of Upper Tropospheric and Stratospheric Water Vapour. (Eds.) D. Kley, J. M. R. III and C. Phillips. WCRP-113, SPARC Office, Verrières le Buisson Cedex, France 2000, 139–141.
- Neudegg, D. A., S. W. H. Cowley, S. E. Milan, T. K. Yeoman, M. Lester, G. Provan, G. Haerendel, W. Baumjohann, B. Nikutowski, J. Büchner, U. Auster, K.-H. Fornacon and E. Georgescu*: A survey of magnetopause FTEs and associated flow bursts in the polar ionosphere. *Annales Geophysicae* **18**, 416–435 (2000).
- Nielsen, E. and F. Honary*: Observations of ionospheric flows and particle precipitation following a Sudden Commencement. *Annales Geophysicae* **18**, 908–917 (2000).
- Nölle, A., G. Pfister, G. Seckmeyer, H. Wilhelms, M. L. Richards and G. K. Hartmann*: DUST: An interactive data visualization tool for selected atmospheric data. *Physics and Chemistry of the Earth* **25**, 635–638 (2000).
- Oltmans, S., K. Rosenlof, H. A. Michelsen, C. Schiller, W. G. Read, G. E. Nedoluha, L. Pan, E. E. Remsberg, J. J. Bates, R. M. Bevilacqua, M. L. Chanin, E. W. Chiou, W. P. Chu, H. Fischer, D. G. Johnson, L. L. Gordley, P. Hartogh, M. Helten, R. L. Herman, E. J. Hintsa, S. Ismail, H. Kanzawa, K. K. Kelly, D. Kley, R. D. May, L. M. Miloshevich, H. Oelhaf, J. Ovarlez, H. C. Pumpfrey, P. N. Purcell, J. M. R. III, G. W. Sachse, V. Sherlock, H. G. J. Smit, G. C. Toon, S. A. Vay, H. Vömel and E. Weinstock*: Data Quality (Chapter 2). In: Stratospheric Processes and their Role in Climate (A project of the WMO/ICSU/IOC World Climate Research Programme): SPARC Assessment of Upper Tropospheric and Stratospheric Water Vapour. (Eds.) D. Kley, J. M. R. III and C. Phillips. WCRP-113, SPARC Office, Verrières le Buisson Cedex, France 2000, 95–193.
- Ortiz, A., S. K. Solanki, M. Fligge, V. Domingo and B. Sanahuja*: On the contrast of faculae and small magnetic features. In: Proc. 1st Solar & Space Weather Euroconference ‘The Solar Cycle and Terrestrial Climate’, (Ed.) A. Wilson. ESA SP-463, ESTEC, ESA Publ. Div., Noordwijk 2000, 399–402.
- Palmer, R. D., P. B. Chilson, A. Muschinski, G. Schmidt, T.-Y. Yu and H. Steinhagen*: Range imaging using frequency diversity: Theory and application. In: Proc. 9th Workshop on Technical and Scientific Aspects of MST Radar, (Ed.) B. Edwards. SCOSTEP Secretariat, Boulder 2000, 43–46.
- Paranicas, C., R. W. McEntire, A. F. Cheng, A. Lagg and D. J. Williams*: Energetic Charged Particles near Europa. *Journal of Geophysical Research* **105**, 16005–16015 (2000).
- Pashin, A. B., E. Y. Grazhdantseva, A. L. Kotikov, M. I. Pudovkin, T. Bösinger and M. T. Rietveld*: Numerical modeling of the auroral electrojet disturbances produced by HF ionosphere heating. In: Proc. 5th International Conference on Substorms, (Ed.) A. Wilson. ESA SP-443, ESTEC, ESA Publ. Div., Noordwijk 2000, 537–540.
- Patra, P. K., S. Lal, V. Sheel, B. H. Subbaraya, C. Brühl, R. Borchers and P. Fabian*: Chlorine partitioning in the stratosphere based on in situ measurements. *Tellus* **52B**, 934–946 (2000).
- Pauluhn, A., S. K. Solanki, I. Rüedi, E. Landi and U. Schühle*: Statistics of quiet Sun extreme ultraviolet intensities. *Astronomy & Astrophysics* **362**, 737–745 (2000).
- Perraut, S., O. Le Contel, A. Roux, R. Pellat, A. Korth, O. Holter and A. Pedersen*: Disruption of parallel current at substorm breakup. *Geophysical Research Letters* **27** (24), 4041–4044 (2000).
- Petrova, E. V., K. Jockers and N. N. Kiselev*: Light scattering by aggregates with sizes comparable to the wavelength: an application to cometary dust. *Icarus* **148**, 526–536 (2000).
- Ploner, S. R. O., S. K. Solanki and A. S. Gadun*: Is solar mesogranulation a surface phenomenon? *Astronomy & Astrophysics* **356**, 1050–1054 (2000).
- Posner, A., V. Bothmer, H. Kunow, J.T. Gosling, B. Heber, A.J. Lazarus, J.A. Linker, R.G. Marsden, Z. Mikic, R. Mueller-Mellin, T.R. Sanderson, A. Szabo and B.J. Thompson*: Energetic particle signatures of a corotating interaction region from a high latitude coronal hole: SOHO, WIND and Ulysses observations. *Advances in Space Research* **126**(5), 865–870, 2000.
- Rempel, M., M. Schüssler and G. Toth*: Storage of magnetic flux at the bottom of the solar convection zone. *Astronomy & Astrophysics* **363**, 789–799 (2000).
- Remsberg, E., C. Schiller, J. J. Bates, R. Bevilacqua, E. Browell, E. W. Chiou, W. P. Chu, G. Ehret, D.*

- Feist, D. Gaffen, L. Gordley, M. R. Gunson, P. Hartogh, M. Helten, R. Herman, E. Hints, F. Irion, S. Ismail, D. Johnson, N. Kämpfer, H. Kanzawa, K. Kelly, D. Kley, R. May, M. McHugh, H. A. Michelsen, L. Miloshevich, G. Nedoluha, H. Oelhaf, S. Oltmans, J. Ovarlez, H. Pumpfrey, W. Read, G. Sachse, V. Sherlock, H. Smit, G. Toon, H. Vömel, J. Waters, E. Weinstock and D. Whiteman:* Instrumentation and Data Sets (Chapter 1). In: *Stratospheric Processes and their Role in Climate* (A project of the WMO/ICSU/IOC World Climate Research Programme): SPARC Assessment of Upper Tropospheric and Stratospheric Water Vapour. (Eds.) D. Kley, J. M. R. III and C. Phillips. WCRP-113, SPARC Office, Verrières le Buisson Cedex, France 2000, 11–92.
- Richter, K., J. R. Combi, H. U. Keller and R. R. Meier:* Multiple Scattering of Hydrogen Lyman alpha Radiation in the Coma of Comet Hyakutake (C/1996B2). *Astrophysical Journal* **531**, 599–611 (2000).
- Rietveld, M. T., B. Isham, H. Kohl, C. La Hoz and T. Hagfors:* Measurements of HF-enhanced plasma and ion lines at EISCAT with high altitude resolution. *Journal of Geophysical Research* **105**, 7429–7439 (2000).
- Robinson, T. R. and K. Schlegel:* The generation of non aspect sensitive plasma density irregularities by field aligned drifts in the lower ionosphere. *Annales Geophysicae* **18**, 799–806 (2000).
- Robinson, T. R., R. Strangeway, D. M. Wright, J. A. Davies, R. B. Horne, T. K. Yeoman, A. J. Stocker, M. Lester, M. T. Rietveld, I. R. Mann, C. W. Carlson and J. P. McFadden:* FAST observations of ULF waves injected into the magnetosphere by means of modulated RF heating of the auroral electrojet. *Geophysical Research Letters* **27**, 3165–3168 (2000).
- Romanovsky, Y., V. Alpatov, Y. Platov, S. Chernouss, M. Kosch and Å. Steen:* Optical investigation in “ERLE” project. *Physics and Chemistry of the Earth* **25**, 503–506 (2000).
- Rosenbush, V. K., N. N. Kiselev, K. Jockers, V. V. Korokhin, N. M. Shakhovskoy and Y. S. Efimov:* Optical polarimetry of the Galilean satellites, Iapetus, and 64 Angelina near opposition. In: *Proceedings “Astronomy in Ukraine - 2000 and Beyond (Impact of International Cooperation)”*. Kinematics and Physics of Celestial Bodies, Supplement 3. (Ed.) Y. S. Yatskiv. Main Astronomical Observatory, National Academy of Sciences of Ukraine, Kyiv 2000, 227–230.
- Röttger, J.:* MST Radar Interferometry. In: *MST Radar, Theory, Techniques and Applications*. (Eds.) K. G. Rao and S. C. Chakravarty. Indian Space Research Organisation, Bangalore, India 2000, 128–186.
- First D-region incoherent scatter and PMSE observations with the EISCAT Svalbard Radar (500 MHz) and comparison with PMSE observed with the collocated SOUSY Svalbard Radar (53.5). In: *Proc. 9th Workshop on Technical and Scientific Aspects of MST Radar*, (Ed.) B. Edwards. SCOSTEP Secretariat, Boulder 2000, 129–132.
- Radar investigations of the mesosphere, stratosphere and the troposphere in Svalbard. *Advances Polar Upper Atmospheric Research* **14**, 202–220 (2000).
- ST radar observations of atmospheric waves over mountainous areas: A review. *Annales Geophysicae* **18**, 750–765 (2000).
- Röttger, J., H. Luce, M. Yamamoto, S. Fukao, C. H. Liu, C. J. Pan, S. Y. Su and C. H. Wu:* Combined high-time resolution SDI-FDI experiments with VHF Radars. In: *Proc. 9th Workshop on Technical and Scientific Aspects of MST Radar*, (Ed.) B. Edwards. SCOSTEP Secretariat Boulder, 2000, 47–50.
- Röttger, J., G. Schmidt, R. Rüster, P. Czechowsky, J. Klostermeyer, J. Trautner, K. Meyer, K.-D. Preschel and H. Becker:* An update on the SOUSY Svalbard Radar: Observations of Polar Mesosphere Summer Echoes. In: *Proc. 9th Workshop on Technical and Scientific Aspects of MST Radar*, (Ed.) B. Edwards. SCOSTEP Secretariat, Boulder, 2000 427–430.
- Röttger, J., S. Y. Su, C. J. Pan, C. H. Liu and C. H. Wu:* SDI-FDI detection of lightning echoes with the Chung-Li VHF Radar: Three-dimensional interferometry. In: *Proc. 9th Workshop on Technical and Scientific Aspects of MST Radar*, (Ed.) B. Edwards. SCOSTEP Secretariat, Boulder 2000, 51–54.
- Röttger, J. and J. Trautner:* Synoptic and meso-scale disturbances observed in the Arctic troposphere and lower stratosphere with the SOUSY Svalbard Radar. In: *Proc. 9th Workshop on Technical and Scientific Aspects of MST Radar*, (Ed.) B. Edwards. SCOSTEP Secretariat, Boulder 2000, 381–384.
- Sauer, K. and E. Dubinin:* The nature of the martian ‘obstacle boundary’. *Advances in Space Research* **26**, 1633–1637 (2000).
- Sauer, K., J. McKenzie and E. Dubinin:* Waves and nonlinear structures in bi-ion plasmas. In: *Waves in Dusty, Solar, and Space Plasmas*, AIP Conference

- Proceedings 537, (Eds.) F. Verheest, M. Goossens, M.A. Hellberg and R. Bharuthram. American Institute of Physics, Melville, N.Y. 2000, 327–339.
- Schieder, R., O. Siebertz, F. Schloeder, C. Gal, J. Stutzki, P. Hartogh and E. Natale:* Wide-Band Spectrometer for HIFI - FIRST. Proc. of SPIE 4013 "UV, Optical and IR Space Telescopes and Instruments", (Eds.) J.B. Breckinridge and P. Jakobsen, ESA, Noordwijk 2000, 313–324.
- Schlegel, K.:* Die Farben des Himmels. Spektrum der Wissenschaft, Spezial 4/2000 'Farben', 14–21.
- In Memoriam Walter E. Dieminger 1907 - 2000. The Radio Science Bulletin **295**, 4–5 (2000).
- Wenn die Sonne verrückt spielt. Physik in unserer Zeit **5**, 222–226 (2000).
- Die stärksten geomagnetischen Stürme im letzten Jahrhundert. Meteoros **3**, 11–13 (2000).
- Schlegel, K. and M. Füllekrug:* Diurnal harmonics in Schumann resonance parameters observed on both hemispheres. Geophysical Research Letters **27**, 2805–2808 (2000).
- Schröer, A. and A. Kopp:* A three-fluid system of equations describing dusty magnetoplasmas with dynamically important dust and ion components. Physics of Plasmas **7**, 3468–3471 (2000).
- Schühle, U., W. Curdt, J. Hollandt, U. Feldman, P. Lemaire and K. Wilhelm:* Radiometric calibration of the vacuum-ultraviolet spectrograph SUMER on the SOHO spacecraft with the B detector. Applied Optics **39**, 418–425 (2000).
- Schühle, U., J. Hollandt, A. Pauluhn and K. Wilhelm:* Mid-term radiance variation of far-ultraviolet emission lines from quiet-Sun areas. In: Proc. 1st Solar & Space Weather Euroconference, 'The Solar Cycle and Terrestrial Climate', (Ed.) A. Wilson. ESA SP-463, ESTEC, ESA Publ. Div., Noordwijk 2000, 427–430.
- Schühle, U., A. Pauluhn, J. Hollandt, P. Lemaire and K. Wilhelm:* Radiance variations of vacuum-ultraviolet emission lines of the quiet Sun observed with SUMER on SOHO. Physics and Chemistry of the Earth (C) **25**, 429–432 (2000).
- Schühle, U., K. Wilhelm, J. Hollandt, P. Lemaire and A. Pauluhn:* Radiance variations of the quiet Sun at far-ultraviolet wavelengths. Astronomy & Astrophysics **354**, L71–L74 (2000).
- Schüssler, M. and D. Schmitt:* Steuert die Sonne das Erdklima? KI Luft- und Kältetechnik **36**, 63–68 (2000).
- Schwenn, R.:* Coupling between high and low latitudes as observed with LASCO in the solar corona and in interplanetary space. Advances in Space Research **26**, 771–780 (2000).
- Heliospheric 3D structure and CME propagation as seen from SOHO: recent lessons for space weather predictions. Advances in Space Research **26**, 43–53 (2000).
- Seele, C. and P. Hartogh:* A case study on middle atmospheric water vapor transport during the February 1998 stratospheric warming. Geophysical Research Letters **27**, 3309–3312 (2000).
- Sergienko, T., B. Gustavsson, Å. Steen, U. Brändström, M. T. Rietveld, T. B. Leyser and F. Honary:* Analysis of excitation of the 630.0 nm airglow during a heating experiment in Tromsø on February 16, 1999. Physics and Chemistry of the Earth **25**, 531–535 (2000).
- Solanki, S. K.:* Sunspots. In: Allen's Astrophysical Quantities, 4th Edition, (Ed.) A. N. Cox. AIP Springer Verlag, New York 2000, 367–370.
- Solanki, S. K. and M. Fligge:* Long-term changes in solar irradiance. In: Proc. 1st Solar & Space Weather Euroconference "The Solar Cycle and Terrestrial Climate", (Ed.) A. Wilson. ESA SP-463, ESTEC, ESA Publ. Div., Noordwijk 2000, 51–60.
- Reconstruction of past solar irradiance. Space Science Review **94**, 127–138 (2000).
- Solanki, S. K., M. Fligge, P. Pulkkinen and P. Hoyng:* Cyclic evolution of sunspots: Gleaning new results from old data. Journal of Astrophysics and Astronomy **21**, 163–165 (2000).
- Solanki, S. K., M. Schüssler and M. Fligge:* Evolution of the Sun's large-scale magnetic field since the Maunder minimum. Nature **408**, 445–447 (2000).
- Spadaro, D., A. C. Lanzafame, L. Consoli, E. Marsch, D. H. Brooks and J. Lang:* Structure and dynamics of an active region loop system observed on the solar disc with SUMER on SOHO. Astronomy & Astrophysics **359**, 716–728 (2000).
- Srivastava, N., R. Schwenn, B. Inhester, S. F. Martin and Y. Hanaoka:* Factors related to the origin of a gradual coronal mass ejection associated with an

- eruptive prominence on 1998 June 21-22. *Astrophysical Journal* **534**, 468–481 (2000).
- St. Cyr, O. C., R. A. Howard, N. R. Sheeley, Jr., S. P. Plunkett, D. J. Michels, S. E. Paswaters, M. J. Koomen, G. M. Simnett, B. J. Thompson, J. B. Gurman, R. Schwenn, D. F. Webb, D. F. Hildner and P. L. Lamy*: Properties of coronal mass ejections: SOHO LASCO observations from January 1996 to June 1998. *Journal of Geophysical Research* **105**, 18169–18185 (2000).
- Stenborg, G., L. G. Bagalá, O. H. Bauer, R. Fernández Borda, C. Francile, G. Haerendel, M. G. Rovira and R. Schwenn*: First combined observations in the German-Argentinean solar observatory: Correlations in quiet and eruptive phenomena at the limb. *Journal of Atmospheric and Terrestrial Physics* **62**, 1553–1559 (2000).
- Stubbe, P. and A. I. Sukhorukov*: Response to “Comment on ‘On the physics of Landau damping’”. *Physics of Plasmas* **7**, 775 (2000).
- Stucki, K., S. K. Solanki, U. Schühle and I. Rüedi*: On the relationship between line shift and intensity in coronal holes and the quiet Sun. *Astronomy & Astrophysics* **362**, L49–L52 (2000).
- Stucki, K., S. K. Solanki, U. Schühle and I. Rüedi*: On the relationship between shift and intensity of ultraviolet lines in coronal holes and the quiet Sun. *Astronomy & Astrophysics* **362**, L49–L52 (2000).
- Stucki, K., S. K. Solanki, U. Schühle, I. Rüedi, K. Wilhelm, J. O. Stenflo, A. Brkovic and M. C. E. Huber*: Comparison of far-ultraviolet emission lines formed in coronal holes and the quiet Sun. *Astronomy & Astrophysics* **363**, 1145–1154 (2000).
- Szegö, K., K.-H. Glassmeier, R. Bingham, A. Bogdanov, C. Fischer, G. Haerendel, A. Brinca, T. Cravens, E. Dubinin, K. Sauer, L. Fisk, T. Gombosi, N. Schwadron, P. Isenberg, M. Lee, C. Mazelle, E. Möbius, U. Motschmann, V. D. Shapiro, B. Tsurutani and G. Zank*: Physics and mass loaded plasmas. *Space Science Review* **94**, 429–671 (2000).
- Tereshchenko, E. D., B. Z. Khudukon, M. O. Kozlova, O. V. Evstafiev, T. Nygrén, M. T. Rietveld and A. Brekke*: Comparison of the orientation of small scale electron density irregularities and F region plasma flow direction. *Annales Geophysicae* **18**, 918–926 (2000).
- Tereshchenko, E. D., M. O. Kozlova, O. V. Evstafiev, B. Z. Khudukon, T. Nygrén, M. Rietveld and A. Brekke*: Irregular structures of the F layer at high latitudes during ionospheric heating. *Annales Geophysicae* **18**, 1197–1209 (2000).
- Thomas, N., S. Eggers, W.-H. Ip, G. Lichtenberg, A. Fitzsimmons, L. Jorda, H. U. Keller, I. P. Williams, G. Hahn and H. Rauer*: Observations of the trans-neptunian objects 1993 SC and 1996 TL66 with the Infrared Space Observatory. *Astrophysical Journal* **534**, 446–455 (2000).
- Thomas, N., L. Jorda and W. J. Markiewicz*: Effect of diffuse sky brightness on the spectrophotometry of rough Martian surfaces. *Journal of Geophysical Research* **105**, 26739–26744 (2000).
- Titov, D. V., A. A. Fedorova and R. Haus*: A new method of remote sounding of the Martian aerosols by means of spectroscopy in the 2.7  $\mu\text{m}$  CO<sub>2</sub> band. *Planetary and Space Science* **48**, 67–74 (2000).
- Titov, D. V., W. J. Markiewicz, N. Thomas, H. U. Keller, M. G. Tomasko, M. Lemmon and P. H. Smith*: On the optical studies of the atmospheric water vapour from the surface of Mars. *Planetary and Space Science* **48**, 1423–1427 (2000).
- Tomasch, G., R. Harboe-Sørensen, R. Müller and T. Tzscheetzsch*: Co-60 total dose test of 14- and 16-bit ADCs. In: IEEE Nuclear and Space Radiation Effects Conference, Workshop Record, IEEE 00TH8527, (Ed.) J. Kinnison. Institute of Electrical and Electronics Engineers, Inc., Nuclear and Plasma Sciences Society, Piscataway, NJ 2000, 26–31.
- Trotignon, J. G., M. Parrot, J. C. Cerisier, M. Menvielle, W. I. Axford, M. Pätzold, R. Warnant and A. W. Wernik*: The plasma environment of Mars: from the shocked solar wind down to the ionosphere. *Planetary and Space Science* **48**, 1181–1191 (2000).
- Unruh, Y. C., S. K. Solanki and M. Fligge*: Modelling solar irradiance variations: Comparison with observations, including line-ratio variations. *Space Science Review* **94**, 145–152 (2000).
- Vacaresse, A., D. Boscher, S. Bourdarie, A. Korth and R. Friedel*: Correlations between measurements and numerical simulation results for ring current protons. *Advances in Space Research* **26**, 173–176 (2000).
- Vasyliunas, V. M.*: Reply. *Journal of Geophysical Research* **105**, 27843 (2000).
- Vasyliunas, V. M. and A. Eviatar*: Outflow of Ions from Ganymede: A Reinterpretation. *Geophysical Research Letters* **27**, 1347–1349 (2000).

- Voiculescu, M., C. Haldoupis, D. Pancheva, M. Ignat, K. Schlegel and S. Shalimov:* More evidence for a planetary wave link with midlatitude E region coherent backscatter and sporadic E layers. *Annales Geophysicae* **18**, 1182–1196 (2000).
- Weber, K.-H., G. K. Hartmann and H. Oberländer:* Literature search on atmospheric ozone and water vapour from three different online-databases. *Physics and Chemistry of the Earth* **25**, 639–641 (2000).
- Westall, F., A. Brack, B. Hofmann, G. Horneck, G. Kurat, J. Maxwell, G. G. Ori, C. T. Pillinger, F. Raulin, N. Thomas, B. Fitton, P. Clancy, D. Prieur and D. Vassaux:* An ESA study for the search for life on Mars. *Planetary and Space Science* **48**, 181–202 (2000).
- Wiegelmann, T. and J. Büchner:* Kinetic simulations of the coupling between current instabilities and reconnection in thin current sheets. *Nonlinear Processes in Geophysics* **7**, 141–150 (2000).
- Wiegelmann, T., K. Schindler and T. Neukirch:* Helmet Streamers with Triple Structures: Simulations of resistive dynamics. *Solar Physics* **191**, 393–410 (2000).
- Wilhelm, K.:* Solar spicules and macrospicules observed by SUMER. *Astronomy & Astrophysics* **360**, 351–362 (2000).
- SUMER observations of the quiet Sun: Transition region and low corona. *Advances in Space Research* **25**, 1723–1730 (2000).
- Wilhelm, K., W. Curdt, I. E. Dammasch and E. Marsch:* Die Quellen des schnellen Sonnenwindes. *Physikalische Blätter* **56**, 51–53 (2000).
- Wilhelm, K., I. E. Dammasch, E. Marsch and D. M. Hassler:* On the source regions of the fast solar wind in polar coronal holes. *Astronomy & Astrophysics* **353**, 749–756 (2000).
- Wilhelm, K., P. Lemaire, I. E. Dammasch, J. Hollandt, U. Schühle, W. Curdt, T. Kucera, D. M. Hassler and M. C. E. Huber:* Solar irradiances of ultraviolet emission lines measured during the minimum of sunspot activity in 1996 and 1997. *Physics and Chemistry of the Earth (C)* **25**, 389–392 (2000).
- Wilhelm, K., U. Schühle, W. Curdt, I. E. Dammasch, J. Hollandt, P. Lemaire and M. C. E. Huber:* Solar spectroradiometry with the telescope and spectrograph SUMER on the Solar and Heliospheric Observatory SOHO. *Metrologia* **37**, 393–398 (2000).
- Wilken, B., Q. G. Zong and P. W. Daly:* CLUSTER and energetic particles in geospace – What can be learned from GEOTAIL. In: *Cluster-II Workshop: Multiscale/Multipoint Plasma Measurements*, (Ed.) R. A. Harris. ESA SP-449, ESTEC, ESA Publ. Div., Noordwijk 2000, 163–170.
- Wilken, B., Q. G. Zong, T. Doke, S. Kokubun, T. Mukai and G. D. Reeves:* Distribution of Energetic Oxygen Events in the Tail Region - a view from HEP-LD/GEOTAIL. *Advances in Space Research* **25**, 1603–1606 (2000).
- Wolff, K. E., G. K. Hartmann, A. Nölle and M. L. Richards:* Conceptual knowledge processing and graphical representation of multidimensional atmospheric ozone data. *Physics and Chemistry of the Earth* **25**, 619–624 (2000).
- Zecha, M., J. Röttger, W. Singer, P. Hoffmann and D. Keuer:* Scattering properties of PMSE irregularities from Doppler beam and spaced antenna observations. In: *Proc. 9th Workshop on Technical and Scientific Aspects of MST Radar*, (Ed.) B. Edwards. SCOSTEP Secretariat, Boulder 2000, 117–120.
- Zecha, M., W. Singer, P. Hoffmann, D. Keuer and J. Röttger:* Simultaneous spaced antenna and doppler beam observation of the polar summer mesosphere. In: *Proc. 9th Workshop on Technical and Scientific Aspects of MST Radar*, (Ed.) B. Edwards. SCOSTEP Secretariat, Boulder 2000, 121–124.
- Zelenyi, L. M., Y. I. Galperin, M. V. Veselov, S. P. Savin, J. Büchner, B. Nikutowski, V. E. Kunitsyn, I. V. Silin, V. Vasyliunas, J. Woch, E. N. Sosnovets and S. A. Pulintsev:* Methods of small-scale multi-satellite measurements for project Roy. In: *Cluster-II Workshop: Multiscale/Multipoint Plasma Measurements*, (Ed.) R. A. Harris. ESA SP-449, ESTEC, ESA Publ. Div., Noordwijk 2000, 249–256.
- Zong, Q. G., B. Wilken, S. Y. Fu, T. Doke and S. Kokubun:* Energetic oxygen ions in the magnetosheath during the passage of a CME event. *Advances in Space Research* **25**, 2421–2424 (2000).
- Zong, Q. G., B. Wilken, S. Y. Fu and Z. Y. Pu:* Energetic oxygen ions sounding the magnetopause. In: *Cluster-II Workshop: Multiscale/Multipoint Plasma Measurements*, ESA SP-449, (Ed.) R. A. Harris. ESA Publ. Div., Noordwijk 2000, 379–385.

#### Publikationen im Internet

*Grieger, B.:* Rendezvous im All. MorgenWelt 2000. Internet: [www.morgenwelt.de/wissenschaft/001218-rendezvous.htm](http://www.morgenwelt.de/wissenschaft/001218-rendezvous.htm).

**Veröffentlichungen 2001/  
 Publications 2001**

*Axford, W. I.:* Solar wind and cosmic rays - collection of OHP's of Prof. Sir Ian Axford. In: Proceedings of the Cosmic-Ray Research Section of Nagoya University, vol. 42. (Ed.) Y. Muraki. Solar-Terrestrial Environment Laboratory, Nagoya University, Chikusa-ku, Nagoya, Japan 2001, 2-151.

*Barrow, C. H., A. Lecacheux and R. J. MacDowall:* Jovicentric latitude effect on the bKOM radio emission observed by Ulysses/URAP. *Astronomy and Astrophysics* **366**, 343–350 (2001).

— Polarization and beaming of the Jovian bKOM and HOM observed at 5 AU from Jupiter by Ulysses/URAP. In: Planetary Radio Emissions V. (Eds.) H. O. Rucker, M. L. Kaiser and Y. Leblanc. Österreichische Akademie der Wissenschaften, Vienna 2001, 127–139.

*Barrow, C. H., A. Lecacheux, R. J. MacDowall and M. L. Kaiser:* The Jovian HOM and bKOM radio emissions observed by Wind/WAVES and by Ulysses/URAP. *Planetary and Space Science* **49**, 377–384 (2001).

*Bedrich, S., N. Lemke, J. Büchner, B. Nikutowski and J. Woch:* SCHWARM - Microsatellite formation flying in the Earth's magnetosphere. In: Proceedings Second International Workshop on Satellite Constellations and Formation Flying. (Ed.) M. Guelman. Technion Israel Institute of Technology, Asher Space Research Institute, Technion City, Haifa 2001.

*Berdyugina, S. V., C. Frutiger and S. K. Solanki:* Magnetic splitting of molecular lines in sunspots. In: Recent Insights into the Physics of the Sun and Heliosphere: Highlights from SOHO and Other Space Missions, IAU Symposium 203. (Eds.) P. Brekke, B. Fleck and J. B. Gurman. Astronomical Society of the Pacific, San Francisco/CA 2001, 254–256.

*Berdyugina, S. V., C. Frutiger, S. K. Solanki and W. Livingston:* Successful spectral synthesis of Zeeman-split molecular bands in sunspot spectra. *Astronomy and Astrophysics* **364**, L101–L104 (2001).

— The molecular Zeeman effect and solar magnetic fields. In: Advanced Solar Polarimetry - Theory, Observation and Instrumentation, ASP Conference Proceedings Series 236. (Ed.) M. Sigwarth. Astronomical Society of the Pacific, San Francisco/CA 2001, 551–558.

*Berdyugina, S. V. and S. K. Solanki:* Zeeman-split opposite-polarity OH lines in sunspot spectra: resolution of a puzzle. *Astronomy and Astrophysics* **380**, L5–L8 (2001).

*Berdyugina, S. V., S. K. Solanki and C. Frutiger:* Solar and stellar magnetic fields: the molecular Zeeman effect as a probe. In: Magnetic Fields Across the Hertzsprung-Russell Diagram, ASP Conference Proceedings Series 248. (Eds.) G. Mathys, S. K. Solanki and D. T. Wickramasinghe. Astronomical Society of the Pacific, San Francisco/CA 2001, 99–104.

*Blagoveshchenskaya, N. F., V. A. Kornienko, T. D. Borisova, B. Thidé, M. J. Kosch, M. T. Rietveld, E. V. Mishin, R. Y. Luk'yanova and O. A. Troschichev:* Ionospheric HF pump wave triggering of local auroral activation. *Journal of Geophysical Research* **106**, 29071–29090 (2001).

*Borisov, N. D. and T. Hagfors:* Excitation of heater-enhanced plasma and ion lines near the reflection level of a height-frequency pump wave. *Journal of Plasma Physics* **66**, 71–89 (2001).

*Bosqued, J. M., T. D. Phan, I. Dandouras, C. P. Escoubet, H. Rème, A. Balogh, M. W. Dunlop, D. Alcaydé, E. Amata, M.-B. Bavassano-Cattaneo, R. Bruno, C. Carlson, A. M. DiLellis, L. Eliasson, V. Formisano, L. M. Kistler, B. Klecker, A. Korth, H. Kucharek, R. Lundin, M. McCarthy, J. P. McFadden, E. Möbius, G. K. Parks and J.-A. Sauvaud:* Cluster observations of the high-latitude magnetopause and cusp: initial results from the CIS ion instruments. *Annales Geophysicae* **19**, 1545–1566 (2001).

*Brkovic, A., S. K. Solanki and I. Rüedi:* Analysis of blinkers and EUV brightenings in the quiet Sun observed with CDS. *Astronomy and Astrophysics* **373**, 1056–1072 (2001).

*Brkovic, A., S. K. Solanki and I. Rüedi:* The quiet-Sun variability as seen by CDS and SUMER. In: Recent Insights into the Physics of the Sun and Heliosphere: Highlights from SOHO and Other Space Missions, IAU Symposium 203. (Eds.) P. Brekke, B. Fleck and J. B. Gurman. Astronomical Society of the Pacific, San Francisco/CA 2001, 381–383.

*Brynildsen, N., P. Maltby, T. Fredvik, O. Kjeldseth-Moe and K. Wilhelm:* Sunspot plumes and flow channels. *Solar Physics* **198**, 89–131 (2001).

*Brynildsen, N., P. Maltby, O. Kjeldseth-Moe and K. Wilhelm:* Dual flows and oscillations in the sunspot transition region. *Astrophysical Journal* **552**, L77–L80 (2001).

- Büchner, J. and G. Belmont*: Theory and simulation of solar system plasmas 2. Nonlinear Processes in Geophysics **8**, 126 (2001).
- Büchner, J., C. T. Dum and M. Scholer*: Space plasma simulation - preface. In: Space Plasma Simulation. (Eds.) J. Büchner, Chr. Dum and M. Scholer, Copernicus Gesellschaft e.V., Katlenburg-Lindau 2001, 2001, I.
- Büchner, J., Chr. Dum and M. Scholer* (Eds.): Space Plasma Simulation. Copernicus Gesellschaft e.V., Katlenburg-Lindau 2001, 413 pp. ISBN 3-9804862-8-1.
- Chilson, P. B., R. D. Palmer, A. Muschinski, D. A. Hooper, G. Schmidt and H. Steinhagen*: SOMARE-99: A demonstrational field campaign for ultrahigh-resolution VHF atmospheric profiling using frequency diversity. Radio Science **36**, 695–707 (2001).
- Crew, S., K.-I. Nishikawa, J. Büchner and P. Kotze*: Particle simulation of collisionless magnetic reconnection in the Harris model. In: Space Plasma Simulation. (Eds.) J. Büchner, Chr. Dum and M. Scholer. Copernicus Gesellschaft e.V., Katlenburg-Lindau 2001, 233–235.
- Curdt, W., P. Brekke, U. Feldman, K. Wilhelm, B. N. Dwivedi, U. Schühle and P. Lemaire*: The SUMER spectral atlas of solar-disk features. Astronomy and Astrophysics **375**, 591–613 (2001).
- The SUMER spectral atlas of solar-disk features. In: Solar and Galactic Composition. (Ed.) R. F. Wimmer-Schweingruber. AIP Conference Proceedings 598, Melville/NY 2001, 45–46.
- Curdt, W. and E. Landi*: Spectral windows of the solar atmosphere. In: Proceedings “Solar Encounter: The First Solar Orbiter Workshop”. (Eds.) B. Battrock and H. Sawaya-Lacoste. ESA SP-493, ESTEC, ESA Publ. Div., Noordwijk 2001, 199–203.
- Spectral windows of the solar atmosphere. In: Proceedings “Solar Encounter: The First Solar Orbiter Workshop”. (Eds.) B. Battrock and H. Sawaya-Lacoste, ESA SP-493, ESTEC, ESA Publ. Div., Noordwijk 2001, 199–203.
- Curdt, W., E. Landi, U. Feldman, D. Innes, B. N. Dwivedi and K. Wilhelm*: Spectroscopic features in the EUV emission of a M8 flare observed by SUMER. In: Recent Insights into the Physics of the Sun and Heliosphere: Highlights from SOHO and Other Space Missions, IAU Symposium 203. (Eds.) P. Brekke, B. Fleck and J. B. Gurman. Astronomical Society of the Pacific, San Francisco/CA 2001, 260–263.
- Czechowski, A., H. J. Fahr, G. Lay and M. Hilchenbach*: Pick-up ions upstream and downstream of the termination shock. Astronomy and Astrophysics **379**, 601–610 (2001).
- Czechowski, A., H. Fichtner, S. Grzedzielski, M. Hilchenbach, K. C. Hsieh, J. R. Jokipii, T. Kausch, J. Kota and A. Shaw*: Anomalous cosmic rays and the generation of energetic neutrals in the region beyond the termination shock. Astronomy and Astrophysics **368**, 622–634 (2001).
- Czechowski, A., S. Grzedzielski, H. Fichtner, M. Hilchenbach and K. C. Hsieh*: Anomalous cosmic rays outside of the termination shock. In: The Outer Heliosphere: The Next Frontiers. COSPAR Colloquia Series 11. (Eds.) K. Scherer, H. Fichtner, H.-J. Fahr and E. Marsch. Pergamon, Amsterdam 2001, 199–202.
- Czechowski, A., M. Hilchenbach and K. C. Hsieh*: Deriving ACR shock spectrum from observations of the energetic neutral atoms. In: Proceedings of the 27th International Cosmic Ray Conference, Hamburg 2001, Vol. 10. Copernicus Gesellschaft e.V., Katlenburg-Lindau 2001, 4227–4230.
- Dammasch, I. E., W. Curdt, B. Kliem, B. N. Dwivedi and K. Wilhelm*: Spectroscopic signatures of a flare observed by SUMER onboard SOHO. In: Recent Insights into the Physics of the Sun and Heliosphere: Highlights from SOHO and Other Space Missions, IAU Symposium 203. (Eds.) P. Brekke, B. Fleck and J. B. Gurman. Astronomical Society of the Pacific, San Francisco/CA 2001, 264–266.
- Dere, K. P., E. Landi, P. R. Young and G. D. Zanna*: CHIANTI - An atomic database for emission lines. IV. Extension to X-ray wavelengths. Astrophysical Journal Supplements **134**, 331–354 (2001).
- Doschek, G. A., U. Feldman, J. M. Laming, U. Schühle and K. Wilhelm*: Properties of solar polar coronal hole plasmas observed above the limb. Astrophysical Journal **546**, 559–568 (2001).
- Dwivedi, B. N., E. Landi and A. Mohan*: Looking for the FIP effect in EUV spectra. In: Recent Insights into the Physics of the Sun and Heliosphere: Highlights from SOHO and Other Space Missions, IAU Symposium 203. (Eds.) P. Brekke, B. Fleck and J. B. Gurman. Astronomical Society of the Pacific, San Francisco/CA 2001, 356–358.

- Eviatar, A., V. M. Vasyliunas and D. A. Gurnett:* The ionosphere of Ganymede. *Planetary and Space Science* **49**, 327–336 (2001).
- Fabian, P. and R. Borchers:* Growth of halocarbon abundances in the stratosphere between 1977 and 1999. *Advances in Space Research* **28**, 961–964 (2001).
- Feldman, U., I. E. Dammasch and K. Wilhelm:* On the unresolved fine structure of the solar atmosphere. IV. The interface with the chromosphere. *Astrophysical Journal* **558**, 423–427 (2001).
- Frolov, V. L., E. N. Sergeev, E. N. Ermakova, G. P. Komrakov and P. Stubbe:* Spectral features of stimulated electromagnetic emission, measured in the 4.3–9.5 MHz pump wave frequency range. *Geophysical Research Letters* **28**, 3103–3106 (2001).
- Frutiger, C. and S. K. Solanki:* Consistent empirical models of solar magnetic flux tubes and the surrounding convection. In: *Cool Stars, Stellar Systems and the Sun XI*. ASP Conference Proceedings Series 223. (Eds.) R. J. García López, R. Rebolo and M. R. Zapatero Osorio. Astronomical Society of the Pacific, San Francisco/CA 2001, CD–632.
- Empirical models of solar magnetic flux-tubes and their non-magnetic surroundings. *Astronomy and Astrophysics* **369**, 646–659 (2001).
- Empirical models of stellar convection. In: *Cool Stars, Stellar Systems and the Sun XI*. ASP Conference Proceedings Series 223. (Eds.) R. J. García López, R. Rebolo and M. R. Zapatero Osorio. Astronomical Society of the Pacific, San Francisco/CA 2001, CD–626.
- Gadun, A. S. and S. K. Solanki:* Small-scale magnetic elements in 2-D nonstationary magnetogranulation. In: *The Dynamic Sun*. *Astrophysics and Space Science Library* 259. (Eds.) A. Hanslmeier, M. Messerotti and A. Veronig. Kluwer, Dordrecht 2001, 295–298.
- Gadun, A. S., S. K. Solanki, V. A. Sheminova and S. R. O. Ploner:* A formation mechanism of magnetic elements in regions of mixed polarity. *Solar Physics* **203**, 1–7 (2001).
- Gizon, L., A. C. Birch, R. I. Bush, T. L. Duvall, Jr., A. G. Kosovichev, P. H. Scherrer and J. Zhao:* Time-distance helioseismology and the Solar Orbiter mission. In: *Proceedings “Solar Encounter: The First Solar Orbiter Workshop”*. (Eds.) B. Battrick and H. Sawaya-Lacoste. ESA SP-493, ESTEC, ESA Publ. Div., Noordwijk 2001, 227–231.
- Granzer, Th., P. Caligari, M. Schüssler and K. G. Strassmeier:* Star spot patterns on young stars: Theoretical approach. In: *Cool Stars, Stellar Systems and the Sun XI*. ASP Conference Proceedings Series 223. (Eds.) R. J. García López, R. Rebolo and M. R. Zapatero Osorio. Astronomical Society of the Pacific, San Francisco/CA 2001, CD–1232.
- Gustavsson, B., T. Sergienko, M. T. Rietveld, F. Honary, Å. Steen, B. U. E. Brändström, T. B. Leyser, A. L. Aruliah, T. Aso, M. Ejiri and S. Marple:* First tomographic estimate of volume distribution of HF-pump enhanced airglow emission. *Journal of Geophysical Research* **106**, 29105–29124 (2001).
- Hagfors, T.:* Time-varying propagation circuits, description and applications. *Journal of Atmospheric and Solar Terrestrial Physics* **63**, 215–220 (2001).
- Hall, C. M. and J. Röttger:* Initial observations of polar mesospheric summer echoes using the EISCAT Svalbard Radar. *Geophysical Research Letters* **28**, 131–134 (2001).
- Hapgood, M., V. Bothmer, N. Crosby and J. Lastovicka (Guest Eds.):* Physics and Chemistry of the Earth, II. *Space Weather* 26. *Physics and Chemistry of the Earth* 26, 593–619, 2001.
- Hartmann, G. K., J. U. Kügler, P. Belouschek, L. Weissflog, K. H. Weiler, H. C. Heydecke, G. Reisinger, G. S. Golitsyn, I. Granberg, N. P. Elansky, E. B. Gabunshina, V. V. Alexeev, E. Putz, G. Pfister and A. Steiner:* Desert soil REcultivation and MONitoring of (phyto-)TOXicity (DEREMOTOX). A pilot project in three phases lasting four years. In: *Sustainable Land Use in Deserts*. (Eds.) S.-W. Breckle, M. Veste and W. Wucherer. Springer Verlag, Berlin 2001, 329–342.
- Hilchenbach, M.:* Neutral particle sensor: goals, objectives and complications. In: *Proceedings “Solar Encounter: The First Solar Orbiter Workshop”*. (Eds.) B. Battrick and H. Sawaya-Lacoste. ESA SP–493, ESTEC, ESA Publ. Div., Noordwijk 2001, 241–244.
- Hilchenbach, M., K. C. Hsieh and A. Czechowski:* Doppler shifted photon emission expected due to reactions of energetic protons with the LISM atoms in the heliosphere. In: *The Outer Heliosphere: The Next Frontiers*. COSPAR Colloquia Series 11. (Eds.) K. Scherer, H. Fichtner, H.-J. Fahr and E. Marsch. Pergamon, Amsterdam 2001, 281–285.
- Hilchenbach, M., K. C. Hsieh, D. Hovestadt, R. Kallenbach, A. Czechowski, E. Moebius and P. Bochsler:* Energetic neutral hydrogen of heliospheric origin observed with SOHO/CELIAS at 1 AU. In:

- The Outer Heliosphere: The Next Frontiers. CO-SPAR Colloquia Series 11. (Eds.) K. Scherer, H. Fichtner, H.-J. Fahr and E. Marsch. Pergamon, Amsterdam 2001, 273-276.
- Hilchenbach, M., H. Sierks, B. Klecker, K. Bamert and R. Kallenbach:* Solar energetic particle events observed by SOHO/CELIAS/STOF. In: Proceedings of the 27th International Cosmic Ray Conference, Hamburg 2001, Vol. 10. Copernicus Gesellschaft e.V., Katlenburg-Lindau 2001, 3144-3147.
- Hocking, W. K. and J. Röttger:* The structure of turbulence in the middle and lower atmosphere seen by and deduced from MF, HF and VHF radar, with special emphasis on small-scale features and anisotropy. *Annales Geophysicae* **19**, 933-944 (2001).
- Holzwarth, V. and M. Schüssler:* Buried magnetic flux tubes in giant stars near the "Coronal Dividing Line". *Astronomy and Astrophysics* **377**, 251-263 (2001).
- Holzwarth, V. and M. Schüssler:* Preferred longitudes of starspots on magnetically active close binaries. In: Magnetic Fields Across the Hertzsprung-Russell Diagram, ASP Conference Proceedings Series 248. (Eds.) G. Mathys, S. K. Solanki and D. T. Wickramasinghe. Astronomical Society of the Pacific, San Francisco/CA 2001, 247-250.
- Holzwarth, V., M. Schüssler and S. K. Solanki:* A model for the decline of coronal X-ray emission of cool giant stars. In: Magnetic Fields Across the Hertzsprung-Russell Diagram, ASP Conference Proceedings Series 248. (Eds.) G. Mathys, S. K. Solanki and D. T. Wickramasinghe. Astronomical Society of the Pacific, San Francisco/CA 2001, 259-262.
- Innes, D. E.:* Coordinated observations of the quiet Sun transition region using SUMER spectra, TRACE images and MDI magnetograms. *Astronomy and Astrophysics* **378**, 1067-1077 (2001).
- Innes, D. E., W. Curdt, R. Schwenn, S. K. Solanki, G. Stenborg and D. E. McKenzie:* Large Doppler shifts in X-ray plasma: An explosive start to coronal mass ejection. *Astrophysical Journal* **549**, L249-L252 (2001).
- Judge, D. L., D. R. McMullin, P. Gangopadhyay, H. S. Ogawa, F. M. Ipavich, A. B. Galvin, E. Möbius, P. Bochsler, P. Wurz, M. Hilchenbach, H. Grünwaldt, D. Hovestadt, B. Klecker and F. Gliem:* Space weather observations using the SOHO CELIAS complement of instruments. *Journal of Geophysical Research* **106**, 29963-29968 (2001).
- Judge, P. G., T. D. Tarbell and K. Wilhelm:* A study of chromospheric oscillations using the SOHO and TRACE spacecraft. *Astrophysical Journal* **554**, 424-444 (2001).
- Kariyappa, R., B. A. Varghese and W. Curdt:* Temporal and spatial variations of the quiet upper chromosphere from SOHO/SUMER observations of hydrogen Lyman lines. *Astronomy and Astrophysics* **374**, 691-696 (2001).
- Keller, H. U., H. Hartwig, R. Kramm, D. Koschny, W. J. Markiewicz, N. Thomas, M. Fernandes, P. H. Smith, R. Reynolds, M. T. Lemmon, J. Weinberg, R. Marcialis, R. Tanner, B. J. Boss and C. Oquist:* The MVACS Robotic Arm Camera. *Journal of Geophysical Research* **106**, 17609-17622 (2001).
- Kiselev, N. N., K. Jockers, V. K. Rosenbush and P. P. Korsun:* Analysis of polarimetric, photometric, and spectroscopic observations of Comet C/1996 Q1 (Tabur). *Solar System Research* **35**, 480-495 (2001).
- Klecker, B., A. T. Bogdanov, A. T. Galvin, F. M. Ipavich, M. Hilchenbach, E. Moebius, and P. Bochsler:* On the variability of suprathermal He<sup>+</sup> ions at 1 AU. In: Proceedings of the 27th International Cosmic Ray Conference, Hamburg 2001, Vol. 10. Copernicus Gesellschaft e.V., Katlenburg-Lindau 2001, 3100-3103.
- Klostermeyer, J.:* Effect of tidal variability on the mean diurnal variation of noctilucent clouds. *Journal of Geophysical Research* **106**, 9749-9755 (2001).
- Knaack, R., M. Fligge, S. K. Solanki and Y. C. Unruh:* Stellar irradiance variations caused by magnetic activity: the influence of an inclined rotation axis. In: Magnetic Fields Across the Hertzsprung-Russell Diagram, ASP Conference Proceedings Series 248. (Eds.) G. Mathys, S. K. Solanki and D. T. Wickramasinghe. Astronomical Society of the Pacific, San Francisco/CA 2001, 227-230.
- The influence of an inclined rotation axis on solar irradiance variations. *Astronomy and Astrophysics* **376**, 1080-1089 (2001).
- Kolokolova, L., K. Jockers, B. Å. S. Gustafson and G. Lichtenberg:* Color and polarization as indicators of comet dust properties and evolution in the near-nucleus coma. *Journal of Geophysical Research* **106**, 10113-10127 (2001).
- Korth, A. and Z. Y. Pu:* Magnetic field configuration and field-aligned acceleration of energetic ions during substorm onsets. *Annales Geophysicae* **19**, 1089-1094 (2001).

- Kosch, M., M. W. J. Scourfield and O. Amm:* The importance of conductivity gradients in ground-based field-aligned current studies. *Advances in Space Research* **27**, 1277–1282 (2001).
- Kosch, M. J., K. Cierpka, M. T. Rietveld, T. Hagfors and K. Schlegel:* High-latitude ground-based observations of the thermospheric ion-drag time constant. *Geophysical Research Letters* **28**, 1395–1398 (2001).
- Kosch, M. J., F. Honary, C. F. del Pozo, S. R. Marple and T. Hagfors:* High-resolution maps of the characteristic energy of precipitating auroral particles. *Journal of Geophysical Research* **106**, 28925–28937 (2001).
- Kosch, M. J. and E. Nielsen:* Statistical average estimates of high latitude field-aligned currents from the STARE and SABRE coherent VHF radar system. *Advances in Space Research* **27**, 1239–1244 (2001).
- Kossacki, K. J., W. J. Markiewicz and H. U. Keller:* Effect of surface roughness on ice distribution in the south subpolar region of Mars. *Planetary and Space Science* **49**, 437–445 (2001).
- Kota, K., K. C. Hsieh, J. R. Jokipii, A. Czechowski and M. Hilchenbach:* Viewing corotating interaction regions globally using energetic neutral atoms. *Journal of Geophysical Research* **106**, 24907–24914 (2001).
- Kotze, P., K.-I. Nishikawa and J. Büchner:* Particle simulation of magnetic reconnection using TRIS-TAN. In: *Space Plasma Simulation*. (Eds.) J. Büchner, Chr. Dum and M. Scholer. Copernicus Gesellschaft e.V., Katlenburg-Lindau 2001, 275–278.
- Krupp, N., E. C. Roelof, J. Woch, D. J. Williams, A. Lagg, B. Wilken and S. Livi:* Global flows of energetic ions in Jupiter's equatorial plane: First-order approximation. *Journal of Geophysical Research* **106**, 26017–26032 (2001).
- Krupp, N., J. Woch, A. Lagg, E. C. Roelof, D. J. Williams, S. Livi and B. Wilken:* Local time asymmetry of energetic ion anisotropies in the Jovian magnetosphere. *Planetary and Space Science* **49**, 283–289 (2001).
- Kucharek, H., B. Klecker, F. M. Ipavich, R. Kallenbach, H. Grünwaldt, M. R. Aellig and P. Bochsler:* Isotopic fractionation in slow and coronal holes associated solar wind. In: *Recent Insights into the Physics of the Sun and Heliosphere: Highlights from SOHO and Other Space Missions*, IAU Symposium 203. (Eds.) P. Brekke, B. Fleck and J. B. Gurman. Astronomical Society of the Pacific, San Francisco/CA 2001, 562–569.
- Kuska, J.-P. and J. Büchner:* Visualization of three-dimensional plasma dynamics. In: *Space Plasma Simulation*. (Eds.) J. Büchner, Chr. Dum and M. Scholer. Copernicus Gesellschaft e.V., Katlenburg-Lindau 2001, 177–179.
- Lagg, A., N. Krupp, S. Livi, J. Woch, S. M. Krimigis and M. K. Dougherty:* Energetic particle measurements during the Earth swing-by of the Cassini spacecraft in August 1999. *Journal of Geophysical Research* **106**, 30209–30222 (2001).
- Lanzafame, A. C., D. Spadaro, L. Consoli, E. Marsch and D. H. Brooks:* Velocity fields in an active region loop system observed on the solar disc with SUMER/SOHO. In: *Cool Stars, Stellar Systems and the Sun XI*. ASP Conference Proceedings Series 223. (Eds.) R. J. García López, R. Rebolo and M. R. Zapatero Osorio. Astronomical Society of the Pacific, San Francisco/CA 2001, CD–691.
- Le Contel, O., A. Roux, S. Perraut, R. Pellat, O. Holter, A. Pedersen and A. Korth:* Possible control of plasma transport in the near-Earth plasma sheet via current-driven Alfvén waves ( $f \sim f_{H^+}$ ). *Journal of Geophysical Research* **106**, 10817–10827 (2001).
- Liu, H., S.-Y. Ma and K. Schlegel:* Diurnal, seasonal, and geomagnetic variations of large field-aligned ion upflows in the high-latitude ionospheric F region. *Journal of Geophysical Research* **106**, 24651–24661 (2001).
- Løvhaug, U. P., T. Hagfors and A. P. van Eyken:* Search for light ion outflow by incoherent scatter radar. *Radio Science* **36**, 1509–1521 (2001).
- Maltby, P., N. Brynildsen, O. Kjeldseth-Moe and K. Wilhelm:* Plumes and oscillations in the sunspot transition region. *Astronomy and Astrophysics* **373**, L1–L4 (2001).
- Mann, I. and H. Kimura:* Dust properties in the local interstellar medium. *Space Science Reviews* **97**, 389–392 (2001).
- Marsch, E.:* Observations and models of the fast and slow solar wind. In: *Recent Insights into the Physics of the Sun and Heliosphere: Highlights from SOHO and Other Space Missions*, IAU Symposium 203. (Eds.) P. Brekke, B. Fleck and J. B. Gurman. Astronomical Society of the Pacific, San Francisco/CA 2001, 447–455.
- Solar wind: Kinetic properties. In: *Encyclopedia of Astronomy and Astrophysics*, vol. 4. (Ed.) P. Mur-

- din. Institute of Physics Publishing, London 2001, 2862–2866.
- Marsch, E., E. Antonucci, P. Bochsler, J.-L. Bougeret, B. Fleck, R. Harrison, R. Marsden, R. Schwenn and J.-C. Vial*: Solar Orbiter, a high-resolution mission to the sun and inner heliosphere. In: *Recent Insights into the Physics of the Sun and Heliosphere: Highlights from SOHO and Other Space Missions*, IAU Symposium 203. (Eds.) P. Brekke, B. Fleck and J. B. Gurman. Astronomical Society of the Pacific, San Francisco/CA 2001, 565–569.
- Marsch, E., R. Harrison, O. Pace, E. Antonucci, P. Bochsler, J.-L. Bougeret, B. Fleck, Y. Langevin, R. Marsden, R. Schwenn and J.-C. Vial*: Solar Orbiter, a high-resolution mission to the sun and inner heliosphere. In: *Proceedings “Solar Encounter: The First Solar Orbiter Workshop”*. (Eds.) B. Battrock and H. Sawaya-Lacoste. ESA SP-493, ESTEC, ESA Publ. Div., Noordwijk 2001, xi–xxvi.
- Marsch, E. and C.-Y. Tu*: Evidence for pitch angle diffusion of solar wind protons in resonance with cyclotron waves. *Journal of Geophysical Research* **106**, 8357–8361 (2001).
- Heating and acceleration of coronal ions interacting with plasma waves through cyclotron and Landau resonance. *Journal of Geophysical Research* **106**, 227–238 (2001).
- Marsch, E., C. Vocks and C.-Y. Tu*: On ion-cyclotron-resonance heating of the corona and solar wind. *Non-linear Processes in Geophysics* **10**, 1–11 (2001).
- McKenzie, J. F.*: Compressive instability driven by ion-cyclotron dissipation in the solar wind. *Solar Physics* **200**, 251–258 (2001).
- Stationary structures in multi-ion plasmas with differential streaming. *Journal of Plasma Physics* **65**, 181–195 (2001).
- McKenzie, J. F. and T. B. Doyle*: Oblique solitons in a cold magnetized plasma. *Physical Plasmas* **8**, 4367–4374 (2001).
- McKenzie, J. F., E. Dubinin and K. Sauer*: Nonlinear waves propagating transverse to the magnetic field. *Journal of Plasma Physics* **65**, 213–233 (2001).
- McKenzie, J. F., K. Sauer and E. Dubinin*: Stationary waves in a bi-ion plasma transverse to the magnetic field. *Journal of Plasma Physics* **65**, 197–212 (2001).
- Mikhailov, A. V. and K. Schlegel*: Equinoctial transitions in the ionosphere and thermosphere. *Annales Geophysicae* **19**, 783–796 (2001).
- Mishin, E. V., T. Hagfors and B. Isham*: A generation mechanism of the topside enhanced incoherent backscatter during high frequency modification experiments in Tromsø. *Geophysical Research Letters* **28**, 479–482 (2001).
- Möbius, E., H. Kucharek, C. Mouikis, E. Georgescu, L. M. Kistler, M. A. Popecki, M. Scholer, J. M. Bosqued, H. Rème, C. W. Carlson, B. Klecker, A. Korth, G. K. Parks, J. C. Sauvaud, H. Balsiger, M.-B. Bavassano-Cattaneo, I. Dandouras, A. M. DiLellis, L. Eliasson, V. Formisano, T. Horbury, W. Lennartsson, R. Lundin, M. McCarthy, J. P. McFadden and G. Paschmann*: Observations of the spatial and temporal structure of field-aligned beam and gyrating ring distributions at the quasi-perpendicular bow shock with Cluster CIS. *Annales Geophysicae* **19**, 1411–1420 (2001).
- Moran, T., N. Gopalswamy, I. E. Dammasch and K. Wilhelm*: A multi-wavelength study of solar coronal-hole regions showing radio enhancements. *Astronomy and Astrophysics* **378**, 1037–1045 (2001).
- Moreno-Insertis, F., S. H. Saar and S. K. Solanki*: Magnetic fields in cool stars. In: *Cool Stars, Stellar Systems and the Sun XI*. ASP Conference Proceedings Series 223. (Eds.) R. J. García López, R. Rebolos and M. R. Zapatero Osorio. Astronomical Society of the Pacific, San Francisco/CA 2001, CD–435.
- Muschinski, A., P. B. Chilson, R. D. Palmer, D. A. Hooper, G. Schmidt and H. Steinhagen*: Boundary-layer convection and diurnal variation of vertical-velocity characteristics in the free troposphere. *Quarterly Journal Royal Meteorological Society* **127**, 423–443 (2001).
- Nielsen, E.*: Direct experimental test of Joule heating damping of a Pc5 pulsation using the STARE radar system. *Journal of Geophysical Research* **106**, 25835–25845 (2001).
- Nielsen, E., W. Engelhardt, B. Chares, L. Bemann, M. Richards, F. Backwinkel, D. Plettemeier, P. Edenhofer, Y. Barbin, J.-P. Goutail, W. Kofman and L. H. Svedhem*: Antennas for sounding of a cometary nucleus in the ROSETTA mission. In: *Proceedings 11th International Conference on Antennas and Propagation*, IEE 2001, Conference Publication No. 480, VENUE UMIST Manchester 2001, 436–441.
- Nielsen, K. P., J. Röttger and F. Sigernes*: Simultaneous measurements of temperature in the upper mesosphere with an Ebert-Fastie spectrometer and a VHF meteor radar on Svalbard (78°N, 16°E). *Geophysical Research Letters* **28**, 943–946 (2001).

- Palmer, R. D., P. B. Chilson, A. Muschinski, G. Schmidt, T.-Y. Yu and H. Steinhagen:* SOMARE-99: Observations of tropospheric scattering layers using multiple-frequency range imaging. *Radio Science* **36**, 681–693 (2001).
- Pauluhn, A., I. Rüedi, S. K. Solanki, J. Lang, U. Schühle, K. Wilhelm, W. T. Thompson, J. Hollandt and M. C. E. Huber:* Intercalibration of SUMER and CDS on SOHO. II. SUMER A and B detectors and CDS NIS. *Applied Optics* **40**, 6292–6300 (2001).
- Pauluhn, A., I. Rüedi, S. K. Solanki, U. Schühle, K. Wilhelm, J. Lang, W. T. Thompson, J. Hollandt and M. C. E. Huber:* Intercalibration of SUMER and CDS on SOHO. II. SUMER detectors A and B and CDS NIS. *Applied Optics* **40**, 6292–6300 (2001).
- Pauluhn, A., U. Schühle, S. K. Solanki, I. Rüedi, J. Lang, C. D. Pike, W. T. Thompson and M. C. E. Huber:* Radiance of solar spectral lines observed with CDS and SUMER on SOHO. In: *Cool Stars, Stellar Systems and the Sun XI*. ASP Conference Proceedings Series 223. (Eds.) R. J. García López, R. Reboló and M. R. Zapatero Osorio. Astronomical Society of the Pacific, San Francisco/CA 2001, CD–721.
- Pauluhn, A., S. K. Solanki, I. Rüedi, E. Landi and U. Schühle:* Statistical features of the quiet Sun in EUV. In: *Recent Insights into the Physics of the Sun and Heliosphere: Highlights from SOHO and Other Space Missions*, IAU Symposium 203. (Eds.) P. Brekke, B. Fleck and J. B. Gurman. Astronomical Society of the Pacific, San Francisco/CA 2001, 416–418.
- Pauluhn, A., S. K. Solanki, U. Schühle, K. Wilhelm, J. Lang, W. T. Thompson, I. Rüedi, J. Hollandt and M. C. E. Huber:* Comparison of quiet-Sun radiances measured by CDS and SUMER on SOHO. *Space Science Reviews* **97**, 63–66 (2001).
- Petrova, E. V., K. Jockers and N. N. Kiselev:* Light scattering by aggregate particles comparable in size to wavelength: Application to cometary dust. *Solar System Research* **35**, 57–69 (2001).
- A negative branch of polarization for comets and atmosphereless celestial bodies and the light scattering by aggregate particles. *Solar System Research* **35**, 390–399 (2001).
- Petrova, E. V., W. J. Markiewicz and H. U. Keller:* Regolith surface reflectance: A new attempt to model. *Solar System Research* **35**, 278–290 (2001).
- Ploner, S. R. O., M. Schüssler, S. K. Solanki and A. S. Gadun:* An example of reconnection and magnetic flux recycling near the solar surface. In: *Advanced Solar Polarimetry - Theory, Observation and Instrumentation*, ASP Conference Proceedings Series 236. (Ed.) M. Sigwarth. Astronomical Society of the Pacific, San Francisco/CA 2001, 363–370.
- Ploner, S. R. O., M. Schüssler, S. K. Solanki, V. A. Sheminova, A. S. Gadun and C. Frutiger:* The formation of one-lobed Stokes V profiles in an inhomogeneous atmosphere. In: *Advanced Solar Polarimetry - Theory, Observation and Instrumentation*, ASP Conference Proceedings Series 236. (Ed.) M. Sigwarth. Astronomical Society of the Pacific, San Francisco/CA 2001, 371–378.
- Popp, J., N. Tarcae, W. Kiefer, M. Hilchenbach, N. Thomas, S. Hofer and T. Stuffer:* Investigations on Mars Model Minerals by in situ Laser Raman Spectroscopy. In: *Proceedings 1st European Workshop on Exo-Astrobiology*. ESA SP-496, ESTEC, ESA Publ. Div., Noordwijk 2001, 193–196.
- Portier-Fozzani, F.:* 3D Coronal observations with the solar cycle. In: *Proceedings “SOLSPA: The Second Solar Cycle and Space Weather Euroconference”*, Vico Equense, Italy 2001. (Ed.) H. Sawaya-Lacoste. ESA SP-477, ESTEC, ESA Publ. Div., Noordwijk 2001, 159–162.
- Portier-Fozzani, F., M. Aschwanden, P. Démoulin, W. Neupert, J.-P. Delaboudinière and the EIT Team:* Measurement of coronal magnetic twists during loop emergence of NOAA 8069. *Solar Physics* **203**, 289–308 (2001).
- Portier-Fozzani, F. and B. Inhester:* 3D Coronal structures and their evolutions measured by stereoscopy, consequences for space weather and the STEREO mission. *Space Science Reviews* **97**, 51–54 (2001).
- Portier-Fozzani, F., B. Vandame, A. Bijaoui, A. J. Maucherat and EIT Team:* A multiscale vision model applied to analyze EIT images of the solar corona. *Solar Physics* **201**, 271–288 (2001).
- Pryor, W., I. Stewart, K. Simmons, M. Witte, J. Ajello, K. Toskiba, D. McComas and D. Hall:* Remote sensing of H from ULYSSES and GALILEO. *Space Science Reviews* **97**, 393–399 (2001).
- Régulo, C., T. Roca Cortés, S. K. Solanki, M. Fligge and the GOLF Team:* Noise reduction in GOLF spectra using wavelets. In: *Cool Stars, Stellar Systems and the Sun XI*. ASP Conference Proceedings Series 223. (Eds.) R. J. García López, R. Reboló and M. R. Zapatero Osorio. Astronomical Society of the Pacific, San Francisco/CA 2001, CD–734.

- Rème, H., C. Aoustin, J. M. Bosqued, I. Dandouras, B. Lavraud, J. A. Sauvaud, A. Barthe, J. Bouyssou, Th. Camus, O. Coeur-Joly, A. Cros, J. Cuwilo, F. Ducay, Y. Garbarowitz, J. L. Medale, E. Penou, H. Perrier, D. Romefort, J. Rouzaud, C. Vallat, D. Alcaydé, C. Jacquey, C. Mazelle, C. d'Uston, E. Möbius, L. M. Kistler, K. Crocker, M. Granoff, C. Mouikis, M. Popecki, M. Vosbury, B. Klecker, D. Hovestadt, H. Kucharek, E. Kuenneth, G. Paschmann, M. Scholer, N. Sckopke, E. Seidenschwang, C. W. Carlson, D. W. Curtis, C. Ingraham, R. P. Lin, J. P. McFadden, G. K. Parks, T. Phan, V. Formisano, E. Amata, M. B. Bavassano-Cattaneo, P. Baldetti, R. Bruno, G. Chionchio, A. DiLellis, M. F. Marcucci, G. Pallochia, A. Korth, P. W. Daly, B. Graeve, H. Rosenbauer, V. Vasylunas, M. McCarthy, M. Wilber, L. Eliasson, R. Lundin, S. Olsen, E. G. Shelley, S. Fuselier, A. G. Ghielmetti, W. Lennartsson, C. P. Escoubet, H. Balsiger, R. Friedel, J.-B. Cao, R. A. Kovrazhkin, I. Papamastorakis, R. Pellat, J. Scudder and B. Sonnerup: First multispacecraft ion measurements in and near the Earth's magnetosphere with the identical Cluster Ion Spectrometry (CIS) experiment. *Annales Geophysicae* **19**, 1303–1354 (2001).
- Rempel, M. and M. Schüssler: Intensification of a magnetic field in a stellar convection zone by conversion of potential energy. In: *Magnetic Fields Across the Hertzsprung-Russell Diagram*, ASP Conference Proceedings Series 248. (Eds.) G. Mathys, S. K. Solanki and D. T. Wickramasinghe. Astronomical Society of the Pacific, San Francisco/CA 2001, 165–168.
- Intensification of magnetic field by conversion of potential energy. *Astrophysical Journal* **552**, L171–L174 (2001).
- Rempel, M., M. Schüssler and F. Moreno-Inertis: Storage of a strong magnetic field below the solar convection zone. In: *Cool Stars, Stellar Systems and the Sun XI*. ASP Conference Proceedings Series 223. (Eds.) R. J. García López, R. Rebolo and M. R. Zapatero Osorio. Astronomical Society of the Pacific, San Francisco/CA 2001, CD–738.
- Rheinisch, B. W., X. Huang, P. Song, G. S. Sales, S. F. Fung, J. L. Green, D. L. Gallagher and V. M. Vasylunas: Plasma density distribution along the magnetospheric field: RPI observations from IMAGE. *Geophysical Research Letters* **28**, 4521–4524 (2001).
- Rietveld, M. T. and B. Isham: Symposium highlights: Results from HF-interaction experiments. *EOS* **82**, 273 (2001).
- Röckmann, T., J. Kaiser, C. A. M. Brenninkmeijer, W. A. Brand, R. Borchers, J. N. Crowley, W. Wollenhaupt and P. J. Crutzen: The position dependent  $^{15}\text{N}$  enrichment of nitrous oxide in the stratosphere. *Isotopes Environment Health Studies* **37**, 91–95 (2001).
- Röckmann, T., J. Kaiser, C. A. M. Brenninkmeijer, J. N. Crowley, R. Borchers, W. A. Brand and P. J. Crutzen: Isotopic enrichment of nitrous oxide ( $^{15}\text{N}^{14}\text{NO}$ ,  $^{14}\text{N}^{15}\text{NO}$ ,  $^{14}\text{N}^{14}\text{N}^{18}\text{O}$ ) in the stratosphere and in the laboratory. *Journal of Geophysical Research* **106**, 10403–10410 (2001).
- Röttger, J.: Observations of the Arctic troposphere and lower stratosphere with the SOUSY Svalbard Radar. *Memoirs of National Institute of Polar Research* **54**, 1–8 (2001).
- Observations of the polar D-region and the mesosphere with the EISCAT Svalbard Radar and the SOUSY Svalbard Radar. *Memoirs of National Institute of Polar Research* **54**, 9–20 (2001).
- Röttger, J., G. Schmidt, R. Rüster, P. Czechowsky, J. Klostermeyer, J. Trautner, I. Pardowitz, K. D. Preschel, M. Bruns and G. Monecke: The SOUSY Svalbard Radar and its contributions to study polar meteorology. In: *Proceedings 30th International Conference on Radar Meteorology*, München 2001. (Eds.) M. Steiner and P. Meischner. American Meteorological Society, Boston 2001, 110–112.
- Rüster, R., J. Röttger, G. Schmidt, P. Czechowsky and J. Klostermeyer: Observations of mesospheric summer echoes at VHF in the polar cap region. *Geophysical Research Letters* **28**, 1471–1474 (2001).
- Rybak, J., A. Kucera, W. Curdt, U. Schühle and H. Wöhl: Chromospheric dynamics as can be inferred from SUMER/SOHO observations. In: *The Dynamic Sun*, Proceedings of the Summer School and Workshop Kanzelhöhe, Kärnten/Austria 1999. *Astrophysics and Space Science Library* 259. (Eds.) A. Hanslmeier, M. Messerotti and A. Veronig. Kluwer Academic Publishers, Dordrecht 2001, 247–250.
- Sauer, K., E. Dubinin and J. F. McKenzie: New type of soliton in bi-ion plasmas and possible implications. *Geophysical Research Letters* **28**, 3589–3592 (2001).
- Sauvaud, J.-A., R. Lundin, H. Rème, J. P. McFadden, C. Carlson, G. K. Parks, E. Möbius, L. M. Kistler, B. Klecker, E. Amata, A. M. DiLellis, V. Formisano, J. M. Bosqued, I. Dandouras, P. Décréau, M. Dunlop, L. Eliasson, A. Korth, B. Lavraud and M. McCarthy: Intermittent thermal plasma acceleration linked to sporadic motions of the magnetopause, first Cluster results. *Annales Geophysicae* **19**, 1523–1532 (2001).
- Savin, S. P., L. M. Zelenyi, A. Amata, J. Blecky, J. Büchner, B. Nikutowski and E. M. Dubinin: Turbulent

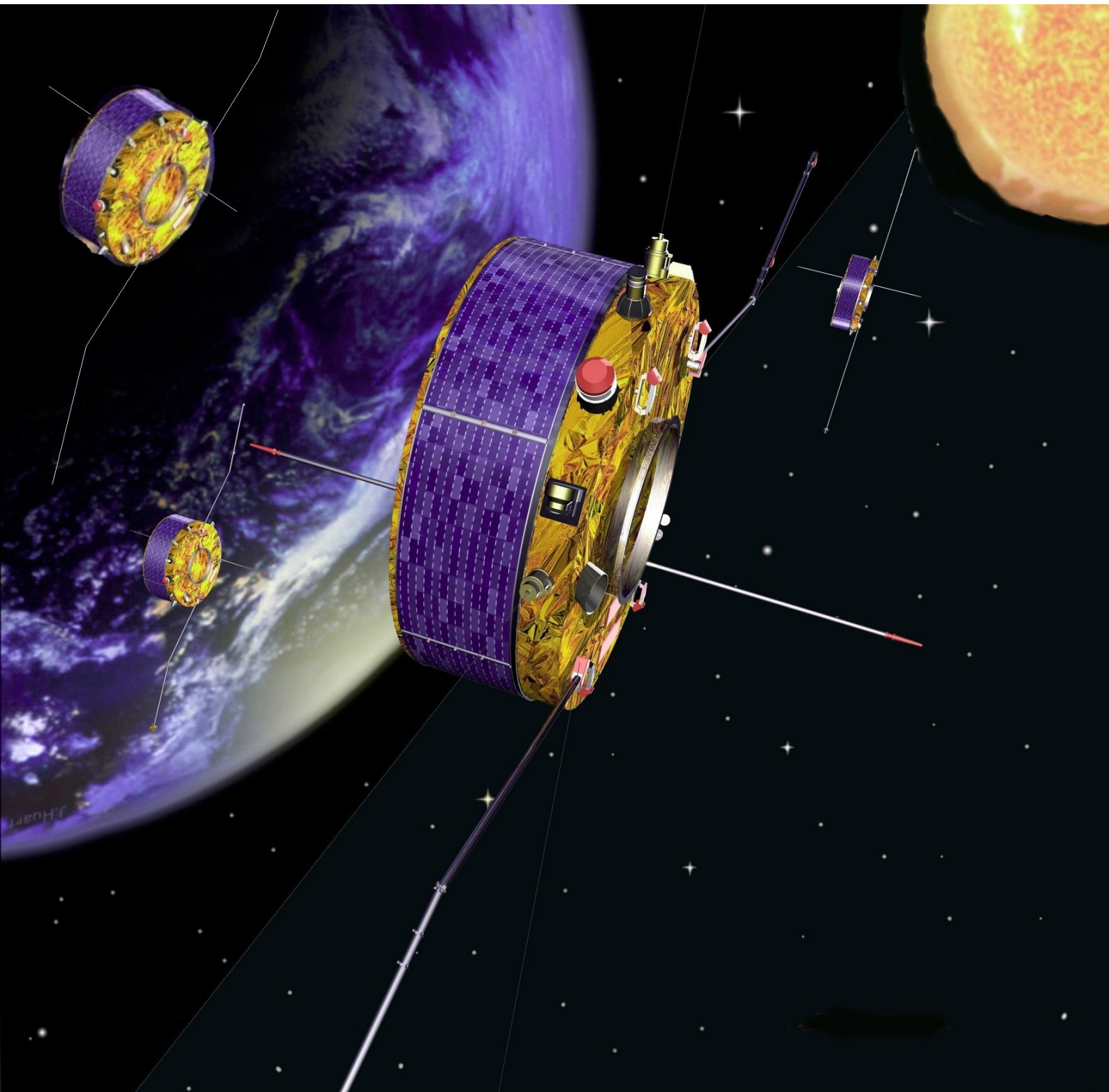
- boundary layer at the border of geomagnetic trap. *JETP Letters* **74**, 620–624 (2001).
- Scherer, K., H. Fichtner, H.-J. Fahr and E. Marsch*: Die Heliosphäre - Schutzschild für die Erde. *Physikalische Blätter* **57**, 55–58 (2001).
- Scherer, K., E. Marsch, R. Schwenn and H. Rosenbauer*: Long-term variations of the flow direction and angular momentum of the solar wind observed by Helios. *Astronomy and Astrophysics* **366**, 331–338 (2001).
- Schlegel, K.*: Die Magnetosphäre der Erde. *Astronomie und Raumfahrt im Unterricht* **38**, 31–34 (2001).
- Polarlicht. *Praxisheft für Amateurfunk und Elektronik in Schule und Freizeit, Arbeitskreis Amateurfunk und Telekommunikation in der Schule* **11**, 51–53 (2001).
- Schlegel, K., G. Diendorfer, S. Thern and M. Schmidt*: Thunderstorms, lightning and solar activity - Middle Europe. *Journal of Atmospheric and Solar-Terrestrial Physics* **63**, 1705–1713 (2001).
- Schüssler, M.*: Numerical simulation of solar magneto-convection (review). In: *Advanced Solar Polarimetry - Theory, Observation and Instrumentation*, ASP Conference Proceedings Series 236. (Ed.) M. Sigwarth. *Astronomical Society of the Pacific, San Francisco/CA* 2001, 343–354.
- Schüssler, M., V. Holzwarth, S. K. Solanki and C. Charbonnel*: Buried flux tubes in the coronal graveyard. In: *Cool Stars, Stellar Systems and the Sun XI*, ASP Conference Proceedings Series 223. (Eds.) R. J. García López, R. Rebolo and M. R. Zapatero Osorio. *Astronomical Society of the Pacific, San Francisco/CA* 2001, CD–1114.
- Schüssler, M. and M. Knölker*: Magneto-convection (review). In: *Magnetic Fields Across the Hertzsprung-Russell Diagram*, ASP Conference Proceedings Series 248. (Eds.) G. Mathys, S. K. Solanki and D. T. Wickramasinghe. *Astronomical Society of the Pacific, San Francisco/CA* 2001, 115–123.
- Schwenn, R. and K. Schlegel*: Sonnenwind und Weltraumwetter. *Spektrum der Wissenschaft, Dossier* **3**, 15–23 (2001).
- Shaw, A., K. C. Hsieh, M. Hilchenbach, A. Czechowski, D. Hovestadt, B. Klecker, R. Kallenbach, E. Moebius and P. Bochsler*: Energetic neutral helium of heliospheric origin at 1 AU. In: *The Outer Heliosphere: The Next Frontiers*. *COSPAR Colloquia Series* 11. (Eds.) K. Scherer, H. Fichtner, H.-J. Fahr and E. Marsch. *Pergamon, Amsterdam* 2001, 219–222.
- Silin, I., J. Büchner and L. M. Zelenyi*: Linear theory and simulation of current sheet instabilities. In: *Space Plasma Simulation*. (Eds.) J. Büchner, Chr. Dum and M. Scholer. *Copernicus Gesellschaft e.V., Katlenburg-Lindau* 2001, 352–355.
- Skorov, Y. V., N. I. Kömle, H. U. Keller, G. Kargl and W. J. Markiewicz*: A model of heat and mass transfer in a porous cometary nucleus based on a kinetic treatment of mass flow. *Icarus* **153**, 180–196 (2001).
- Skorov, Yu. V., W. J. Markiewicz, A. T. Basilevsky and H. U. Keller*: Stability of water ice under a porous nonvolatile layer: implications to the south polar layered deposits of Mars. *Planetary and Space Science* **49**, 59–63 (2001).
- Smith, P. H., R. Reynolds, J. Weinberg, T. Friedmann, M. T. Lemmon, R. Tanner, R. J. Reid, R. L. Marcialis, B. J. Bos, C. Oquest, H. U. Keller, W. J. Markiewicz, R. Kramm, F. Gliem and P. Rueffer*: The MVACS surface stereo imager on Mars Polar Lander. *Journal of Geophysical Research* **106**, 17589–17608 (2001).
- Solanki, S. K.*: Small-scale photospheric structure of the solar magnetic field outside sunspots. In: *Magnetic Fields Across the Hertzsprung-Russell Diagram*, ASP Conference Proceedings Series 248. (Eds.) G. Mathys, S. K. Solanki and D. T. Wickramasinghe. *Astronomical Society of the Pacific, San Francisco/CA* 2001, 45–53.
- Solar photospheric magnetic flux tubes: Observations. In: *Encyclopedia of Astronomy and Astrophysics*, vol. 3, (Ed.) P. Murdin. *Institute of Physics Publishing, London* 2001, 2675–2682.
- Sunspot magnetic fields. In: *Encyclopedia of Astronomy and Astrophysics*, vol. 4, (Ed.) P. Murdin. *Institute of Physics Publishing, London* 2001, 3177–3180.
- Sunspot models. In: *Encyclopedia of Astronomy and Astrophysics*, vol. 4, (Ed.) P. Murdin, *Institute of Physics Publishing, London* 2001, 3180–3187.
- The lower polar atmosphere and the solar dynamo: Perspectives for the Solar Orbiter. In: *Proceedings “Solar Encounter: The First Solar Orbiter Workshop”*. (Eds.) B. Battrick and H. Sawaya-Lacoste. *ESA SP-493, ESTEC, ESA Publ. Div., Noordwijk* 2001, 35–41.

- Solanki, S. K., M. Fligge and Y. C. Unruh*: Variations of the solar spectral irradiance. In: *Recent Insights into the Physics of the Sun and Heliosphere: Highlights from SOHO and Other Space Missions*, IAU Symposium 203. (Eds.) P. Brekke, B. Fleck and J. B. Gurman. Astronomical Society of the Pacific, San Francisco/CA 2001, 66–77.
- Solanki, S. K., C. Régulo, M. Fligge and A. G. Kosovichev*: Noise reduction in helioseismic power spectra by non-orthogonal wavelets. *Astronomy and Astrophysics* **379**, 1039–1044 (2001).
- Torsti, J., L. Kocharov, D. E. Innes, J. Laivola and T. Sahla*: Injection of energetic protons during solar eruption on 1999 May 9: Effect of flare and coronal mass ejection. *Astronomy and Astrophysics* **365**, 198–203 (2001).
- Tsurutani, B. T., X.-Y. Zhou, J. K. Arballo, W. D. Gonzalez, G. S. Lakhina, V. Vasyliunas, J. S. Pickett, T. Araki, H. Yang, G. Rostoker, T. J. Hughes, R. P. Lepping and D. Berdichevsky*: Auroral zone dayside precipitation during magnetic storm initial phases. *Journal of Atmospheric and Solar-Terrestrial Physics* **63**, 513–522 (2001).
- Tu, C.-Y. and E. Marsch*: On cyclotron wave heating and acceleration of solar wind ions in the outer corona. *Journal of Geophysical Research* **106**, 8233–8252 (2001).
- Wave dissipation by ion cyclotron resonance in the solar corona. *Astronomy and Astrophysics* **368**, 1071–1076 (2001).
- Unruh, Y. C., R. Knaack, M. Fligge and S. K. Solanki*: Are the Sun's brightness variations really tamer than those of other comparable solar-type stars? In: *Cool Stars, Stellar Systems and the Sun XI*. ASP Conference Proceedings Series 223. (Eds.) R. J. García López, R. Rebolo and M. R. Zapatero Osorio. Astronomical Society of the Pacific, San Francisco/CA 2001, CD–748.
- Vasyliunas, V. M.*: Comment on 'Simulation Study on Fundamental Properties of the Storm-Time Ring Current' by Y. Ebihara and M. Ejiri. *Journal of Geophysical Research* **106**, 6321–6322 (2001).
- Electric fields and plasma flow: What drives what? *Geophysical Research Letters* **28**, 2177–2180 (2001).
- Vocks, C. and E. Marsch*: A semi-kinetic model of wave-ion interaction in the solar corona. *Geophysical Research Letters* **28**, 1917–1920 (2001).
- Voitenko, Y., M. Gossens and E. Marsch*: On the role of ion-cyclotron kinetic Alfvén waves in the solar wind: Results from Helios and expectations for Solar Orbiter. In: *Proceedings "Solar Encounter: The First Solar Orbiter Workshop"*. (Eds.) B. Battrock and H. Sawaya-Lacoste. ESA SP-493, ESTEC, ESA Publ. Div., Noordwijk 2001, 411–416.
- von Steiger, R., J.-C. Vial, P. Bochsler, M. Chaussidon, C. M. S. Cohen, B. Fleck, V. S. Heber, H. Holweger, K. Issautier, A. J. Lazarus, K. W. Ogilvie, J. A. Paquette, D. B. Reisenfeld, L. Teriaca, K. Wilhelm, S. Yusaïnee, J. M. Laming and R. C.*
- Wiens*: Measuring solar abundances. In: *Solar and Galactic Composition*. (Ed.) R. F. Wimmer-Schweingruber. AIP Conference Proceedings 598, Melville/NY 2001, 13–22.
- Wiegmann, T. and J. Büchner*: Evolution of magnetic helicity in the course of kinetic magnetic reconnection 1. B=0 reconnection. *Nonlinear Processes in Geophysics* **8**, 127–140 (2001).
- Wiegmann, T., T. Neukirch and J. Büchner*: Tests and limits of Vlasov code simulations and its application to null-helicity and co-helicity reconnection. In: *Space Plasma Simulation*. (Eds.) J. Büchner, Chr. Dum and M. Scholer. Copernicus Gesellschaft e.V., Katlenburg-Lindau 2001, 58–61.
- Wilken, B., P. W. Daly, U. Mall, K. Aarsnes, D. N. Baker, R. D. Belian, J. B. Blake, H. Borg, J. Büchner, M. Carter, J. F. Fennell, R. Friedel, T. A. Fritz, F. Gliem, M. Grande, K. Kecskemety, G. Kettmann, A. Korth, S. Livi, S. McKenna-Lawlor, K. Mursula, B. Nikutowski, C. H. Perry, Z. Y. Pu, J. Roeder, G. D. Reeves, E. T. Sarris, I. Sandahl, F. Søraas, J. Woch and Q.-G. Zong*: First results from the RAPID imaging energetic particle spectrometer on board Cluster. *Annales Geophysicae* **19**, 1355–1366 (2001).
- Wilken, B. and Q. Zong*: Die Cluster-Flotte. *Sterne und Weltraum* **10**, 836–844 (2001).
- Zecha, M., J. Röttger, W. Singer, P. Hoffmann and D. Keuer*: Scattering properties of PMSE irregularities and refinement of velocity estimates. *Journal of Atmospheric and Terrestrial Physics* **63**, 201–214 (2001).
- Zong, Q. G., B. Wilken, S. Y. Fu, T. A. Fritz, A. Korth, N. Hasebe, D. J. Williams and Z. Y. Pu*: Ring current oxygen ions escaping into the magnetosheath. *Journal of Geophysical Research* **106**, 25541–25556 (2001).

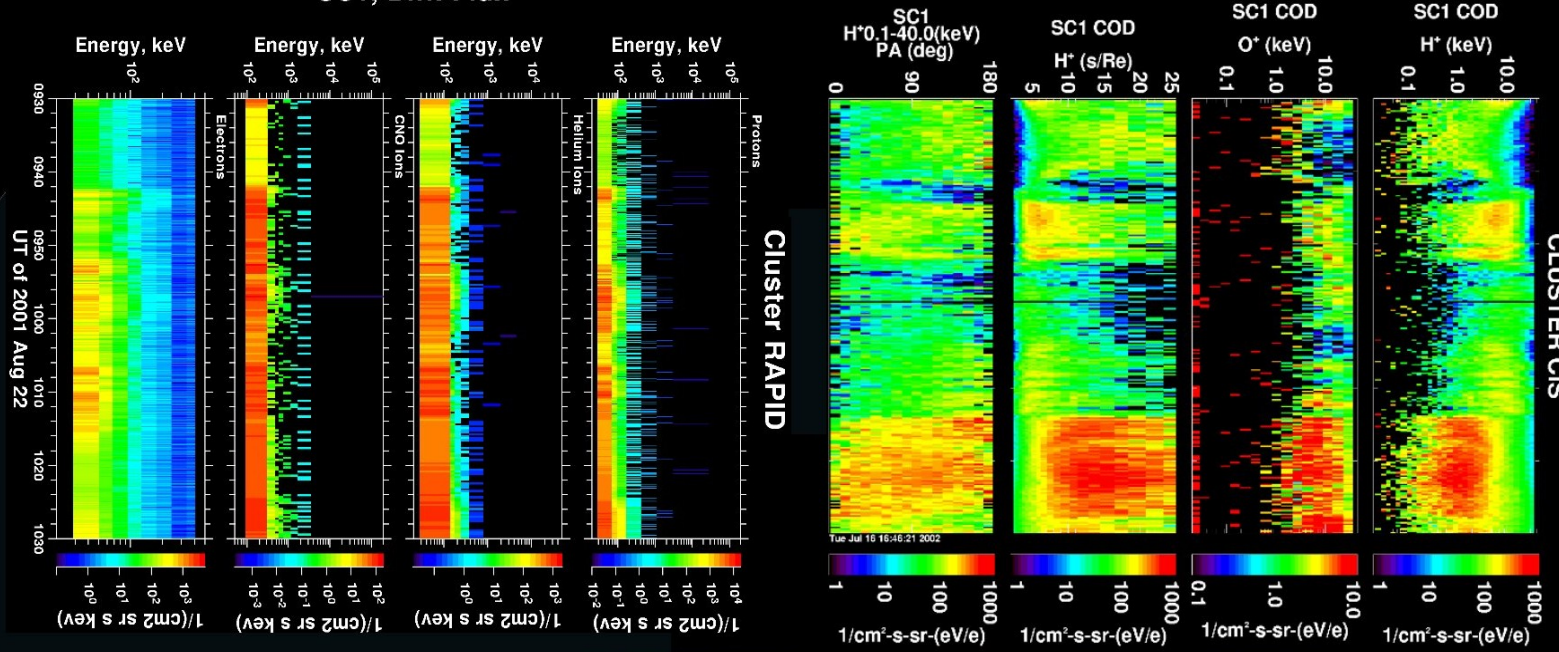
*Publikationen im Internet*

*Grieger, B.*: Von einsamen Wanderern und braunen  
Zwergen. wissenschaft-online 2001.

Internet: [www.wissenschaft-online.de/page/fe\\_seiten&article\\_id=586172](http://www.wissenschaft-online.de/page/fe_seiten&article_id=586172).



SC1, Diff. Flux



Cluster RAPID

CLUSTER CIS