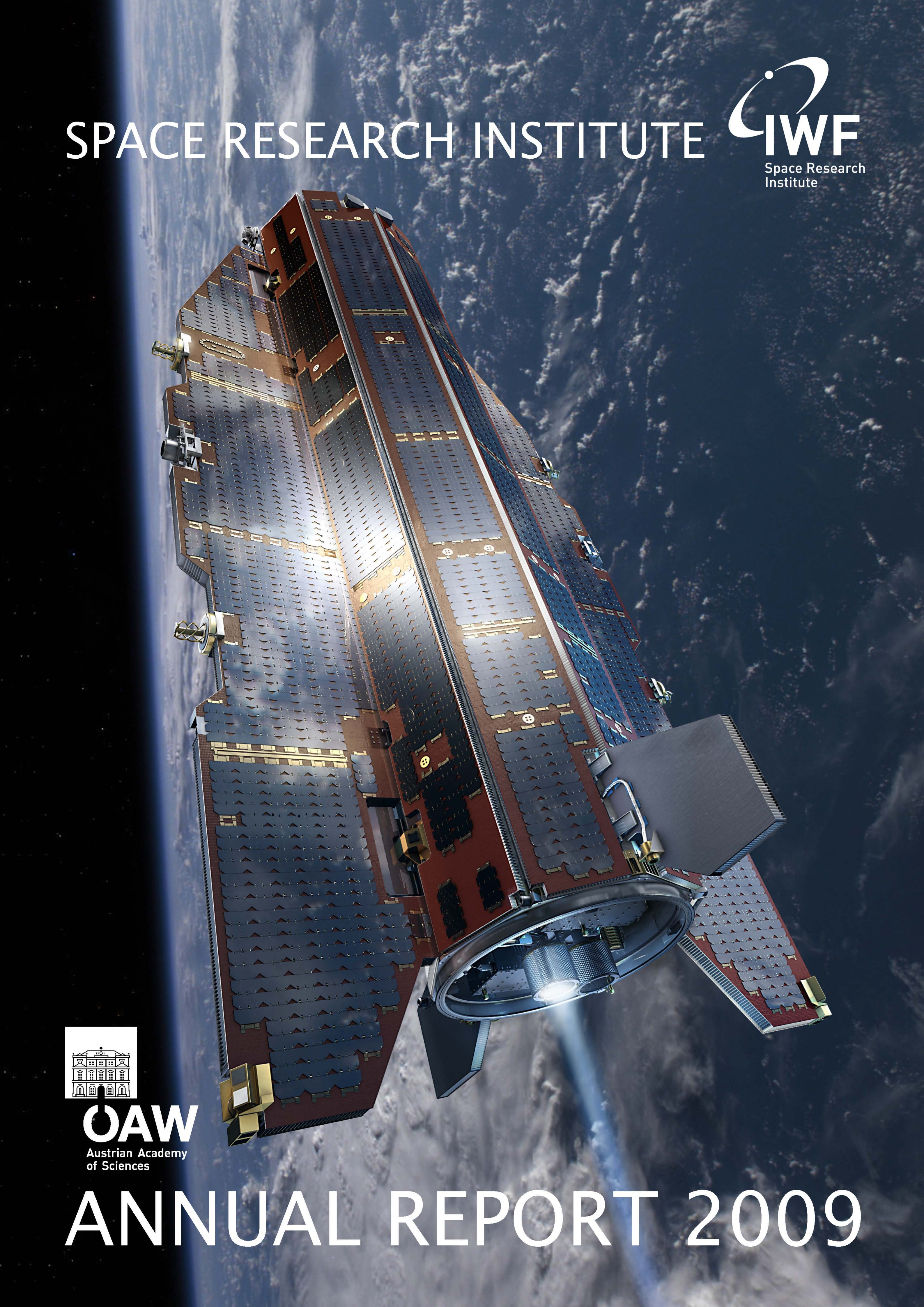

SPACE RESEARCH INSTITUTE

IWF
Space Research Institute

ÖAW
Austrian Academy of Sciences

ANNUAL REPORT 2009

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SPACE RESEARCH INSTITUTE GRAZ
AUSTRIAN ACADEMY OF SCIENCES

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Cover Image:

GOCE (Gravity field and steady-state Ocean Circulation Explorer) was launched on 17 March 2009. Its mission is to measure the Earth's gravity field and its variations in order to get a better understanding of the mechanisms building and driving the Earth's crust and ocean currents.

Table of Contents

1 Introduction

The Space Research Institute (Institut für Weltraumforschung, IWF) of the Austrian Academy of Sciences (Österreichische Akademie der Wissenschaften, ÖAW) is the focus of Austria's scientific space activities. It cooperates closely with space agencies all over the world and with numerous other national and international research institutions. A particularly intense cooperation exists with the European Space Agency (ESA). IWF participates in various interplanetary missions as well as in missions dedicated to the exploration of our own planet Earth and its neighbourhood:

- *Cassini* is orbiting Saturn and exploring its system.
- *Cluster*, the four-spacecraft mission is still providing unique data leading to a new understanding of space plasmas.
- *Rosetta* is on its way to comet 67P/Churyumov-Gerasimenko.
- *Venus Express* explores the space plasma environment around Venus.
- *COROT* searches for extra-solar planets and analyzes oscillation modes of stars.
- *THEMIS* has been reduced to a near-Earth three-spacecraft mission. The two outermost spacecraft are on their way to the moon for the *ARTEMIS* mission.
- *GOCE* will begin to determine the structure of the terrestrial gravitational field with unprecedented accuracy.
- *STEREO* studies solar(wind) structures with two spacecraft orbiting the Sun approximately at Earth distance.
- *Yinghuo* is the first Chinese mission to Mars, planned for launch in October 2011.
- *RBSP* (Radiation Belt Storm Probes) are two NASA spacecraft that will quantify processes in the Earth's radiation belts.
- *BepiColombo* will investigate the planet Mercury, using two orbiters: one with instruments specialized for magnetospheric studies, and the other for remote sensing of the planet.
- *MMS* will use four identically equipped spacecraft to explore the acceleration processes that govern the dynamics of the Earth's magnetosphere.
- *Resonance* is a Russian space mission of four identical spacecraft, orbiting within the same magnetic flux tube.

IWF is naturally engaged in analyzing data from these and other space missions. This analysis is supported by theory, simulation, and laboratory experiments. Moreover, at the Lustbühel Observatory in Graz, one of the most accurate laser ranging stations of the world is operated. Its data are used to determine the orbits of more than 30 satellites.

Scientific highlights in 2009 were:

- After many delays, GOCE has been successfully launched on 17 March 2009.
- CoRoT has detected the, up to now, most Earthlike exoplanet, with a mass of 1.7 times that of the Earth and an orbit very close to its host star.
- The 1000th *Cluster* paper was published this year. In honour of this a top-10 of first-authors papers was presented, with four IWF members in it.

- The longest lasting thunderstorm in the solar system was observed by *Cassini.*

In closing some numbers: in 2009 members of the institute published over 134 articles in refereed international journals, more than 38 of these as first author. During the same period, articles with authors from the institute were cited about 2200 times in the international literature. In addition, more than 140 talks and posters have been presented at international conferences by members of the IWF, including 20 by special invitation from the conveners. In national and international press media, the institute was mentioned about 280 times. Last but not least, institute members have organized two international conferences, as well as 13 sessions at international meetings.

IWF structure and funding

IWF is structured into three departments:

- Experimental Space Research (Head: Prof. Dr. Wolfgang Baumjohann)
- Extraterrestrial Physics (Head: Prof. Dr. Helmut O. Rucker)
- Satellite Geodesy (Head: Prof. Dr. Hans Sünkel)

Prof. Dr. Wolfgang Baumjohann serves as Executive Director.

The bulk of financial support for the research is provided by the ÖAW. Substantial support is also provided by other national institutions, the Austrian Research Promotion Agency (Österreichische Forschungsförderungsgesellschaft, FFG), the Province of Styria, and the Austrian Science Fund (Fonds zur Förderung der wissenschaftlichen Forschung, FWF). Furthermore, European institutions like ESA and the European Union contribute substantially.

2 Solid Earth

Understanding the dynamics of the solid Earth is crucial for developing an interconnected view of Earth science. Earth's surface and interior are undergoing a constant process of change. Variations in the land cover and ice sheets impact the climate and the environment. Satellite-based instruments are a global and cost-effective means to provide a valuable data set for Earth scientists over a wide range of spatial and temporal scales.

Measurements of the Earth's gravity field and its variations as provided by the European *GOCE* mission, contribute to a better understanding of the mechanisms building and driving the Earth's crust and ocean currents. The *GOCE*-derived geoid will also be used for practical applications in areas such as surveying and leveling. Global permanent position monitoring (GPS) and Satellite laser ranging (SLR) to geodetic satellites contribute to the realization of reference frames, which are important to describe the driving forces of the Earth's dynamics.

2.1 Gravity Field

The gravity field of the Earth is the sum of the gravitational and centrifugal force, with the first being the response to the Earth's interior density distribution, and the latter caused by its rotation.

GOCE Mission

The satellite gravity mission *GOCE* (Gravity field and steady-state Ocean Circulation Explorer), the first core Earth Explorer mission of ESA's Living Planet Programme, strives for a high-accuracy, high-resolution model of the Earth's static gravity field (see cover page for an image of the satellite). *GOCE* is based on a sensor fusion concept: the satellite's orbit information is exploited applying satellite-to-satellite tracking in high-low mode (hl-SST) using GPS, delivering the long and medium wavelengths of the Earth's gravity field, while satellite gravity gradiometry (SGG) using an on-board gradiometer (Fig. 2.1) will provide its detailed structure.

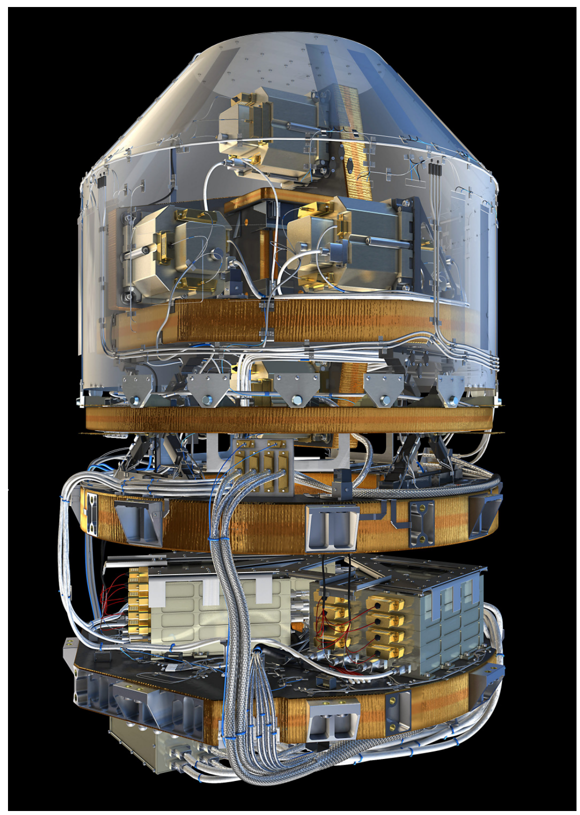

Fig. 2.1: GOCE's gravity gradiometer.

The gradiometer instrument, built and flown for the first time in history, is composed of six accelerometers positioned on three orthogonal axes measuring acceleration differences on a baseline of 0.5 meters. The relative accuracy in the measuring bandwidth is 10^{-13}. Thus, gradiometer data represent the 2^{nd} order derivatives of the gravity potential, finally yielding the gravity field coefficients (Fig. 2.2).

Satellite Status

On 17 March 2009 the *GOCE* satellite was launched from Plesetsk (Russia). The commissioning phase and the following calibration phases of the mission have been completed successfully. The satellite reached its final orbit altitude of 255 km on 15 September and is in Science Mode since the beginning of October. First analyses reveal that *GOCE*'s payload is healthy and working properly. Data collection and operational processing has now started and will last beyond 2011, and the first official *GOCE* gravity model is to be expected in mid 2010.

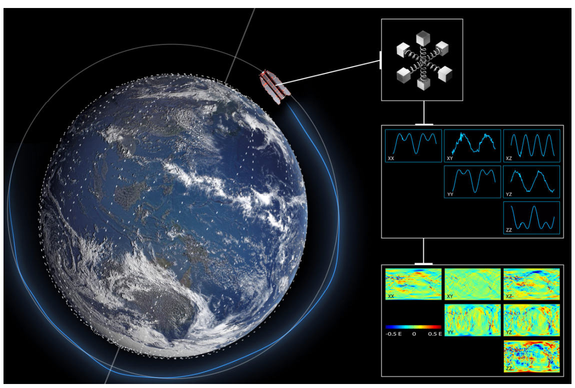

Fig. 2.2: Gravity gradiometer measurement principle.

Gravity Field Processing

The scientific data processing and gravity field modeling is performed by the "European GOCE Gravity Consortium" (EGG-C). One key component of this software system is the processing of an Earth's global gravity field model and the corresponding full variance-covariance matrix from the satellite's precise orbit (SST) data, and gradiometry (SGG) data. This key component is operated by the *GOCE* team Graz, which is a close co-operation of IWF with the Institute of Navigation and Satellite Geodesy of the Graz University of Technology (TU Graz). During the at least two measurement phases a huge amount of several hundred millions of orbit and gradiometry data will be collected. The mathematical model of the parameterization of the gravity field incorporates a finite series of spherical harmonic functions. In the envisioned case of a model of degree and order 250 this corresponds to about 63000 unknown parameters. Fig. 2.3 gives an overview of the gravity field processing scheme, the modular architecture and data flow, as well as the I/O products.

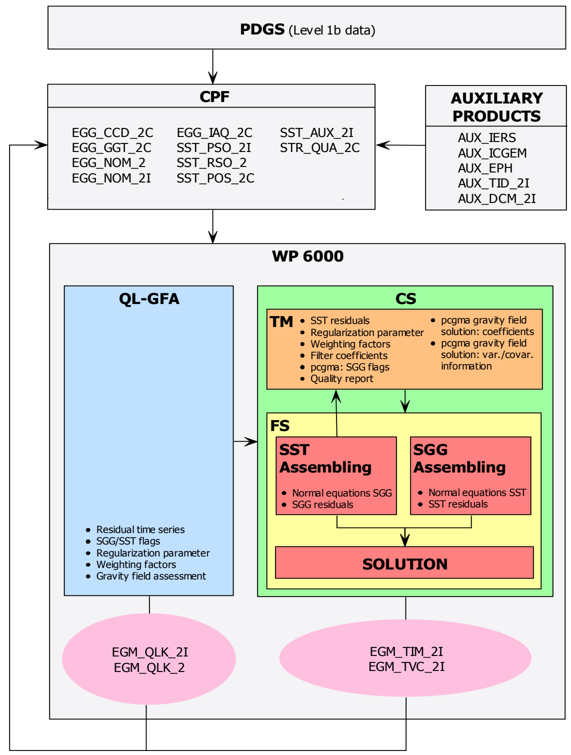

Fig. 2.3: Flowchart of the processing system, with data flow from ESA Payload Data Ground Segment (PDGS), the Central Processing data Facility, and the gravity field processor WP6000.

The subprocessing system comprises two main components: The Quick-Look branch (QL-GFA), for delivering fast approximate solutions, computed in parallel to the mission, is used for the satellite's system diagnosis and data quality control, whereas the rigorous Core Solver approach (CS) is implemented to solve the very large linear equation systems using parallel software and hardware facilitating "Scientific Supercomputing" clusters at TU Graz.

Core Solver

Gravity field computation from GPS orbit information (SST processing) is based on the principle of energy conservation in a closed system (energy integral approach). The SGG processing assembles the full normal equation systems based on the gradiometry data measurements (mathematically corresponding to 2nd order derivatives of the gravity potential). The problem of colored noise of the gradiometer instrument is handled by using recursive filter processes in time domain. The SST and SGG normal equations are combined using an optimal weighting strategy based on variance component estimation (TM module). The solution process of the combined system is based on a parallelized Cholesky reduction.

The numerical instability of the equation system due to the sun-synchronous orbit of *GOCE* and thus resulting in data gaps over the poles is coped with tailored regularization techniques. Additionally to the solution of the gravity field coefficients, the strict inversion of the whole system delivers the full variance-covariance matrix as a statistical error measure of the derived coefficients. This covariance information, essential for many gravity applications, and up to now not available with current Earth gravity models, will be realized with *GOCE*.

2.2 Geodynamics

The institute's GPS Data and Analysis Centre provides the basis for investigation within national and international scientific projects, like IGS, EUREF, CERGOP and others, containing observations of GNSS permanent and epoch stations. It is Europe's second-largest data centre (DC) and – concerning GNSS (Global Navigation Satellite Systems) – data one of the top 10 worldwide.

Starting in 2005 as a European DC the number of stations, files and therefore the hosted disc space increased steadily. Every year up to five million files are uploaded, checked and stored.

An attached Analysis Centre is working on three main topics: reference frames, geodynamics and disturbances of the ionosphere. It is one of the three leading ACs out of 16 in total which generate and maintain the European Reference Frame EUREF. The realization of EUREF in Austria is determined from AMON (Austrian Monitoring Network), one of the Austrian GNSS networks. The realization of early 2009 was now selected for official use.

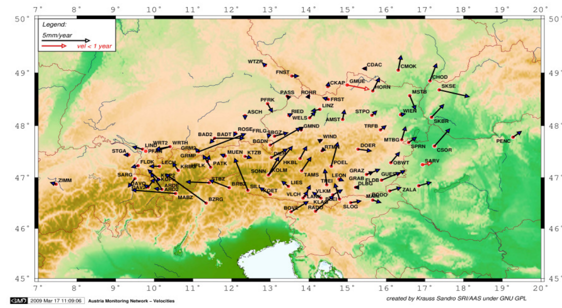

Fig. 2.4: AMON station velocities in ETRF2000.

The coordinates of the permanent GNSS stations in and around Austria are given in ETRF2000, epoch 2002.5. The epoch was chosen because the new coordinates should be as close as possible to those of the campaign in 2002 which are already used for realization. The realization is designed as a set of fixed coordinates. However, yearly changes of 0-8 mm occur together with local and plate movements (Fig. 2.4).

Ionospheric disturbances degrade the accuracy of positioning as well as endanger space navigation and may cause damages to the infrastructure on Earth. To mitigate these effects, the ionosphere needs to be monitored to give warnings about expected turbulences. IWF is participating in a project which improves the positioning by GNSS satellites, e.g. *GPS* and *GLONASS* and in the future *Galileo*. A test bed around the city of Rottenmann (A) was chosen to find an adequate model of the regional impact of the ionosphere onto the EGNOS (Eurpean Geostationary Navigation Overlay Service) signals. Because of the low disturbances, presently the different models (global, regional, local) do not show significant variations among each other (Fig. 2.5). However, all of the tested models reduce the error in the coordinates significantly compared to the results where no ionospheric model was used.

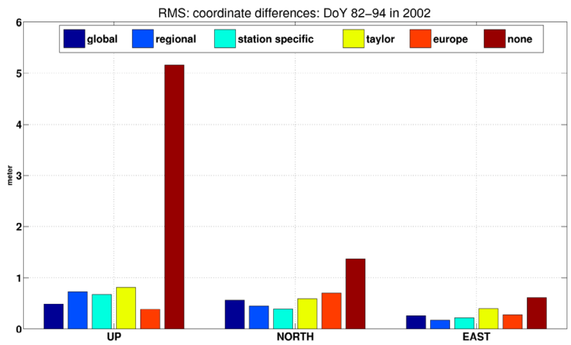

Fig. 2.5: RMS values of coordinate differences including 13 contributing stations.

The accuracy can reach the sub-meter range with any of these models as long as it considers the daily variations. The impact of the troposphere was modeled in a similar way, but is less important since the variations are always in the sub-meter region.

Satellite Altimetry

In preparation for the upcoming Cryosat-2 mission we equipped the microwave altimeter transponder operated on Gavdos/Crete with a GSM/GPRS modem for remote control and telemetry. The operation was successfully tested with *Jason-2* passes in close cooperation with CNES.

Numerous waveform datasets (Fig. 2.6) have already been analyzed and will further be processed to derive precise altimeter instrument biases.

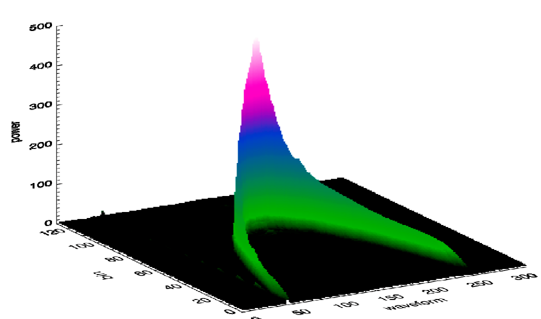

Fig. 2.6: Jason-2 altimeter waveform recorded on Nov. 10, 2009

2.3 Atmosphere

Atmospheric Density

During the maximum of the 11-year solar cycle the number and intensity of geomagnetic storms increases significantly. Phenomena like solar flares or coronal mass ejections where material of the solar corona induces heating and expansion of the thermosphere are causing density variations. In the accelerometer data from Low Earth Orbiters (LEO) like *CHAMP* and *GRACE* are used to calculate the thermospheric density at an altitude of 400 km. The investigation covered time periods with both quiet and extremely perturbed solar conditions.

On 28 October 2003 one of the largest geomagnetic storms ever happened. Variations of the neutral density during this event are displayed in Fig. 2.7.

The plots show how the geomagnetic storm was observed by *GRACE* (left) and *CHAMP* (right) during day (top) and night (bottom) by means of accelerations acting on the spacecraft. The derived density perturbations reached up to 400% compared to those of quiet conditions. The in-situ measurements are also essential for improvements of state of the art models and thus achieve a high level of importance for studies related to the evolution of the atmosphere of the early Earth.

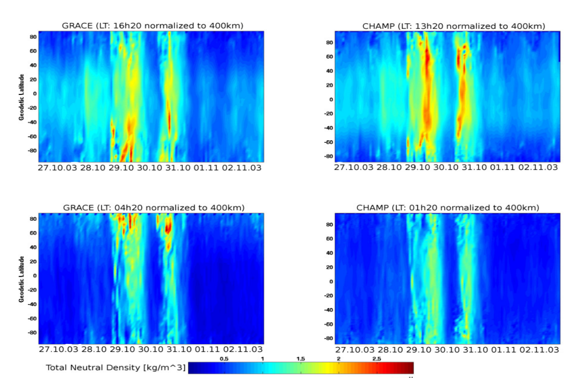

Fig. 2.7: Density impact of X17.2 flare (28th Oct. 2003) observed by GRACE (left) and CHAMP (right) – day (upper) and night side (lower) panel.

Lithospheric Electricity

On 6 April 2009 an M=6.3 earthquake (EQ) struck the city of L'Aquila and surroundings (Central Italy) causing 60,000 to lose their homes and a death toll of 300. Various seismo-electromagnetic methods have been used to investigate the lithospheric-ionospheric coupling related to this disaster. VLF observations onboard the micro-satellite *DEMETER* in the vicinity of the EQ revealed a typical drop of signals from ground-transmitters and from natural ionospheric sources 5 days before the EQ. As part of a European VLF network the station in Graz observed clear anomalies in the intensity of night time signals and in the evening terminator times 2-8 days before the EQ. A preliminary TEC analysis showed no anomalies before the EQ.

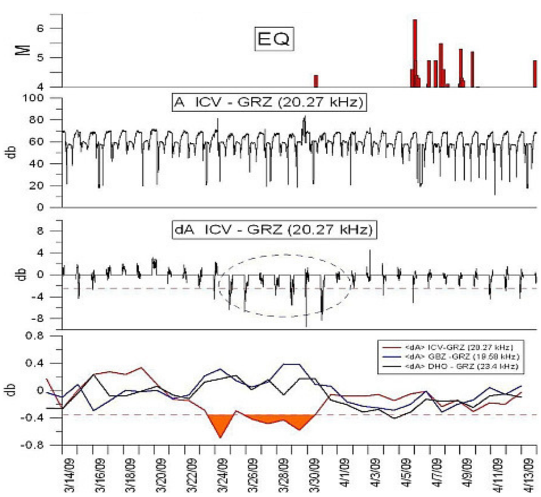

Fig. 2.8: In the two panels at the top, the nighttime amplitude of the ICV transmitter (Sardinia, Italy) signal and its residual amplitude are shown.

In the frame of the South European Ground Magnetometer Array (*SEGMA*) seismo-magnetic ULF studies have been performed one year before and several months after the EQ (see Fig. 2.8). The classical polarization method revealed only magnetic field variations which can be explained in terms of geomagnetic and man-made disturbances. However, the application of the improved polarization method, developed several years ago, showed a typical increase of the polarization parameter two weeks before the EQ only for the *SEGMA* station closest to the epicenter. The remote stations showed no fluctuations indicating the seismic origin of the observations.

2.4 Satellite Laser Ranging

SLR-Technology / Hardware

During 2009 the implementation of our serial bus control system was completed: Single BNC cables connect the major SLR station units with the PC, allowing now software controlled flipping of mirrors, filter settings, piezo drives in the mount, and also accepting observer command inputs. This enables a fast setting of multiple components via single observer commands or via software which brings a big benefit when tracking very low satellites like e.g. *GOCE*. In addition, it helps to slightly compensate the reduction of our routine night observations necessary due to financial constraints.

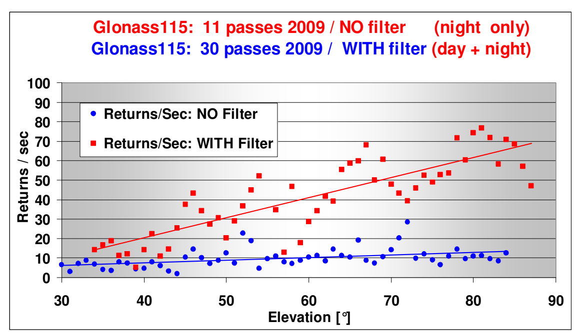

Fig. 2.9: Increase of returns for distant satellites: 3 times more returns when filter is removed during night.

Mechanics, electronics and software now allow to remove the wavelength filter for HEO satellites (*LAGEOS* and above) during night. Because our narrow bandwidth filter transmits only 35%, ranging without such a filter during the night increases the return rate three times (Fig. 2.9). For *GLONASS* satellites, this results now in passes with several 100.000 returns, and with the potential capability for > 1 million returns per pass. This is especially important for the upcoming *Galileo* satellites: All of them will be equipped with retro reflectors, and all of them will be in a distance of about 24,000 km, with correspondingly low return rates.

The filter is also removed for the *LAGEOS 1/2* satellites: Besides getting more returns, here the fraction of multi-photon returns is also significantly increased, reducing satellite signature, and favoring our "leading edge post-processing method" developed last year.

For special satellites, like *BLITS* ("Ball Lens In The Space"), the filter is also removed: The relatively weak return signals (in spite of only about 830 km distance, due to its small retro cross section), can be increased, giving an RMS of 2-2.5 mm, and allowing significantly better spin parameter determinations.

The removal of the filter (glass body of 8 mm) shortens the measured distance by 15 ps which is corrected automatically during all ranging and calibration activities by software.

Spin Parameter Determination

The spin period of the satellite *AJISAI* for the last 5 years was determined with an accuracy of <0.005% (for the 2 s period, this is <100 µs), using the 2 kHz SLR data of Graz only. The spin period residuals calculated to an exponential trend function show a significant modulation (Fig. 2.10: blue dots). The grey line models a function which depends on the total solar irradiance (TSI) acting on *AJISAI*: the spin rate slow-down of *AJISAI* is slower if it orbits in Earth shadow and faster if it is exposed to the sun (Yarkovsky-Schach effect).

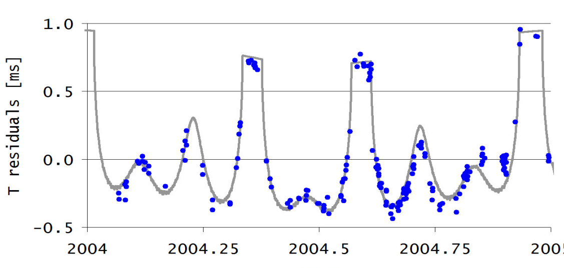

Fig. 2.10: AJISAI spin period residuals (blue dots) and the model function (grey line) which depends on TSI acting on AJISAI (plotted for the year 2004).

Eclipsing Binary Stars

In the frame of a diploma thesis a Single Photon Counting Module (SPCM) was installed to measure the photon flux of eclipsing binary stars. These observations are intended as a complementary application to the standard SLR activities. They contribute to observations of already known variable stars. In spite of the non-optimum location of SLR Graz for such experiments, photon flux variations were measured. Fig. 2.11 shows residuals (i.e. deviations of eclipsing intervals from a constant period, due to at least one additional orbiting mass) of international CCD and photometric data (red and blue dots) and the Graz SPCM measurements (red arrows).

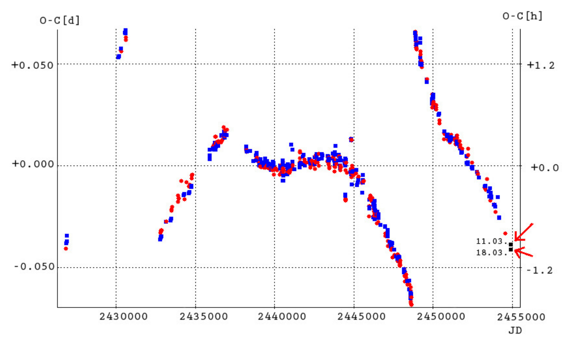

Fig. 2.11: Eclipsing binary star HD 197433: Deviations of eclipsing intervals from a constant period (black dots (with red arrows) indicate Graz SPCM measurements).

3 Near-Earth Space

The Earth's space environment is dominated by the interaction between the solar wind and the terrestrial magnetic field. The structures that are created in this interaction region around the Earth are the bow shock, in which the supersonic solar wind is decelerated, a transition layer called the magnetosheath, the magnetopause (the boundary of the magnetosphere), and the magnetosphere itself, where the magnetic field from the Earth's dipole is dominating. Understanding how the energy of the magnetic field and particles travel from the sun through interplanetary space, enter the magnetosphere and are further transported and processed, is the general theme of the solar-terrestrial physics. Near-Earth space is also an ideal natural laboratory to study the physics of space plasmas with in-situ measurements of particles and electric and magnetic fields. Research of near-Earth space at IWF is performed on experimental and theoretical bases and by means of data analysis of different solar-terrestrial missions.

3.1 Missions

One of the important components of the investigation of near-Earth space at IWF is the active involvement in different spacecraft missions throughout their entire phases, i.e., providing hardware, processing and analysing the measured data, constructing new models, and participating in future planning. These include the ongoing missions, Cluster (launched in 2000) and THEMIS (launched in 2007), in which a wealth of new and exciting data is taken leading to successful new results, and also the future mission, MMS (launch planned in 2014), in which IWF is presently involved in building advanced instruments.

Cluster

The four *Cluster* spacecraft, launched in 2000, are still in operation, taking data while circling the Earth in polar orbits. By now, the spacecraft have made observations in the Earth's magnetotail at several different separation distances of the tetrahedron, varying from 200 km to 10,000 km. Since 2005, modified configurations have been realized to be able to compare large scale (10,000 km) with smaller scale processes (30 km – 3000 km). This ESA mission has now officially been extended until the end of 2012. As PI institution of *ASPOC* and holding CoI status for four more instruments, IWF is maintaining the *Austrian Cluster Data Center* and is analysing *Cluster* data in many studies, a part of which are introduced in the next subsection. The instrument team at IWF is processing and providing data to *Cluster Active Archive (CAA)*, which is a database consisting of all the *Cluster* high resolution data and other allied products.

THEMIS

The NASA mission *THEMIS (Time History of Events and Macroscale Interactions during Substorms)* is designed to explore the origin of magnetic storms and auroral phenomena. *THEMIS* was successfully launched in February 2007 and flies five identical satellites through different regions of the magnetosphere. The spacecraft successfully measured numerous substorms during the tail science phases in the last two winter seasons 2007/8 and 2008/9 and completed the prime mission phase. As Co-I institution of the *FGM*, IWF is participating in processing and analysing data. A part of these studies is introduced in the next subsection. Two of the five THEMIS probes became a new mission, "Acceleration Reconnection and Turbulence and Electrodynamics of the Moon's Interaction with the Sun" (ARTEMIS), to study moon as well as tail sciences and the separation among the other three THEMIS spacecraft becomes 100 km to study dynamics of the inner magnetosphere.

MMS

The purpose of the NASA mission *MMS (Magnetospheric Multiscale)* is to explore the dynamics of the Earth's magnetosphere and its underlying energy transfer processes. Four identically equipped spacecraft are to carry out three-dimensional measurements in the Earth's magnetosphere. *MMS* will determine the small-scale basic plasma processes which transport, accelerate and energize plasmas in thin boundary and current layers – and which control the structure and dynamics of the Earth's magnetosphere. *MMS* is scheduled to be launched in 2014. IWF will take the lead for the spacecraft potential control and participate in an electron beam instrument and a magnetometer. In mid 2009 the phase C/D for these instruments was started, which covers all further activities until in-orbit commissioning.

Active Spacecraft Potential Control (ASPOC) instrument: The Preliminary Design Review for ASPOC was successfully concluded in February 2009, followed by the participation in reviews of the instrument suite and the mission. The design of the controller (see Fig. 3.1) has been handed over to industry for building the Engineering-Qualification Model *(EQM)*. IWF was handling the parts procurement for the *EQM* and long-lead flight components and was supervising the manufacturing and test activities at Research Studios Austria (RSA) for the electronics and at Austrian Institute of Technology (AIT) for the ion emitters.

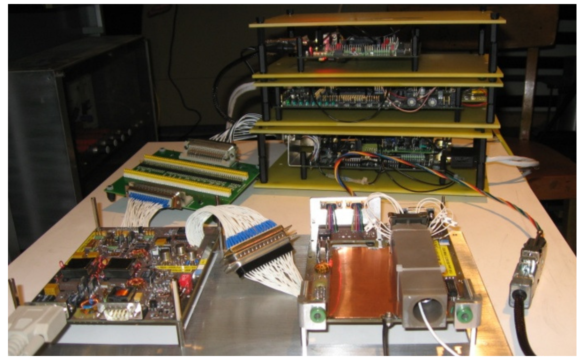

Fig. 3.1: Test Set-up of the ASPOC Interface Verification Model Electronics including the controller.

Together with South West Research Institute (SwRI) and Goddard Space Flight Center (GSFC), IWF worked to refine the specifications, to establish and exercise the appropriate product assurance, and to plan the further activities. A major fraction of the technical development work at IWF was devoted to the detailed design and coding of the Field Programmable Gate Array (RTAX2000S) in the controller and the software for the embedded processor core.

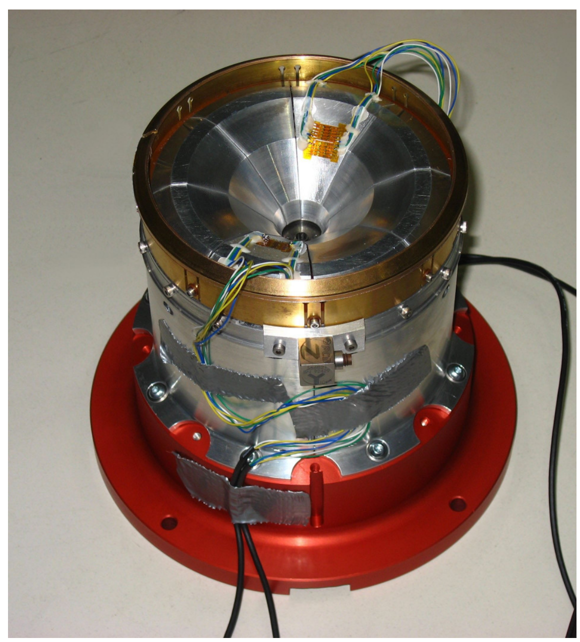

Fig. 3.2: The EDI gun prototype ready assembled for the vibration test. Strain gauges are glued onto the deflection plates for detailed analysis of the local stress.

Electron Drift Instrument (EDI): IWF contributes to EDI with the *Gun Detector Electronics (GDE)* and the electron gun (Fig. 3.2). The *GDE* is developed by Austrian industry in close cooperation with the institute, while the electron gun is entirely developed by IWF.

The *EDI* instrument for *MMS* is based on the *Cluster* development with several improvements. The major change for the gun is the usage of field emission cathodes (FEC) as electron sources instead of filaments. The latest *FEC* technology is made from *Carbon Nano Tubes (CNT),* which turned out to be very robust against contamination. Three elements have been purchased for the *EQM*. All are characterized and tested for several thousand hours prior to the selection of one element for implementation in the *EQM*.

In 2009 the institute concentrated on the design of the electron gun. The development of the gun mechanics is finished and the elements for the *QM* are already in house for surface treatments and final assembly. The development of the gun electronics is almost finished. First boards for the *QM* will be ordered. The population of the *QM* boards will start at the beginning of 2010. The delivery of *QM* to University of New Hampshire (*UNH*) for further integration and test is scheduled for the second quarter of 2010.

Digital Flux Gate magnetometer (DFG): DFG is based on a triaxial fluxgate sensor developed by the University of California, Los Angeles and a front-end Application Specific Integrated Circuit (ASIC) for magnetic field sensors. The ASIC has been developed by IWF in cooperation with the Fraunhofer Institute for Integrated Circuits (under an ESA contract) in order to reduce the size, mass and power consumption of the near sensor electronics.

In 2009, the flight ASIC has been manufactured, assembled and screened according to NASA's level 2 standard. Its micrograph is shown in Fig. 3.3. The ASIC was produced on a 350 nm process from austriamicrosystems. The 4x5.5 mm^2 wide die contains approximately 25,000 logic gates in the digital upper and 14,000 transistors in the analogue lower part of Fig. 3.1. It consumes only 65 mW and consists of four advanced digital-to-analogue converters for a sensor direct digitization of the three magnetic field components as well as the measurement of up to 8 additional temperatures and supply voltages.

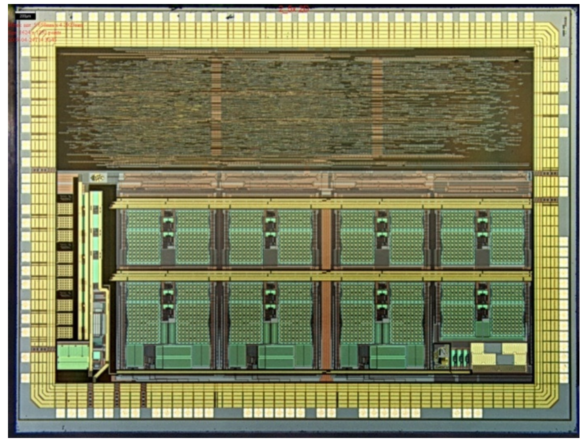

Fig. 3.3: Micrograph of the flight ASIC.

RESONANCE

The aim of the russian *RESONANCE* mission is the investigation of wave-particle interactions and plasma dynamics in the inner magnetosphere of Earth, with the focus on phenomena occurring along the same field line and within the very same flux tube of the Earth's magnetic field. Four spacecraft will be launched (~2015) to perform observations and measurements. Amongst a variety of instruments and probes several low- and high-frequency electric sensors will be onboard which can be used for simultaneous remote sensing and in-situ measurements.

The IWF has performed dedicated analyses of electrical field sensors with focus on the high-frequency electric antennas. For that purpose experimental (rheometry) and numerical methods (wire-grid and patch-grid) have been applied. The obtained results show that parasitic effects on the antenna-spacecraft assembly alter the antenna reception properties significantly. The antenna directions and lengths, represented by the "effective length vector" are changed by 4 degrees in direction and 50% in length, for the quasi-static range. High frequency analyses (up to 40 MHz, Fig. 3.4) illustrate massive antenna pattern changes beyond the quasi-static frequency limit of approximately 1.5 MHz.

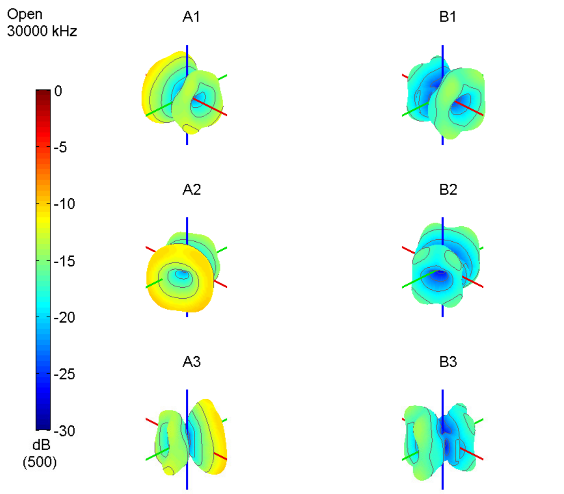

Fig. 3.4: Resonance spacecraft antenna pattern (30 MHz). A1 through A3 and B1 through B3 refer to different spacecraft antennas.

3.2 Physics

High-resolution data are provided by missions introduced in the previous section, such as *Cluster* and *THEMIS,* and also from other missions such as e.g. *Geotail* and *STEREO.* At IWF these various data are analyzed and theoretical models are developed to describe the physical processes responsible for the formation of structures and phenomena in the sun-Earth system at different scales. These studies deal with: large-scale interactions between solar surface, solar wind and magnetosphere; meso-scale disturbance and waves in the magnetotail; and also plasma instabilities and waves including magnetic reconnection.

Modelling of a flapping current sheet: Cluster observations in the Earth's magnetotail have shown the existence of flapping oscillations of the current sheet, which are strong wave perturbations propagating across the current sheet perpendicular to magnetic field lines. As a generation mechanism of these flapping oscillations, the double gradient mechanism has been considered and analytical solutions were obtained. In the frame of this mechanism, flapping waves appear due to the combination of two magnetic field gradients: dBx/dz and dBz/dx (x and z are directions tangential and normal to the current sheet). The current sheet can be stable or unstable depending on the product of these two gradients: the stable state (flapping waves) corresponds to a positive product and the unstable state (growing perturbations) – to a negative one.

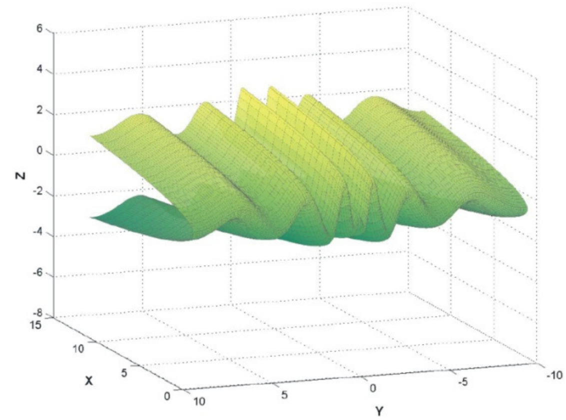

Fig. 3.5: Flapping waves produced by the fixed source (analytical solution).

While the double gradient mechanism allows to obtain analytical solutions in several simple cases as shown in Fig. 3.5 a numerical solution is needed to obtain a more realistic behaviour of the flapping. A new numerical code is under development which simulates flapping waves in the frame of ideal linearised MHD. This code will enable to investigate the possible connection between flapping waves and BBFs (Bursty Bulk Flows) generated by magnetic reconnection in the tail.

Deflection of fast flows in the plasma sheet: Bursty bulk flows (BBF) are localized and transient fast plasma flows that contribute a major part of the magnetic flux transport process into the magnetotail. These fast Earthward flows from the midtail are assumed to brake or deflect when they arrive at the inner magnetosphere where the Earth dipole field acts as an obstactle for the jetting plasmas. How these interactions between the plasma flows and the ambient fields take place is yet an unexplained important topic in magnetospheric physics. Five-point *THEMIS* observations in these key regions between 10 and 15 R_E downtail revealed that during the interaction of the earthward-flowing plasma with the Earth's dipolar field lines, the flow can be deflected producing vortices with a radius of about 5 R_E as shown in Fig. 3.6 left.

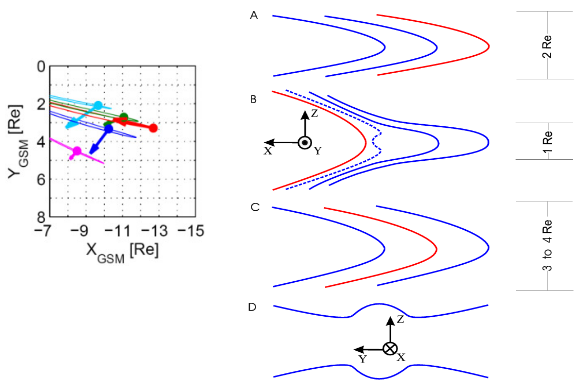

Fig. 3.6: (left) Flow velocity field in (X,Y) GSM plane, as observed by THEMIS on 17 March 2008 at 10:24 UT. (right) Schematics showing the changes in the plasma sheet shape associated with the fast flow evolution.

As a plasma flow propagates inside the plasma sheet, it affects the plasma sheet's shape. *THEMIS* revealed that the plasma sheet can be thinning and thickening simultaneously. That is, at 13-15 R_E the two spacecraft detected first thinning and then thickening of the plasma sheet around the time of the flow direction change. Meanwhile, in a more dipolar region (at 9-11 R_E) the other three spacecraft indicated first plasma sheet thickening and then thinning as illustrated in Fig. 3.6 right. In addition, thinning/thickening was more prominent near the center of the fast flow region in dawn-dusk direction.

Dipolarization and plasma sheet fast flows: Dipolarization, i.e. enhancement in Bz in combination with a decrease in Bx, has been known as a signature of substorm onset. These signatures, accompanied by BBFs, can be observed at near-Earth as well as midtail regions showing the change in the tail current sheet configuration locally and/or globally. To understand the role of the flux transport from the tail in the evolution of the near-Earth current sheet disturbances and to validate the different scenarios of the dipolarization, four spacecraft data from *Cluster* have been analyzed during 3 successive rapid transport events (indicated as A-C in Fig. 3.7).

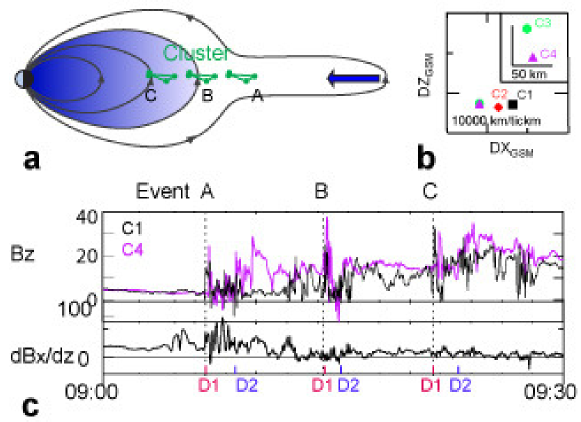

Fig. 3.7: (a) Illustration of Cluster location relative to the thin current sheet region. (b) Relative postion of the four Cluster spacecraft. (c) Bz from C1 and C4 showing the dipolarization and dBx/dBz calculated using data from C1 and C2 indicating the current sheet thickness during the three events indicated by A-C.

A unique constellation of *Cluster* (Fig. 3.7 b) for this event allowed to resolve for the first time the two different types of dipolarizations quantitatively at multi-scales: dipolarization due to Earthward moving rapid flux transport (D1) and dipolarization due to flux pileup (D2) as indicated in Fig. 3.7 c.

An important finding is also that a current sheet disturbance is induced by the first dipolarization pulse (D1). However, the resulting types of disturbances depend on the configuration of the current sheet: when the ambient current sheet is thin (Event A) a dipolarization pulse caused further thinning with a kink-mode like oscillation; when the ambient field is more dipolar as in Event B and C, the dipolarization is accompanied by disturbances in small scale vertical current sheets and signatures of flow braking.

Energetic electron acceleration in the near-Earth flow braking region: A key consequence of energy conversion during substorms is the acceleration of particles to energies much larger than their typical thermal energy. A fraction of energetic particles are accelerated around the reconnection X-line forming at $-30\ R_E \leq X \leq -20\ R_E$ in the magnetotail. However numerical simulations indicate that stronger acceleration occurs in the flow braking region around $X \sim -10\ R_E$, where fast earthward reconnection flows stop/divert and magnetic flux tubes dipolarize upon interaction with the Earth's dipole.

The braking region and associated electron acceleration has been studied using Cluster measurements of distribution functions, electric (E) and magnetic (B) fields, and waves. Two spacecraft (C3 and C4) were separated by a few electron inertial lengths, while being apart many ion inertial lengths (MHD scales) from the C2 and C1, allowing a multi-scale investigation of the braking region.

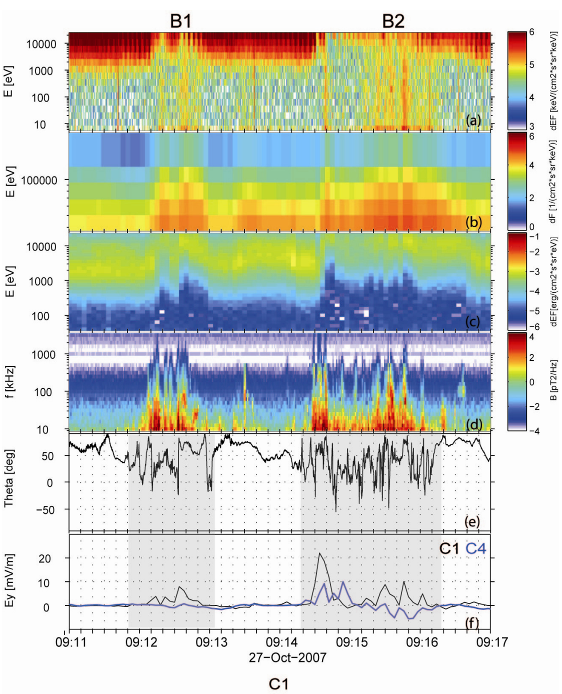

Fig. 3.8: Particles and fields data taken in the flow braking region by Cluster.

The braking region, gray shaded in Fig. 3.8, is characterized by strong fluctuations of B and E, strong waves, and particle energization. The braking of fast flows occurs at MHD-scales, as indicated by the drop of Ey between C1 and C4 during interval B2 when both are in the braking region. During B1, a comparison between C3 and C4 indicates that magnetic fluctuations are ion scale spatial structures which are edged by electron scale current layers. In the layers electrons are accelerated up to ~ 400 keV. Non-MHD electron acceleration in the braking region can be an important process of particle acceleration during substorms.

Magnetic energy inside Travelling Compression Regions (TCRs): TCRs are signatures of compressed magnetic field associated with magnetic reconnection. They are observed often in the course of magnetospheric substorms. Magnetotail reconnection leads to the acceleration of plasma, which propagates along the current sheet in opposite directions. These outflow regions compress the background magnetic field above and beyond them, leading to regions of compressed magnetic fields travelling together with the outflowing plasma, forming TCRs (see Fig. 3.9).

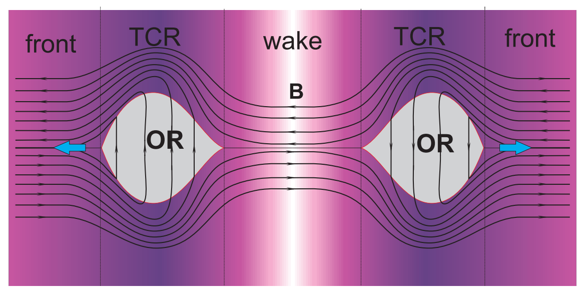

Fig. 3.9: Magnetic field line configuration and plasma outflow regions (OR) due to magnetic reconnection. The color code symbolizes the magnetic field strength.

Transport of the magnetic energy inside TCRs has been studied based on MHD theory and comparison with observations. Since magnetic reconnection leads to a reconfiguration of the magnetic field line topology, the magnetic field line density in the wake of the outflow region is decreased, and hence, also the magnetic field energy is decreased in this region. On the other hand, the appearance of reconnected field lines and the compression of field lines inside the TCR lead to an enhancement of the magnetic energy inside the TCR. It can be shown that the decrease of magnetic energy in the wake of the outflow region and the increase inside the TCR balance each other.

Using a time-dependent Petschek-type reconnection model for incompressible plasmas, it can also be shown that the magnetic energy inside the TCR is two times bigger than the kinetic energy inside the outflow region. Using the *Cluster* spacecraft separation, simultaneous observations inside and outside the TCR and plasma outflow regions confirmed this theoretical result.

Auroral Kilometric Radiation (AKR): AKR is the intense radio radiation emitted in the acceleration zone of auroras. The daily variations of the Terrestrial AKR have been detected in course of the AKR recorded by *STEREO-B/WAVES*. It has been found that the intensities of the AKR are modulated with a period of ~24 hours (see Fig. 3.10). The occurrence frequency of the AKR has been shown to be strongly dependent on the orientation of the rotating oblique magnetic dipole of the Earth relative to the Sun. AKR is found to occur more often and emit in a broader frequency range when the axis of the terrestrial magnetic dipole in the given hemisphere is oriented toward the nightside. We suggest that this effect is connected with diurnal changes of the ambient plasma density in the auroral region, caused by the varying solar illumination of the auroral ionosphere. The detected daily variations of the AKR look very similar to seasonal and solar cycle AKR variations.

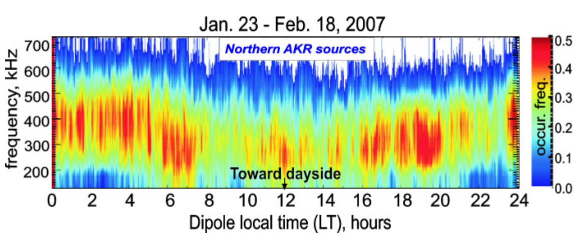

Fig. 3.10: Normalized occurrence frequency of the AKR as functions of the emission frequency and local time of the axis of the magnetic dipole.

Dust Kinetic Alfvén waves (DKAW): Theoretical studies on dispersion properties of Kinetic Alfvén waves and acoustic waves are perfomed in a plasma with charged dust grains. This is expected to have wide application not only in space plasma, such as in the intersteller medium, comets and planetary rings, but also in laboratory plasma including tokamaks. Kinetic Alfvén waves can be viewed as a modification of the fluid Alfvén waves resulting from the gyroradius effects. In the low frequency regime, the dynamics of Alfvén waves may be influenced due to the presence of dust grains and the circulation of their mass is essentially determined by their kinetic temperature. The charged dust grains couple to the plasma via the electric and magnetic fields and affect the spectrum of very low frequency Alfvén and magnetosonic waves through its inertia and cyclotron frequency. Polarization drift of dust grains and bending of magnetic field lines give rise to DKAWs. In this study plasma with a non-maxwellian distribution with high-energy tail, called Lorentzian plasma, is considered in a low plasma beta regime. Such distribution has been often observed in space. It is shown that Lorentzian plasma is able to support a number of DKAW and Dust Alfven Waves. The wave frequency decreases by increasing the nonthermality of the distribution. Parallel phase velocity and the grain's surface charge fluctuations are found to be unaffected with the form of the distribution, but at the same time we have seen its effectiveness in the perpendicular direction.

4 Solar System

IWF is engaged in many missions, experiments and corresponding data analysis addressing solar system phenomena. The physics of the Sun and the solar wind, its interaction with solar system bodies, and various kinds of planetary atmosphere/surface interactions are under investigation.

4.1 Sun & Solar Wind

Solar Type IV bursts: Solar type IV bursts were observed for the first time by the Giant Radio Telescope UTR-2 (Kharkov, Ukraine) at frequencies 10-30 MHz. Their overall storm durations vary from 1.5 hours to 6 hours or more and the corresponding radio emission fluxes exceed 10-100 times that of the quiet Sun at these frequencies. All Type IV (see Fig. 4.1) bursts have a fine structure in the form of fiber bursts in emission and absorption. Since the burst drift rates df/dt can be both positive and negative, this radio phenomenon may be interpreted as propagation of electron beams directed towards and away from the Sun.

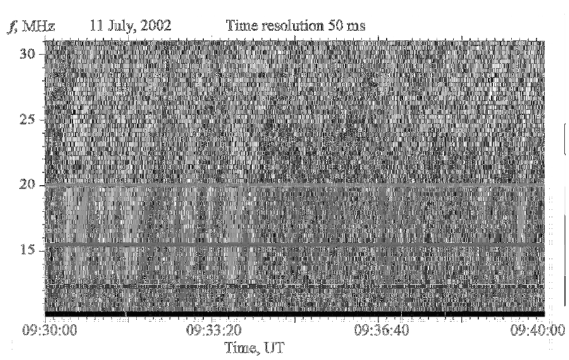

Fig. 4.1: A fragment of Type IV bursts as observed by UTR-2 (Kharkov, Ukraine). The train of fiber bursts in emission (white) is followed by fibers in absorption (black).

Fiber-bursts in absorption are a rather seldom phenomenon. They also seem connected to fast electrons, but their velocity distributions are such that electrons absorb effectively the background emission of Type IV bursts.

Bursts in emission exhibit a duration of about 6 s, in absorption up to 20-23 s, values are closely related to Type III radio burst duration. This means that electron beams responsible for fiber bursts do not change their spatial sizes in the course of propagation through the magnetoplasma close to the sun. Fiber bursts in emission are independent with regard to the position of a corresponding active region on the solar disk. However, this does not apply for bursts in absorption.

Images of solar eruptions in the heliosphere: Coronal mass ejections (CMEs) are massive expulsions of plasma and magnetic fields from the outer solar atmosphere into the interplanetary medium. Understanding their initiation and propagation is one of the main goals of the NASA *STEREO* mission, which consists of two spacecraft orbiting the Sun approximately at Earth distance, and increasingly separating themselves from Earth in longitude. Their unique "Heliospheric Imager" instruments are able to deliver images of solar eruptions all the way between the Sun and Earth orbit. Before the *STEREO* era this was a huge "blind" spot complicating the link between images of CMEs and the disturbances measured in the solar wind days later.

Using images of a CME which erupted in June 2008 (Fig. 4.2), it was possible for the first time to connect images of the CME with its in situ measured geometry. The CME morphology reflects its inclination to the ecliptic, which was proved by modelling the solar wind in situ data. Also its direction was shown to be predictable because four different techniques gave similar results to within a few degrees.

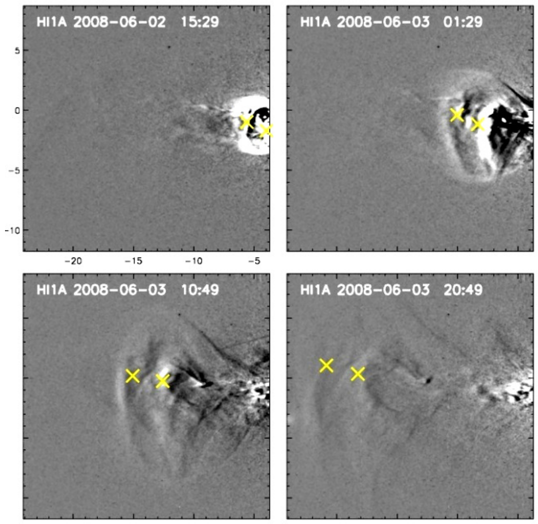

Fig. 4.2: Images of a coronal mass ejection at a distance of 0.1 to 0.35 AU from the Sun. Two Yellow X mark two distinct density fronts bracketing a magnetic flux rope.

The solar source of the magnetic cloud: Direct comparison between the activities near the sun and those in the Earth's magnetosphere have been perfomed to study the magnetic reconnection properties associate with a flare event and its consequences. A close correspondence between the magnetic flux reconnected in the flare on 2007 May 19 and the poloidal flux of the magnetic cloud observed at the Earth three days later were obtained. Evidence was shown that at least half of the magnetic flux of the ejected flux rope has been formed by magnetic reconnection during the flare/CME event.

Fig. 4.3 a) outlines the area that brightens up in the course of the flare. Two separating flare ribbons are observed that sweep areas of opposite magnetic polarity (cf. panel b, where the area contours are superimposed on the photospheric magnetogram of the flaring region). Panel c) shows the *GOES* 1-8 Å soft X-ray emission and the cumulated reconnection flux (positive, negative, and total). Panel d) gives a temporal comparison of the derived magnetic reconnection rate and the observed nonthermal hard X-ray flare emission, which is used as a proxy for the energy release rate in a flare. The first and highest peak in the nonthermal emission is clearly reflected in the magnetic reconnection rate.

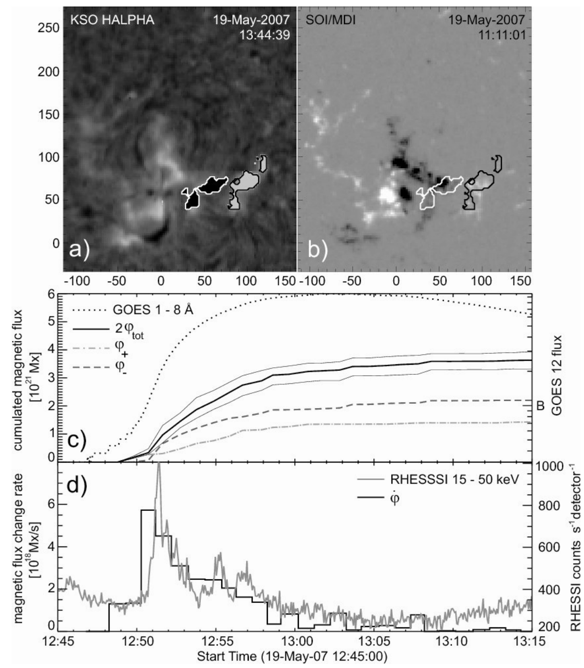

Fig. 4.3: Total flare area, soft X-ray flux, cumulated reconection flux, observed nonthermal emission, as well as derived magnetic reconnection rate in the two-ribbon flare on 2007 May 19.

Mirror mode structure in the solar wind: Venus Express, the first European spacecraft to Venus, is a planetary mission with its main scientific objective being a comprehensive investigation of the Venus atmosphere and plasma environment. Due to the absence of any significant intrinsic magnetic field, the interaction of the solar wind with Venus is limited to a rather small volume in space. Thus *Venus Express* spends its majority orbital time, typically 20 to 22 hours per day, in the solar wind and it provides us an excellent opportunity to study space weather effects and solar wind properties at 0.72 AU.

Magnetic holes in the solar wind with little or no directional change across the magnetic depression are related to mirror mode structures. Recent study has determined the characteristic size and shape of such mirror mode structures in the solar wind at 0.72 AU (see

Fig. 4.4). When examining the size and shape of isolated magnetic holes and train of holes separately, it is found that the isolated holes are slightly smaller in width and more elongated than the multiple holes. This observation suggests a particular evolutionary history of mirror mode structures in the solar wind in which multiple holes coalesce with time into isolated structures more elongated parallel to the magnetic field.

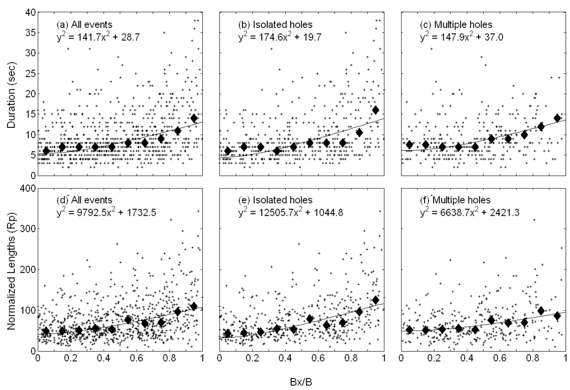

Fig. 4.4: Dependence of the normalized lengths on the orientation of the magnetic field to the solar wind flow.

4.2 Mercury

Mercury is the planet nearest to the Sun. It is a significantly dense planet, which suggests a large iron core and possesses a weak global magnetic field and a special exo-ionosphere.

BepiColombo

The ESA/JAXA mission *BepiColombo* to be launched in 2014 will explore the planet and its environment with two spacecraft simultaneously: the Japanese *Magnetospheric (MMO)* and ESA's *Planetary Orbiter (MPO)*.

IWF plays a major role in developing the magnetometers for the two spacecraft: it is leading the magnetometer investigation aboard the *MMO (MERMAG-M)* and is responsible for the overall technical management of the *MPO* magnetometer *(MERMAG-P)*. For *MPO,* IWF also leads the development of an ion mass spectrometer with imaging capability *(PICAM*, Fig. 4.5), which is part of the *SERENA* instrument suite, to explore the composition, structure, and dynamics of the exo-ionosphere.

In 2009, the Engineering-Qualification Model of *MERMAG-M* has already been delivered to JAXA and undergoes its test programme while the Structural-Thermal Models of the MPO instruments *MERMAG-P* and *PICAM* are being manufactured. The design of PICAM has further matured since the Preliminary Design Review, and thermally critical elements have been tested.

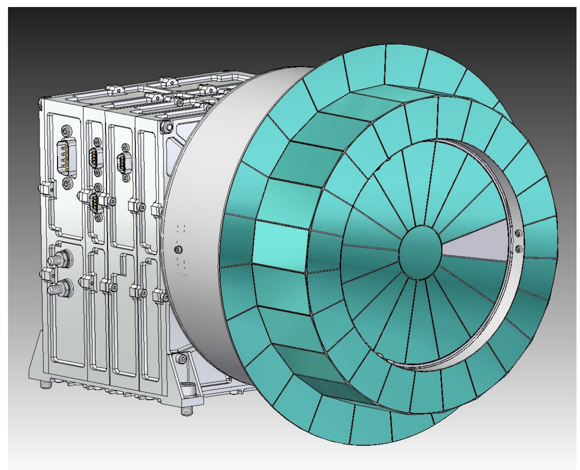

Fig. 4.5: The Planetary Ion Camera PICAM for MPO.

Physics

Mercury's exosphere: The exosphere model has been further developed by treating the ion-induced sputtering process, photon-stimulated desorption and micro-meteorite impact vaporization in a self-consistent way. Based on spectroscopic observations and available data, a global model for the surface mineralogy of Mercury was established and from that an average elemental composition of the surface was derived. For modeling purposes a group of end-member compositions were selected, that were then weighted to be consistent with observational constraints. By applying the surface mineralogical map the exosphere model shows that sputtering and micro-meteorite impact vaporization contribute only a small fraction of Mercury's exosphere, at least close to the surface. Because of the considerably larger scale height of atoms released via sputtering into the exosphere (see Fig. 4.6), sputtered atoms start to dominate the exosphere at altitudes exceeding around 1000 km.

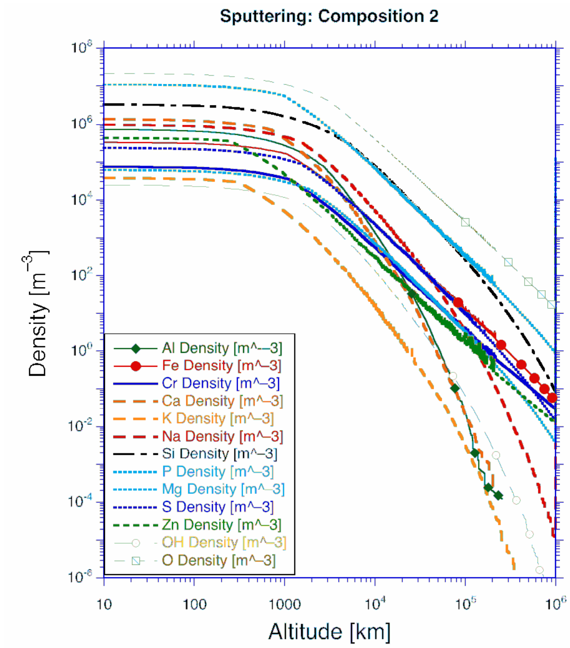

Fig. 4.6: Density profiles of atoms sputtered from Mercury's surface for a solar wind velocity of v_{SW} = 440 km/s, a flux hitting the surface of f_{SW} = 4.10 × 10^{12} m^{-2} s^{-1}, composed of 95 % protons and 5 % alpha particles.

4.3 Venus

Venus Express, ESA's first mission to Venus, was launched successfully on November 9, 2005 in Baikonur. IWF takes the lead on one of the seven payload instruments, the magnetometer *VEX-MAG*. The *Venus Express* magnetometer measures the magnetic field vector with a cadence of 128 Hz. It maps the magnetic properties in the magnetosheath, the magnetic barrier, the ionosphere, and the magnetotail. It is instrumented to identify the plasma boundaries between the various plasma regions and to study the solar wind and the solar wind interaction with Venus's atmosphere.

During 2009, *Venus Express* continued operating normally. The magnetometer remains ON during the whole year and collects both near Venus magnetic field data and interplanetary magnetic field data. Routine data processing and cleaning for the magnetic field measurements is undertaken for 1 Hz data. It shows that the software for data cleaning and processing are robust and error-free. All data are cleaned and issued to the science community. Further cleaning on 32 Hz data has been performed for part of the data. Data archiving on all available orbits has been performed and all data have been delivered to ESA's Planetary Science Archive.

The operation of the *Venus Express* spacecraft and its payload is under its first extension of the nominal mission until May 2009, further extension of the *Venus Express* mission till the end of 2012 has been proposed to and been agreed by ESA. Now that the mission is in long lasting mission extension era, further new manoeuvre using air-braking is under consideration.

Physics

The solar wind interacts directly with the atmosphere of Venus in contrast to the situation at the Earth where the internal magnetic field protects the upper atmosphere. Venus's atmosphere is partially shielded by an induced magnetic field, but the efficiendy of that shield is non understood. The effectiveness is expected to vary with solar activity but current understanding of the solar wind interaction with Venus is derived from measurements at solar maximum. *Venus Express*, with improved instrumentation, a different orbital trajectory, and observations at solar minimum, enables us to extend our understanding of the evolution of the Venus atmosphere caused by the solar wind interaction.

Disappearing induced magnetosphere: The solar wind interaction with a planetary atmosphere produces a magnetosphere-like structure near the planet whether or not the planet has an intrinsic global magnetic field. In the case of planets like Venus or Mars, which have no global intrinsic magnetic field but possess an atmosphere, a magnetosphere is induced in the highly conducting ionosphere by the time-varying magnetic field carried by the solar wind. The induced magnetosphere at Venus and Mars is almost a “permanent” feature of the solar wind interaction. However, recent *Venus Express* observations show the absence of the dayside part of the induced magnetosphere, when the interplanetary magnetic field (IMF) is nearly aligned with the solar wind flow. Using MHD simulations for this extreme IMF orientation, the global interaction of the solar wind with Venus is examined when the magnetic barrier disappears (see Fig. 4.7).

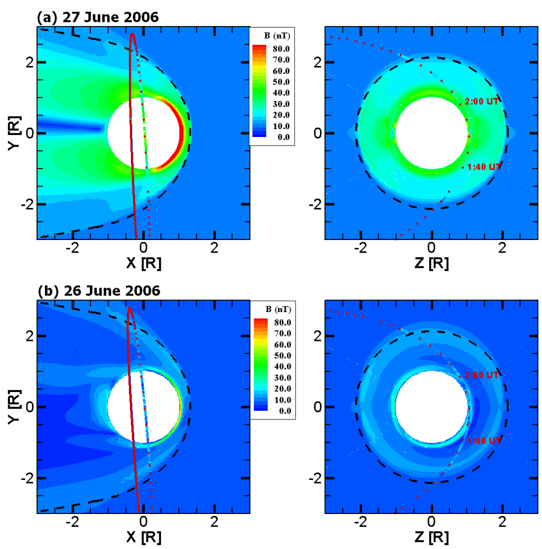

Fig. 4.7: MHD model calculated magnetic fields for cases with and without the induced magnetosphere

Furthermore, the atmospheric loss under this extreme situation is estimated. While this solar wind aligned IMF interaction with a planet case is presently rare, and even rarer over solar system history, it might be an appropriate analogue of the interaction of a stellar wind with a close-in exoplanet. Thus the solar wind interaction with Venus under this extreme condition might provide a natural laboratory for studying the evolution of the atmospheres of “hot Jupiters” as well as close-in “terrestrial” exo-planets.

Fig. 4.8a illustrates a typical example of the magnetic barrier (shadowed area) as seen in the time series magnetometer data, while in Fig. 4.8b there is no magnetic barrier.

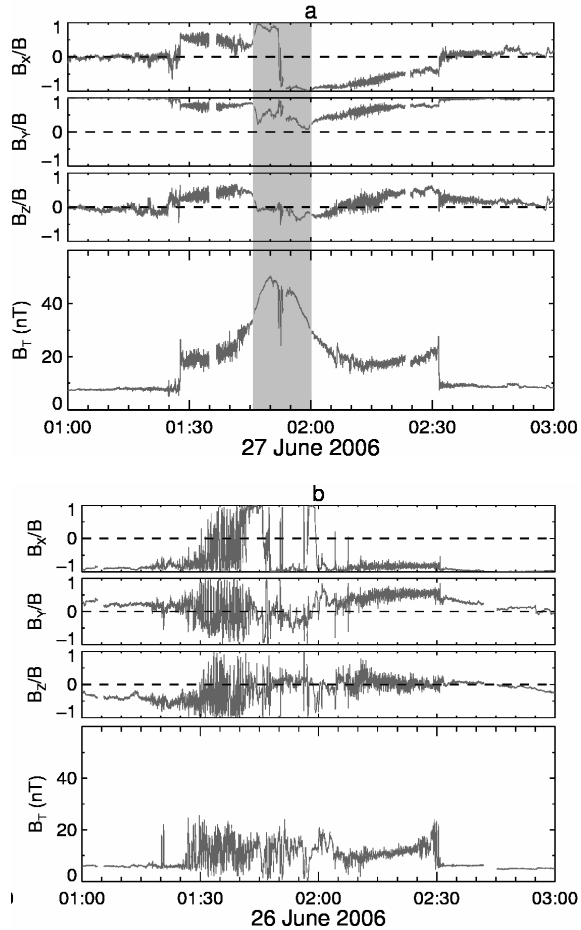

Fig. 4.8: Magnetic field measurements around periapsis for two consecutive passes of Venus Express on 26 and 27 June 2006.

Venus hot oxygen corona: Based on energy and mass dependent collision cross sections, the energy distributions of hot atomic oxygen created via dissociative recombination of O_2^+ were calculated in the daytime thermosphere by means of a new 3-D Monte Carlo test particle approach. The exosphere density is obtained from the corresponding energy density and angular distribution at 240 km altitude by using a test particle model which traces the trajectories of hot O atoms in the exosphere.

This study indicates that upon taking into account proper input parameters, the hot oxygen corona appears to be less dense than suggested by previous simulations. It appears that the resulting energy distribution functions are very sensitive to the size of the cross section for the collision of the hot atoms with the ambient gas: in case of a higher collision probability less particles will arrive at the exobase (see Fig. 4.9) and those entering the exosphere will exhibit on average smaller kinetic energies.

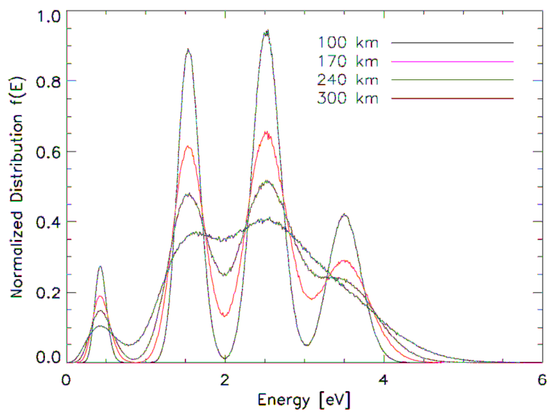

Fig. 4.9: Probability distribution function for the energy E of produced hot oxygen atoms at different altitudes above the surface of Venus.

Other properties of the collision cross sections, such as angular distribution, forward directed or isotropic scattering have important effects on the energy transfer and escape probabilities of the hot atoms. The efficiency of these parameters on corona density and escape of hot atoms will be further investigated.

The Kelvin-Helmholtz instability: The Kelvin-Helmholtz instability can arise at a boundary between two plasma layers due to a velocity shear across that boundary. A total variation diminishing (TVD) algorithm to solve the two-dimensional magnetohydrodynamic equations was implemented. Fig. 4.10 shows a density map of growing Kelvin-Helmholtz waves that are already forming vortices, resulting in a turbulent boundary. The upper fluid moves to the right, the lower to the left, and the density is shown in normalized units.

At Venus, there exist boundaries (e.g. the magnetic barrier boundary or the ionopause) at which waves and instabilities can develop, and indeed Pioneer Venus Orbiter and Venus Express observed wave-like and vortex-like structures at such boundaries.

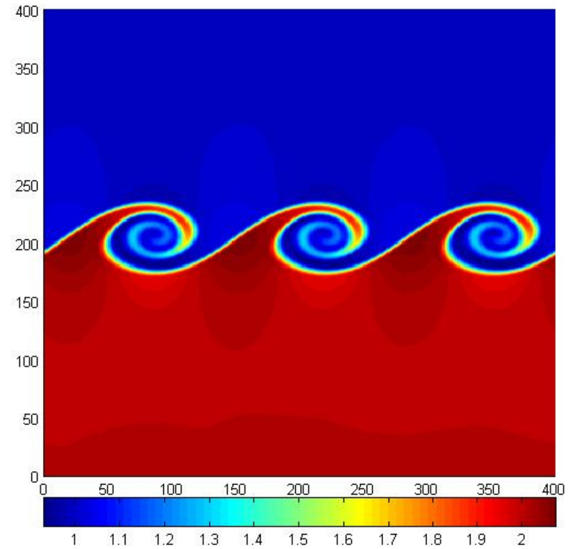

Fig. 4.10: Density map of Kelvin-Helmholtz waves already evolving into vortices. The lower fluid layer is denser than the upper one.

4.4 Jupiter

Jupiter, the largest planet of our solar system, is a strong source of radio emissions. Some of these are generated by an interaction with the satellite Io, others also by the interaction of the solar wind with the strong Jovian magnetic field.

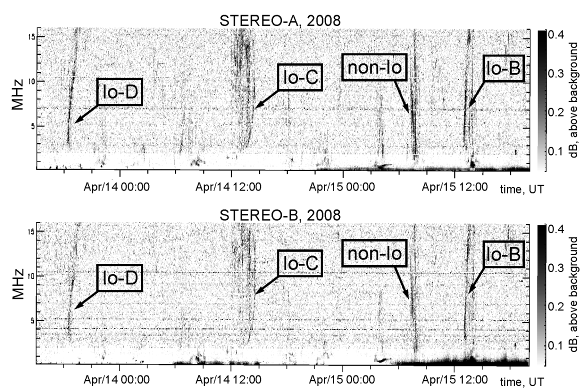

Fig. 4.11: Jovian arc-like radio emission observed by STEREO/WAVES

Jovian decametric radio emission: The *SWAVES* experiment onboard Solar TErrestrial RElations Observatory *(STEREO)*, mainly dedicated for measuring solar radio emission, also provides unique stereoscopic observations of the

Jovian radio emission in a frequency range from few kHz up to ~ 16 MHz. A large amount of the episodes of non-Io and Io controlled Jovian decametric radio emission (DAM) has been recorded (Fig. 4.11). The stereoscopic measurements facilitate unambiguous recognition of the DAM in the observed spectra as well as identification of its components by means of time delay between sequential detection of the radio bursts from the same source by two spacecraft separated in space. The data from the years 2007-2009 were analyzed in order to estimate the emission cone mantle width of the Io controlled DAM. In particular the previous findings that an averaged width of the Io-C and Io-D emission cone mantle is smaller than 1 degree were confirmed.

From *STEREO/WAVES* data a new periodicity in the non-Io DAM has been detected. The periodic radio bursts which recurred during several Jupiter's days with a period ~1.4% longer than the Jupiter System III rotation have been observed. All the bursts were detected within the same sector of Jovian Central Meridian Longitude (System III), between 300˚ and 60˚ of CML (System III), close to the region of the non-Io-C source.

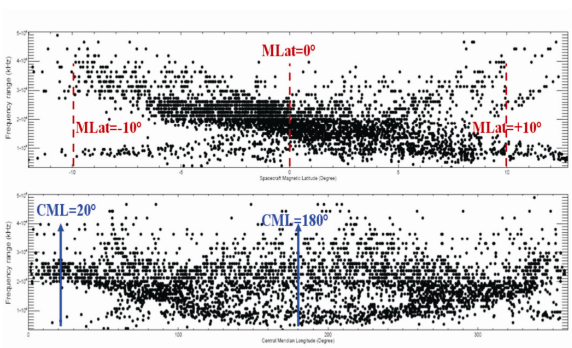

Fig. 4.12: Variation of the frequency of attenuation band versus magnetic latitude (upper panel) and CML (lower panel).

Radio HOM sounding of Io torus: The Jovian radio wave propagation through the Io plasma torus is studied using observations recorded during the Cassini Jupiter flyby. It is shown that the Jovian hectometric (HOM) spectrum is subject to emission extinction. A clear sinusoid band due to the torus effect appears on the HOM dynamic spectra. This attenuation band depends on the latitude of the spacecraft (see Fig. 4.12) with regard to the Jovian magnetic equator. In addition clear modulations are observed at two specific central meridian longitudes (CML) which are related to the position of the magnetic field axis associated to Northern (at CML ~ 180°) and Southern hemispheres (at CML ~ 20°).

Also Jovian HOM radio wave exhibits different spectral features when it propagates through the Io plasma torus. In particular there are three main cases: total emission extinction; partially decrease of the radiation; and an enhancement of the intensity before and after the attenuation of HOM emission. Such spectral effects are depending on the source location, the observer position (e.g. *Cassini*) with regard to the magnetic equator of the planet, and the electron density in the Io torus.

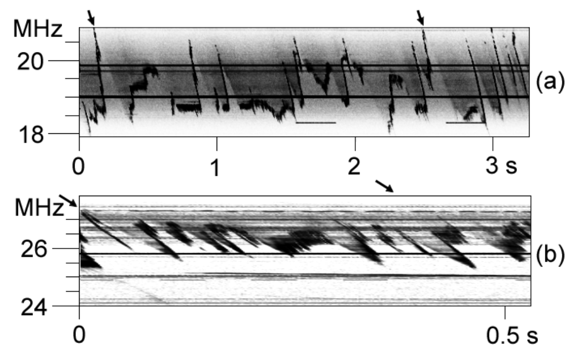

Fig. 4.13: The S-bursts and NB-events form the clear shadows (whitish) in the diffuse background emission (grey) analogously to barriers in flow with the arrowed directions: a) the low-resolution spectrum of 2002 August 2, 9:00 UT (UTR-2); b) the high-resolution spectrum of 2000 March 30, 12:15 UT (UTR-2).

Narrowband events and short bursts in Jupiter DAM emission: Narrow band (NB) events of Jovian decametric emission (DAM) appear in a dynamic spectrum as a stripe of radiation with a frequency band $\Delta f \leq 0.1$ MHz oscillating near a certain frequency $f \gg \Delta f$. Such an NB-stripe at frequency f forms distinctive temporal features in the dynamic spectrum ("hooks") with an amplitude of ~2 MHz and a cycle of ~0.05 s to 0.2 s (Fig. 4.13). There is a connection between NB-events and short (S-) bursts which are also narrow-band emissions, but with a fast frequency drift of ~−20 MHz/s.

The study of the S/NB-phenomenology showed the so-called shadow-effect, i.e. a radio source deactivates or blocks the upward flux of electrons. The “inter-shadowing” between various S-bursts or narrow band-oscillations can explain the various features in the dynamic spectra in form of S-burst groups and sinusoidal NB with positive frequency drifts, flag-like features, zigzag bursts, periodical points and streaks.

4.5 Saturn

In 2009 the Cassini orbiter has continued its investigation of the Saturnian system. The current mission phase is called extended mission or equinox mission. One highlight was this year’s solar equinox on August 11 when the sun was exactly located in Saturn’s equatorial plane.

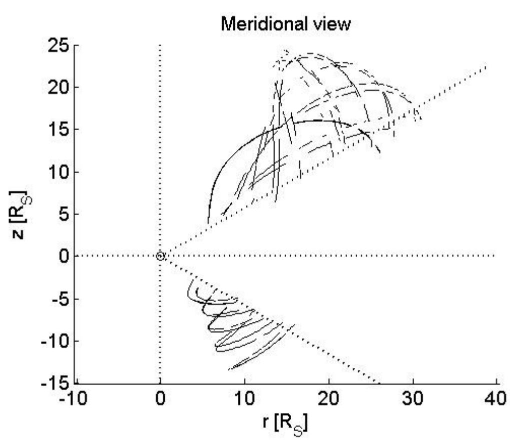

Fig. 4.14: Position of Cassini during occurrence of elliptically polarized SKR from September 2006 until May 2007 in meridional view. Saturn’s rotation axis, its equatorial plane, and the latitudes of ±30° are indicated by dotted lines.

Saturn Kilometric Radiation (SKR): A surprising discovery was the elliptical polarization of SKR observed by the *Radio and Plasma Wave Science Experiment (RPWS)*. Above 30° in observational latitude (see Fig. 4.14) a large amount of SKR is strongly elliptically polarized in marked contrast to previous observations from low latitudes from where SKR showed exclusively circular polarization. “Transitional” latitudes where circularly as well as elliptically polarized SKR co-exist were found (Fig. 4.15), and the elliptical component has an average degree of linear polarization of ~0.7. The reason for this peculiar behaviour is not yet clear, but it can be said that it has important implications for the cyclotron maser instability theory which describes the generation of auroral radio emissions.

Lightning on Saturn: In 2009 there has been significant lightning activity in Saturn’s atmosphere, monitored by the *RPWS* instrument via detection of the lightning radio signatures called SEDs (Saturn Electrostatic Discharges). In mid-January a lightning storm started and lasted for ~9 months making it the longest continuously observed lightning storm in the solar system. Like previous storms, this storm was again related to a prominent cloud feature in Saturn’s “storm alley” located at a latitude of 35° south.

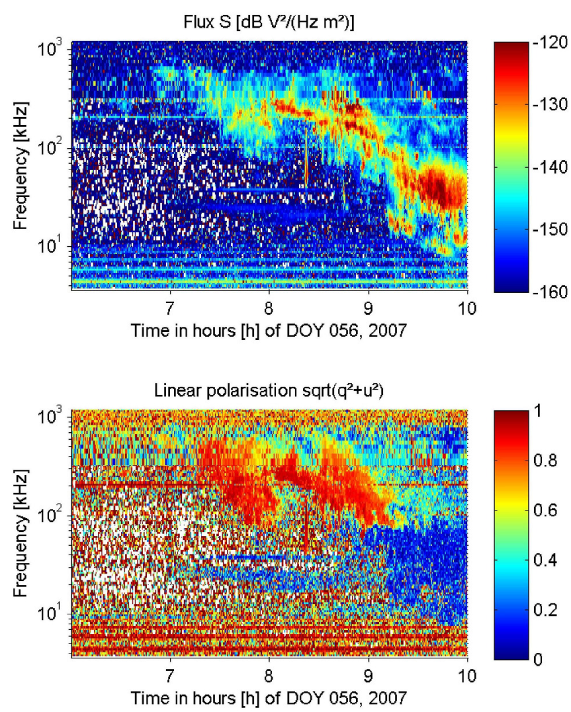

Fig. 4.15: Color-coded flux (upper panel) and linear polarization degree (lower panel) of SKR as a function of time and frequency. Cassini was located at a distance of 27 Saturn radii at a latitude of 40° north.

Acceleration of electrons from Titan's ionosphere: As Titan moves through the magnetic field of Saturn, an electric field is induced ($v \times B$) over the ionosphere. This electric field can accelerate a certain fraction of the electrons in the partially ionized plasma of Titan's ionosphere along the Kronian magnetic field. The power of the acceleration mechanism is estimated to be sufficiently large for the generation of SKR. This supports the interpretation of recent observational indications that Titan influences the occurrence of SKR.

4.6 Comets

Rosetta mission: ESA's *Rosetta* probe continues its journey to comet Churyumov-Gerasimenko, where it will arrive in 2014 to investigate the evolution of the comet during its approach to the Sun by an orbiter and a landing module which will be dropped onto its nucleus. Under the leadership of IWF an atomic force microscope *MIDAS* was built. Furthermore, the institute has built parts of the mass spectrometer *COSIMA*, parts of the two magnetometers *RPC-MAG* and *ROMAP* on both orbiter and lander, and participated in developing and building the penetrometer *MUPUS*, which will measure the heat conduction and elasticity of the cometary surface.

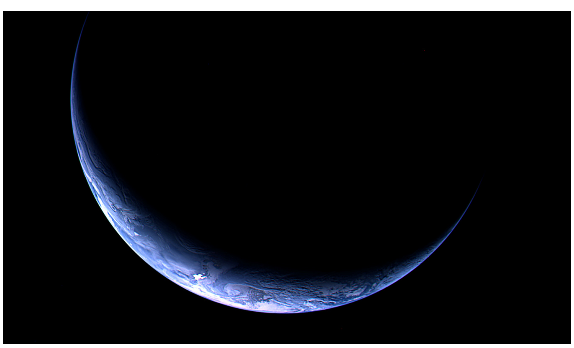

Fig. 4.16: Image of the Earth acquired with the OSIRIS narrow-angle camera from a distance of 633 000 km on 12 November 2009 at 13:28 CET.

On 13 November, after 5.5 years since its launch, *Rosetta* made its final Earth flyby, and is now headed for the outer part of the solar system. As a parting gift, a picture of the Earth, Fig. 4.16, was send down.

4.7 Exoplanets

CoRoT mission and physics: In 2009 CoRoT has discovered the first transiting rocky planet with a size of about 1.65 Earth radii and 5 Earth-masses around a Sun-like star. An atmospheric mass loss model was applied, which reproduces results that are comparable with the full hydrodynamic approach to 57 known transiting exoplanets. The results indicate that one can rule out that the first discovered transiting "Super-Earth" CoRoT-7b is a remnant of a thermally evaporated hot gas giant. Moreover it was found that only close-in low density "Hot Jupiters" could have lost up to 10 % of their initial mass. Due to the Roche lobe effect the mass loss from close-in gas giants can be very efficient at orbital distances ≤0.02 AU (Fig 4.17). Fast CMEs cannot be balanced by the planetary ion pressure at orbital distances between ~0.02- 0.1 AU. During such collisions, "Hot Jupiters" may experience high non-thermal escape rates. Future research on fast CME interaction with "Hot Jupiters" will help us to understand if such extreme events are behind the phenomenon that no gas giants with masses <1.0 M_{Jup} have been discovered so far at orbital distances ≤ 0.035 AU.

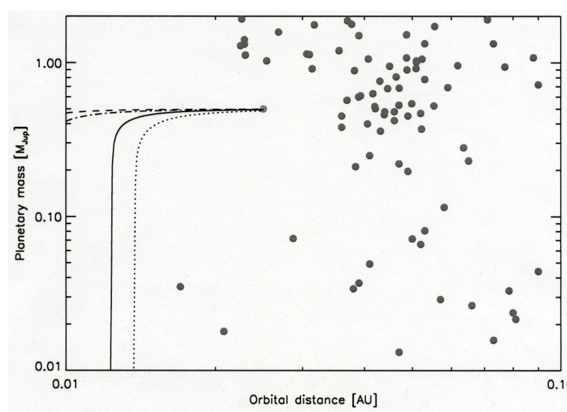

Fig 4.17: Final masses corresponding to thermal mass loss integrated over 4 Gyr for high (ρ = 1.24 g cm−3 dashed and dash-dotted lines) and low (ρ = 0.4 g cm−3 solid and dotted lines) density gas giants with initial masses of 0.5 MJup. Test planets with stronger mass loss have heating efficiencies of 25 %, instead of 10 %.

5 Engineering & Testing

Instruments onboard spacecraft are exposed to harsh environments, e.g., vacuum, large temperature ranges, radiation and high mechanical loads during launch. Furthermore, these instruments are expected to be highly reliable, providing full functionality over the entire mission time, which could last for even more than ten years.

5.1 Test Facilities

Vacuum Chambers

Small Size Vacuum Chamber: This is a manually controlled, cylindrical vacuum chamber (dimensions: 160 mm diameter, 300 mm length) for small electronic components or printed circuit boards. The system features a turbo molecular pump and an oil lubricated rotary vane forepump. A pressure level of 10^{-10} mbar can be achieved. Installed electrical feed-troughs are a 19-pin circular connector and 14 high voltage connectors.

Large Vacuum Chamber: This large size vacuum chamber features a stainless steel body and door with a horizontal cylindrical configuration, a vision panel, two turbo molecular pumps (500 litres/s each) and a dry scroll forepump (500 litres/min). A vacuum chamber pressure of 10^{-7} mbar can be achieved. The cylinder has a diameter of 650 mm and a length of 1650 mm. During shutdown the chamber is vented with nitrogen. Electrical feed-through to the experiments is provided by sub-D connectors as well as light wave conductor plugs. A target manipulator inside the chamber allows for computer-controlled rotation of the target around three mutually independent perpendicular axes. The vacuum chamber is enclosed by a permalloy layer for magnetic shielding. In order to enable the baking of structures and components to outgas volatile products and unwanted contaminations, the chamber is equipped with a heater placed symmetrically around the circumference.

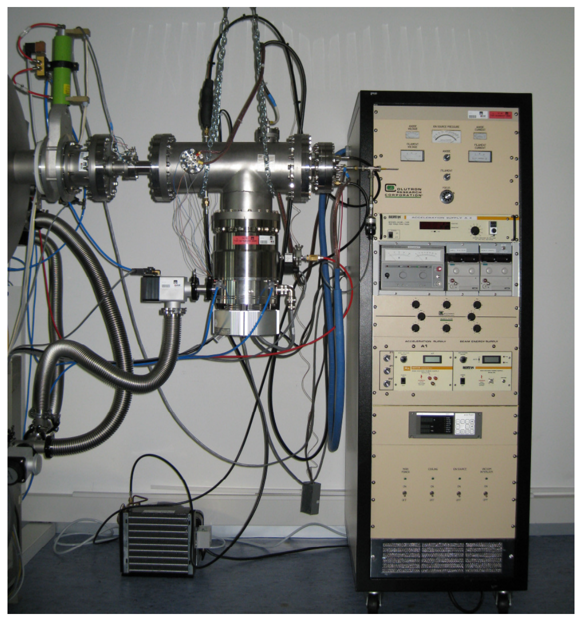

Fig. 5.1: Set-up for the ion gun connected to a vacuum chamber.

Thermal Vacuum Chamber: This thermal vacuum chamber is fitted with a turbo pumping system which allows quick changeover of components. The test chamber supports a temperature range between −90 °C up to +140 °C at a pressure level of 10^{-6} mbar. The vertically oriented cylindrical chamber allows a maximum experiment diameter of 410 mm and a maximum experiment height of 320 mm. The system is equipped with a turbo molecular pump, a dry scroll forepump (300 litres/min), and an ion getter pump (500 litres/s). A thermal plate is installed in the chamber which is used for the thermal cycling of electronic boxes and other components. Nitrogen is used for cooling and venting. Several electrical feed-throughs are installed (1 x 37-pin sub D connector, 1 x 61-pin sub D connector, 2 x Space Wire; 2 x 8-pin connectors).

Temperature Test Chamber: The temperature test chamber allows to verify the resistance of the electronic components and circuits to all temperature conditions that occur under natural conditions. The chamber has a test space of 190 litres and is equipped with a powerful 32-bit control and communication system. The temperature ranges from -40 °C to +180 °C.

Surface Laboratory Chamber: Dedicated to surface science research, LN2 cooled. Diameter 40 cm, height 40 cm with extensions to 80 and 120 cm. Two rotary vane pumps, one turbo-molecular pump, minimum pressure 10^{-5} mbar.

Sample chamber: Dedicated to the measurement of sample electrical permittivity. One rotary vane pump, minimum pressure 10^{-3} mbar, 8µ particle filter.

Other Facilities

Clean Bench: The laminar flow clean bench is a work bench which has its own filtered air supply. It provides product protection by ensuring that the work in the bench is exposed only to HEPA-filtered air (HEPA = High Efficiency Particulate Air). The clean bench is class B certified according to the EG-GMP regulations. The internal dimensions are 1.18 x 0.60 x 0.56 metres.

Vapour Phase Soldering Machine: The vapour phase soldering machine IBL SLC304 for in-line use is suitable for mid size volume production. The maximum board size is 340 x 300 x 80 mm. Vapour phase soldering, also known as VP soldering, or vapour phase reflow, is currently the most flexible, simplest and most reliable method of soldering. It is ideally suited for all types of surface mounted device (SMD) components and base materials. It allows processing of all components without the need of any complicated calculations or having to maintain temperature profiles.

Clean Room: Class 10000 (according to U.S. Federal Standard 209e) certified laboratory with a total area of 30 square metres. The laboratory is used for flight hardware assembling and testing and accommodates up to six engineers.

Penetrometry Test Stand: A penetrometry test facility designed to measure mechanical soil properties, like bearing strength, is available since January 2004.

UV Exposure Facility: The UV exposure facility is capable to produce radiation between 200-400 nm (UV-A, B, C).

Magnetometer Calibration: A three-layer magnetic shielding made from mu-metal is used for all basic magnetometer performance and calibration tests. The remaining DC field in the shielding is <10 nT and the remaining field noise is <2 pT/√Hz at 1 Hz. A special coil system allows the generation of a 3-D field vector with an absolute value of up to +/-30000 nT around the sensor under test.

Temperature Test Facility: With the IWF temperature test facility magnetic field sensors can be tested over an extended temperature range from -170 °C up to +220 °C in a low field and low noise environment. Liquid nitrogen is the base substance for the regulation which is accurate to +/-0.1°C. A magnetic field of up to +/-100000 nT can be applied to the sensor during the test cycles.

ERSA IR 550: This is an IR rework system. The safe and proven medium wavelength IR heating technology allows for uniform heat distribution from the top and bottom side across the printed circuit board (PCB) and component without the use of hot-air nozzles. The DynamicIR technology allows for maximum use of the system power via the dynamic control of the top (800 W / 60 mm x 60 mm) and bottom (800 W / 135 mm x 260 mm) IR heaters, depending on the actual temperature of the component, and where it is in the temperature profile. Combined with the enhanced capability to run an extended or flat peak, this instrument will produce the lowest temperature deltas across the component, and greatly reduces PCB warpage. Precise control of the temperature profile on the board and component is an advantage and the actual component temperature is acquired, through an infrared sensor, and is used as the primary control mechanism for the dynamic heating system.

ERSA PL 550: This is a precision placement system for positioning all types of fine pitch BGA/SMT components in sizes from 1 mm x 1 mm to 40 mm x 40 mm. The integrated high resolution CCD motorized zoom camera makes precise alignment of the components by means of two superimposed images extremely simple. The images can be brought into alignment through X / Y and rotational fine adjustments.

5.2 New Instruments

Coupled Dark State Magnetometer (CDSM): In 2006, IWF started a cooperation with the Graz University of Technology (TUG) in prototyping a Coupled Dark State Magnetometer (CDSM). IWF is responsible for the low frequency sensor electronics and the digital data processing.

The measuring of the Coupled Dark State Magnetometer is based on two-photon-spectroscopy of free alkali atoms using a multi chromatic laser field. The measurement of the scalar magnetic field is so reduced to a frequency measurement which can be converted to magnetic field by applying an appropriate form of the so called Breit-Rabi formula where only fundamental natural constants (such as Landé factors, Bohr's magneton and Planck's constant) are contained.

Fig. 5.2: CDSM test setup with control PC, electronics rack and magnetic shielding can.

In 2009, first closed loop CDSM measurements were performed with the help of the breadboard electronics and Field Programmable Gate Array logic developed at IWF (see test setup in Fig. 5.2). At the moment the noise performance is in the order of 70 pT/$\sqrt{}$Hz with a realistic goal of <10 pT/$\sqrt{}$Hz. This will be reached in early 2010 by a rather simple upgrade of the laser regime.

Melting Probe: The ESA contract for the construction of a so-called Melting Probe for the investigation of icy subsurface layers in the Mars polar areas and on the ice-covered planetary satellites (like e.g. Jupiter's moon Europa) was successfully completed. In the course of this study, two prototypes were built and tested; the second one is shown in Fig. 5.3. It has a square cross section of 4×4 cm and a pyramidal tip that can be heated with a power of up to 70 W. Supplementary heaters, activated on demand are attached to the side surfaces of the probe.

Experiments performed with both prototypes gave an improved understanding regarding the performance of a melting probe under low pressure conditions. The main result of the study is that there are two modes of behaviour when the probe starts to enter the ice surface in response to tip heating. If – for a given cross section – the heater power is below a certain threshold, no significant penetration into the ice surface is observed and a crater forms around the probe. Only for higher power values (in the case of our second prototype this would be around 70 – 90 W) and a reasonable weight over cross section ratio, penetration occurs approximately with the velocity predicted by a simple theoretical model including only ice sublimation. The main difficulty for a good performance in vacuum is, however, that there is usually a high thermal resistance at the interface between the tip and the adjacent ice. This has the consequence that the heat flow into the ice and thus the probe penetration is effectively blocked. This behaviour is quite different from terrestrial conditions, where the existence of the liquid phase always allows good thermal contact and thus a much faster melting penetration.

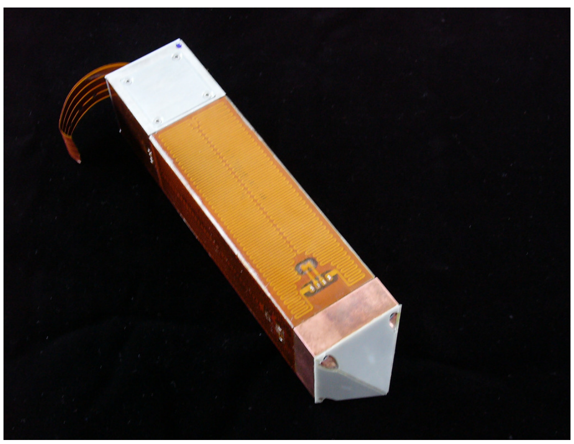

Fig. 5.3: Prototype-2 of the melting probe

Permittivity Probe: A working prototype of the HP3 Permittivity Probe (PP, see Fig. 5.4) was developed and is currently tested and calibrated. A full scale Laboratory Model will be implemented within the next year. This prototype will be proposed as part of the HP3 package to upcoming mission studies for Lunar and Martian landers. It is now also planned to propose an adapted version of PP for the upcoming 2016 mission to Mars for the Entry and Descent Module.

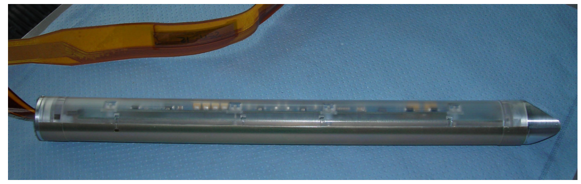

Fig. 5.4: The integrated Permittivity Probe at the HP3 PDR.

Thermal sensor for Regolith: Work with the procured sensors was continued. Two new, short and robust sensors (LNP02/LNP03, see Fig. 5.5) were included in the investigations. Measurements on granular material under pressure conditions varying from high vacuum up to normal air pressure were carried forward using all the sensors. The range of tested samples was expanded to materials like the JSC-1A lunar mare analog and higly porous lava. The data evaluation is currently concentrated to studies of sensor dependent effects found at pressures below 1mbar, where the thermal conductivity of a granular material like e.g. lunar regolith becomes extremely low.

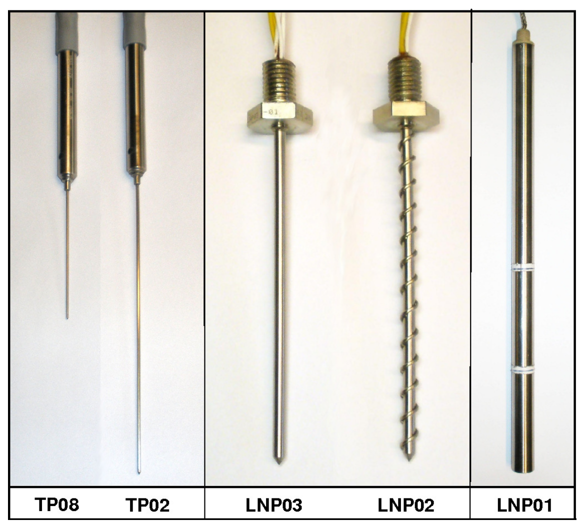

Fig. 5.5: The various thermal conductivity sensors used for the measurements.

6 Publications & Talks

6.1 Refereed Articles

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6.2 Proceedings and Book Chapters

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6.4 Invited Talks

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Besser, B.P.: Carl Weyprecht und das Internationale Polarjahr, Vortragsreihe zum Internationalen Polarjahr, Naturhistorisches Museum Wien, Wien, Apr 2009.

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Delva, M., C. Mazelle, C. Bertucci, M. Volwerk, T.L. Zhang, Z. Vörös: Proton cyclotron wave generation mechanisms upstream of Venus, IAGA 2009, Sopron, Aug 2009.

Fischer, G.: Lightning activity in the saturnian system, Japan Geosciences Union Meeting, Chiba City, Apr 2009.

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Krauss, S., W. Hausleitner, G. Stangl: Recent studies on the Earth ionosphere, IONO-Workshop 2009, Vienna, Jul 2009.

Magnes, W., M. Diaz Michelena: Future directions for sensors for space applications, IEEE, International Magnetics Conference, Sacramento, May 2009.

Nakamura, R.: Keynote, HighHeels@HighEnd, Graz, Oct 2009.

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Zhang, T.L.: Responses of the induced magnetosphere under extreme solar conditions, EGU General Assembly, Vienna, Apr 2009.

6.5 Oral presentations

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Bentley, M.S., N.I. Kömle, G. Kargl, E. Hütter: Fluidisation of cometary mantles, *EPSC 2009*, Potsdam, Sep 2009.

Besser, B.P.: Carl Weyprecht – Initiator der internationalen Polarforschung, *Vortragsreihe "Die Eroberung der Polarregionen"*, Urania Graz, Graz, May 2009

Besser, B.P.: Buchpräsentation "Österreichs Weg in den Weltraum", *Space:Art*, Herbstmesse Graz, Graz, Oct 2009

Besser, B.P., R. Huber: Der lange Weg zum 1. Internationalen Polarjahr. Carl Weyprecht und Hans Wilczek, *3. Österreichisches Polarsymposium*, Wien, Mar 2009.

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6.6 Posters

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7 Teaching & Workshops

7.1 Lecturing

IWF members are actively engaged in teaching at three universities. In summer 2009 and in the current winter term 2009/2010 the following lectures are given:

KFU Graz

Solar Wind – Magnetospheres – Ionospheres – Modelling (Biernat)

Special Lectures Theoretical Physics (Biernat):

- Plasma Physics – Basics
- Plasma Physics – Transport

Upper Atmosphere 1: Aeronomy of the Earth and the Planets (Biernat)

Upper Atmosphere 2: Earth and Planetary Ionospheres (Biernat)

Selected Topics in Physical Space Research (Biernat/Kargl)

Stellar Interactions With Exoplanets (Lammer)

Gravity, Shape, Seismics and Structure of the Earth (Kömle)

Selected Topics of Space Physics and Aeronomy: Ice and Fire in the Solar System (Kömle)

Introduction to Plasma Physics (Rucker)

Measuring Methods in Space Physics and Aeronomy (Kargl/Rucker)

Planetary Magnetospheres (Rucker)

Planetary Radio and Plasma Waves (Rucker)

TU Graz

Applied Space Physics 1 & 2 (Riedler)

High Frequency Techniques (Riedler)

Signal Processor Techniques (Magnes)

Antennas and Wave Propagation (Riedler et al.)

JKU Linz

Mathematics for Computer Scientists in Economics I & II (Hausleitner)

Advanced Course

The two-years post-graduate university course Space Sciences in cooperation with both KFU Graz and TU Graz leads to the internationally acknowledged Master of Science (MSc) "Space Sciences." Several members of IWF are lecturers of this inter-university course led by H.O. Rucker continued in 2009.

7.2 Theses

Besides lecturing, members of the institute are supervising Diploma, Master and Doctoral Theses. In 2009, the following theses have been completed:

Crailsheim, H.: Selection and testing of suitable electron sources for an Electron Drift Instrument, Diploma Thesis, Technische Universität Graz, 115 p., 2009.

Dusleag, A.: Observing variable stars and transiting exoplanets with single photon counting, Diploma Thesis, Technische Universität Graz, 70 p., 2009.

Hagen, C.: Development of a test bench for an ASIC based magnetometer, Diploma Thesis, Technische Universität Graz, 109 p., 2009.

Hasenleitner, D.: Numerical simulation of hydrogen blow-off: One dimensional considerations, Diploma Thesis, Karl-Franzens-Univeristät, 127 p., 2009.

Koechle, B.: Thermal conductivity of snow – Systematic comparison of measurement

methods, Diploma Thesis, Karl-Franzens-Universität Graz, 59 p., 2009.

Kogler, C.: Boundary detection in space plasmas within ESA's Cluster II mission, Diploma Thesis, Technische Universität Graz, 114 p., 2009.

Kucharski, D.: Spin parameters determination of LAGEOS-1 Satellite from laser observations, Doctoral Thesis, Warsaw University of Technology, 106 p., 2009.

Möstl, C.: Multi-spacecraft modeling of magnetic clouds, Doctoral Thesis, Karl-Franzens-Universität Graz, 134 p., 2009.

Schiffer, B.: Design of a sensor simulator for an active plasma probe, Diploma Thesis, Technische Universität Graz, 68 p., 2009.

Taubenschuss, U.: Ideal MHD simulation of magnetic clouds in the solar wind, Doctoral Thesis, Karl-Franzens-Universität Graz, 111 p., 2009.

Zechner, B.: In situ resource utilization for the supply of hydrogen on Mars, Master Thesis, Karl-Franzens-Universität, 75 p., 2009.

7.3 Meetings

An ISSI workshop on "Characterization and evolution of habitable exoplanets" was organized by Helmut Lammer.

In addition Boujada, Fischer, Kargl, Kaufmann, Khodachenko, Kömle, Lammer, Nakamura, Rucker, Volwerk and Zhang organized 13 sessions at international conferences.

7.4 Awards and Recognition

In 2009 Wolfgang Baumjohann was elected full member of the Austrian Academy of Sciences and was awarded an honorary professorship at the TU Graz (Fig. 7.7.1).

Fig. 7.7.1 The group of 4 award receivers at the TU Graz, where Baumjohann (2nd from right) received his " honorarprofessur" from the hands of Sünkel (most left).

Stefan Kiehas won the "Research Award for Simulation and Modeling, Styria 2009" in the category "Young Researchers."

Hans Sünkel was elected chairman of the Austrian Rectors' Conference.

Helmut O. Rucker was elected member of the Austrian National Committee of the International Astronomical Union.

7.5 Public Outreach

In honour of the International Year of Astronomy, there was a space exhibition "Im Feuer der Sonne" in the atrium of FZG, which attracted more than 1000 visitors. Also a lecture series was presented to the public with four evenings over the year: topics in astronomy and space physics were addressed by members of IWF.

During summer seven highschool students had the opportunity to perform an internship at IWF in the framework of "Generation Innovation" funded by the Austrian Research Promotion Agency (FFG). The intention was to find hidden talents and to spark incentives towards a scientific-technical career choice by integrating young people in current research activities. The report written by two of these students, Dino Mehic and Peter Temmel, were chosen to be among the best 20 out of 850, for which they were awarded a price by the

Bundesministerin for „Traffic, Innovation and Technology“ Doris Bures (see Fig. 7.1.2).

Fig. 7.1.2: Minister Bures with the prize winning students Temmel (supervisor Magnes, left) and Mehic (supervisor Fischer, right).

During the Graz “Herbstmesse” (autumn fair) IWF, together with other institutions participating in space physics, organized an exhibition “Faszination Weltraum.” During the week-long fair, members of IWF were present in the “IWF lounge” to answer questions and provide guided tours through the exhibition (see Fig. 7.1.3). Also a “Space-Art” evening was organized with art, a book presentation, a kosmonaut and a discussion about the universe.

Fig. 7.1.3: A model of the Cluster spacecraft at the “Herbstmesse” with next to it a description of CoRoT.

In October the “Theme of the Month” of the Austrian Academy of Sciences was “Astronomy,” with an interview given by Helmut O. Rucker and contributions on “Astronomy: Global cooperation for universal interest”, “Radioemissions: An important tool in astronomy and “A question of the atmosphere”, which appeared on the Academy’s homepage.

On 7 November the “Lange Nacht der Forschung” took place in Austria from sunset until midnight. On this occasion IWF organized an event together with the other institutes of FZG. 600 enthusiasts from eight to eighty years old visited our research center. The entertaining program of IWF included experiments, computer animations, movie shows, guided tours through the labs and an exhibition. One of the highlights this year was a remote controlled Mars Rover which could be driven over a Mars surface (Fig. 7.1.4), after a Mars-drivers licence was obtained.

Fig. 7.1.4: Miniature Mars Rover at the “Lange Nacht der Forschung.”

A delegation of the Chinese Academy of Sciences, including its president, visited IWF on 13 November (Fig. 7.1.5).

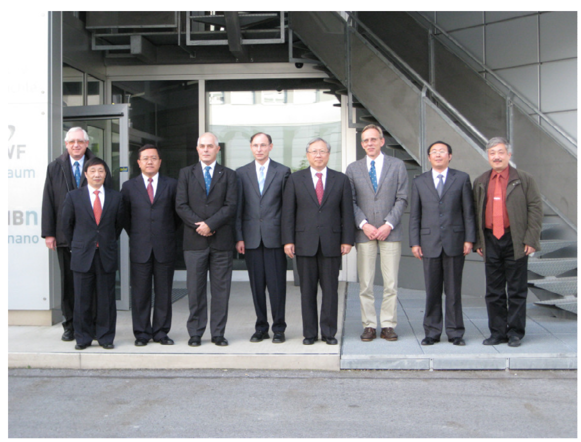

Fig. 7.1.5: Delegation of the Chinese Academy of Sciences.

Furthermore, several classes and groups visited IWF throughout the year. During guided tours through the laboratories, members of the institute have imparted the fascination of space to possible future scientists.

8 Personnel

Aichhorn, Cornelia, Dipl.-Ing. (S)
Amerstorfer, Ute, Dr. (P)
Aydogar, Özer, Dipl.-Ing. (E)
Baumjohann, Wolfgang, Prof. (E)
Bentley, Mark, Dr. (P)
Berghofer, Gerhard, Ing. (E)
Besser, Bruno P., Dr. (E)
Biernat, Helfried K., Prof. (P)
Boudjada, Mohammed Y., Dr. (P)
Crailsheim, Hartwig, Dipl.-Ing. (E)
Delva, Magda, Dr. (E)
Du, Jian, Dr. (E)
Eichelberger, Hans U., Dipl.-Ing. (E)
Fischer, David, Dipl.-Ing. (E)
Fischer, Georg, Dr. (P)
Flock, Barbara, Mag. (A)
Fremuth, Gerhard, Dipl.-Ing. (E)
Giner, Franz, Dipl.-Ing. (E)
Graf, Christian, Ing. (S)
Grill, Claudia (A)
Gröller, Hannes, MSc, (P)
Hagen, Christian, Dipl.-Ing. (E)
Hartl, Harald, Dr. (E)
Hasiba, Johann, Dipl.-Ing. (E)
Hausleitner, Walter, Dr. (S)
Höck, Eduard, Dipl.-Ing. (S)
Hütter, Erika, Mag. (P)
Ivanova, Victoria, Dr. (P)
Jernej, Irmgard, Ing. (E)
Jeszenszky, Harald, Dipl.-Ing. (E)
Kargl, Günter, Dr. (P)
Khodachenko, Maxim L., Dr. (P)
Kiehas, Stefan, Dr. (P)
Kirchner, Georg, Dr. (S)
Koidl, Franz, Ing. (S)
Kögler, Gerald (A)
Kömle, Norbert I., Univ.-Doz. (P)
Krauss, Sandro, Dipl.-Ing. (S)
Kürbisch, Christoph, Ing. (E)
Laky, Gunter, Dipl.-Ing. (E)
Lammer, Helmut, Dr. (P)
Lichtenegger, Herbert I.M., Dr. (E)
Macher, Wolfgang, Dr. (P)
Magnes, Werner, Dr. (E)
Maier Andrea, Dipl.-Ing. (S)
Miklenic, Christiane, Mag. (P)
Močnik, Karl, Dr. (E)
Möstl, Christian, Dr. (P)
Nakamura, Rumi, Dr. (P)
Neukirchner, Sonja, Ing. (E)
Nischelwitzer-Fennes, Ute, Ing. (E)
Ottacher, Harald, Dipl.-Ing. (E)
Panchenko, Mykhaylo, Dr. (P)
Panov, Evgeny, Dr. (E)
Pollinger, Andreas, Dipl.-Ing. (E)
Prattes, Gustav, Dipl.-Ing. (E)
Pregetter, Richard (E)
Retinò, Alessandro, Dr. (E)
Rieger, Sonja, Mag. (FH) (A)
Rucker, Helmut O., Prof. (P)
Sampl, Manfred, Dipl.-Ing. (P)
Scherf, Manuel, Mag. (P)
Scherr, Alexandra, Mag. (A, on maternity leave)
Schwingenschuh, Konrad, Dr. (E)
Stachel, Manfred, Dipl.-Ing. (A)
Stangl, Günter, Dr. (S, BEV)
Steller, Manfred B., Dr. (E)
Stiegler, Alexander, (P)
Stieninger, Reinhard, Ing. (S)
Stöckler, Robert, (P)
Sünkel, Hans, Prof. (S, BMWF)
Tatschl, Florian (E)
Topf, Florian, (P)
Torkar, Klaus M., Prof. (E)
Valavanoglou, Aris, Dipl.-Ing. (E)
Voller, Wolfgang G., Mag. (P)
Volwerk, Martin, Dr. (E)
Voronezhskaya, Anna (A)
Wallner, Robert, Ing. (E)
Weingrill, Jörg, Mag. (S)
Zaqarashvili, Teimuraz, Dr. (P)
Zehetleitner, Sigrid, Mag.(A)
Zhang, Tie-Long, Dr. (E)
Zieger, Bertalan, Dr. (E)

As of 31 December 2009
E: Experimental Space Research
P: Extraterrestrial Physics
S: Satellite Geodesy
A: Administration
BEV: Federal Office for Metrology and Surveying
BMWF: Federal Ministry for Science and Research