Space Research

2005 – 2006

in Switzerland

Artist's impression of INTEGRAL satellite

Schweizerische Akademie der Naturwissenschaften SANW
Académie suisse des sciences naturelles ASSN
Accademia svizzera di scienze naturali ASSN
Academia svizra da scienzas natüralas ASSN
Swiss Academy of Sciences SAS

Contents

1 Astrophysics

1.1 Cryogenic Receivers for the Herschel/HIFI Spectrometer

Institute: Institute of Astronomy, ETH Zurich
in cooperation with ESA

Principal Investigator: T. de Graauw.

Co-investigators:
T. Phillips (JPL)
J. Stutzki (Cologne)
A. O. Benz (ETH)

Method: Development and construction of own instruments (specify): Demonstration models and flight models of the Common Optics Assembly and Mixer Subassemblies. Low-noise and low-power amplifiers (InP HEMTs) and assembly box for intermediate frequency amplification.

Purpose of research: The Herschel Space Observatory will be located far away from Earth (Lagrangian point 2) and have the advantage of little heating by Earth. It will be ideal to search for water in star forming regions, protostellar envelopes and the rest of the universe. As a wide spectrum is completly covered at high spectral resolution for the first time Herschel has also the potential for discovering new molecules in a region of the spectrum that is inaccessible from the ground. The HIFI spectrometer is the larges of three instruments on board. It will investigate the frequency range from 0.5 to 1.9 THz (150 to 800 microns).
The focus in Switzerland is on water and other hydrides in the envelopes of very young stellar objects of both high and low mass (ETH Zurich). The main goal is to study the effects on water and other molecules produced by the irradiation of far UV and X-rays. These reactions can destroy or enhance water, depending on irradiation, temperature and density. A minor project is the investigation of water in the atmosphere of Mars, using the high spectral resolution of HIFI to derive the water distributiojn from the line profile (University of Bern).
The Swiss hardware contribution for the HIFI instrument grantees observing time on HERSCHEL (forth cornerstone of ESA). ETH Zurich has lead the production of some hardware and is now contributing to develop software.
The satellite will be located far away from Earth (Lagrangian point 2) and have the advantage of little heating by Earth. It will be ideal to search for water in star forming regions and protostellar envelopes and for new molecules in a region of the spectrum that is inaccessible from the ground.

Status: The hardware project is financed by a Swiss PRODEX contribution to HERSCHEL. The development of InP HEMT amplifiers at ETH (Microwave Lab.) is successfully completed. The flight hardware was produced by a collaboraton lead by Contraves and including Baumer Electronics, Frauenfeld. The IF2 Box containing amplifiers, isolators and other devices was tested.tested at ETH and delivered to the principal investigator (SRON) in February 2006. The Common Optics Assembly flight model has been constructed by HTS Wallisellen and delivered to SRON in June 2005, some last parts in December 2006. Phase C/D of our hardware contribution has finished in February 2006, when all the flight model and spares were delivered to SRON. No major problems have appeared.
At ETH Zurich we have started to develop software for the interface between the incoming data and the user. A PRODEX grant covers the development of pipline sofware, archive browsing tools

and quick-look checks of data. The software development is part of our preparation for the data analysis, starting after launch in 2008.

Publications:

1. P. Stäuber, S.D. Doty, E.F. van Dishoeck, J.K. Jorgensen and A.O. Benz): Influence of UV radiation from a massive YSO on the chemistry of its envelope. Astronomy and Astrophysics 425, 577 - 589 (2004)

2. P. Stäuber, S.D. Doty, E.F. van Dishoeck, J.K. Jorgensen, and A.O. Benz: X-ray Chemistry in the Envelopes Around Young Stellar Objects. Astronomy and Astrophysics 440, 949 - 966 (2005)

3. P. Stäuber, S.D. Doty, E.F. van Dishoeck, J.K. Jorgensen, and A.O. Benz: Water Destruction by X-rays in Young Stellar Objects. Astronomy and Astrophysics , in press (2006)

Abbreviations:

HIFI:	Heterodyne Instrument for the Far Infrared
HEMT:	High Electron Mobility Transistor
SRON:	Space Research Organization of the Netherlands

1.2 IBEX: Interstellar Boundary Explorer

Institute: Physikalisches Institut, University of Bern
In cooperation with:
Southwest Research Institute, Austin, TX, USA
Lockheed Martin Advanced Technology Laboratory, Palo Alto, CA, USA
University of New Hampshire, Durham, NH, USA
APL/JHU, Larel, MD, USA

Principal Investigator: D. McComas, Southwest Research Institute, Austin, TX, USA

Co-investigators:
P. Wurz
P. Bochsler
J. Scheer

Method: Instrument for low-energy ENAs

Purpose of research: The IBEX mission (NASA SMEX class) is designed to record energetic neutral atoms arriving from the interface of our heliosphere with the neighbouring interstellar medium in an energy range from 10 eV to 6 keV. This energy range is covered two sensors, IBEX-Lo measuring from 10 eV to 2 keV, and IBEX-Hi measuring from 500 eV to 6 keV. For each energy channel a full-sky map will be compiled, which will allow to study the physical processes at the interface between the heliosphere and the interstellar medium.

Status: At the University of Bern we built the IBEX-Lo prototype and fully calibrated this sensor to demonstrate to NASA that the mission goals can be realised with such instrumentation. Currently, we are manufacturing flight hardware for IBEX-Lo and IBEX-Hi. Upon completion of IBEX-Lo, it will be callibrated at the MEFISTO facility at the University of Bern. The launch of the IBEX mission is forseen for June 2008.

Publications:

1. D. McComas, F. Allegrini, P. Bochsler, M. Bzowski, M. Collier, H. Fahr, H. Fichtner, P. Frisch, H. Funsten, S. Fuselier, G. Gloeckler, M. Gruntman, V. Izmodenov, P. Knappenberger, M. Lee, S. Livi, D. Mitchell, E. Moebius, T. Moore, D. Reisenfeld, E. Roelof, N. Schwadron, M. Wieser, M. Witte, P. Wurz, and G. Zank, "The Interstellar Boundary Explorer (IBEX)," AIP Conference Proceedings 719 (2004) 162-181.

2. M. Wieser, P. Wurz, P. Bochsler, E. Moebius, J. Quinn, S.A. Fuselier, A. Ghielmetti, J. DeFazio, T.M. Stephen, and R.J. Nemanich, "NICE: An Instrument for Direct Mass spectrometric Measurement of Interstellar Neutral Gas," Meas. Sci. Technol. 16, (2005) 1667-1676.

3. J.A. Scheer, M. Wieser, P. Wurz, P. Bochsler, E. Hertzberg, S.A. Fuselier, F.A. Koeck, R.J. Nemanich, and M. Schleberger, "High Negative Ion Yield from Light Molecule Scattering," Nucl. Instr. Meth. B 230 (2005) 330-339.

Abbreviations:

AGN:	Active Galactic Nuclei
IUE:	International Ultraviolet Explorer
XTE:	X-ray Timing Explorer

1.3 Developments and Activities on COROT Data Processing and ground segment operations (follow-up)

Institute: Observatoire de Genève, Université de Genève
In cooperation with: CNES, ESA

Principal Investigator: A. Baglin, Meudon, France PI of the COROT mission SepInv D. Queloz, University Geneva, PI of the Swiss contribution

Co-investigators:
74 persons (amongst them D. Queloz)

Method: use of COROT satellite (built by CNES and ESA), Upgrade of the Coralie spectrograph (used for ground-based, follow-up observations)

Purpose of research: The main goals of the COROT mission are twofold: First the detection and the study of stars vibrations (stellar seismology), second, the search for extra-solar planets and more particularly the small rocky planets. Our main interest is the search for extra-solar planets. The detection of planets is made by the analysis of stellar light curves and in particular by the measurement of planet transits. The exciting aspects of COROT lie in its capability to detect a telluric planet on short orbit.
A very interesting prospect for each transit detected by COROT is the potential to combined it with accurate radial velocity measurements that may provides us with a direct measurement of planet density. Our special access to specialized spectrographs for that purpose provides us a good opportunity to measure the mass of the planet to be detected by COROT, and thus to get their density with possibly the first true identification of a rocky planet.
In general, the statistical analysis of COROT results should provide us with a wealth of new information for an improved understanding of planet formation and planet structures in a broad context.

Status: We are carrying on software developments and preparation of ground segment operations (follow-up) related to our participation to the COROT mission as member of the Extra-solar planet working group and COROT Co-I. Our activities include developments of algorithms for transit signal processing and modification of the CORALIE spectrograph to improve its sensitivity and its efficiency to carry out efficient ground follow-up and characterization of COROT detections.
We are working according to expected schedule. The contract to modify the CORALIE spectrograph is ongoing. Selected Swiss company is FISBA optic. Tasks of FISBA optics include the design and the manufacture of the optical fiber-link and cross-disperser mechanics.
Works on software and preparation of follow-up observations have been redirected to consider important changes in the data flow strategy resulting from the conclusion of our work on the end-to-end data simulator COROTLUX. We are consolidating the design of the software interactive tool. In parallel we are testing software prototypes of the data analysis package on various data coming from ground-based experiments as well as on HST.
Intensive preparation of ground-based follow-up is ongoing with our partners to have a working structure operational shortly after the launch.

Publications:

1. Pont, F., Moutou, C., Bouchy, F., Behrend, R., Mayor, M., Udry, S., Queloz, D., Santos, N., Melo, C. 2006, Radius and mass of a transiting M dwarf near the hydrogen-burning limit. OGLE-TR-123, Astronomy and Astrophysics, 447, 1035

2. 0.Pont, F., Bouchy, F., Melo, C., Santos, N. C., Mayor, M., Queloz, D., Udry, S. 2005, Doppler follow-up of OGLE planetary transit candidates in Carina, Astronomy and Astrophysics, 438, 1123

3. Pont, F., Melo, C. H. F., Bouchy, F., Udry, S., Queloz, D., Mayor, M., Santos, N. C. 2005, A planet-sized transiting star around OGLE-TR-122. Accurate mass and radius near the hydrogen-burning limit, Astronomy and Astrophysics, 433, L21

1.4 Star and Planet Formation in Taurus and Orion

Institute: Paul Scherrer Institute, Laboratory for Astrophysics
In cooperation with several institutes in Europe and the US

Principal Investigator: M. Güdel (PSI)

Co-investigators:
Taurus XMM-Newton project team (30 members), associated with:
CFHT near-IR survey team (PI institute: Grenoble)
and Spitzer Taurus survey team (PI institute: Caltech)

Method: XMM-Newton, Chandra,Spitzer Space Telescope, coordinated with ground-based instruments (CFHT)

Purpose of research: The Taurus Molecular Cloud (TMC) is the nearest galactic star-forming region and has become the standard testbed for star formation theory. Orion is the classic high-mass star formation region. We are conducting a comprehensive project to deeply study various facets of star and planet formation across all stages of evolution, in particular concentrating at the youngest stages that are accessible only by means of radio, millimeter, infrared, and X-ray observations. A central point in our project is a closer understanding of high-energy mechanisms in protostars and T Tauri stars associated with large-scale magnetic fields. Feedback mechanisms between X-ray radiation, disk ionization, accretion, and stellar spin-down will be studied. The project also addresses the formation of jets and outflows and the role that magnetic fields may play.

Status: We have conducted a large X-ray survey of the Taurus Molecular Cloud (TMC) using XMM-Newton. The total exposure time used for this project amounts to 1.3 Msec, spread over 28 different exposures. These observations have provided the first deep X-ray study of the TMC with X-ray detectors up to 10 keV in order to penetrate dense molecular clouds. The observations started in summer 2004.
This survey is complemented with the deepest optical and near-IR survey of the entire TMC, reaching sensitivity levels down to brown dwarf luminosities. These observations have been conducted, and follow-up campaigns have been approved (lead by Grenoble team).
A large project (about 130 hrs in the mid-IR) has been conducted to observe TMC with the Spitzer Infrared Telescope in a team effort related to the above two projects. Another 65 hours have been approved to extend the surveyed area to about 45 square degrees.
Several Chandra observations of jet-driving protostars in TMC and Orion have been obtained. They show X-ray detections that will help understand the disk structure and composition.
A large field around the Orion Nebula Cluster has been obtained in X-rays with XMM-Newton. The data sets are being analyzed in the context of relations between activity and rotation in young stars.
Among the key results of these studies are: - Discovery of a new type of X-ray spectrum, part of which may originate from shocks at the base of stellar jets. - A large sample of brown dwarfs in X-rays, characterizing their magnetic behavior coherently. - Discovery of a soft excess in accreting T Tau stars. - Characterisation of different X-ray emission levels for accreting and non-accreting T Tau stars. - The first high-resolution X-ray spectrum of an intermediate-mass Herbig star suggests an X-ray source at some distance from the star. - An ultraviolet outburst in a brown dwarf may be related to a sudden increase of the mass accretion rate. - A list of several dozen new candidate members of the Taurus Cloud.

Publications:

1. Güdel M., Padgett D.L., Dougados C. (2006): The Taurus Molecular Cloud: Multi-Wavelength Surveys with XMM-Newton, the Spitzer Space Telescope, and CFHT (refereed review). In: Protostars and Planets V, ed. B. Reipurth et al., in press

2. Güdel M., Briggs K.R., Arzner K., Audard M., Bouvier J., Feigelson E.D., Franciosini E., Glauser A., Grosso N., Micela G., Monin J.-L., Palla F., Pillitteri I., Rebull L., Scelsi L., Silva B., Skinner S.L., Stelzer B., Telleschi A. (2006): The XMM-Newton Extended Survey of the Taurus Molecular Cloud Astron. Astrophys., submitted (for special section in AA)

Abbreviations:

IR: Infrared spectral range
XMM-NEWTON: X-Ray Multi Mirror Mission (ESA Cornerstone)
TMC: Taurus Molecular Cloud

1.5 Particle acceleration and coronal heating

Institute: Paul Scherrer Institut, Laboratory for Astrophysics
In cooperation with: Columbia University, New York, USA
Osservatorio Astronomico Palermo
Technion, Israel

Principal Investigator: M. Güdel (PSI)

Co-investigators:

K. Arzner (PSI)
E. Behar (Technion)
R. Nordon (Technion)
M. Audard (Columbia)
B. Stelzer (Palermo)
G. Micela (Palermo)
L. Scelsi (Palermo)
E. Flaccomio (Palermo)
I. Pillitteri (Palermo)
M. Audard (Columbia Univ. , USA)
K. Briggs (PSI)

Method: XMM-Newton, Chandra, EUVE

Purpose of research: We study and simulate observational parameters that probe the role of particle acceleration and flare energy release in coronal heating of magnetically active stars. Differential emission measure distributions probe the distribution of plasma in temperature both during flares and during quiescence. Such distributions can be modeled by performing hydrodynamic computer simulations of flare-heated magnetic coronal loops. The accelerated electrons reveal themselves by their observable gyrosynchrotron emission at radio wavelengths. The correlation between radio and optical signatures and X-ray responses yields insight into the role of accelerated particles for coronal heating. Lastly, the statistical distribution of flares in energy as detected in long time series at EUV and X-ray wavelengths are key to our understanding of the importance of flare energy release for the coronal energy budget.

Status: Many data sets have been obtained with X-ray and EUV satellites and ground-based instruments.
We have studied several cases of the Neupert effect in coordinated X-ray and radio/optical data of large flares on active stars (i.e., a delay of the X-rays with respect to optical and radio signals), giving strong support for the chromospheric evaporation scenario and impulsive heating by accelerated coronal electrons. A recent observation of Proxima Centauri has given evidence for continual chromospheric evaporation. The increased steady luminosity appears to be a consequence of increased densities due to chromospheric evaporation.
We have studied the statistical distribution of flares on active stars in EUV and X-ray energy in order to determine the role of small-scale flares ("microflares") in the coronal energy budget. We have developed analytical methods to study this problem, but also follow conventional light curve analysis based on flare identification. We found that the flare energy distribution favors an important contribution of small flares to the overall coronal heating, to an extent that all of the coronal energy release could be due to flares.

Publications:

1. Arzner K., Güdel M (2004): Are Coronae of Magnetically Active Stars Heated by Flares? III. Analytical Distribution of Superimposed Flares Astrophys. J., 602, 363

2. Güdel M., Audard M., Reale F., Skinner S.L., Linsky J.L. (2004): Flares from Small to Large: X-Ray Spectroscopy of Proxima Centauri with XMM-Newton Astron. Astrophys., 416, 713

3. Stelzer B., Flaccomio E., Micela G., Pillitteri I., Briggs K.R., Audard, M., Güdel M. (2006): A Statistical Analysis of X-Ray Variability in Pre-Main Sequence Objects of the Taurus Molecular Cloud. Astron. Astrophys., submitted

Abbreviations:

EUVE: Extreme Ultraviolet Explorer (NASA)
XMM-NEWTON: X-Ray Multi Mirror Mission (ESA Cornerstone)

1.6 The Sun in Time

Institute: Paul Scherrer Institute, Laboratory for Astrophysics
In cooperation with:

Columbia University, New York, USA
Villanova University, Villanova, PA, USA
SRON, Utrecht, The Netherlands
Institut d'Estudis Espacials de Catalunya, Bellaterra, Spain

Principal Investigator: M. Güdel (PSI), E.F. Guinan (Villanova)

Co-investigators:

A. Telleschi (PSI), M. Audard (Columbia),
E.F. Guinan (Villanova)
I. Ribas (Bellaterra)

Method: XMM-Newton, Chandra, ROSAT, ASCA, BeppoSAX, FUSE)

Purpose of research: By studying a sample of stars with masses and sizes like the Sun's, but with different rotation periods and thus ages, we can infer the role of declining rotation periods on the operation of the magnetic dynamo in a star like the Sun. By implication, we derive information about the young Sun which are of prime importance for the formation of planetary atmospheres and the prebiotic Earth. We are particularly interested in the much-enhanced high-energy emission (UV, FUV, X-rays) of the young Sun. Satellite observations are required to get access to the relevant data. The project will indicate to what extent the overall magnetic activity level reflects in the coronal heating efficiency, the coronal temperature structuring, and coronal abundances.

Status: From the analysis of a comprehensive sample of ROSAT, ASCA, and EUVE data, we previously derived the temperature stratification of the coronal plasma at different stages of a solar-mass star's evolution. New observations now obtained with XMM-Newton and Chandra complement this picture.
Characteristic temperature decay laws suggest that coronal heating works with an increasing efficiency for increasing activity levels. X-ray spectroscopic means are now providing insight into coronal densities and composition. The coronal composition shows a marked evolution from an iron-poor to an iron-rich state.
The thermal structure in young solar analogs shows a peak around or slightly above 10 MK, with extensions up to 50 MK. The high-energy radiation of the young Sun was thus several orders of magnitude stronger, and also harder, which had consequences for the early planetary atmospheres and environments. It is speculated that the evaporation of a denser and warmer early atmosphere on Mars is related to the intense high-energy irradiation. The latter may also have been relevant for the dispersion of light elements from the young Mercury.

Publications:

1. Telleschi, A., Güdel, M., Briggs, K., Audard, M., Ness, J.-U., Skinner, S.L. (2005): Coronal Evolution of the Sun in Time: High-Resolution X-Ray Spectroscopy of Solar Analogs with Different Ages. Astrophys. J., 622, 653

2. Ribas, I., Guinan, E. F., Güdel, M. (2005): Evolution of Solar Magnetic Activity over Time and Effects on Planetary Atmospheres: I. High-Energy Irrandiances (0.1-170 nm). Astrophys. J., 622, 680

Abbreviations:

XMM-NEWTON: X-Ray Multi Mirror Mission (ESA Cornerstone)

1.7 X-Ray Spectroscopy with XMM-Newton and Chandra

Institute: Paul Scherrer Institute, Laboratory for Astrophysics
In cooperation with:
Columbia University, New York, USA
SRON, Utrecht, The Netherlands
University of Colorado, Boulder, USA

Principal Investigator: M. Güdel (PSI)

Co-investigators:
A. Telleschi (PSI)
K. Briggs (PSI)
M. Audard (Columbia)
A. J. Raassen (SRON/Utrecht)
S. L. Skinner (Univ. of Colorado)

Method: XMM-Newton, Chandra, coordinated with ground-based instruments (VLA, VLBA))

Purpose of research: XMM-Newton and Chandra provide for the first time high-resolution X-ray spectroscopy of a large number of cosmic sources. X-ray spectra give unique access to the temperature statification of sources, their density, and their composition. We are systematically studying these properties from X-ray spectroscopy of numerous magnetically active stars, obtained either within the guaranteed time section of XMM-Newton, or within the guest observer programs of XMM-Newton and Chandra. X-ray spectroscopy of hot stars provides a new window to the composition and dynamics of stellar winds.

Status: Using X-ray lines from various chemical elements, we study effects in the elemental composition of stellar atmospheres, their densities, temperature structure, and opacity. A large "guaranteed project" from XMM-Newton, obtained between 2000-2002, forms the basis of our comprehensive investigation, complemented by several more recent XMM-Newton and Chandra observations.
Systematic effects in the coronal composition have been investigated with XMM-Newton on giant stars, on solar analogs, and on pre-main sequence stars, finding various types of First-Ionization Potential Effects (some at variance with those known from the Sun).
We have studied coronal electron densities in a large sample of stars in order to find systematic trends. The results were used to infer general models on coronal structure. We studied densities on accreting T Tau stars for which high electron densities have been claimed before. These are

not confirmed on several objects, questioning the previously proposed accretion shock scenario for X-ray production.
A study of an outbursting EXor variable (a young, strongly accreting star) has shown a softening of the spectrum during outburst. We have speculated that increased accretion dampens the production of hot magnetic loop systems.
The spectrum of FU Ori, prototype of another outbursting stellar class, shows two unrelated components, a very soft and a strongly absorbed very hard component. Several models on the location of the sources in this star-disk system have been discussed.

Publications:

1. Audard, M., Güdel M., Skinner S.L., Briggs K.R., Walter F.M., Stringfellow G., Hamilton R.T., Guinan E.F. (2005): X-Ray Spectral Variability during an Outburst in V1118 Ori.Astrophys. J., 635, L81

2. Suh J.A., Audard M., Güdel M., Paerels, F.B.S. (2005): An XMM-Newton Study of the Coronae of sigma2 Coronae Borealis. Astrophys. J., 630, 1074

3. Skinner S.L., Briggs K.R., Güdel M. (2006): The Unusual X-Ray Spectrum of FU Orionis. Astrophys. J., 643, 995

Abbreviations:

XMM-NEWTON: X-Ray Multi Mirror Mission (ESA Cornerstone)

1.8 High energy emission from active galactic nuclei (AGN).

Institute: ISDC

Principal Investigator: T. Courvoisier

Co-investigators:

M. Tuerler
M. Chernyakova
S. Soldi
C. Steiner
R. Walter

Method: Development and construction of own instruments:IUE, Beppo-SAX, Rossi-XTE, INTEGRAL.)

Purpose of research: We use data from a large set of instruments on satellites to observe active galactic nuclei.This allows us to probe the emission in regions of the electro-magnetic spectrum that cannot be observed from the ground. Over the last years we have concentrated on UV, X-ray and gamma ray observations. Our aim is to understand the radiation processes and beyond this to understand how the energy that is liberated as matter falls in the central supermassive black holes is transformed in radiation. For one part we use archival data and for the other we perform observations now. Our findings include a description of the events that make the observed ultraviolet variations in a sample of objects observed during 17 years, a comparative study of different types of AGN that allowed us to find differences that cannot be due solely to orientation effects and observations of the spectral region where most of the energy is radiated.

Status: This project has been going on for several years. The basics elements of the physics of AGN has been understood shortly after their discovery in the 1960s and 70's. The next steps have proved very difficult and elusive. Although a large effort went over many years in trying to model the accretion processes with accretion disks, the models and observations have not yet been brought in agreement. We are therefore tryin to explore some further avenues that do not rely on the existence of classical accretion disks. We are also exploring the parallels between the supermassive black holes at the centre of galaxies and those, much lighter, that are observed within our Galaxy.

Publications:

1. Tuerler M., Courvoisier T.J.-L., Chaty S., Fuchs Y., 2004, A+A 415, L35

2. Courvoisier T.J.-L. and Turler M., 2005, A+A 444, 417

3. Favre et al. 2005, A+A 443, 451

Abbreviations:

AGN:	Active Galactic Nuclei
IUE:	International Ultraviolet Explorer
XTE:	X-ray Timing Explorer

1.9 Extended sources observed with INTEGRAL

Principal Investigator: T. Courvoisier

Co-investigators:
D. Eckert
A. Neronov

Method: Research based on existing instuments: INTEGRAL - Satellite

Purpose of research: We can now start to use INTEGRAL also to study sources that are slightly extended when compared with the point spread function. In this frame we develop a methodolgy to extract the flux from the coded mask image data.
This method is applied to the study of clusters of galaxies. These objects have indeed be shown in recent years to have very complexe structures that form shocks in which non thermal particles can be accelerated. This would then give rise to non thermal emission at energies higher than those characteristic of the hot (few keV) gas.

Status: This project has started in the last year with the development of the method. We expect to obtain the first quantitative results in 2007.

Publications:

1. We do not yet have published results. The first paper is in preparation

1.10 POLAR. Measuring for the first time polarization in Gamma Ray Bursts

Institute: ISDC
DPNC
PSI
In cooperation with:
LAPP Annecy
LIP lisbon

Principal Investigator: N. Produit

Co-investigators:
T. Courvoisier
M. Pohl
W. Hajdas

Method: Development and construction of own instruments: POLAR detector on Chinese or Indian platform)

Purpose of research: POLAR is a compact detector to be flown on-board of a small satellite and dedicated to measure polarization of Gamma Ray Bursts in hard X-ray ener- gies. Gamma Ray Bursts (GRB) belong to the most important subjects of the contemporary astrophysics. Even 35 years after their discovery, they remain a challenge for both experimenters and theoreticians. Yet our knowledge is already adequate to bond them with explosive births of the black holes and recognize their cosmological origin. Our design goals comprise a wide viewing angle and an energy range from few tens up to several hundred keV, in order to reach a polarization detection capability around 10

Status: Currently we are performing a series of the laboratory tests checking detec- tor parameters and verifying simulation results. For this purpose a small 8x8 detector array is constructed and exposed with polarized gamma rays from radioactive sources. In the next step the detector will be tested with the po- larized X-rays from the synchrotron light sources to check the low energy efficiency. We are almost ready to start ordering material to start the building of a space qualification detector.

Publications:

1. N. Produit et al. NUCL.INSTRUM.METH.A 550 616 (2005)

2. C. Wigger et al. ApJ 613:1088-1100, 2004

3. W. Hajdas, SPIE 2006 conference proceedings.

Abbreviations:

GRB:	Gamma Ray Bursts
DPNC:	Département de physique nucléaire et corpusculaire
ISDC:	INTEGRAL Science data centre
PSI:	Paul Scherrer Institute
LAPP:	Laboratoire d’Annecy pour la physique des particules
LIP:	Labóratorio de Instrumentação e Física Experimental de Partículas

1.11 Software development for ESA's Planck mission

Institute: ISDC/GADC
In cooperation with LFI DPC in Trieste, Italy

Principal Investigator: T. Courvoisier

Co-investigators:
M. Tuerler
R. Rohlfs
N. Morisset
M. Meharga
R. Walter
M. Beck

Method: Data processing software development

Purpose of research: ESA's Planck mission is foreseen to be launched in 2008 by an Ariane 5 rocket. Planck will scan the complete sky to produce full-sky images in the radio to sub-millimeter range. The main scientific goal is the study of the cosmic microwave background radiation emitted about 400'000 years after the Big Bang and which is the key to derive the cosmological parameters describing the history and fate of the Universe. The other scientific goals of the mission are the study of the foreground objects, in particular galaxy clusters, active galactic nuclei and our own Galaxy, the Milky Way.
The Planck payload is composed of two instruments: the low-frequency instrument (LFI) and the high-frequency instrument (HFI). The LFI data processing centre (DPC) is located in Trieste, Italy and the HFI DPC in Paris, France.
The INTEGRAL Science Data Centre (ISDC) is responsible to develop the software for the Level 1 processing of the LFI data. During operations, this software will run at the DPC of Trieste. Level 1 processing consists in retrieving daily the available scientific and housekeeping data of the instrument. It shall then sort these data by type (detector, observing mode, etc.) as well as in time; attach the spacecraft attitude information from auxiliary files; flag the data according to some criteria and archive the resulting time ordered data (TOD). The TOD will then be used by the Level 2 processing to produce maps of the sky at different frequencies. The ISDC is also responsible to provide tools to display the data as they arrive and are processed. These tools will be used both at the mission operation centre (MOC) in Garching, Germany and at the DPC in Trieste.

Status: A first instance of the LFI Level 1 software with most processing and display functionalities is already built and will be heavily used in 2006 for the tests of the radiometer array assembly (RAA).
The architecture for the operational model to be used during the actual operations of Planck has been defined and was reviewed on 15 September 2005. It includes in addition the treatment of the auxiliary files (attitude, time correlation, etc.), checking of out-of-limit data, data flagging and the final way to retrieve the data from the MOC including checking for completeness, avoiding duplications, etc. It is also foreseen to be able to ingest the final TOD data into a database rather than in FITS files.
All these new developments are to be ready for the system verification tests (SVT) foreseen for early 2007.

Publications:

1. Planck LFI Data Processing During Instrument Calibration Tests In: Proceedings of ADASS XV (2-5 October 2005) Morisset, N.; Rohlfs, R.; Türler, M.; et al., 2006, ASP Conf. Series Vol.351, p.287

2. From INTEGRAL to Planck: Geneva's contribution to the LFI data processing In: Proceedings of ADASS XIII (12-15 October, 2003) Türler, M.; Rohlfs, R.; Morisset, N.; Meharga, M. T.; Courvoisier, T. J.-L.; Walter, R., 2004, ASP Conf. Series Vol.314, p.440

Abbreviations:

ADASS:	Astronomical Data Analysis Software and Systems
DPC:	Data Processing Centre
ESA:	European Space Agency
GADC:	Geneva Astronomical Data Centre
ISDC:	INTEGRAL Science Data Centre
HFI:	High Frequency Instrument
LFI:	Low Frequency Instrument
MOC:	Mission Operation Centre
RAA:	Radiometer Array Assembly
SVT:	System Verification Tests
TOD:	Time Ordered Data

1.12 Gaia CU7 Variability Processing

Institute: Geneva Observatory/ISDC

Principal Investigator: Dr Laurent Eyer

Co-investigators:
Prof. Michel Grenon
Prof. Gilbert Burki

Method: Satellite

Purpose of research: The Gaia mission is a unique and major mission of the ESA astrophysics program, with a launch foreseen in 2011. This mission will repeatedly collect information on one billion stars and will provide a map of our Galaxy in the 3 space dimensions as well as the velocity field for a large fraction of the observed objects. This mission will allow to decipher the structure and evolution of our Galaxy, so that to uncover its formation and history. However the impact of the mission is going well beyond the structure of the Galaxy, it will impact in a major way topics related to asteroids, stellar evolution and variability, binary stars, exo-planets, general relativity and cosmology.
Very early in the mission preparation, the data processing of the incoming data from the satellite has been recognized to be a major challenge, therefore a structuration of this task has been done. The work at the highest level has been shared between grouped in Coordination Units (CU), following natural divisions of thematics.
As the satellite is measuring repeatedly the source light and spectra, one Coordination Unit has been created to set up a highly automated pipeline for the processing of time series. The Gaia Coordination Unit for Variability Processing (CU7) is in charge of characterizing the photometric and spectral variability of the observed sources. This includes deriving statistical parameters, searching for periods and fitting models to the data, classifying the variable objects. Furthermore specific analysis of particular types will be carried out at a high detail level, depending on their scientific importance.

Status: In order to structure the effort around the Gaia data processing, a committee, the DACC (Data Analysis Coordination Committee), has been set up by the GST (Gaia Science Team). It was charged with defining and putting into place the Gaia Data Processing and Analysis Consortium (GDPAC). The DPAC has to conceive, implement and operate the Gaia data processing system. In this structure, CU7 (variability processing) is one of the Coordination Unit created by DACC.
Following ECSS standard a work breakdown has been done for CU7, interests have been identified across Europe and tasks have been assigned to groups in Universities. A planning of the tasks has been done. A DPC (Data Processing Centre) is now being setup in Geneva in order to cope with the tasks related to the CU7. The CU7 collaborators will have to develop software, that will be later integrated in the DPC, so that running algorithms will be fully operational when the data will start flowing.

Publications:

1. Eyer, Mignard, 2005, "Rate of correct detection of periodic signal with the Gaia satellite", Monthly Notices of the Royal Astronomical Society 361, 1136

2. Eyer, 2005, "Variability Analysis: Detection and Classification", ESA SP-576, 513

3. Eyer, 2006, "Astronomical Databases, Space Photometry and Time Series Analysis: Open Questions", ASPCS 349, 15

Abbreviations:

IR: Infrared spectral range
XMM-NEWTON: X-Ray Multi Mirror Mission (ESA Cornerstone)
TMC: Taurus Molecular Cloud

2 Atmosphere

2.1 TerraSAR-X: Geometric Error Budget Analysis and Estimation and Correction of Atmospheric Path Delay in Radar Signal Propagation

Institute: Remote Sensing Laboratories (RSL)
University of Zurich-Irchel
Winterthurerstrasse 190
CH-8057 Zurich

In cooperation with German Aerospace Center (DLR)
Principal Investigator: Prof. Dr. D. Nuesch

Co-investigators:
Dr. E. Meier
Dr. D. Small SepCoinv O. Frey SepCoinv M. Jehle

Method: Theory

Purpose of research:
- Geometric Error Budget Analysis

This study is focused on geocoding of SAR data. On behalf of the German Aerospace Center (DLR) a geometric error budget analysis for the geocoding procedure of the future TerraSAR-X system has been carried out. We have analyzed the imaging model regarding the high spatial resolution and the ScanSAR mode and defined requirements for a high accuracy terrain geocoding of Spotlight mode data. In particular, we have investigated the magnitude of potential errors originating from orbit position, datum shift parameters, cartography, geoid models, digital elevation and surface models, sampling window start time, atmospheric refraction and Doppler frequency, and their influence on the geometric accuracy of the geocoded image. In addition, the impact of terrain elevation differences within a SAR scene on the radiometric distortion has been examined in terms of an optimized antenna gain pattern correction.

- Atmospheric Path Delays

As a result of the geometric error budget analysis study a further task was to estimate in detail the different contributions of path delay of electromagnetic waves traveling through the atmosphere and to develop a software which accounts for this delays. We have implemented state of the art models for calculating ionospheric and tropospheric path delays. Well-calibrated spaceborne ENVISAT-ASAR data are used to simulate atmospheric effects and to investigate improvements of the geometry of the scene.

Status: In order to perform the analysis efficiently an error budget analysis tool has been developed in MATLAB. The software comes with a graphical user interface. It features forward and backward geocoding simulation and calculation of error budgets for the error sources mentioned above. The geometric error budget analysis has been finished by end of March 2003. The results have been delivered to DLR in the form of a technical note. The software tool calculating the different contributions of atmospheric path delay was developed in C++. Software-tests have been running successfully and formal changes to adapt to the DLR-environment have been made. Within an Integration Test Week (ITW) the Prototype software has been installed and intensively tested at DLR. After this ITW the DLR has performed some more tests and finally accepted the software without any modifications. Another technical note including all results and acceptance tests was delivered to DLR.

Publications:

1. FREY, O., MEIER, E., NUESCH, D., ROTH A. [2004]: Geometric Error Budget Analysis for TerraSAR-X; Proc. of EUSAR 2004, Ulm, Germany

2. JEHLE, M., FREY, O., SMALL, D., MEIER, E., NUESCH, D. [2004]: Improved Knowledge of SAR Geometry through Atmospheric Modelling; Proc. of EUSAR 2004, Ulm, Germany

3. JEHLE, M., FREY, O., SMALL, D., MEIER, E., NUESCH, D. [2004]: Estimation of Atmospheric Path Delay in Radar Signal Propagation; Technical Note, TX-PGS-TN-3016 Zürich, Switzerland

Abbreviations:

SAR:	Synthetic Aperture Radar
DLR:	German Aerospace Center
ITW:	Integration Test Week

2.2 A snow cover map of the Alps for assimilation in operational meso-scale numerical weather prediction based on MSG data

Institute: Chair of Photogrammetry and Remote Sensing, Inst. for Geodesy and Photogrammetry, ETH Zürich

Principal Investigator: Prof. Dr. A. Grün

Co-investigators:

Dr. M. de Ruyter de Wildt SepCoinv Dr. G. Seiz

Method: Research based on existing instuments: IUE, Beppo-SAX, Rossi-XTE, INTEGRAL.

Purpose of research: Snow cover influences several processes that occur at or near the Earth?s surface. It affects the exchange of energy and moisture between the surface and the atmosphere and is an important aspect of the hydrological cycle. Furthermore, snow cover extent is an indicator of climatic change and affects many human activities. Information about the surface snow cover is therefore important for studies and applications in many disciplines, including Numerical Weather Prediction (NWP), hydrology and climatology. A valuable tool for detecting snow cover is remote sensing, because it allows us to monitor large areas of the Earth at regular time intervals. The most frequent observations are acquired by geostationary satellites, which monitor an entire hemisphere. Their data can be used to monitor the earth and its atmosphere with very high high frequency in near real-time and also to monitor dynamic processes and the behaviour of pixels in time.
Until recently, however, geostationary satellites did not posses all of the spectral channels that are of interest for snow mapping. In 2002, the first of a new series of geostationary satellites was launched by EUMETSAT, the European Organisation for the Exploitation of Meteorological Satellites. Meteosat-8, also called Meteosat Second Generation 1 (MSG-1) carries the Spinning Enhanced Visible and Infrared Imager (SEVIRI), which has improved spectral, spatial and temporal resolution with respect to its predecessors on board of the previous Meteosat satellites. SEVIRI is the first geostationary satellite sensor with a spectral resolution that is comparable to polar orbiting sensors like AVHRR and MODIS. It thus offers an unprecedented data set with high spectral (12 channels) and temporal resolution (15 minutes). This may be of interest for cases where spectral information alone is insufficient for image classification. A problem where this is the case, is the discrimination between snow and clouds with ice particles. Such clouds

can have similar reflectances, brightness temperatures and phase as snow and are sometimes difficult to distinguish from snow with spectral information alone.
The objective of this project is to develop an algorithm that uses the high frequency of Meteosat-8 in two ways. First, it can be used to improve the discrimination between clouds and snow, by taking the temporal context of pixels into account. Also, the high frequency makes it possible to detect all cloud-free situations and to continuously provide the latest information about surface snow cover. The algorithm will be used by MeteoSwiss for their operational meso-scale NWP model.

Status: We have explored ways to use the high temporal frequency of Meteosat-8 SEVIRI. Many clouds are more variable in time than the surface and this property can be used to identify them. We quantified the temporal variability of a pixel with the standard variation within a short time series for the pixel. When the temporal variability of a pixel is high in one or more of the SEVIRI channels, the pixel is classified as cloudy. Not detectable in this way are clouds that are very homogeneous and static, which mainly applies to low-level water clouds but also to some ice clouds. On the other hand, spectral classification masks all water clouds and most ice clouds, but fails to detect ice clouds with a similar spectral signature as snow. Therefore, for a complete detection of cloud cover both spectral and temporal information must be used.
The algorithm has been implemented at MeteoSwiss, where it now fully automatially produces snow cover maps in near-real time. A validation of the results from the winter of 2005/2006 with ground measurements showed that virtually all clouds are detected and that 94
Each satellite image is classified about two hours after it is acquired, and thus a snow map is produced every 15 minutes. When a pixel is cloud free in an instantaneous snow map, the classification result (snow or no snow), is transferred immediately to a running composite snow map. Whenever a surface snow cover map is required by the NWP model of Meteoswiss, which is several times per day, the latest version of the running composite snow map can be used.

Publications:

1. M. de Ruyter de Wildt, G. Seiz and A. Grün. Snow mapping using multi-temporal meteosat-8 data. EARSeL eProceedings, 5(1), 18-31, 2006.

2. Steiner, P.A.J., F. Schubiger, M. de Ruyter de Wildt and M. Buzzi. Numerical Weather Prediction at MeteoSwiss. Proceedings of the 27th EWGLAM ant 12th SRNWP meetings, 3rd - 5th October 2005, Ljubljana, Slovenia.

3. M. de Ruyter de Wildt, G. Seiz and A. Grün. Improved methods for cloud and snow mapping using multitemporal Meteosat-8 SEVIRI imagery. Submitted to Int. J. Remote Sensing.

Abbreviations:

EUMETSAT:	European Organisation for the Exploitation of Meteorological Satellites
MSG:	Meteosat Second Generation
NWP:	Numerical Weather Prediction
SEVIRI:	Spinning Enhanced Visible and Infrared Imager

3 Earth resources

3.1 Airborne Ultra-Wideband Low-Frequency SAR

Institute: Remote Sensing Laboratories (RSL)
Department of Geography
University of Zurich-Irchel
Winterthurerstrasse 190
CH-8057 Zurich
In cooperation with:
armasuisse
Swedish Procurement Agency FOI

Principal Investigator: Prof. Dr. D. Nuesch

Co-investigators:
Dr. E. Meier Sep CoInv A. Barmettler

Method: Research based on existing instuments: airborne; sensor: CARABAS (FOI, Sweden)

Purpose of research: Low-frequency imaging radar, i.e. radar using wavelengths in the order from 1 to 10 meters (VHF-band), has the potential to penetrate the vegetation canopy, because the electromagnetical waves interact only slightly with objects smaller than the wavelengths. In combination with ultra-wideband (UWB) signals, VHF UWB synthetic aperture radar (SAR) has a high potential for airborne applications because it makes high-resolution mapping feasible. In combination with other SAR frequency bands, topographic or even tomographic mapping will be possible, making it possible to determine biophysical and geophysical parameters.
Data from Swiss test sites collected with the Swedish airborne SAR CARABAS was used during this research project. CARABAS transmits and receives radio waves from 20 - 90 MHz (HF-/VHF-Band). The project mainly addresses the processing of the radar raw data to geocoded radar maps. Since about 15Õ000 radar echoes are collected during about 120 seconds of flight time, motion compensation and computing time (generating a focused image) are key problems.

Status: High resolution processing of a 10km x 10km scene requires about 35 days of processing time on a single workstation. To reduce this time, several optimization steps have been undertaken, including parallelization of the algorithm to fit on the University of ZurichÕs large computer cluster ÒMatterhornÓ. The time could be reduced significantly without degrading the image quality.
Since VHF SAR requires a large synthetic aperture the sensor looks at a target from different angles (the beam opening spans over 90¡). The scattering response from a given target varies within this angle. In particular, metallic linear features scatter only within a narrow angle interval and are therefore imaged at a reduced resolution. More importantly, they obscure the underlying signatures. Algorithms have been developed and implemented to identify such signals, extract them (e.g. for mapping applications) remove them from the signal.

Abbreviations:

HF: Active Galactic Nuclei
RSL: International Ultraviolet Explorer

SAR: X-ray Timing Explorer
UWB: Ultra-Wideband
VHF: Very High Frequency

3.2 SPECTRA End-to-end Mission Simulator

Institute: Remote Sensing Laboratories (RSL),
University of Zurich-Irchel
Winterthurerstrasse 1
CH-8057 Zurich
In cooperation with
ESA/ESTEC, ALTERRA (NL)
ONERA (F)
ACRI (F)
Universitat de Valencia (E)

Principal Investigator: Prof. Dr. K. I. Itten

Co-investigators:
Dr. S. Dangel SepCoInv Dr. M. Kneubuehler

Method: Simulation, Satellite

Purpose of research: The goal of the SPECTRA end-to-end mission simulator project was to define and architect a simulator for modelling proposed SPECTRA data processing. The architecture includes hardware, software and proposals for integration of key modules. This simulator study made part of the accompanying scientific studies for SPECTRA, being one of ESA's Earth Explorer Core Missions Candidates in Phase A during the reporting period. In 2005, the SPECTRA mission was not selected to go into Phase B and supporting scientific studies were all successfully terminated during 2005.
As far as the SPECTRA mission is concerned, the response of vegetation to climate variability is a major scientific question. Analyses of the global carbon cycle and of terrestrial ecosystems demonstrate strong links with the observed climatic trends. The monitoring of the carbon stock in terrestrial environments, as well as the improved understanding of the surface-atmosphere interactions controlling their exchanges of matter, energy and momentum, is of immediate interest for an improved assessment of the various components of the global carbon cycle. Studies of the Earth System processes at the global scale rely on models that require an advanced understanding and proper characterisation of processes at smaller scales. The objective of this mission is to improve the description of those processes by means of better constraints on and parameterisations of the associated models. With SPECTRA, a mission was proposed that shall focus on providing the critical information needed to improve biome specific parameterizations of canopy functioning models, for a range of scales from tens of meters to tens of kilometers, and help improve the description of carbon, energy, and water cycles in global models of Earth system processes. It was therefore planned to systematically observe a series of well identified globally distributed sites representing a large range of biomes and ecosystems. A combination of model up-scaling efforts and observations from a panoply of coarse spatial resolution sensors would link this local description of processes to global modeling of the Earth System. Therefore, the mission aimed at improving the consistency of the biome and ecosystem specific model parameterization when global models are assimilating remote sensing data provided by the series of coarse resolution sensors.

The SPECTRA mission would be characterised by a single satellite - single instrument solution composed of - a platform anticipated to fly in a near-polar orbit, providing access to all land areas with the required spatial and temporal characteristics, and - a sensor providing the required radiometric, spectral and directional performance in the visible to the thermal infrared domains

Status: The first progress meeting of the SPECTRA mission end-to-end simulator was successfully held in Zurich on January 20, 2004. The second progress Meeting was successfully held in Zürich on July 6, 2004. The final meeting was successfully held at ESA/ESTEC on February 24, 2005.
The SPECTRA mission was an Earth Explorer Core Mission Candidate. However, it was not selected for a Design/Development Study (Phase B) in 2005 and all accompanying scientific studies were successfully terminated during 2005. The SPECTRA End-to-end Mission Simulator Study was finished by the end of February 2005.

Publications:

1. ESA (M. Rast (ed.)), SPECTRA - Surface Processes and Ecosystem Changes Through Response Analysis, ESA-Publication SP-1257(5), September 2001

2. Menenti, M., Rast, M., Baret, F., van den Hurk, B., Knorr, W., Mauser, W., Miller, J.R., Moreno, J.F., Schaepman, M.E., Verstraete, M.M. (2003) Understanding vegetation response to climate variability from space: recent advances towards the SPECTRA Mission. In Sensors, Systems, and Next-Generation Satellites VII; (eds R. Meynart, S.P. Neeck, H. Shimoda, J.B. Lurie, M.L. Aten), Vol. 5234, pp. 76-85. SPIE, Barcelona.

3. Dangel, S., Kneubühler, M., Itten, K.I., Peticolin, F., Brazile, J., Piesbergen, J., Miesch, Ch., Poutier, L, Briottet, X., Jia, L., Moreno, J., Gloor, M., Carnicero, B. and Rast, M. (2005) SPECTRA End-to-End Simulator, ESA-Contract No 17600/03/NL/CB, Remote Sensing Laboratories, University of Zürich.

Abbreviations:

SPECTRA: Surface Processes and Ecosystem Changes Through Response Analysis

3.3 Investigation of the Potential of Imaging Spectrometry as an Earth Observation Method for Environmental Analysis

Institute: Remote Sensing Laboratories (RSL)
University of Zurich-Irchel
Winterthurerstrasse 1
CH-8057 Zurich
In cooperation with WSL Swiss Federal Institute for Forest Snow and Landscape

Principal Investigator: Prof. Dr. K.I. Itten

Co-investigators:
Dr. M. Kneubuehler SepCoInv Dr. S. Dangel

Method: Simulation, Theory, Research based on existing instuments: airborne: HyMap, DAIS, spaceborne: MERIS, CHRIS/PROBA, Aircraft, Satellite, Ground based instruments: Goniometer, Sun-Photometer

Purpose of research: Within this project the potential of imaging spectroscopy as an Earth Observation method for Environmental Analysis is investigated. In the ongoing phase, special emphasis is being put on the quantification of the dynamic representation of the land surface in the framework of the Kyoto Protocol.
The primary goals of the study are the demonstration of the utility of spectro- directional remote sensing data and selected variable estimation algorithms for carbon cycle estimations on the one hand, and the use of field and laboratory goniometer measurements to assess the spectro-directional reflectance properties of ground surface targets on the other hand.

Status: As for the vegetation part, the definition of relevant parameters for carbon cycle estimations derivable from remote sensing data was addressed in an initial phase of the project. The proposed approach now enables the vegetation product generation as well as the determination of the product uncertainty, a requirement for further use in regional to global ecological and climate change mapping and modelling.
The directional part presently deals with sophisticated methods for adequate preprocessing, measurement, correction and management of spectro-directional remote sensing data. Many applications, such as BRDF (bidirectional reflectance distribution function) correction of remote sensing data heavily depend on the accuracy of such data. The study of the relationship between field and laboratory measurements of spectro-directional effects includes also concepts to improve measurement and correction accuracy.

Publications:

1. Dangel, S., Verstraete, M.M., Schopfer, J., KneubY"hler, M., Schaepman, M. and Itten, K. (2005) Toward a Direct Comparison of Field and Laboratory Goniometer Measurements, IEEE Transactions on Geoscience and Remote Sensing, 43(11), pp: 2666-2675.

2. Huber, S., Zimmermann, N.E., KneubY"hler, M., and Itten, K. (2005) Estimating Nitrogen in Mixed Forests from HyMap Data using Band-Depth Analysis and Branch-and-Bound AlgorithmÓ, Proc. 9th Int. Symposium on Physical Measurements and Signatures in Remote Sensing (ISPMSRS), 17-19 October 2005, Beijing, ISPRS Vol. XXXVI(7/W20), pp: 533-535, ISSN 1682-1750.

3. Schopfer, J., Dangel, S., Verstraete, M.M., KneubY"hler, M. Schaepman, M. and Itten, K., 2005: ÒIntercomparison of Field and Laboratory Goniometer MeasurementsÓ, Proc. 9th Int. Symposium on Physical Measurements and Signatures in Remote Sensing (ISPMSRS), 17-19 October 2005, Beijing, ISPRS Vol. XXXVI(7/W20), pp: 465-467, ISSN 1682-1750.

Abbreviations:

BRDF: Bidirectional Reflectance Distribution Function

3.4 ENVISAT ASAR Calibration and Validation

Institute: Remote Sensing Laboratories (RSL)
University of Zurich-Irchel
Winterthurerstrasse 190
CH-8057 Zurich
In cooperation with European Space Agency

Principal Investigator: Prof. Dr. D. Nuesch

Co-investigators:
Dr. E. Meier SepCoInv Dr. D. Small

Method: Research based on existing instuments: ENVISAT ASAR

Purpose of research: In this project, RSL works directly with ESA and other partners to calibrate and validate parameters describing the imaging geometry of the advanced synthetic aperture radar (ASAR) instrument on the ENVISAT satellite.
In particular, accurate timing parameters are crucial in guaranteeing a precise geolocation in the processing step known as geocoding. The geocoding process transforms a radar image from its native grid aligned in the satellite along-track (path or azimuth) direction to a conventional map geometry (e.g. Swiss national map coordinates) by solution of range and Doppler equations in combination with cartographic and geodetic transformations.
Accurate geocoding requires acceptably low errors in the estimates of the satellite state vector locations, as well their timing annotations and the sampling window start time (SWST) used to specify the onset of the receive window for recording the reflected echoes of pulses sent previously. The project described here calibrates and validates these timing parameters to reduce geolocation errors for all ASAR users.

Status: Interfaces were constructed to the ENVISAT orbit state vector formats of variable timeliness and quality. Software for prediction of a ground or transponder position was used to determine the quality of a product type's geometry. The predicted location is compared with a measurement of a strong target in a single-look-complex (SLC) image using a high oversampling factor to enable measurement resolution at a small fraction of the sample size.
The timing parameters associated with across-track (range) and along-track (azimuth) directions of the radar imagery were validated using measurements of the positions of corner reflectors and radar transponders in data sets acquired over the Netherlands, Switzerland, and Canada. Within the scope of this project, a data acquisition campaign was organised involving multiple ASAR passes over corner reflectors placed on the Duebendorf airfield outside of Zurich, Switzerland. Conventional ground control points (bridges, road intersections, etc.) were also measured in some cases for comparison.
These measurements were used to first refine the geometry parameters used in production of ASAR imagery by ESA and then validate the updated values using reprocessed campaign data. Results were presented at ESA's ENVISAT calibration review and validation workshops, IGARSS 2003, the CEOS 2004 calibration workshop, and the 2004 ENVISAT symposium in Salzburg, Austria.
For validation, data sets were procured that were processed with refined SWST values that had resulted from corner reflector and transponder measurements from Switzerland, the Netherlands, and Canada. For all such available data, comparisons of predicted vs. measured image locations confirmed that the the prediction made on the basis of range, Doppler, state vector, and target position (and in the case of transponders, internal delay) was accurate to within the size of a single range sample. Such accuracy is striking (accuracy better than 8m for a satellite at a range of approximately 1000km, and is well within the original ENVISAT ASAR specifications.
It was found that accuracy in the along-track (azimuth) direction is even higher if one corrects for along-track timing annotation convention slightly inconsistent with the original documentation. In particular, the time (and therefore distance) that the spacecraft travels between transmission of a pulse and the reception of its echo must be accounted for in the geolocation algorithm. With-

out correction of this bias, scene-dependent errors in along-track prediction of approximately 20m will deter more accurate predictions.

An additional along-track timing bias was found in the case of ASAR AP (alternating polarisation) type products. The along-track timing annotations sometimes had a significant bias in products generated before late 2005. A bias correction algorithm was validated, and these timing biases can now be corrected by the user in post-processing. Newer AP products are now routinely generated by ESA bias-free.

Publications:

1. SMALL D., ROSICH B., SCHUBERT A., MEIER E., N+ESCH D. [2005]:Geometric Validation of Low and High-Resolution ASAR Imagery, Proc. of the 2004 ENVISAT, ERS Symposium, Salzburg, Austria, Sept. 6-10, 2004 (ESA SP-572, April 2005). 9p.

2. SMALL D., ROSICH B., MEIER E., N+ESCH D. [2004]:Geometric Calibration and Validation of ASAR Imagery, Proc. of CEOS SAR Workshop 2004, Ulm, Germany, May 27-28, 2004.

3. SMALL D., HOLZNER J., RAGGAM H., KOSMANN D., SCHUBERT A. [2003]: Geometric Performance of ENVISAT ASAR Products,Proc. of IGARSS'03, Toulouse, France, July 21-25, 2003, pp. 1121-1123.

Abbreviations:

AP :	ENVISAT ASAR Alternating Polarisation Mode
ASAR:	Advanced Synthetic Aperture Radar
CEOS:	Committee on Earth Observation Satellites
DLR:	German Aerospace Research Centre
ESA:	European Space Agency
IGARSS:	International Geoscience and Remote Sensing Sypmposium
IM:	ENVISAT ASAR Image Mode
RSL:	Remote Sensing Laboratories
SLC:	Single Look Complex
SWST:	Sampling Window Start Time

3.5 Stereo-Assisted Interferometric SAR

Institute: Remote Sensing Laboratories (RSL)
University of Zurich-Irchel
Winterthurerstrasse 190
CH-8057 Zurich

In cooperation with: European Space Agency, Intermap Technologies

Principal Investigator: A. Schubert

Co-investigators:
Dr. D. Small SepCoInv Prof. Dr. Daniel Nuesch, SepCoInv Dr. E. Meier

Method: Research based on existing instuments: ENVISAT ASAR, ERS-1/2, AeS-1

Purpose of research: The two most reliable methods for extracting surface topography from SAR image pairs are interferometry (InSAR) and stereogrammetry (stereo SAR). The high-resolution results obtained by interferometry have been the main focus for research into digital surface model (DSM) generation in recent years. While a more accurate technique, InSAR has several weaknesses as compared to stereo SAR:
- InSAR topography estimation requires a delicate phase-unwrapping step, which is especially difficult, or even impossible, in alpine terrain. - Ground control points (GCPs) are required for interferometric phase calibration in the form of reflectors whose positions have been measured, or tiepoints visible in the SAR images and topographic maps. This hinders the automatability of the InSAR technique. - Areas of low coherence in interferograms, due to temporal decorrelation in the multi-pass case, vegetation presence, and steep topography lead to erroneous or altogether missing height estimates (data holes).
Although a stereo DSM will not provide nearly the height resolution of an InSAR DSM, it was shown in this project that first processing a SAR stereo pair for the same area can assist in the phase-unwrapping, phase- calibration, and hole-filling steps of the InSAR chain. Depending on the particular scene, acquisition parameters, and processing algorithms, these three weaknesses may be more or less relevant. The stereo-assisted technique developed can address each of these points individually, making it case-adaptable.
The core of the stereo processing chain is a wavelet-based multiresolution matching algorithm. The multiresolution framework proved to be successful in coping with certain particularities of SAR images, namely, the slant- range geometry and the presence of speckle noise. However, problems were encountered for image areas dominated by radar shadow or layover. A useful secondary product is also generated during matching: the match confidence, which provides an indication of the quality of the final derived heights. This information is then used during the automatic GCP selection and hole-filling steps of the stereo-assisted InSAR processing chain.
The technique developed is intended for use in those cases where no reliable digital elevation model (DEM) is already available, or automation of the InSAR processing chain is desired. With the increasing availability of stereoscopic and interferometric data generated by air- and spaceborne sensors, the combination of stereo SAR with InSAR will become increasingly feasible.

Status: Three test sites were studied in the context of this work, with stereo and interferometric acquisitions obtained for each. Interferometric data were obtained over two Swiss test sites near Berne and Lucerne by a pair of X-band sensors mounted in the cross-track orientation on an aircraft. Parallel flight tracks were flown, providing the larger baseline required for stereo SAR at the same time. A spaceborne case was also studied, for the general area between Lucerne and Zurich, Switzerland. Stereo data were obtained from the European Space Agency's (ESA) ENVISAT Advanced SAR (ASAR) C-band sensor, using its swaths IS3 and IS6. InSAR data came from ESA's ERS-1/2 satellites, the C-band pair acquired in tandem mode one day apart.
DSMs were created from both the air- and spaceborne datasets using stereo and InSAR techniques individually and combined. The results were compared to the best references (DSMs, DHMs, or GCPs) available for the particular site, and the optimal combination of stereo and InSAR was determined for each case.
The limits of the stereoscopic technique were determined through simulation of the radar backscatter using a reference DSM and nominal backscatter values mapped from the DSM into radar geometry. Stereo pairs for various combinations of incidence angles were generated for one of the

airborne test sites. It was determined that same-side stereo SAR, with both sensors having incidence angles of about 45 degrees, is the preferred configuration for the matching method used. The real data from the X-band airborne sensors were, in fact, obtained under nearly these conditions. For the airborne cases, it was discovered that for scenes containing flat- to-rolling terrain, for which the interferometric phase does not vary too quickly, phase-flattening using the stereo DSM was not necessary. The stereo-based GCP generation did, however, provide the means to automatically perform the subsequent combined phase-calibration and baseline estimation. Finally, if data holes remained in the InSAR DSM, such as may be due to volume scattering within forested areas, the stereo-InSAR hole-filling method developed was helpful in increasing the total DSM coverage without severely damaging the overall accuracy of the DSM.
The use of the stereo DSM for phase unwrapping was helpful in the case of the spaceborne data, where the fringe rates caused by alpine terrain were beyond the capability of the available phase-unwrapping software. Stereo- based phase calibration and hole-filling also proved beneficial. For all cases studied, the stereo-assisted InSAR technique generated results superior to those obtained with InSAR alone. Finally, the combined technique requires no reflectors or searches for tiepoints, which would normally be required by InSAR alone. The method described therefore provides the basis for a fully-automatic processing chain.

Publications:

1. SCHUBERT A., SMALL D., MEIER E., NUESCH D. [2002]: Robustness of Wavelet-Based Stereo Matching for Variable Acquistion Geometries Using Simulated SAR Images, Proc. of IGARSS'02 Toronto, Canada, June 24-28, 2003, pp. 2759-61.

2. SMALL D. [1998]: ASAR Generation of Digital Elevation Models through Spaceborne SAR Interferometry, Remote Sensing Series, Vol. 30, Dept.of Geography, University of Zurich, Switzerland, 1998.

3. MAGAREY J., KINGSBURY N. [1998]: Motion Estimation Using a Complex-Valued Wavelet Transform, IEEE Trans. on Signal Processing, Vol. 46 No. 4, 1998, pp. 1069-1084.

Abbreviations:

AES:	AeroSensing (currently Intermap Technologies, GmbH)
DLR:	German Aerospace Research Centre
DEM:	Digital Elevation Model
DHM:	Digital Height Model
DSM:	Digital Surface Model
ERS:	European Remote-Sensing Satellite
ESA:	European Space Agency
GCP:	Ground Control Point
IGARSS:	International Geoscience and Remote Sensing Sypmposium
INSAR:	Interferometric Synthetic Aperture Radar
RSL:	Remote Sensing Laboratories
SAR :	Synthetic Aperture Radar

3.6 APEX- Airborne Prism Experiment

Institute: Remote Sensing Laboratories (RSL)
University of Zurich-Irchel
Winterthurerstrasse 190
CH-8057 Zurich

Principal Investigator: Prof. Dr. K.I. Itten

Co-investigators:

Dr. J. Nieke SepCoInv Dr. W. Debruyn

Method: Development and construction of own instruments: APEX

Purpose of research: Based on the present demand for airborne and spaceborne imaging spectroscopy data in remote sensing, the European Space Agency (ESA) has initiated a project to build a new generation airborne hyperspectral imager named APEX. APEX is a pushbroom imager with 300-500 spectral bands, operational in the spectral region from 380 to 2500 nm, and with 1000 pixels across track. It will be flown in an aircraft at operating altitudes between 2 and 14 km having a spatial resolution of 1-7 meters.
The mission objectives of APEX are mainly being a simulator, calibrator, and validator for spaceborne multispectral and hyperspectral instrument (such as ENMAP). APEX shall also foster the application development for hyperspectral imaging in Europe and worldwide. The project shall be an European answer to the scientific success of American hyperspectral instruments. Its specifications are state-of-the-art in resolution and overall radiometric performance.

Status: RSL is responsible for the scientific management of the project, for industrial consulting concerning the specialities of imaging spectrometer instrument, and for the construction of the Processing and Archiving Facility (PAF). The latter will be an universal, database driven system supporting the processing and distribution of all APEX data acquisitions. Sophisticated information technology tools are used for a versatile processing system, which will be persistent throughout the operational phase of the instrument.
ESA EOEP has taken the lead within APEX by providing the SWIR detector technology, the calibration home base, and the technical management.
The project is currently in Phase C/D, the first flight is expected for 2008.

Publications:

1. Nieke, J., Itten, K.I., Debryun, W., and the APEX team, The airborne imaging spectrometer APEX: From concept to realization, Proc. 4th EARSeL Workshop on Imaging Spectroscopy, Warsaw, 27-29 April, CD-ROM (2005)

2. Schlaepfer D., Kaiser J.W., Brazile J., Schaepman M.E. and Itten K.I., Calibration concept for potential optical aberrations of the APEX pushbroom imaging spectrometer, International Symposium on Remote Sensing. In: Sensors, Systems, and Next Generation Satellites VII. SPIE, Barcelona, Vol. 5234, pp. 221-231. (2003)

3. Schlaepfer D., and Schaepman M., Modelling the noise equivalent radiance requirements of imaging spectrometers based on scientific applications. Applied Optics, OSA41(27):5691-5701. (2002)

Abbreviations:

APEX:	Airborne Prism Experiment
EOEP:	Earth Observation Envelope Programme
PRODEX:	PROgramme de Developement d'EXperiences Scientifiques
RSL:	Remote Sensing Laboratories
ENMAP:	ENvironmental Mapping and Analysis Program
VITO:	Vlaamse Instelling voor Technologisch Onderzoek

4 Planets

4.1 ASPERA-3/Mars Express: Remote particle sensing of ion populations in Mars' extended atmosphere

Institute: Physikalisches Institut, University of Bern
In cooperation with:
Swedish Space Research Institute, Kiruna (R. Lundin, S. Barabash)
Max-Planck-Institut fY"r Aeronomie, Lindau, Germany (J. Woch)
Instituto di Fisica dello Spazio Interplanetari, Rome, Italy (S. Orsini)

Principal Investigator: R. Lundin, Swedish Space Research Institute, Kiruna, Sweden

Co-investigators:
P. Wurz
A. Galli
P. Bochsler

Method: The ASPERA-3 instrument on the Mars Express Spacecraft

Purpose of research: The general scientific objective of the ASPERA-3 instrument is to study the solar wind Ð atmosphere interaction and characterize the plasma and neutral gas environment in the near-Mars space through energetic neutral atom (ENA) imaging and in situ plasma measurements. The main scientific objectives of the ASPERA-3 instrument are to
- Determine the instantaneous global distributions of plasma and neutral gas near the planet,
- Study the atmospheric escape induced by the highly variable solar wind and solar UV irradiation,
- Investigate the modification of the atmosphere through the solar wind ion bombardment,
- Investigate the energy deposition from the solar wind to the ionosphere,
The Neutral Particle Detector (NPD) provides measurements of the ENA flux, resolving velocity and mass (H and O) of the coming particles with a coarse angular resolution.

Status: The Mars Express spacecraft and the ASPERA-3 experiment still perform fine. The Mars Express (MEX) mission was extended by ESA in September 2005 by one Martian year (e.g. until October 2007). At Bern, data analysis concentrates on NPD data where the neutral exosphere, martian atmospheric loss via energetic neutral atoms, and energetic atoms of interstellar origin are investigated in detail.

Publications:

1. R. Lundin, D. Winningham, S. Barabash, R. Frahm, M. Holmstrs(m, J.-A. Sauvaud, A. Fedorov, K. Asamura, A.J. Coates, Y. Soobiah, K.C. Hsieh, M. Grande, H. Koskinen, E. Kallio, J. Kozyra, J. Woch, M. Fraenz, D. Brain, J. Luhmann, S. McKenna-Lawler, R.S. Orsini, P. Brandt, and P. Wurz, "Plasma Acceleration Above Martian Magnetic Anomalies," Science 311 (2006) 980-983.

2. A. Galli, P. Wurz, S. Barabash, A. Grigoriev, R. Lundin, Y. Futaana, H. Gunell, M. Holmstr?m, E.C. Roelof, C.C. Curtis, K.C. Hsieh, A. Fedorov, J.D. Winningham, R.A. Frahm, R. Cerulli-Irelli, P. Bochsler, N. Krupp, J. Woch, and M. Fraenz, "Direct Measurement of Energetic Neutral Hydrogen in the Interplanetary Medium," Astrophys. Jou. (2006) in press.

3. S. Barabash, R. Lundin, H. Andersson, J. Gimholt, M. Holstrs(m, O. Norberg, M. Yamauchi, K. Asamura, A.J. Coates, D.R. Linder, D.O. Kataria, C.C. Curtis, K.C. Hsieh, B.R. Sandel, A. Fedorov, A. Grigoriev, E. Budnik, M. Grande, M. Carter, D.H. Reading, H. Koskinen, E. Kallio, P. Riihela, T. SS(les, J. Kozyra, N. Krupp, S. Livi, J. Woch, J. Luhmann, S. McKenna-Lawlor, S. Orsini, R. Cerrulli-Irelli, A. Mura, A. Milillo, E. Roelof, D. Williams, J.-A. Sauvaud, J.-J. Thocaven, D. Winningham, R. Frahm, J. Scherer, J. Sharber, P. Wurz, and P. Bochsler, "The Analyzer of Space Plasmas and Energetic Atoms (ASPERA-3) for the Mars Express Mission," ESA-SP 1240 (2004), 121-139.

Abbreviations:

ASPERA-3:	Analyzer of Space Plasmas and Energetic Atoms
ENA:	Energetic Neutral Atoms
MEX:	Mars Express
NPD:	Neutral Particle Detector

4.2 ASPERA-4/Venus Express: Remote particle sensing of ion populations in Venus' extended atmosphere

Institute: Physikalisches Institut, University of Bern
In cooperation with:
Swedish Space Research Institute, Kiruna (S. Barabash, R. Lundin, H. Anderson)
Max-Planck-Institut fŸ"r Aeronomie, Lindau, Germany (J. Woch)
Instituto di Fisica dello Spazio Interplanetari, Rome, Italy (S. Orsini)

Principal Investigator: S. Barabash, Swedish Space Research Institute, Kiruna, Sweden

Co-investigators:
P. Wurz
A. Galli
P. Bochsler

Method: The ASPERA-4 instrument on the Venus Express Spacecraft

Purpose of research: The general scientific objective of the ASPERA-4 instrument is to study the solar wind Ð atmosphere interaction and characterize the plasma and neutral gas environment in the near-Venus space through energetic neutral atom (ENA) imaging and local plasma measurements. ASPERA-4 is an almost identical copy of the ASPERA-3 instrument on Mars Express. The main scientific objectives of the ASPERA-4 instrument are to
- Determine the instantaneous global distributions of plasma and neutral gas near the planet, - Study the atmospheric escape induced by the highly variable solar wind and solar UV irradiation, - Investigate the modification of the atmosphere through the solar wind ion bombardment, - Investigate the energy deposition from the solar wind to the ionosphere, The Neutral Particle Detector (NPD) provides measurements of the ENA flux, resolving velocity and mass (H and O) of the coming particles with a coarse angular resolution.

Status: -enus Express was successfully launched on 9 November 2005 from Baikonur /Kazakhstan, followed by an interplanetary cruise of 153 days and a successful insertion into an orbit around Venus was on 11 April 2006. Final operational orbit will be attained in May 2006. Commissioning of the ASPERA-4 instrument during cruise phase and early turn-on after venus orbit insertion were successful and some scientific data have already been recorded.

Publications:

1. S. Barabash, J.-A. Sauvaud, H. Gunell, H. Andersson, A. Grigoriev, K. Brinkfeldt, M. Holmstrs(m, R. Lundin, M. Yamauchi, K. Asamura, W. Baumjohann, T. Zhang, A.J. Coates, D.R. Linder, D.O. Kataria, C.C. Curtis, K.C. Hsieh, B.R. Sandel, A. Fedorov, C. Mazelle, J.-J. Thocaven, M. Grande, H.E.J. Koskinen, E. Kallio, T. SS(les, P. Riihela, J. Kozyra, N. Krupp, J. Woch, J. Luhmann, S. McKenna-Lawlor, S. Orsini, R. Cerulli-Irelli, A. Mura, M. Milillo, M. Maggi, E. Roelof, P. Brandt, C.T. Russel, K. Szego, J.D. Winningham, R.A. Frahm, J. Scherrer, J.R. Sharber, P. Wurz, and P. Bochsler "The Analyzer of Space Plasmas and Energetic Atoms (ASPERA-4) for the Venus Express Mission," Planet. Space Science (2006) in press.

2. P. Wurz, J. Scheer, and M. Wieser, "Particle scattering off surfaces: application in space science," e-Jou. Surf. Science Nanotechn. 4 (2006) 394-400.

3. P. Wurz, "Detection of Energetic Neutral Particles," The Outer Heliosphere: Beyond the Planets, (eds. K. Scherer, H. Fichtner, and E. Marsch), Copernicus Gesellschaft e.V., Katlenburg-Lindau, Germany, (2000), 251Ñ288.

Abbreviations:

ASPERA-4 :	Analyzer of Space Plasmas and Energetic Atoms
ENA:	Energetic Neutral Atoms
NPD:	Neutral Particle Detector

4.3 SARA/Chandrayaan-1

Institute: Physikalisches Institut, University of Bern
In cooperation with:
Swedish Space Research Institute, Kiruna (S. Barabash, R. Lundin, H. Anderson)
Space Physics Laboratory, Trivandrum, India (A. Bhardwaj)

Principal Investigator: S. Barabash, Swedish Space Research Institute, Kiruna, Sweden

Co-investigators:
P. Wurz
J. Scheer

Method: SARA: Instrument for low-energy ENA remote sensing

Purpose of research: The Sub-keV Atom Reflecting Analyzer (SARA) experiment will be flown on the first Indian lunar mission Chandrayaan-1. The SARA instrument consists of three major subsystems: a LENA sensor (CENA), a solar wind monitor (SWIM), and a digital processing unit (DPU).
SARA will be used to image the solar windÐsurface interaction to study primarily the surface composition and surface magnetic anomalies and associated mini-magnetospheres. Studies of lunar exosphere sources and space weathering on the Moon will also be attempted. SARA is the first LENA imaging mass spectrometer of its kind to be flown on a space mission. A replica of SARA is planned to fly to Mercury onboard the BepiColombo mission.

Status: The Sub-keV Atom Reflecting Analyzer (SARA) experiment will be flown on the first Indian lunar mission Chandrayaan-1. The SARA is a low energy neutral atom (LENA) imaging mass spectrometer, which will perform remote sensing of the lunar surface via detection of neutral atoms in the energy range from 10 eV to 3 keV from a 100 km polar orbit. The University of Bern participates in the design and development of the instrument and contributes hardware to the two sensors of SARA, SWIM and CENA. After completion of the engineering model by end 2005, and successful testing, we are currently producing the flight model with a scheduled completing in summer 2006.

Publications:

1. A. Bhardwaj, S. Barabash, Y. Futaana, Y. Kazama, K. Asamura, R. Sridharan, M. Holmstrs(m, P. Wurz, and R. Lundin, "Low Energy Neutral Atom Imaging on the Moon with the SARA Instrument aboard Chandrayaan-1 Mission," Jou. Earth System Science 114(6), (2005) 749-760.

2. Y. Kazama, S. Barabash, A. Bhardwaj, K. Asamura, Y. Futaana, M. Holmstrs(m R. Lundin, R. Sridharan, and P. Wurz, "Energetic neutral atom imaging mass spectroscopy of the Moon and Mercury," Adv. Space Res. 37 (2006) 38-44.

4.4 BepiColombo: Composition of crust, exosphere, surface evolution, formation and evolution of planet Mercury

Institute: Physikalisches Institut, University of Bern
In cooperation with:
Instituto di Fisica dello Spazio Interplanetari, Rome, Italy (S. Orsini)
Swedish Space Research Institute, Kiruna, Sweden (S. Barabash, R. Lundin)
APL/JHU, Laurel, USA (S. Livi)

Principal Investigator: S. Orsini, Instituto di Fisica dello Spazi Interplanetari, Rome, Italy

Co-investigators:
P. Wurz
J. Scheer
P. Bochsler
W. Benz

Method: Two mass spectrometers are currently being developed, one for the Planetary Orbiter (MPO) and one for the Magnetospheric Orbiter (MMO) of the BepiColombo Mission for the measurement of the composition of the neutral particles in the planetary environment

Purpose of research: The European Space Agency (ESA) has defined the Cornerstone Mission, named BepiColombo, for the detailed exploration of planet Mercury. Because of observational difficulties Mercury is a largely unknown planet and therefore a high scientific return is expected from such an exploratory mission. Launch of BepiColombo is foreseen for August 2013 and the transfer to Mercury will take until August 2019. Thus the dataphase will start late in 2019, the earliest.
We participate, within an international collaboration, in the BepiColombo mission by developing two mass spectrometers. One mass spectrometer is on BepiColombo/MMO spacecraft to perform Energetic Neutral Atom (ENA) imaging of the space around Mercury, the second instrument will go on the BepiColombo/MPO spacecraft to measure the elemental, chemical, and isotopic

composition of MercuryÕs exosphere with a sensitive gas mass spectrometer. With these two instruments we would substantially contribute to three out of the six main scientific goals set for BepiColombo.

Status: Presently prototypes of the various sensors are being developed. In parallel, there is an industrial study for the BepiColombo spacecraft under way, which will be completed in November 2006.

Publications:

1. A. Milillo, P. Wurz, S. Orsini, D. Delcourt, E. Kallio, R.M. Killen, H. Lammer, S. Massetti, A. Mura, S. Barabash, G. Cremonese, I.A. Daglis, E. DeAngelis, A.M. Di Lellis, S. Livi, V. Mangano, and K. Torkar, "Surface-exosphere-magnetosphere system of Mercury," Space Science Review, 117 (2005) 397-443.

2. H. Lammer, P. Wurz, M.R. Patel, R. Killen, C. Kolb, S. Massetti, S. Orsini, and A. Milillo, "The variability of Mercury's exosphere by particle and radiation induced surface release processes," Icarus, 166(2), (2003), 238-247.

3. P. Wurz and H. Lammer, "Monte-Carlo Simulation of Mercury's Exosphere," Icarus, 164(1), (2003), 1-13.

Abbreviations:

ENA:	Energetic Neutral Atom
MPO:	Mercury Planetary Orbiter
MMO:	Mercury Magnetospheric Orbiter

4.5 Phobus-Grunt: Miniature mass spectromters for in situ planetary research

Institute: Physikalisches Institut, University of Bern
In cooperation with G. Managadze, IKI, Moscow, Russia

Principal Investigator: G. Managadze, IKI, Moscow, Russia

Co-investigators:
P. Wurz
J.A. Whitby

Method: Laser-ablation mass spectrometer (LASMA)

Purpose of research: We are participating in the development and the construction of a laser-ablation mass spectrometer, LASMA, which is part of the scientific payload of Phobos-Grunt. Phobos-Grunt will land on the martion moon Phobos and investigate surface material in great detail. LASMA will measure the elemental and isotopic composition of samples from the surface and the near surface, with the goal to identify the mineralogical composition of Phobos' surface. These measurements will assist in the possible identification of the origin of Phobos.

Status: Currently a prototype of the LASMA instrument is being developed and constructed. In parallel a laboratory programme is under way using a prototype laser mass spectromter to establish a large data base of mass spectra from minerals, which are possible analogues of Phobos surface material.

Publications:

1. U. Rohner, J. Whitby, P. Wurz, and S. Barabash, "A highly miniaturised laser ablation time-of-flight mass spectrometer for planetary rover," Rev. Sci. Instr., 75(5), (2004), 1314-1322.

2. U. Rohner, J. Whitby, and P. Wurz, "A miniature laser ablation time-of-flight mass spectrometer for in situ planetary exploration," Meas. Sci. Technol., 14 (2003), 2159-2164

3. U. Rohner, W. Benz, J.A. Whitby, P. Wurz, R. Schulz, and J. Romstedt, "Miniaturised time-of-flight mass spectrometer," proceedings of the 37th ESLAB Symposium, ESTEC/ESA, Noordwijk, The Netherlands, 2-4 December 2003, ESA SP-543 (2004) 131-136.

4.6 The BepiColombo Laser Altimeter Experiment on the ESA mission, BepiColombo

Institute: Physikalisches Institut, University of Bern
In cooperation with DLR fuer Planetary Research, Berlin

Principal Investigator: Nicolas Thomas and Tilman Spohn (DLR)

Co-investigators:
W. Benz
G. Beutler
U. Christensen
R. Rodrigo
and 30 others et al.

Method: Development and construction of own instruments: Instrument construction

Purpose of research: The BepiColombo laser altimeter (BELA) is a joint Swiss-German project with smaller involvements from Spain and France. The scientific objectives of the experiment are to measure
- the figure parameters of Mercury to establish accurate reference surfaces - the topographic variations relative to the reference figures and a geodetic network based on accurately measured positions of prominent topographic features - the tidal deformations of the surface - the surface roughness, local slopes and albedo variations, also in permanently shaded craters near the poles
BELA will form an integral part of a larger geodesy and geophysics package, incorporating radio science and stereo imaging. The package will cover the problems of planetary figure and gravity field determination, interior structure exploration, surface morphology and geology, and extend into the measurement of tidal deformations. The offset between the centre of mass and the centre of figure will also be derived. The reference surfaces and the geodetic network will provide the coordinate system for any detailed geological, physical, and chemical exploration of the surface. The topography is needed to develop digital terrain models which will allow quantitative explorations of the geology, tectonics, and age of the surface. The topography is further needed for a reduction of the gravity field data to account for the effects of topography. This will allow the measurement of the mass associated with the topography and the Hermean crust density. The reduction of the gravity data by removal of the effects of the topography will then reveal density variations rooted deeply in the interior. The tidal deformations measured by BELA and the radio science instrument will constrain global models of the interior structure. BELA will contribute the deformation of the surface while the radio science package will measure the mass

relocations. Under favourable conditions, it will even be possible to constrain the rheology of the interior of the planet by measuring the time lag between the motion of the tidal bulge and the disturbing potential (see Thomas et al., 2006).

Status: The BepiColombo mission will achieve final approval in November 2006. This will allow initiation of the construction of the flight model unit for BELA. Work in all countries within the project is concentrating on instrument development and risk reduction. Bread-boards are being developed and qualification of critical components has been initiated.

Publications:

1. Thomas et al. (2006) Planetary and Space Science, submitted.

4.7 The Optical Spectroscopic and Infrared Remote. Imaging System (OSIRIS) on the ESA mission, Rosetta

Institute: Physikalisches Institut, University of Bern
In cooperation with Max-Planck-Institut fuer Sonnensystemforschung

Principal Investigator: H.U. Keller (MPS)

Co-investigators:

P. Lamy
C. Barbieri
R. Rodrigo
D. Koschny
N. Thomas et al.

Method: Observation based on existing instuments: OSIRIS was built by a German-French-Italian-Spanish consortium. Thomas was science manager and calibration scientist for OSIRIS before moving to University of Bern. UBE is now involved as a co-I on the project.

Purpose of research: The Optical, Spectroscopic, and Infrared Remote Imaging System (OSIRIS) is the main camera system on board the Rosetta spacecraft. OSIRIS comprises a high resolution narrow angle camera (NAC) unit and a wide angle camera (WAC) unit. The NAC is designed to provide high resolution images of the surface of comet P/Churyumov-Gerasimenko through 12 discrete filters over the wavelength range 250 - 1000 nm at an angular resolution of 18.56 rad px-1. The WAC is optimised to provide images of near-nucleus dust and gas in 14 discrete filters at an angular resolution of 101 rad px-1. For the NAC, a special re-focussing system has been used to maintain the nucleus in focus at just 1 km from the surface. The two systems use identical shutter, filter wheel, front door, and detector systems. They are driven by a common digital processing unit. The total mass of the system is 35 kg. Hardware for the experiment is provided by 6 countries within Europe (see Keller et al., 2006).
Some of the key problems of the cosmogony of comets and the Solar System include the nature of the accretion process in the protoplanetary disc, the physical and chemical conditions (temperature, pressure, molecular composition) that prevailed there, the relationship between the original interstellar composition (both gaseous and solid) and the disc's composition, and the variation of its properties with both time and heliocentric distance. To derive the maximum scientific return, the camera system on Rosetta has been designed to address many of these questions.
OSIRIS will directly determine the outflow of gas and dust from different regions of the nucleus and will also compare those variations with variations in surface mineralogy, in topography, and in local insolation. This will provide the context in which to interpret the results from the

Rosetta lander (Philae). The unique strength of OSIRIS is the coverage of the whole nucleus and its immediate environment with excellent spatial and temporal resolution and spectral sensitivity across the whole reflected solar continuum.

Status: The Rosetta spacecraft is currently in a cruise phase. It will perform a gravity assist at Mars on 27 Feb 2007. OSIRIS is fully operational. Data has been acquired from several comets including a monitoring campaign focussed on the target of NASA's Discovery mission, Deep Impact. The OSIRIS observations are unique in that 9P/Tempel 1 was observed continuously between 3 days before and 10 days after the impact with time resolution down to one minute. The total amount of excavated dust and water ice is derived from these observations. It corresponds to a crater radius of at least 30 m. The steep increase of brightness during the first hour after the impact provides information on the sublimation and disintegration of the excavated icy grains. The slower brightness decay due to the motion of the dust cloud out of the aperture yields the expansion speed of the dust particles. We derive the number of water molecules generated by the impact to be 1.5.1032, or 4.5.106 kg. The surface area of the dust ejected by the impact was 660 km2 assuming a standard albedo of 0.05 (Kueppers et al., 2005).

Publications:

1. Keller et al. (2006) Space Science Reviews, submitted.

2. Kueppers et al. (2005) Nature, 437, 987.

4.8 The High Resoultion Imaging Science Experiment on the Mars Reconnaissance Orbiter

Institute: Physikalisches Institut, University of Bern
In cooperation with Lunar and Planetary Lab., University of Arizona

Principal Investigator: Alfred McEwen

Co-investigators:
J. Grant
C. Weitz
S. Squyres,
K. Herkenhoff
W.A. Delamere
M. Mellon
V. Gulick
L. Kesleythi
R. Kirk
N. Thomas, et al.

Method: Development and construction of own instruments:Instrument constructed by Ball Aerospace contracted to NASA. Swiss participation in co-I team involved in overseeing instrument development andprimary exploitation.

Purpose of research: The HiRISE camera features a 0.5 m diameter primary mirror, 12 m effective focal length, and a focal plane system that can acquire images containing up to 28 Gb of data in as little as 6 seconds. HiRISE will provide detailed images (0.25 to 1.3 m/pixel) covering 12-year Primary Science Phase (PSP) beginning November 2006. Most images will include color data (blue-green, red, near-IR) covering 20field of view. A top priority is to acquire 1000 stereo pairs and apply precision geometric corrections to enable topographic measurements to

better than 25 cm vertical precision. We expect to return more than 12 Tb of HiRISE data during the 2-year PSP, and use pixel binning, conversion from 14 to 8 bit values, and a lossless compression system to increase coverage. HiRISE images are acquired via 14 CCD detectors, each with 2 output channels, and with multiple choices for pixel binning and number of Time Delay and Integration lines. HiRISE will support Mars exploration by locating and characterizing past, present, and future landing sites, unsuccessful landing sites, and past and potentially future rover traverses. We will investigate cratering, volcanism, tectonism, hydrology, sedimentary processes, stratigraphy, aeolian processes, mass wasting, landscape evolution, seasonal processes, climate change, spectrophotometry, glacial and periglacial processes, polar geology, regolith properties, and other science themes. An Internet web site (HiWeb) will enable anyone in the world to suggest HiRISE targets on Mars and to easily locate, view, and download HiRISE data products.
(Taken from McEwen et al., 2006, J. Geophys. Res., in press.)

Status: MRO is currently (June 2006) in orbit about Mars and using aerobraking to lower its orbit. It is expected that the primary science orbit will be reached in November 2006 (on schedule). HiRISE has been tested in orbit immediately after orbit insertion (March 2006) and provided well-focussed test images. The science team is currently working on observation planning tools, data reduction tools, target selection, and preparation.
The University of Bern is involved in all aspects of this process.

Publications:

1. McEwen, A.S. et al. (2006) MRO's High Resolution Imaging Science Experiment (HiRISE), J. Geophys. Res., in press.

4.9 The Descent Imager/Spectral Radiometer Experiment on Cassini/Huygens

Institute: Physikalisches Institut, University of Bern
In cooperation with Lunar and Planetary Lab., University of Arizona

Principal Investigator: Martin G. Tomasko

Co-investigators:

P.H. Smith
L. Doose
H.U. Keller
M. Combes
B. Schmitt
B. Bezard
E. Lellouch
A. Coustenis
C. de Bergh
F. Gliem
N. Thomas, et al.

Method: Observation based on existing instuments: Instrument constructed by US, French, and German consortium for ESA's Huygens mission to Titan. Thomas is a co-I on the instrument team.

Purpose of research: The main aim of the Huygens mission was to study the atmosphere and surface of Saturn's largest moon, Titan. The atmosphere is mostly composed of nitrogen but is rich in organics which have led some to argue that it is similar to that of the early Earth.

The Voyager fly-bys of Saturn in 1981 showed that aerosols in Titan's atmosphere were optically thick thereby preventing a clear view of the surface. Ethane and methane lakes/oceans were then postulated on the surface. The aim of the Descent Imager/Spectral Radiometer experiment was to study the atmospheric methane and aerosol content, to determine the atmospheric heat budget, and to obtain the first unobstructed view of the surface.

Status: Huygens landed on the surface of Titan on January 14, 2005. DISR returned the first pictures of the satellite's surface. Due to its proximity to the surface, The Descent Imager / Spectral Radiometer (DISR) camera on the Huygens Probe was capable of a linear resolution of some meters from a height of 10 km. In addition, the lower the probe descended the less haze lay between the camera and the ground. The DISR was capable of orders of magnitude better linear resolution than has been available from orbit, though of a much smaller portion of Titan's surface.
DISR took measurements of solar radiation in the atmosphere. Spectrometers looking upward as well as downward at continuum wavelengths (between the major methane absorptions) measured the vertical distribution and wavelength dependence of the aerosol haze opacity. Measurements of the polarization of light at 90º scattering angle constrained the small dimension of the haze particles. Measurements of the brightness in the solar aureole around the sun determined the projected area of the haze particles. Observations in the methane bands determined the methane mole fraction profile. (Taken from Tomasko et al., 2005).
Work at the University of Bern is currently concentrating on determining the bidirectional reflectance distribution function (BRDF) from the imaging data. This will form part of a PhD thesis.

Publications:

1. Tomasko et al. (2005) Rain, winds, and haze; a close-up view from the descent to Titan's surface, Nature, 438, 765.

4.10 MIRI - MidInfrared Instrument on the James

Institute: Laboratory for Astrophysics at the Paul Scherrer Institut, 5232 Villigen-PSI
In cooperation with European Consortium ESA and NASA

Principal Investigator: Dr. Gillian Wright, UK Astronomy Technology Center
at the Royal Observatory in Edinburgh

Co-investigators:
PSI: Dr. A. Zehnder
PD Dr. M. Güdel

Method: Development and construction of own instruments: Cryogenic Harness and Contamination Control Cover Mechanism

Purpose of research: The mid-infrared range is one of the astrophysically most interesting but least studied parts of the electromagnetic spectrum. The James Webb Space Telescope (JWST, formerly the "Next Generation Space Telescope") is designed to observe the Universe in the near- and mid-IR wavelength range at unprecedented sensitivity and spatial resolution. Its instruments are fed by a 6.5 m mirror. It will allow to penetrate deep clouds of dust to access objects in their formation phase, namely forming stars, planets, and galaxies. The instruments will obtain first-hand diagnostics of the chemical composition and the basic structure of these young objects. The three instruments on board obtain both imaging and spectroscopy. Our participation in the MIRI mid-IR instrument (performing both spectroscopy and imaging together) will hold promise for our long-term involvement in the area of star and planet formation studies.

Status: The program is being financed under the PRODEX program. In this period a cryogenic test chamber and the STM harness have been built. PSI is as well responsible for the qualification at a temperature of 7K of the cryomechanics in collaboration with MPIA, Heidelberg. MIRI is now in Phase C/D. The program on the structural and thermal model (STM) has been completed. The construction of the verification model (VM) is under way.
A PhD project at PSI is related to the development phase of MIRI and stellar infrared investigations using existing data.

Publications:

1. Lemke D., Hofferbert R., Grözinger U., Rohloff R.-R., Böhm A., Henning T., Huber A., Mertin S., Ramos J., Wright G., Hastings P., Zehnder A., Salasca S., Kroes G., Straubmeier C., Eckart A. (2004): Positioning of optical elements in the cryogenically cooled mid-infrared instrument MIRI for the James Webb Space Telescope. SPIE, 5495, 31

2. Wright G.S., Rieke G., Colina L., et al. (2004): The JWST MIRI instrument concept. SPIE, 5487, 653

Abbreviations:

MIRI:	MidInfraRed Instrument
JWST:	James Webb Space Telescope, formerly NGST Next Generation Space Telescope

5 Solar physics

5.1 Reuven Ramaty High Energy Solar Spectroscopic Imager (RHESSI)

Institute: Institute of Astronomy, ETH Zurich
In cooperation with:
University of California, Berkeley, USA
NASA, Goddard Space Filght Center, Greenbelt, USA
Paul Scherrer-Institut, Villigen, CH

Principal Investigator: R. P. Lin, UCB

Co-investigators:
A. O. Benz (ETHZ)
B.R. Dennis (Goddard SFC
A. Zehnder (PSI)

Method: At ETH Zurich we have developed software for data analysis and the European HESSI Data Center (HEDC). The data center has started to operate after launch in 2002 and is still recieveing data. Science data analysis software, user interface, data archive and internet connections are continuing to be developed.

Purpose of research: The RHESSI mission is devoted primarily to the study of solar flares in X-rays and gamma-rays. It also has observed cosmic gamma-ray bursts, high-energy radiations of the supernova nebulae, X-rays produced by terrestrial lightening. The energy release of flares is a nonthermal process that accelerates electrons and ions to relativistic velocities. In large flares up to 1027 MWh are released. The primary products are energetic particles that can best be studied by emissions in hard X-rays, gamma-ray lines and radio waves.
RHESSI is a Small Explorer class satellite of NASA with a strong Swiss envolvement. The HESSI Experimental Data Center (HEDC) has been developed as a collaboration between three ETH institutes (Astronomy, Computer Systems and Information Systems) to cope with the flow of RHESSI data and distribute them in Europe. Images and light curves are reconstructed at HEDC from single photon energy and time data. The data products demand considerable computing time. They are stored and can be browsed through the Internet. This greatly facilitates the overview on existing data and the selection for further analysis.The user also can have more products computed on-line and store them in the archive that is automatically growing in information on interesting events.

Status: RHESSI was launched on February 5, 2002. The data are transmitted to the ground station in Berkeley every 12 hours and distributed through Internet to be stored in HEDC. First data products are being produced for quick look browsing, data evaluation and selection every night. The satellite is in excellent conditions and delivers high quality data. The observations in 2005 show solar activity in the declining phase of the solar 11 year cyle, and include the observation of an extremely powerful gamma-ray burst.
RHESSI data are complemented by radio observations by the ETH spectrometer PHOENIX-2 in Bleien (Switzerland). Software development is continuing and focusses mostly on imageing spectroscopy.
The data analysis at ETH has focussed on the spectral properties of the acceleration process. We have quantitatively measured the relation between X-ray flux and hardness for the first time. The motion of the X-ray sources on the disk has shown surprising results, contradicting the

existing scenario of steady reconnection.The future analysis will focus on spectroscopy in picture elements (imaging spectroscopy), on relating the coronal source (representing the acceleration process) with the footpoints, and derive the energetics in a new scenario.

Publications:

1. Paolo C. Grigis and Arnold O. Benz: The Evolution of Reconnection Along an Arcade of Magnetic Loops. Astrophysical Journal 625, L143 - L146 (2005)

2. Marina Battaglia, Paolo C. Grigis, and Arnold O. Benz: Size Dependence of Solar X-ray Flare Properties. Astronomy and Astrophysics 439, 737 - 747(2005)

3. Kaspar Arzner and Arnold O. Benz: Temporal Correlation of Hard X-rays and Meter/Decimeter Radio Structures in Solar Flares. Solar Physics, 231, 117 - 141 (2005)

Abbreviations:

RHESSI:	Reuven Ramaty High Energy Solar, Spectroscopic Imager
PHOENIX:	Radio spectrometer of ETH Zurich in Bleien, near Graenichen, AG
HEDC:	HESSI European Data Center

5.2 SOHO/CELIAS: Solar Wind and Suprathermal Particles. Abundances of elements, charge states and isotopes and kinetic properties of heavy ions.

Institute: Physikalisches Institut, University of Bern
In cooperation with:
Max-Planck-Institut für Extraterrestrische Physik, Garching, Germany
Max-Planck-Institut für Aeronomie, Lindau, Germany
University of Maryland, College Park, NH, USA
University of New Hampshire, Durham, NH, USA

Principal Investigator: Peter Bochsler, Physikalisches Institut, University of Bern

Co-investigators:
H. Balsiger
P. Wurz

Method: CELIAS instrument on the SOHO spacecraft.

Purpose of research: Investigation of the solar wind composition. Abundances of approximately 20 elements and their isotopes are studied in detail for different solar wind conditions. Diagnostics of coronal conditions with charge state distributions of heavy ions. Study of the temporal evolution of transient events (e.g. Coronal Mass Ejections) in the main energy range of the solar wind and for suprathermal particles.

Status: SOHO was launched on December 2nd, 1995 and is operating since then. In May 2006 ESA approved a mission extension of SOHO until December 2009. The CELIAS instrument is still operating and produces valueable data. Data anaylsis, interpretation, and modelling of solar wind measurements are in progress.

Publications:

1. P. Wurz, "Solar Wind Composition," in The Dynamic Sun: Challenges for Theory and Observations, ESA SP-600 (2005) 5.2, 1-9.

2. P. Wurz, P. Bochsler, J.A. Paquette, and F.M. Ipavich, "The Calcium Abundance in the Solar Wind," Astrophys. Jou, 583 (2003), 489-495.

3. M. Uzzo, Y.-K. Ko, J. C. Raymond, P. Wurz, and F. M. Ipavich, "Elemental abundances for the 1996 streamer belt," Astrophys. Jou., 585 (2003) 1062-1072.

Abbreviations:

SOHO:	Solar and Heliospheric Observatory
CELIAS:	Charge, Element and Isotope Analysis System

5.3 STEREO/PLASTIC: Solar Wind and Suprathermal Particles. Abundances of elements, charge states and isotopes and kinetic properties of heavy ions.

Institute: Physikalisches Institut, University of Bern
In cooperation with:
University of New Hampshire, Durham, NH, USA
Max-Planck-Institut fŸ"r Extraterrestrische Physik, Garching, Germany

Principal Investigator: A. Galvin, University of New Hampshire, Durham, NH, USA

Co-investigators:
Peter Bochsler
L. Blush
P. Wurz

Method: PLASTIC instrument on the two STEREO spacecraft.

Purpose of research: The STEREO mission consists of two spacecraft located at Earth orbit, with one spacecraft flying ahead of the Earth and one spacecraft flying behind the Earth, both with increasing distance to the Earth with time. STEREOs main focus is on transient events in the solar wind, for example coronal mass ejections, which will be observed from two vantage points, perhaps from a third if the SOHO spacecraft is still operating then. The PLASTIC instrument (one on each spacecraft) will perform measurements of the solar wind elemental and charge composition. Measurements allow diagnostics of coronal conditions with charge state distributions of heavy ions. Study of the temporal evolution of transient events (e.g. Coronal Mass Ejections) in the main energy range of the solar wind and for suprathermal particles.

Status: The University of Bern built part of the PLASTIC instrument, namely the entrance system and electrostatic deflector, an ion-optical system to select the energy and arrival direction of the ions. The two flight models have been completed at UNH and were calibrated at the University of Bern. The two STEREO spacecraft are ready for lauch, which is currently scheduled for July 2006.

Publications:

1. L.M. Blush, P. Bochsler, H. Daoudi, A. Galvin, R. Karrer, L. Kistler, B. Klecker, E. Ms(bius, A. Opitz, M. Popecki, B. Thompson, R.F. Wimmer-Schweingruber, and P. Wurz, "Development and Calibration of Major Components for the STEREO/PLASTIC (Plasma and SupraThermal Ion Composition) Instrument," Adv. Space Res. 36(8), (2005) 1544-1556.

Abbreviations:

PLASTIC: PLasma and SupraThermal Ion Composition
STEREO: Solar Terrestrial Relations Observatory

5.4 Solar wind noble gases in GENESIS targets

Institute: Institute for Isotope Geology and Mineral Resources, ETH Zürich
In cooperation with NASA

Principal Investigator: Prof. Donald Burnett, Caltech, USA

Method: Laboratory analyses of noble gases in targets collecting solar wind ions on the Genesis spacecraft.

Purpose of research: The aim of NASA's Genesis mission is to substantially improve our knowledge of the elemental and isotopic composition of the sun, on a level of precision required for cosmochemistry, which is mostly not yet obtainable by direct analysis in space. Ultimately, Genesis should help us to better understand solar system formation. We plan the following experiments: Elemental (He-Xe) and isotopic (He, Ne, Ar) abundances of the noble gases in the solar wind and its different regimes. To reach the goals of Genesis, compositional differences between photosphere and solar wind or "fractionations" upon or after implantation into targets need to be quantified. Our strategy will be to analyse several different target materials from all solar wind regimes sampled by Genesis, partly by different techniques. The analyses will be complemented by measurements of targets with artificially implanted noble gases.
The isotopic composition of He, Ne, and Ar as a function of implantation depth in the metallic glass target. An amorphous metallic glass was selected as a special target on Genesis. This was motivated mainly by the search for an apparently ubiquitous but ill-understood noble gas component in lunar samples, dubbed SEP for Solar Energetic Particles. The amorphous target is well suited to be analysed by the in-vacuo etch technique developed and uniquely mastered in our laboratory. Can we verify the presence of SEP as an isotopically distinct high energy solar component in the Genesis metallic glass or may the lunar data finally have to be explained as an artefact caused by different implantation depths of different isotopes?
Variations of the Ne isotopic composition in the gold cross as function of the distance from the center of the concentrator target. The top priority of Genesis is the precise determination of the oxygen isotopic composition in the solar wind in targets where the solar wind was concentrated by an electrostatic mirror. Theoretical isotopic fractionation factors induced by this device need to be checked experimentally, by analysing Ne isotopes with high precision and high spatial resolution.
Kr and Xe isotopic analyses. To measure the Kr and Xe isotopic composition in the solar wind is probably the highest priority for Genesis apart from oxygen and nitrogen. Analyses of the small amounts of Kr and Xe will be performed with a high-sensitivity mass spectrometer equipped with 10 electron multipliers, allowing simultaneous detection of all isotopes.

Status: Depth profiles of the Ne isotopic composition in the metallic glass targets determined by closed system stepped etching are very comparable to expected depth profiles based on the measured solar wind speed distribution during the Genesis exposure period. This indicates that the putative high energy noble gas component "SEP" is not required to explain the data. It appears very likely that this apparent SEP component as deduced in lunar samples is an experimental artefact. First analyses of the Ne isotopic composition along one arm of the gold cross exposed within the Genesis concentrator target indicate a considerable isotopic fractionation along the radial position in the concentrator target. Basically, the observed fractionation is of the same order of magnitude as expected values. This means that ultimately the Genesis concentrator target should allow a precise determination of the ogygen isotopic composition in the solar wind.

Publications:

1. Grimberg A., Bühler F., Bochsler P., Heber V. S., Tosatti S., Jurewicz A. J. G., Hays C. C., McNamara K., Allton J. H., Burnett D. S., Baur H., and Wieler R. (2005) Solar Wind Noble Gases - Preliminary Results from Bulk Metallic Glass flown on Genesis. In Meteoritics Planet. Sci., Vol. 40, suppl., pp. A60.

2. Grimberg A., Bühler F., Burnett D. S., Jurewicz A. J. G., Hays C. C., Bochsler P., Heber V. S., Baur H., and Wieler R. (2006) Solar wind he and Ne from metallic glass flown on Genesis - preliminary bulk and velocity-dependant data. Lunar Planet Sci, XXXVII, Lunar Planet. Inst., Houston(abstract 1782).

3. Heber V. S., Wiens R. C., Burnett D. S., Baur H., Wiechert U., and Wieler R. (2006) Solar wind Ne in the Genesis concentrator gold cross by UV laser ablation: first preliminary data. Lunar Planet Sci, XXXVII, Lunar Planet. Inst., Houston, abstract 2175.

Abbreviations:

SEP: solar energetic particles

5.5 Solar flare research with RHESSI

Institute: Paul Scherrer Institut (PSI), Laboratory for Atsrophysics
In cooperation with:
Institut of Astronomy, ETHZ
Aristotle University (AUTH), Thessaloniki
Universite libre de Bruxelles (ULB)
University of California at Berkeley (UCLB)

Principal Investigator: Kaspar Arzner (PSI)

Coinvestigateurs: Arnold Benz (ETHZ)
Loukas Vlahos (AUTH)
Bernard Knaepen (ULB)
the RHESSI team (PSI, UCLB)

Method: Simulation, Research based on existing instuments

Purpose of research: Solar flares show violent and sudden X-ray and radio emission. While there is general agreement on the photon emission processes (i.e., bremsstrahlung, gyrosynchrotron emission, or plasma waves which are converted into electromagnetic radiation), the origin of high-energy electrons is still controversial. Possible acceleration mechansims include scattering on MHD type waves, and DC electric fields in reconnection sites. Our investigations are based on two approaches: data analysis and numerical simulations. The latter are supported by theoretical estimates whenever possible. Comparing data from the Reuven Ramaty High Energy Solar Spectroscopic Imager (RHESSI) and the frequency-agile Phoenix-2 radiometer at Bleien, Switzerland, we search for co-occurring temporal fine structures which indicate a common electron population responsible for both HXR and radio emissions. On the simulation side, ab-initio particle orbits in turbulent MHD fields with an Ohmic component provide theoretical predictions on acceleration times and energy spectra, and allow to switch on/off individual physical processes in order to investigate their influence, which is not possible for real data.

Status: Prior to the RHESSI launch in February 2002, the investigations were carried out on a purely theoretical and numerical basis. In particular, a percolation model of stochastic acceleration in dissipative MHD turbulence was proposed. As soon as RHESSI data became available, need for additional analysis software arose, which has in the sequel been developed at PSI. The purpose of this software is the identification of temporal fine structures in the RHESSI data, which, owing to the indirect RHESSI imaging principle, poses an inverse problem. Several approaches to solutions have been (and are) followed, with the goal of having different independent methods for benchmarking. The results have then then compared to radio (Phoenix-2) data. Theoretical work on particle acceleration and turbulence has been continued and published.

Publications:

1. Arzner K., Benz A.O. (2005):Temporal Correlation of Hard X-Rays and Meter/Decimeter Radio Structures in Solar Flares. Solar Phys., 231, 117.

2. Arzner, K., Vlahos, L. (2004): Particle Acceleration in Multiple Dissipation Regions. Astrophys. J. Letters, 605, L69

3. Arzner K., Knaepen B., Carati D., Denewet N., Vlahos L. (2006):The Effect of Coherent Structures on Stochastic Acceleration in MHD Turbulence. Astrophys. J., 637, 322

Abbreviations:

MHD:	Magnetohydrodynamics
RHESSI:	Reuven Ramaty High-Energy Solar Spectroscopic Imager

6 Others

6.1 The Zimmerwald Geodynamics Observatory

Institute: Astronomical Institute University of Berne
In cooperation with:
Federal Office of Topography
Federal Institute of Technology
Federal Office of Metrology

Principal Investigator: Werner Gurtner

Co-investigators:
Elmar Brockmann

Method: Research based on existing instuments: Laser telemeter, GPS/GLONASS receivers, optical telescope, gravimeters.

Purpose of research: Development, maintenance and operation of instruments for the collection of relevant data to be used in the determination of parameters like station position and velocities, earth rotation, the Earth's gravity field, atmospheric parameters (water vapor, free electron contents of the ionosphere), precise orbits of satellites (navigation/positioning systems, altimeter satellites, gravity missions), detection and tracking of near-earth objects, space debris. For this purpose some of the instruments are running permanently and fully automated (GPS/GLONASS receivers, earth tide gravimeter), others whenever weather permits (satellite laser ranging telemeter, optical (CCD) observations.

Status: In 1976 a dome with a dedicated Satellite Laser Ranging (SLR) system consisting of a cassegrain telescope, a pulsed laser and the necessary electronic components a was built at the Zimmerwald observatory. In 1997 a 1-meter telescope designed for both SLR and optical observations, a very advanced dual-frequency Laser, new electronics and computers replaced the previous system. Today, the Zimmerwald observatory is one of the most accurate and productive SLR-facilities in the International Laser Ranging Service (ILRS). Currently it is the only facility capable of performing dual-frequency SLR observations on a routine basis. The high productivity is mainly due to the advanced observation management, allowing for a quasi-simultaneous multi-satellite tracking and the high degree of automation.
Optical observations are performed using two different high-precision CCD cameras mounted on the same 1-meter telescope.
Depending on the scheduled laser satellites and optical targets the two operating modes are tightly interleaved.
The observatory is equipped with modern GPS (Global Positioning System) receivers, one of which is owned and operated by the Swiss Federal Office of Topography. It is one of the founding stations of the International GPS Service (IGS). Some of the receivers observe, in additon to GPS, also the Russian GLONASS satellite system.
The ETH Zurich owns a so called Earth tide gravimeter to monitor periodic changes of the Earth's gravity field in Zimmerwald.
The Federal Office of Metrology periodically determines the value of the Earth's gravity in Zimmerwald using an absolute (free-fall) gravimeter.

Publications:

1. W. Gurtner, E. Pop, J. Utzinger (2002). "Zimmerwald Dual-Wavelength Observations: First Experiences". Proceedings of the 13th International Workshop of Laser Ranging, Washington, DC, October 7-11, 2002.

2. W. Gurtner (2003). "Die Fundamentalstation Zimmerwald". Orion, No 316, June 2/2003

3. Schildknecht, T., R. Musci, M., W. Flury, J. Kuusela, J. de Leon, and L. de Fatima Dominguez Palmero, Properties of the High Area-to-Mass Ratio Space Debris Population In GEO, AMOS Technical Conference, September 5-9, Maui, Hawaii, 2005.

Abbreviations:

IGS:	International GPS Service
ILRS:	International Laser Ranging Service
SLR:	Satellite Laser Ranging
CCD:	Charge-Coupled Device
GPS:	Global Positioning System
GLONASS:	GLObal NAvigation Satellite System

6.2 CCD-Astrometry applied to fast moving objects

Institute: Astronomical Institute University of Berne
In cooperation with European Space Agency

Principal Investigator: T. Schildknecht

Method: Research based on existing instuments: Optical telescopes (1-meter telescope in Zimmerwald, 1-meter ESA telescope in Tenerife)

Purpose of research: The optical astronomy group of the AIUB is primarily conducting optical observations of artificial objects in the geostationary ring (GEO) and in the geostationary transfer (GTO) region. During the previous years a substantial set of observations of GEO objects has been acquired at the Zimmerwald Observatory. This data set consists of repeated astrometric measurements of about a dozen abandoned geostationary satellites. The data is used to investigate the long-term evolution of the orbits of these GEO objects. One particular goal of this work is an independent determination of the geopotential parameters C22 and S22 (Hugentobler et al., 1999).
The CCD-group is also involved in several search campaigns for ?unknown? objects in the GEO and the GTO region (Schildknecht et al., 2005). By ?unknown? objects in these regions we understand un-controlled, man-made objects, so-called space debris. The term space debris encompasses ?dead? satellites, spent rocket upper stages, mission related objects like jettisoned instrument covers, as well as satellite or upper stage fragments from in-orbit explosions. The size of these objects ranges from tens of meters to micrometers. AIUB regularly performs space debris surveys using the 1 m ESA telescope at Izaña, Tenerife (in the context of collaborations with the European Space Agency ESA) and limited test surveys at Zimmerwald.
The results from the GEO space debris surveys revealed a hitherto unknown but significant population of small-sized GEO debris in the size range from one meter to one decimeter. The distribution of this population is steeply increasing towards smaller sizes. The apparent ?cutoff? in the number of objects smaller than about 15 centimeters is entirely due to the sensitivity limit of the observation system. The real population of unknown objects smaller than about one decimeter could therefore still increase. The results have been confirmed to a certain extent by

the NASA measurements for object sizes around one meter. Measurements for smaller objects in GEO were, however, not yet obtained by any other group. The several clusters of small objects sharing similar dynamical characteristics are the most remarkable result. The only rational explanation for the origin of these clusters are explosions.
The CCD group is active in the field of space surveillance were it provided and still provides substantial contributions to several feasibility studies for a Europen space surveillance system. Observations from Zimmerwald are used to maintain the orbits of 100+ uncatalogued objects in high-altitude orbits in collaboration with a worldwide network of partners.

Status: Optical observations played an essential role at the Astronomical Institute of the University of Bern (AIUB) since its establishment in 1922. Such observations were first performed at the Muesmatt observatory, then at the Zimmerwald observatory (built 1956 by Prof. Max Schürer). The Zimmerwald observatory was extensively used for astrometric purposes. More than 100 asteroids and a hand full of comets (among them the comet Wild-II, the target of the NASA stardust mission) were discovered in Zimmerwald and named by the discoverer.
The 1-m telescope of the Zimmerwald observatory, inaugurated in 1997, was also designed as an astrometric telescope using the CCD-technique (Charge-Coupled Device). AIUB's astrometry group made extensive use of this facility to develop, as a broad-band facility, the astrometric observation technique, in particular for observing fast moving objects like artificial Earth satellites, space debris, Near Earth Asteroids (NEAs), etc.
The astrometry group of the AIUB today has a world-leading position in the domain of CCD-Astrometry applied to fast moving objects. This is underlined by the fact that the group developed the software system for ESA's Space Debris Telescope on the island of Tenerife (1-m Zeiss-telescope at the Teide Astrophysical Observatory). Survey campaigns performed at Tenerife, planned jointly by ESA and AIUB, and processed at AIUB using its software, significantly improved the knowledge of the space debris population, in particular in the so-called geostationary belt.
In 2003 the Zimmerwald astrometry facility could be successfully used for the first time to perform a significant number of so-called NEO follow-up observations. In view of the attention this field of celestial mechanics attracts in the scientific community and in public, the observation of NEOs at Zimmerwald should be viewed as a remarkable success.

Publications:

1. Schildknecht, T., R. Musci, W. Flury, J. Kuusela, J. de Leon, and L. de Fatima Dominguez Palmero, Optical Observations of Space Debris in High-Altitude Orbits, 4th European Conference on Space Debris, April 18-20, ESOC, Darmstadt, Germany, pp. 113?118, 2005.

2. Schildknecht, T., Wiedergeburt der traditionellen Himmelsüberwachung und Astrometrie dank moderner Techniken. Orion, No 316, June 2/2003.

3. Flohrer, T., T. Schildknecht, R. Musci, E. Stöveken, Performance Estimation for GEO Space Surveillance, 35th COSPAR Scientific Assembly, Jul. 18-25, Paris, France, 2004, and Advances in Space Research, Vol 35, No. 7, pp. 1226?1235, 2005.

Abbreviations:

CCD:	Charge-Coupled Device
ESA:	European Space Agency
GEO:	Geostationary Earth Orbit
GTO:	Geostationary Transfer Orbit

6.3 Center for Orbit Determination in Europe (CODE)

Institute: Astronomical Institute University of Berne
In cooperation with:

Swiss Federal Office of Topography, Wabern
Bundesamt für Kartographie und Geodaesie, Frankfurt a.M., Germany
Institut Geographique National, Paris, France.

Principal Investigator: Stefan Schaer

Co-investigators:

Urs Hugentobler SepCoInv Rolf Dach SepCoInv Michael Meindl

Method: Research based on existing instuments:GPS and GLONASS navigation satellites, IGS global tracking network

Purpose of research: In the framework of "global change" precise continuous surveying of the Earth's geometrical shape and deformations as well as the realization of a global reference frame at the millimeter level are of crucial importance, e.g., for monitoring sea level changes. Loading processes causing crustal deformations provide independent information, e.g., on the hydrological cycle, studying the Earth's rotation provides insight in motions and mass redistributions in the atmosphere, the oceans, and the deep interior of our planet.
CODE is an Analysis Center of the International GNSS Service (IGS). It determines for each day since 21 June 1992 the orbits of all active GPS (Global Positioning System) satellites and the clock corrections of all GPS satellites w.r.t. GPS time. The coordinates of a global network of about 150 tracking sites are computed on a daily basis for studying of vertical site displacements and plate motions, and to provide information for the realization of the International Terrestrial Reference Frame (ITRF). The daily position of the Earth's rotation axis with respect to the Earth's crust as well as the exact length-of-day is determined for each day and provided to the International Earth Rotation and Reference Systems Service (IERS). CODE also produces global map of the total free electron content in the atmosphere for each time interval of two hours.

Status: CODE is operating routinely since June 1992. The processing is currently based on the 30-seconds tracking data of about 150 globally distributed IGS (International GNSS Service) tracking sites. The products are computed and made available with latencies between a few hours and one week. Since May 2003 CODE computes precise orbits for the GLONASS navigation satellites, the Russian counterpart of the GPS, as the only IGS analysis center applying a fully combined GPS/GLONASS data analysis. Concrete plans to include data from the future European navigation system GALILEO into the processing are already established. In this context an involvment in a project aiming at realizing and maintaining the future Galileo Terrestrial Reference Frame can be mentioned. Current investigations include scale and origin of the realization of the ITRF, GNSS orbit model improvements, and the influence of satellite antenna phase patterns on the results.
Products with various latencies (few hours to seven days) are available. The accuracy of the GPS orbits is at the 1-3 cm level per satellite coordinate, at the few picoseconds level for the clock corrections. GLONASS orbits have currently an accuracy of 5 cm as confirmed by independent SLR (Satellite Laser Ranging) observations. Station coordinates for about 150 tracking stations are determined with an accuracy of few millimeters in latitude, longitude, and height. The daily position of the Earth's rotation axis with respect to the Earth's crust is determined with an accuracy of 0.1 mas, the exact length-of-day with an accuracy of 0.01 msec. Time series of Earth rotation parameters are available with high (2-hours) temporal resolution.

Time series of total electron content in the Earth's ionosphere as measured by GPS are available for an entire Solar cycle. The range of values span one order of magnitude between Solar minimum and maximum. Differential code biases for all satellites are monitored and made available for precise navigational applications. More information is available under http://www.aiub.unibe.ch/igs.html.

Publications:

1. G. Beutler, U. Hugentobler, M. Ploner, M. Meindl, T. Schildknecht, C. Urschl (2005). "Determining the orbits of EGNOS satellites based on optical or microwave observations". Advances in Space Research, Volume 36, pp. 392-401.

2. U. Hugentobler, M. Meindl, G. Beutler, H. Bock, R. Dach, A. Jaeggi, C. Urschl, L. Mervart, M. Rothacher, S. Schaer, E. Brockmann, D. Ineichen, A. Wiget, U. Wild, G. Weber, H. Habrich, C. Boucher (2006). "CODE IGS Analysis Center Technical Report 2003/2004", in "IGS 2003/2004 Technical Reports", K. Gowey, R. Neilan, A. Moore (Eds.), IGS Central Bureau, JPL, CA, USA, in press. http://www.aiub.unibe.ch/download/papers/codar_0304.pdf

3. M. Meindl (editor, 2005). "Celebrating a decade of the International GPS Service", Workshop and Symposium, 2004, Bern. Astronomical Institute, University of Bern, Switzerland, 256 pages.

4. M. Meindl, S. Schaer, U. Hugentobler, G. Beutler (2003). "Tropospheric Gradient Estimation at CODE: Results from Global Solutions". Special issue Journal of Meteorological Society of Japan, Volume 82, No. 1B, pp. 331-338.

Abbreviations:

CODE:	Center for Orbit Determination in Europe
GNSS:	Global Navigation Satellite System
GLONASS:	Global Navigation Satellite System
GPS:	Global Positioning System
IERS:	International Earth Rotation and Reference Systems Service
IGS:	International GNSS Service
ITRF:	International Terrestrial Reference Frame
SLR:	Satellite Laser Ranging

6.4 Precise Orbit Determination for Low Earth Orbiters Using the Global Positioning System

Institute: Astronomical Institute University of Berne

Principal Investigator: Urs Hugentobler

Co-investigators:

Heike Bock
Adrian Jaeggi
Gerhard Beutler

Method: Research based on existing instuments: Global Positioning System (GPS) tracking data from satellites CHAMP, GRACE-A and B, SAC-C, and JASON-1.

Purpose of research: Low Earth Orbiters (LEOs) are orbiting the Earth at altitudes up to about 2000 km. Modern navigation satellite systems like the Global Positioning System (GPS) are at much higher altitudes, provide a global coverage and may, therefore, be used for determining orbits using spaceborne GPS receivers. In a few years already more than a dozen LEO satellites will be equipped with GPS receivers for precise orbit determination.
Depending on the observation type and the analysis method used, LEO orbits may be established with the accuracy of a few meters, a few decimeters or at the centimeter level. Different applications ask for different methods. Existing and planned missions for acquiring globally distributed atmospheric temperature profiles on a routine basis using the GPS occultation technique require a satellite velocity accuracy of better than 0.1 mm/sec, an accuracy which can be provided by GPS with modern data analysis techniques. For the European GOCE (Gravity Field and Steady State Ocean Circulation Explorer) planned for launch in 2006 to an altitude of only 250 km and measuring the Earth's gravity field with an unprecedented accuracy, an orbit accuracy of 1-2 cm is required, a challenging goal which can only be met with the GPS.

Status: With a sound background in precise orbit determination and GPS data analysis the Astronomical Institute, University of Bern, started in 1999 with the analysis of GPS data from low Earth orbiters. A Ph.D. study (Heike Bock) focused on methods for efficient and robust algorithms for generating reduced-dynamic orbits and kinematic trajectories for low orbiting satellites.
The Ph.D. candidate Adrian Jaeggi is investigating the procedures promising the highest possible orbit accuracies. The focus is currently on the computation of orbits with highly reduced dynamic information that may be well suited for gravity field recovery. For the estimation of a large number of coefficiens of the Earth gravity field efficient algorithms were developed and tested.
Validation of reduced-dynamic orbits computed for CHAMP show an orbit accuracy of 3 cm. With resolution of phase ambiguities between the two satellites GRACE A and B relative satellite positions with an accuracy of a few mm rms are obtained and validated with independent K-band range measurements. Further improvements in stochastic orbit determination and inclusion of accelerometer measurements into the data analysis using undiffenced as well as differenced GPS observations are current study topics. The work is supported by the Swiss National Science Foundation.
In a consortium of ten European institutions the AIUB participates in the scientific data analysis for ESA's GOCE satellite mission striving for a mapping of the Earth's gravity field with unprecedented accuracy. The AIUB is responsible for the computation of the precise orbits for the satellite with a goal of 1-2 cm accuracy.

Publications:

1. G. Beutler, A. Jaeggi, U. Hugentobler, L. Mervart (2006). "Efficient orbit modelling using pseudo-stochastic parameters", Journal of Geodesy, accepted for publication.

2. A. Jaeggi, G. Beutler, U. Hugentobler (2005). "Reduced-dynamic orbit determination and the use of accelerometer data", Advances in Space Research, 36, 438-444, doi:10.1016/j.asr.2004.11.

3. A. Jaeggi, U. Hugentobler, G. Beutler (2006). "Pseudo-stochastic orbit modeling techniques for low Earth orbiters", Journal of Geodesy, 80, 47-60, doi:10.1007/s00190-006-002-9.

Abbreviations:

AIUB:	Astronomical Institute, University of Bern
GNSS:	Global Navigation Satellite System
GPS:	Global Positioning System
IGS:	International GNSS Service
LEO:	Low Earth Orbiter
GOCE:	Gravity Field and Steady State Ocean Circulation Explorer

6.5 Processing of high-resolution satellite images

Institute: Chair of Photogrammetry and Remote Sensing,Inst. for Geodesy and Photogrammetry, ETH Zürich
In cooperation with:
University of Melbourne, Melbourne
STARLABO Corp., Tokyo
Swissphoto Group AG, Regensdorf - Watt
CNES-ISPRS Study Team, -MeteoSwiss / EUMETSAT
Japan Aerospace Earth Exploration Agency (JAXA)
Space Imaging

Principal Investigator: Prof. Dr. A. Grün

Co-investigators:
Dr. Emmanuel Baltsavias

Method: Satellite

Purpose of research: High-resolution satellite images, with ground pixel size of 0.5 to 2.5 m, offer new application possibilities. We develop algorithms and methods to analyse the quality and potential of such images, and derive various products, especially for the following tasks: modelling of the sensors, image quality analysis and quality improvement, measurement of single points, measurement of digital terrain and surface models, generation of orthoimages and maps, 3D measurement of objects (e.g. roads, buildings), 3D visualisation and animation. Our methods are to a large extent automated, accurate (in the best case of well-defined single points 0.3-0.4 m), with high success rate and high reliability, using often simple sensor models.

Status: Methods: The processing of high-resolution satellite images provides a challenge for algorithmic redesign and this opens the possibility to reconsider and improve many photogrammetric processing components, like image enhancement, multi-channel color processing, triangulation, orthophoto and DTM generation and object extraction in general. Different software have been developed for the processing of HRSI, including these aspects:
-Radiometric analysis and improvement. -Image orientation. Different approaches, both rigorous and non-rigorous, have been investigated. A rigorous sensor model for the georeferencing of linear array sensors has been developed for the external and internal orientation estimation, according to the physical properties of pushbroom acquisition. Alternative non -rigorous methods include Rational Polynomial Functions and relief-corrected 2D affine transformation. -Matching and DTM generation. A hybrid image matching procedure, which exploits the characteristics of linear array imagery and its image geometry, is used to produce dense, precise and reliable results for DSM / DTM generation. The quality is controlled by automated assigning different

quality levels and reliability indicators to matched features. -Analysis of the DSM/DTM generation results -Orthophoto production -3D object extraction. Features can be collected manually or semi- automatically in stereoscopic and multi-image monoscopic mode.
We also develop a software system, called SAT-PP, which may be commercialised soon, that includes all these steps for the processing of satellite images, including high-resolution ones.
Results: We have processed data in various areas of Switzerland but also in Italy, Greece, Australia, Afghanistan, Germany and Japan. In all cases, Ground Control Points (GCPS) have been used, often having a high accuracy of 1-3 dm. Processed sensors include Ikonos-2, EROS-A1, Quickbird-2, Orbview-3 and SPOT-5/HRG and HRS with respectively 2.5 m and 5 m x 10 m ground pixel size. The results from our IKONOS testfield (Switzerland) in Thun shows, that the accurate matching allowed the detection and quantification of errors in the interior orientation of the sensor, caused by changes in the relative position of the 3 CCDs forming the virtual CCD line. These errors were verified through a cooperation with Space Imaging and recomputation of the sensor interior orientation. Depending on the accuracy of the matching method and of the reference DSM, we estimate that this in-flight calibration method can detect interior orientation errors causing parallax errors of 0.3-0.5 pixels or more.
Latest investigations: The Advanced Land Observing Satellite (ALOS) follows the Japanese Earth Resources Satellite-1 (JERS-1) and the Advanced Earth Observing satellite (ADEOS) and will be used for precise land observation. Japan Aerospace Earth Exploration Agency (JAXA) launched the satellite in january 2006. Prof. A. Grün is a Member of the Calibration / Validation Team and Principal Investigator for JAXA's ALOS/PRISM mission. As such his responsibilities include the followings tasks: establishment of test sites, calibration and validation of ALOS/PRISM images and products. The testfield for the calibration and validation in Switzerland is placed in the area of Bern/Thun, including urban, mountainous and open areas. The size of the testfield is around 35 km by 35 km and its height range is around 550 m to 2200 m above sealevel. The reference DSM/DTM was generated from 3 sets of 3x3 aerial images at a scale 1:25000 - 1:35000. As ground control and check points, natural points measured with GPS are used.

Publications:

1. Baltsavias, E., Zhang, L., Eisenbeiss, H., 2006: DSM Generation and Interior Orientation Determination of IKONOS Images Using a Testfield in Switzerland. Photogrammetrie, Fernerkundung, Geoinformation, (1), pp. 41-54.

2. Fraser, C., Baltsavias, E.P., Gruen, A., 2002. Processing of Ikonos imagery for sub-metre 3D positioning and building extraction. PRS, 56(3): 177-194.

3. Poli, D., Zhang, L., Gruen, A., 2004: SPOT-5/HRS stereo images orientation and automated DSM generation (Invited Paper). International Archives of Photogrammetry and Remote Sensing, Vol. 35, Part B1, Istanbul, pp. 421-432.

Abbreviations:

CCD:	Charge Coupled Device
DSM:	Digital Surface Model
DTM:	Digital Terrain Model
HRG:	High Resolution Geometric
HRS:	High Resolution Stereoscopic
HRSI:	High Resolution Satellite Images

6.6 Time-Domain Back-Projection Processor for Synthetic Aperture Radar Data of Spaceborne Sensors

Institute: Remote Sensing Laboratories (RSL) University of Zurich-Irchel

Principal Investigator: Prof. Dr. D. Nuesch

Co-investigators:
Dr. E. Meier, O. Frey

Method: Research based on existing instuments: ENVISAT/ASAR

Purpose of research: As for any type of remotely sensed data, accurate geographical localization as well as geometric and radiometric accuracy are key requirements in order to retrieve application-oriented data products from SAR data. The conventional SAR processing chain, which leads to geographically referenced SAR data, consists of two main steps: first, the image generation and, in a second step, the resulting SLC image is transformed to the favored map coordinate system. We investigated a time-domain back-projection approach that replaces the two steps, image formation and accurate geographical localization, by one algorithm leading directly to SAR images in the desired map coordinates.
SAR data of rugged terrain show considerable geometric and radiometric distortions, which are a result of the topographic undulation combined with the slant-range geometry of the SAR system as well as the antenna gain pattern. Approximative corrections of these distortions are commonly applied as a post-processing step. Our goal was to introduce more rigour into the calibration procedure by integrating it into the image formation step (time-domain back-projection).

Status: The time-domain back-projection processing technique was evaluated with spaceborne ENVISAT/ASAR image mode data. We assessed the geolocation accuracy and the radiometric performance of dedicated point targets such as transponders and a corner reflector. In addition, we compared our findings with results from corresponding products processed at the European Space Agency (ESA), which were validated within the scope of ENVISAT/ASAR Cal/Val activities. In general, the geolocation accuracy and the radiometric performance were found to be comparable to the conventional two-step technique. For certain quality measures the performance could be slightly improved. In addition, a correction for geometric and radiometric distortions of SAR images was developed and integrated into the time-domain back-projection algorithm. Experimental results using ENVISAT/ASAR image mode data are promising with respect to the performance of the radiometric calibration. Currently, we are investigating other radiometric calibration approaches as well as an extension of the algorithm towards airborne SAR data.

Publications:

1. FREY O., MEIER E., NUESCH D. [2005]: A Study on Integrated SAR Processing and Geocoding by Means of Time-Domain Back-Projection, Proc. of the Int. Radar Symposium, Berlin, Germany, Sept. 6-8, 2005

2. FREY O., MEIER E., NUESCH D. [2005]: Processing SAR Data of Rugged Terrain by Time-Domain Back-Projection, Proc. SPIE Vol. 5980: SAR Image Analysis, Modeling, and Techniques X, Francesco Posa; Ed., Oct. 2005, p. 71-79

Abbreviations:

ASAR:	Advanced Synthetic Aperture Radar
SAR:	Synthetic Aperture Radar
ESA:	European Space Agency
IM:	ENVISAT ASAR Image Mode
RSL:	Remote Sensing Laboratories
SLC:	Single Look Complex

6.7 EO application to hazard mapping

Institute: Gamma Remote Sensing AG

Principal Investigator: A. Wiesmann

Co-investigators:
U. Wegmüller SepCoInv T. Strozzi SepCoInv C. Werner

Method: EO data processing and interpretation

Purpose of research: Evaluate potential and develop applications of SAR data for the mapping of natural hazards (forest storm damage, flooding, avalanches, landslides). The main methods used are change detection techniques applied to multi-temporal and interferometric SAR. The research also includes signal processing and modeling aspects. In additions methods to combine the potential of optical and SAR EO data for mapping applications, in particular the mapping of natural hazards, are evaluated.

Status: The related KTI project Combined Remote Sensing Natural Monitoring, CIRSTEN, in co-operation between the Institute of Geodesy and Photogrammetry of the ETH Zürich and GAMMA to combine the potential of optical and SAR EO data for mapping applications, in particular the mapping of natural hazards, with GAMMA's main focus on SAR based applications was finalized in 2002.

The related ESA GSTP Study on Multi-Sensor and Interferometric Retrieval Techniques study (done in cooperation with Joanneum Research, Graz, and the University of Innsbruck) was a two years project (2000-2002) in which GAMMA investigated the potential of remote sensing, and in particular SAR, to map natural hazard events, including forest storm damage, flooding, and avalanches.

In 2002 a project was started to better develop the use of EO based information in the context of disaster management and humanitarian aid projects. Currently it is plan to continue such activity in the frame of the ESA GMES Project RESPOND (coordinated by Infoterra UK).

The related ESA DUP Projects ALPS and SLAM focused on the detection and mapping of creeping slopes using differential SAR interferometry. The main application area is the alpine zone. In 2005 landslide monitoring related activities were continued in the frame of the ESA GMES Project Terrafirma (coordinated by Nigel Press Associates, UK) and as part of the FP6 Project ASSIST (coordinated by VCS, Germany).

So far the hazard types investigated included: forest storm damage (Lothar) avalanche mapping flood mapping land slide mapping

Publications:

1. Wiesmann A., U. Wegmüller, M. Honikel, T. Strozzi T., and C. Werner, "Hazard mapping with multi-temporal SAR and InSAR", Proc. 3rd Int. Symp. on Retrieval of Bio- and Geophysical Parameters from SAR data for land applications, Sheffield, UK, 11-14 Sep. 2001, ESA SP-475, pp. 133-138, 2002.

2. Wegmüller U., A. Wiesmann, M. Honikel, T. Strozzi T., and C. Werner, "Potential roles for space-borne SAR in disaster management and humanitarian relief", Proc. 3rd Int. Symp. on Retrieval of Bio- and Geophysical Parameters from SAR data for land applications, Sheffield, UK, 11-14 Sep. 2001, ESA SP-475, pp. 307-311, 2002.

3. Strozzi T., U. Wegmüller, C. Werner, and A. Wiesmann, Alpine landslide periodical survey, Proc. IGARSS 2002, Toronto, Canada, pp. 3629-3631, 24-28 June 2002.

Abbreviations:

EO: Earth Observation
SAR: Synthetic Aperture Radar
ESA: European Space Agency
DUP: Data User Program

6.8 EO application to environmental monitoring

Institute: Gamma Remote Sensing AG
In cooperation with:
VTT-Automation, Finland
European Forest Institute (EFI)
Stora Enso, Finland
Univ. Jena, Germany

Principal Investigator: U. Wegmüller

Co-investigators:
C. Schmullius, (Univ. Jena)
T. Häme (VTT)
A. Wiesmann
T. Strozzi
C. Werner
M. Santoro

Method: EO data processing and interpretation

Purpose of research: Evaluate potential and develop applications of EO data in the context of environmental monitoring, with one main focus on forest and forest change mapping and the development of carbon monitoring services related to the implementation of the Kyoto protocol. Another focus is on the use of EO data based products as input to carbon cycle and green-house gas models.

Status: In the frame of ESA's programme TESEO (Treaty enforcement services using Earth Observation) a project for the development of carbon monitoring services related to the implementation of the Kyoto Treaty, was successfully proposed by a team lead by VTT-Automation, Finland, with the European Forest Institute (EFI), Stora Enso, Finland, and GAMMA as partners. A project duration of 16 months is planned. GAMMA's responsibilities are to review the potential of existing and near future SAR techniques and sensors and to propose, implement, and demonstrate Kyoto related services.
GAMMA participates in the EC Framework 5 project SIBERIA II (2002-2005), which concentrates on research related to the use of EO data based products as input to carbon cycle and greenhouse gas models.

Publications:

1. Strozzi T., P. B. G. Dammert, U. Wegmüller, J-M. Martinez, A. Beaudoin, J. Askne, and M. Hallikainen, Landuse mapping with ERS SAR interferometry, IEEE Trans. Geosci. Remote Sensing, Vol. 38, No. 2, pp. 766-775, 2000.

2. Wiesmann A., L. Demargne, F. Ribbes, M. Honikel, H. Yésou, and U. Wegmüller , "Forest storm damage assessment with ERS Tandem data", Proceedings of ERS-ENVISAT Symposium, Gothenburg, Sweden, 16-20 Oct. 2000.

3. Wiesmann A., Wegmüller U., T. Strozzi, and C. Werner, "The use of JERS SAR within the boreal forest mapping project SIBERIA", Proceedings of IGARSS 2000, Honolulu, USA, 24-28 July 2000.

Abbreviations:

EO:	Earth Observation
SAR:	Synthetic Aperture Radar
ESA:	European Space Agency

6.9 EO application to land surface displacement mapping

Institute: Gamma Remote Sensing AG
In cooperation with:
CNR-ISDGM, Venice, Italy
2e Deutsch Steinkohle DSK, Deutsche Montan Technologie (DMT)

Principal Investigator: T. Strozzi

Co-investigators:
L. Tosi (CNR-ISDGM)
V. Spreckels (DSK), Deutsche Montan

Method: EO data processing and interpretation

Purpose of research: Land surface deformation mapping with differential SAR interferometry. Evaluate potential and develop applications for different types of land surface deformations (subsidence caused by ground-water extraction and natural compaction, mining induced subsidence, glacier motion, land slides, seismic deformation, volcanic deformation).

Status: In the frame of projects supported by the ESA Data User Programme (DUP) and Earth Observation Market Development Programme (EOMD) and GMES GAMMA developed and demonstrated SAR interferometric deformation mapping services. The applications included subsidence caused by ground-water extraction and natural compaction, as well as subsidence related to exploration of the underground resources coal, oil, and gas. The work was supported by contacts to authorities as well as the mining and oil industry. Between Nov. 2001 and Nov. 2003 a land subsidence monitoring service in the lagoon of Venice for regional and administrative authorities, will be developed in cooperation with CNR-ISDGM, Venice, Italy as project partner. Between 2003 and 2006 deformation mapping services for the mining sector are being developed in cooperation with DMT, Essen, Germany.
The interferometric techniques necessary for land slide monitoring are being developed and applied to the Swiss and Italian Alps. First promising results indicated a good potential, so that this work was continued.
In 2005 landslide monitoring related activities were continued in the frame of the ESA GMES Project Terrafirma (coordinated by Nigel Press Associates, UK) and as part of the FP6 Project ASSIST (coordinated by VCS, Germany).

Publications:

1. Wegmüller U., T. Strozzi, and L. Tosi, "Differential SAR interferometry for land subsidence monitoring: methodology and examples", Proceedings of SISOLS 2000, Ravenna, Italy, 25 -29 September 2000.

2. Strozzi T., U. Wegmüller, L. Tosi, G. Bitelli, and V. Spreckels, Land subsidence monitoring with differential SAR interferometry, Photogrammetric Engineering and Remote Sensing, Vol. 67, No. 11, pp. 1261-1270, Nov. 2001.

3. Spreckels V., J. Musiedlak, U. Wegmüller, T. Strozzi, and C. Wichlacz, "Detection of underground coal mining-induced surface deformation by differential InSAR data", ISPRS WG I/2, I/5, IV/7 Workshop on High resolution mapping from space, Hannover, Germany, 19-21 Sep. 2001.

Abbreviations:

EO:	Earth Observation
SAR:	Earth Observation
ESA:	European Space Agency
DUP:	Data User Programm
EOMD:	Earth Observation Market Development Program

6.10 SAR and SAR interferometric algorithms and software

Institute: Gamma Remote Sensing AG

Principal Investigator: C. Werner

Co-investigators:

U. Wegmüller
T. Strozzi
A. Wiesmann,

Method: EO data processing and interpretation

Purpose of research: SAR and SAR interferometric algorithms and software research and development as technology push to the development of EO based applications. The activity strongly interacts with GAMMA's EO application development projects. Another objective is to keep GAMMA's high level commercial software package up-to-date

Status: Recent SAR and SAR interferometric algorithms and software research and development included: -the combination (stacking) of multiple interferograms to significantly reduce deformation estimation errors -the investigation and development of alternative methods for surface deformation mapping such as intensity and coherence tracking -phase unwrapping algorithm development using triangular network and minimum cost flow methods
In 2001, research and development of a new technique for the interferometric interpretation of the SAR image phase of point targets was started. In 2003 a software package for interferometric point target analysis (IPTA) could be launched.
In 2002 adaptations to the ASAR sensor on ENVISAT, were realized including the development of tools to explore the additional functionality of this new sensor.
Adaptations of processing routines to the ALOS PALSAR a Japanese space-borne SAR to launched in Jan. 2006 are ongoing.
Preparations to adapt processing routines to the TerraSAR-X, and Radarsat 2, SAR sensors to be launched in late 2006 have started.
In 2005 an important aspect was the development of ScanSAR interferometry routines. This development will be ongoing in 2006.

Publications:

1. Werner C., U. Wegmüller, T. Strozzi, and A. Wiesmann, "Gamma SAR and Interferometric Processing Software", Proceedings of ERS-ENVISAT Symposium, Gothenburg, Sweden, 16-20 Oct. 2000.

2. Wegmüller U., C. Werner, T. Strozzi, A. Wiesmann, "Automated and precise image registration procedures", Proceedings of MultiTemp2001 Workshop, Trento, Italy, 13-14 Sep. 2001 (published by World Scientific).

3. Werner C., U. Wegmüller, T. Strozzi, and A. Wiesmann, "Interferometric point target analysis for deformation mapping", Proc. IGARSS 2003, Toulouse, France, 21-25 July 2003

Abbreviations:

EO:	Earth Observation
SAR:	Synthetic Aperture Radar
ESA:	European Space Agency