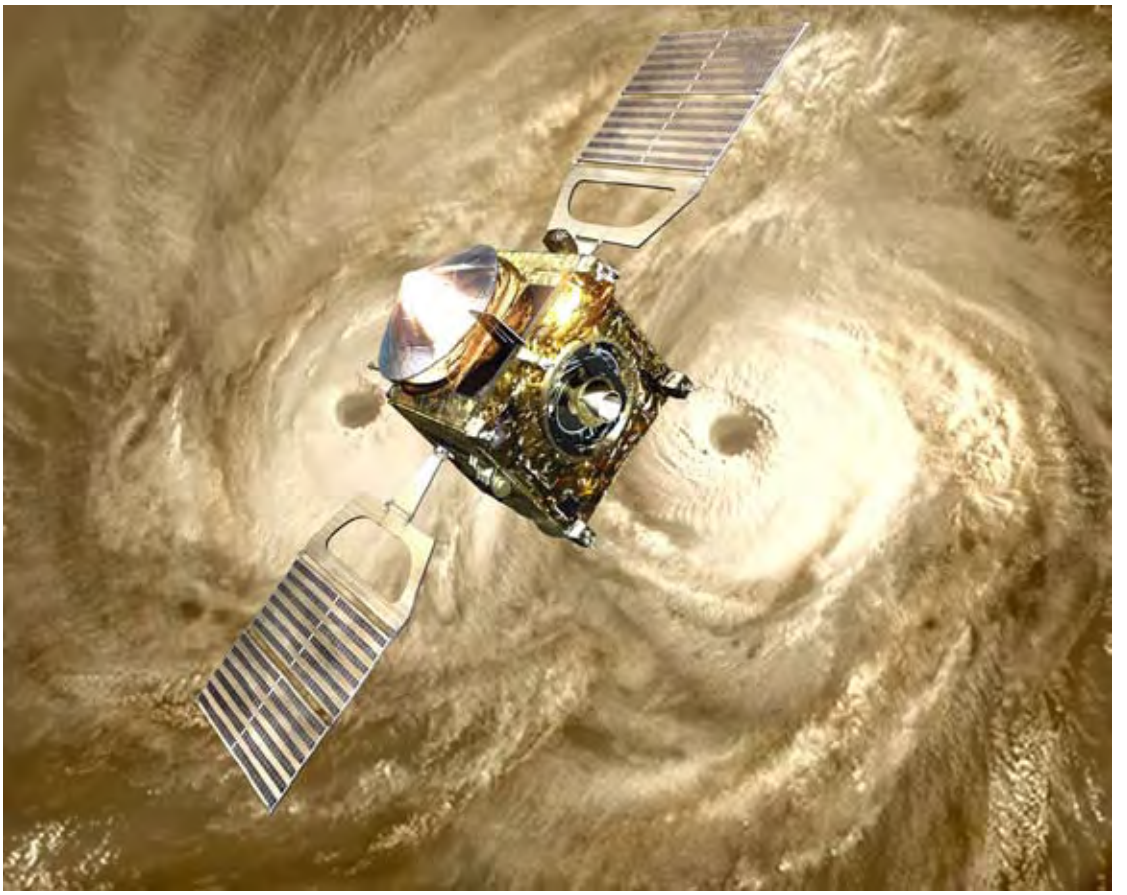
Space Research in Finland

Report to COSPAR 2008



COSPAR
Finnish National Committee

Tekes

Academy of Finland

Space Research in Finland

Report to COSPAR 2008

Editors

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Sini Merikallio
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COSPAR
Finnish National Committee

ACADEMY
OF FINLAND

Helsinki 2008

Front cover:

Venus Express is the first Venus exploration mission of the European Space Agency. It was launched in November 9, 2005 and is currently in orbit around Venus and collecting scientific data. Finlands contributions in Venus Express are participation in Aspera 4 instrument and in providing power distribution units for the spacecraft. Picture credits: ESA

Back cover:

Metop-A, the first of three satellites of the EUMETSAT Polar System, was launched in October 2006. Finland participated via Gome-2 instrument electronichs and satellite bus S/W development. Finland is also leading the international Satellite Application Facility for ozone and atmospheric chemistry (O3M-SAF) –project where the aim is to process, validate, archive and distribute the ozone and atmospheric chemistry data from Metop satellite and especially from the GOME-2 instrument. At the end of 2007 first O3M-SAF products were in pre-operational phase.

Tekes, the Finnish Funding Agency for Technology and Innovation

Tekes is the main public funding organisation for research and development (R&D) in Finland. Tekes funds industrial projects as well as projects in research organisations, and especially promotes innovative, risk-intensive projects. Tekes offers partners from abroad a gateway to the key technology players in Finland.

Tekes programmes
– Tekes´ choices for the greatest impact of R&D funding

Tekes uses programmes to allocate its financing, networking and expert services to areas that are important for business and society. Programmes are launched in areas of application and technology that are in line with the focus areas in Tekes' strategy. Tekes allocates about half the financing granted to companies, universities and research institutes through the programmes. Tekes programmes have been contributing to changes in the Finnish innovation environment for twenty years.

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Foreword

This is the bi-annual report of Finnish Space Research to the Committee on Space Research (COSPAR) prepared jointly by the Finnish National Committee of COSPAR and Tekes (Finnish Funding Agency for Technology and Innovation). The report describes the overall structure of Finnish space activities, the presently applied strategy, and main funding sources. The major space programmes are briefly listed. The main body of the report describes the progress during 2006-2007 in pure and applied space sciences within the domain of COSPAR activities.

The highlights of Finnish space science during the years 2006-2007 were the arrival of ESA's Venus Express to the orbit around Venus in 2006, the launch of NASA's Phoenix mission to Mars in 2007, carrying a Finnish atmospheric pressure instrument, completion of hardware to the Low Frequency Instrument of ESA's Planck satellite in 2007 and the start of the next major scientific project the solar X-ray instrument SIXS for ESA's BepiColombo mission in 2006. In the field of Earth observations and atmospheric research the Finnish research community has strong interests in Metop-A, the first of three satellites of the EUMETSAT Polar System, that was launched in 2006 and in the Canadian Radarsat-2, launched in 2007.

A list of Finnish peer-reviewed articles in space research in 2006-2007 can be found in the pdf-format together with this report on the web-site of the Finnish National Committee of COSPAR:
http://www.cospar.fi/reports

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List of COSPAR-related publications is available in the web site http://www.cospar.fi/reports

1. Overview of Finnish Space Activity

1.1 Finnish space research 50 years after the first artificial satellite

Finnish space research utilising space elements began already 50 years ago with the first man-made satellites, Sputnik-1 and -2, whose orbital motions were used in studies of the Earth's gravitational field. The International Geophysical Year 1957-1958, which led to the establishment of the Committee on Space Research (COSPAR), also brought several ground-based space research instruments to Finland, in particular all-sky cameras whose modern successors are still today utilized together with other ground-based and space-borne insturments in studies of the aurora borealis and the physics behind this magnificent phenomenon.

Finland joined COSPAR in 1964. However, it took more than 20 years before the first Finnish instrument contributions to spacecraft materialized with the Russian Phobos-mission launched in 1988. A year earlier Finland had become an associate member of ESA and a full member of ESA's Science Programme, which made it possible for Finland to immediately join the first Cornerstone missions of the Horizon 2000 Programme, Cluster and SOHO, with significant scientific impact. Today Finnish scientists and industry participate in practically all present and future ESA science missions in various roles (Principal Investigator, Co-Investigator, hardware supplier, system level contractor, etc.). In addition to the Science Programme the second main pillar of Finland's ESA activities is the Earth Observation Programme, where the Envisat mission and, in particular, its GOMOS instrument introduced Finnish scientists to the European field. Today the Finnish Earth observation activities cover a wide range of topics with scientific, societal, and technological interests.

While COSPAR as an organization has strong focus in space-borne observations, the Finnish space research community has strong ties to the various ground-based means of observing space from the immediate Earth environment to as far as it is possible with modern telescopes. Finland has been an active member in the European Incoherent Scatter Radar Facility (EISCAT) and the Nordic Optical Telescope (NOT). In 2004 a major step for the Finnish ground-based astronomy was taken when Finland joined the European Southern Observatory (ESO) and thus got a full access to this first-class space research infrastructure.

Now, 50 years after the days when scientists were following the motion of the first satellites in the sky, the Finnish space research has reached a strong international position. We have been able to educate a new generation of space scientists and obtained a healty mixture of experienced researches and enthusiastic young scientists who are capable of harvesting the fruits of the rapid growth of Finnish activities during the past 20 years.

1.2 Summary of the Finnish space policy

Space activities in Finland are administrated in decentralised way mainly involving Tekes (Finnish Funding Agency for Technology and Innovation), the Academy of Finland and the Ministry of Trade and Industry (MTI; 1 January 2008 onwards reorganized as the Ministry of Employment and the Economy).

The Finnish Space Committee (established in 1983) acts as the overall coordinating body for the Finnish space activities. It makes propositions and proposals and gives statements on matters related to space research, education and industrial development, exploitation of knowledge derived from space activities, and national and international cooperation.

The Committee is nominated on MTI's proposal by the Government for a period of three years. It is chaired by MTI and has members from relevant ministries and main actors. The Committee meets on average six times per year. From 1 April 2007 to 30 March 2010 Finnish Space Committee members and advisors are presented on the next page.

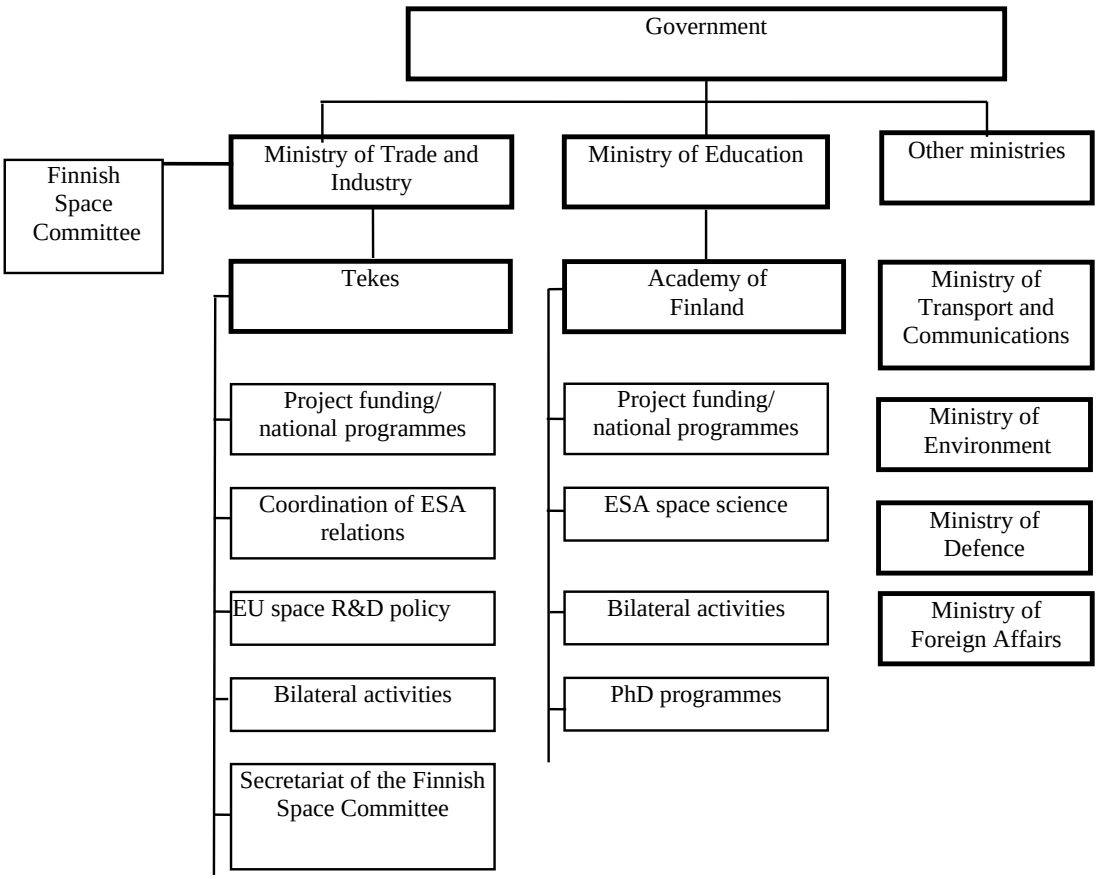

Figure 1.2
Organisation for administration of space activities in Finland

Chairman

Mr. Antti Joensuu Ministry of Trade and Industry
From April 1, 2008, the Chairman is Mr. Petri Peltonen from the Ministry of Employment and the Economy

Vice Chairman

Ms. Mirja Vihma-Kaurinkoski Ministry of Education
From April 1, 2008 the Vice Chairman is Mr. Markku Suvanen from the Minstry of Education.

Members

Dr. Susan Linko	Academy of Finland
Mr. Kimmo Myllyoja	Patria Systems Oy
Mr. Kari T. Ojala	Ministry of Transport and Communications
Ms. Tarja Pesämaa	Ministry of Foreign Affairs
Prof. Eeva-Liisa Poutanen	Finnish Institute of Marine Research
Prof. Tuija Pulkkinen	Finnish Meteorological Institute
Dr. Kari Tilli	Tekes
Gen. Veli-Pekka Valtonen	Finnish Defence Forces
Mr. Juha Vuorimies	Ministry of Environment

Permanent Advisors

Ms. Johanna Hakala	Ministry of Interior
Dr. Juhani Huovelin	University of Helsinki
Prof. Tuomas Häme	VTT
Mr. Kimmo Kanto	Tekes
Prof. Hannu Koskinen	University of Helsinki
Prof. Jarkko Koskinen	Finnish Meteorological Institute
Prof. Risto Kuittinen	Finnish Geodetic Institute
Dr. Heikki Sipilä	Oxford Instruments Analytical
Mr. Yrjö Sucksdorff	Finnish Environment Institute (SYKE)
Ms. Tuija Ypyä	Ministry of Trade and Industry

Secretaries

Dr. Anna Kalliomäki	Academy of Finland
Mr. Pauli Stigell	Tekes

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1.3 International co-operation

ESA is Finland's main international collaborative partner in space activities. Finland has formal co-operation agreements with the following space organisations (the Finnish body which has the responsibility of this collaboration is indicated):

COSPAR
Finnish National Committee of COSPAR

ESA
Tekes (Finnish Funding Agency for Technology and Innovation)

ESO
Academy of Finland

EISCAT
Academy of Finland

EUMETSAT
Finnish Meteorological Institute

EUTELSAT
Telia-Sonera Corporation

INTELSAT
Telia-Sonera Corporation

INMARSAT
Telia-Sonera Corporation

EARSeL
Helsinki University of Technology

SARSAT/COSPAT
Frontier Guard of Finland

2. Finnish National Strategy for Space Research and Development

2.1 Vision and goals of Finnish space activities

In Finland the guiding principles in the space sector are science and technology policy and the desire to satisfy the needs of the society using the means enabled by space technology. The benefits derived from investment in the space sector are seen in the form of accumulation of human capital, improvement in the international competitiveness of companies, more effective public services and improvements in the quality of life.

The goals are:

- collection of data and scientific research of Earth environment and objects and phenomena in outer space,
- improvement technological competitiveness of industry and service sector thus supporting economical growth through more efficient service provision for society and increase of business activity,
- production of information for the needs of environmental monitoring, protection and sustainable development.

2.2. Strategy for Finnish space activities

The national space strategy for years 2005-2007 is outlined in The Space Activities in Finland, National Strategy and Development Objectives that was published (in Finnish) in June 2005. Strategic areas of the public sector investment are space science, satellite Earth observation, satellite telecommunications, satellite navigation and the industrial production of equipment for space vehicles.

The strategy for the development of space science is:

- the high standard of Finnish space science will be maintained by participation in international projects in key research themes.
- utilisation of new satellite Earth observation methods will be increased in public sector data use and in geographic information systems. Collaboration agreement in this field was signed between Tekes and Canadian Space Agency in May 2003 and the collaboration has evolved within the Tekes' AVALI-programme.
- international research cooperation concentrates on ESA and EU research projects and on bilateral research projects with e.g. Canada, Sweden, Russia, and the United States

In the autumn of 2007 the Finnish Space Committee initiated a process with a goal to forumulate a new strategy by the summer of 2008. In addition to guiding the local decision making the strategy will also set the Finnish priorities for the ESA Council at ministerial level to be held in November 2008.

2.3 Funding sources

The public funding responsibilities concerning space activities are divided between the Ministry of Trade and Industry, Tekes and the Academy of Finland, and several universities and research institutes.

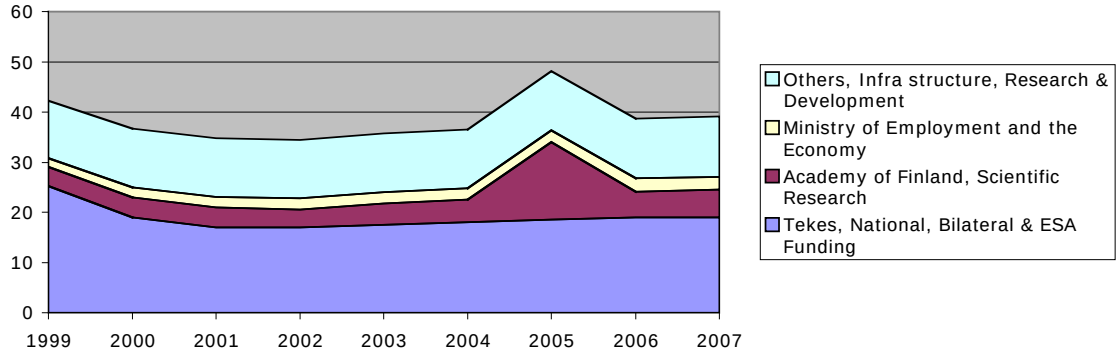

Figure 2.1
Funding of Finnish space activities 1999-2007 (million euros). Note that the strong peak in the funding from the Academy of Finland in 2005 was due to the entrance fee of ESO. The total fee was 12.8 M€ of which 10.5 M€ was paid cash and the rest as in-kind contributions. Note also that operative space activities and EUMETSAT payments are not included.

TEKES

Tekes, the Finnish Funding Agency for Technology and Innovation (established in 1983), is the main financing organisation for applied and industrial R&D in Finland. Its funds are awarded from state budget. Tekes offers channels for cooperation with Finnish companies, universities and research institutes.

Tekes' primary objective is to promote the competitiveness of Finnish industry and the service sector by technological means. Activities diversify production structures, increase production and exports, and improve the foundation for employment and social well-being.

Tekes coordinates and offers financial support for participation in international technology initiatives, including EU research programmes, EUREKA, research activities of OECD's energy organisation IEA (International Energy Agency), European Cooperation in Scientific and Technical research (COST), European Space Agency (ESA) and Nordic cooperation.

Tekes' programmes aim at gaining new technology expertise, product development and in growth of the companies in important business areas of today and the future. Programmes are an effective form of cooperation for companies and the research sector. In the

end of 2008 Tekes had 26 national technology programmes.

In 2007 Tekes total financing for national and international R&D-projects was 469 million euros. From this 19 million euros was provided for space activities (ESA, national and bilateral).

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Select interest area: Space

Finnish Space Portal
http://www.avaruus.info/en

ACADEMY OF FINLAND

The Academy of Finland is an expert organisation for research funding within the administrative sector of the Ministry of Education. The Academy has a board and four research councils, as well as an Administrative Office. The research councils are the Research Council for Biosciences and Environment, the Research Council for Culture and Society, the Research Council for Natural Sciences and Engineering, and the Research Council for Health.

The Academy's function is to improve the quality and prestige of Finnish basic research through selective, long-term funding (typically 3-4 years) based on competition, systematic evaluation, and relevant science policy. The Academy's development initiatives focus on developing professional researcher careers and promoting creative research environments. The various forms of support for research, such as research posts, research projects, and research grants, provide opportunities for versatile funding of research in different disciplines.

The research funding of the Academy of Finland to space research and astronomy has also been quite stable, at the level of about 3 million euros annually, excluding membership fees to international organizations (NOT, EISCAT, most recently ESO), which make about 2,5 million euros annually.

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2.4 The Finnish National Committee on Space Research

The Committee on Space Research (COSPAR) was established by the International Council of Scientific Unions (ICSU) in October 1958 to continue the co-operative programmes of rocket and satellite research, successfully undertaken during the International Geophysical Year of 1957-1958. The ICSU resolution creating COSPAR stated that the primary purpose of COSPAR was to "provide the world scientific community with the means whereby it may exploit the possibilities of satellites and space probes of all kinds for scientific purposes, and exchange the resulting data on a co-operative basis."

Consequently, COSPAR is an interdisciplinary scientific organisation concerned with the progress on an international scale of all kinds of scientific research carried out with space vehicles, rockets, and balloons. COSPAR's objectives are carried out by the international community of scientists working through ICSU and its adhering National Academies and International Scientific Unions. Operating under the rules of ICSU, COSPAR ignores political considerations and considers all questions solely from the scientific viewpoint.

The Finnish National Committee of COSPAR has participated in the international and national co-operation of scientific space research since 1964 by submitting proposals, issuing statements, arranging meetings, and keeping contact with the international COSPAR and its subcommittees.

The National Committee is an expert body nominated by the Delegation of the Finnish Academies of Science and Letters. The members of the National Committee represent the active community of space researchers in Finland. The members during 2006-2007 were:

Chairman	Hannu Koskinen	University of Helsinki
Members	Martti Hallikainen	Helsinki University of Technology
	Juhani Huovelin	University of Helsinki
	Tuomo Nygrén	University of Oulu
	Petri Pellikka	University of Helsinki
	Risto Pellinen	Finnish Meteorological Institute
	Juri Poutanen	University of Oulu
	Markku Poutanen	Finnish Geodetic Institute
	Pekka Tanskanen	University of Oulu
	Erkki Tomppo	Finnish Forest Research Institute
	Merja Tornikoski	Metsähovi Radio Observatory
	Martti Tiuri	Parliament of Finland
	Esko Valtaoja	University of Turku
	Martin Vermeer	Helsinki University of Technology
Secretary	Sini Merikallio	Finnish Meteorological Institute

At the end of 2007 Risto Pellinen retired from the committee and Tuija Pulkkinen was selected as a new member from the beginning of 2008.

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http://www.cospar.fi

Figure 2.2. Finnish National Committee of COSPAR meeting January 19th 2007. Back row from left: Juhani Huovelin, Erkki Tomppo, Markku Poutanen, Esko Valtaoja, Juri Poutanen, Tuomo Nygren, Martti Tiuri, Risto Pellinen. Sitting in the front are Martin Vermeer and Hannu Koskinen. Photo by Sini Merikallio

3. Space Programmes Supported by Finland

3.1 ESA Programmes Supported by Finland

Finland participates in ESA's space science, earth observation, telecommunications, navigation and technology R&D programmes. Finland has not participated in launch vehicle nor human space flight programmes.

Space science

Table 3.1 in the next page summarises the ESA space science missions in which Finland has participated either in providing nationally funded scientific instruments or in construction of satellite platform equipment.

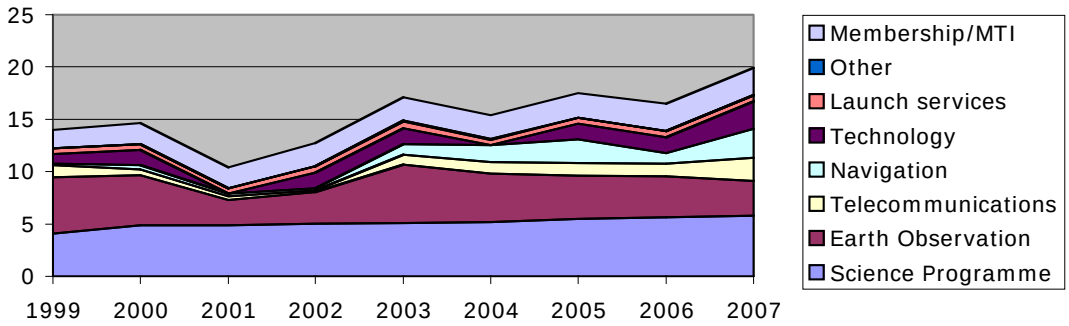


Figure 3.1. Payments to ESA Programmes 1999-2007 by Tekes and Ministry of Trade and Industry (MTI); in million euros.

Table 3.1. Finnish space science instrumentation and industrial participation in ESA space science missions

Programme	Finnish participation	Schedule
SOHO	SWAN and ERNE instruments	Launched 1995
Cluster / Cluster-2	EFW instruments; satellite power system electronics units	Launch failure 1996, launched 2000
Huygens	HASI instrument; ESA funded radar altimeter	Launched 1997, descent 2005
XMM-Newton	Telescope structure and satellite electronics	Launched 1999
Integral	JEM-X instrument	Launched 2002
SMART-1	XSM and SPEDE instruments	Launched 2002
Mars Express	ASPERA-3 instrument, participation in Beagle-2-lander; satellite power electronics	Launched 2003
Rosetta	COSIMA, PP, MIP instruments and lander CDMS; satellite structure and power electronics	Launched 2004
Venus Express	ASPERA-4 instrument participation; power distribution units for spacecraft	Launched 2005
Herschel/Planck	LFI microwave receivers onboard Planck; mirror polishing for Herschel, onboard software for both	Launch 2009
LISA Pathfinder	Solar array structures	Launch 2010
BepiColombo	PI of SIXS , participation in MIXS (X-ray instruments), participation in SERENA particle instrument.	Launch 2013

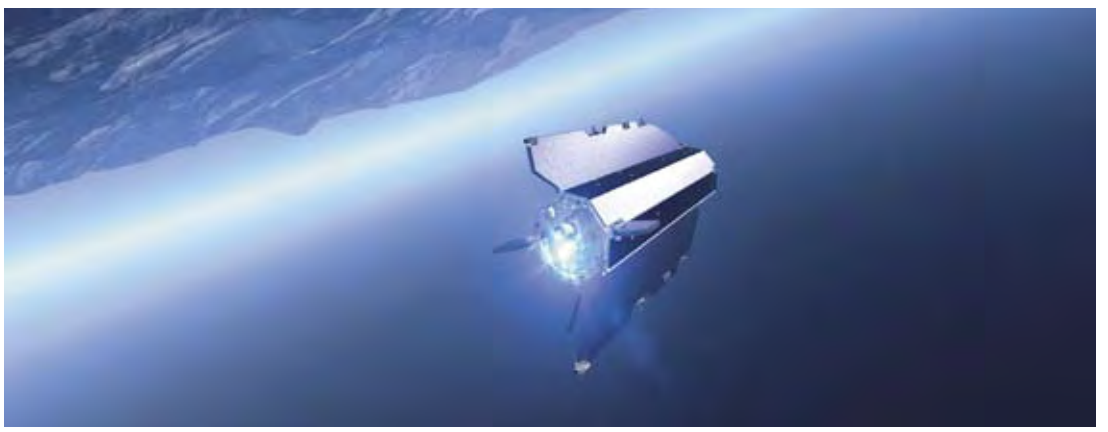


Figure 3.2. GOCE is ESA's first satellite dedicated to measuring the Earth's gravity

Earth Observation

The table below is a summary of the ESA earth observation programmes and missions in which Finland has participated either in the construction of satellite platform units or remote sensing instruments.

Telecommunications and Navigation

Table 3.3 on the next page is a summary of the ESA telecommunication and navigation programmes in which Finland participates.

Table 3.2. Finnish participation in ESA remote sensing programmes and their satellites.

Programme	Finnish participation	Schedule
EOPP	Earth Observation technology programme	1986-
EOEP	Earth Observation Envelope Programme developing scientific Earth observation satellites	1998-
Earth Watch – GMES	Global Monitoring of Environment and Security – collaborative programme by ESA and EU. (Sentinels 1-5 missions)	2001-
Earth Watch – Infoterra/ TerraSAR	Synthetic Aperture Radar mission development programme	2001-
ENVISAT-1 satellite	Software and hardware for GOMOS observation instrument.	Launched 2002
Meteosat Second Generation MSG-1 satellite	Software for the satellite platform, hardware for the SEVIRI observation instrument.	Launched 2002
METOP-A, -B and -C	ESA/EUMETSAT polar orbit weather satellite series, GOME-2 instrument electronics and satellite bus S/W development	Launches 2006, 2010, 2015
GOCE mission	Gravity Field and Steady-State Ocean Circulation Mission; Onboard software	Launch 2008
ADM-Aeolus-mission	Atmospheric Dynamics Mission; instrument electronics	Launch 2009
SMOS mission	Soil Moisture and Ocean Salinity; radiometer modules, aircraft campaigns for reference measurements	Launch 2009
Cryosat-mission	Radar altimetry mission; secondary structures	Launch failure 2005, Re-flight 2009
SWARM	Earth magnetic field measurement mission; power distribution unit	Launch 2010

Table 3.3 Finnish participation in ESA telecommunication programmes.

Programme	Finnish participation	Schedule
ARTES 1	System analysis and market surveys	1993-
ARTES 5	Telecommunication systems and equipment technology programme	1994-
ARTES 8	Large platform development - telecommunications satellite programme (AlphaBus)	2002-
ARTES 9	Galileo satellite navigation system development	1998-
ARTES 11	Small geostationary orbit telecommunications satellite development programme	2006-

Technology programmes

Finland participates in the development of technologies for ESA's future missions in the mandatory Basic Technology Research Programme (TRP), General Studies Programme (GSP) and in optional General Support Technology Programme (GSTP).

Furthermore, Finland participates in the DEBIE micrometeoroid and space debris monitor on the International Space Station.

3.2 Bilateral Co-Operation and Programmes

In the mid-1980s Finland entered space activities through bilateral space programmes in space science missions. Bilateral programmes, now including also Earth observation missions, have still an important role in the Finnish space strategy. A list of the bilateral programmes is given in table 3.4.

3.3 Finnish National Space Programmes

During 2006 and 2007 no national space progammes were ongoing. The Academy of Finland directed specific funding for Earth observations and the Ministry of Education supported national graduate schools in Astronomy and Space Physics (currently until the end of 2011) and in Earth Observations (ended at the end of 2006). Tekes was planning Security and Water technology programmes (started in 2008) that contain themes of interest to the Earth observation community.

Figure 3.3. Phoenix was launched towards Mars 4th August 2007. It landed in May 25th 2008 carrying a Finnish pressure instrument to the surface of Mars.

Table 3.4. The main Finnish operative bilateral space programmes.

Programme	Main Partners	Finnish participation	Schedule
Phobos	USSR, SE, D	Electronics for ASPERA instrument and test system for LIMA-D instrument	Launched 1988, mission ended
Freja	SE	Plasma and wave instruments	Launched 1992, mission ended
Astrid-1	SE	Instrument electronics	Launched 1995 mission ended
Interball	USSR/RUS, SE	Electronics for Promics-3 instrument	Launched in 1995 and 1996, mission ended
Polar	USA	Mechanisms for EFI instrument	Launched 1996
Mars-96	RUS	Central electronics units, sensors and software for two landers	Launch failure in 1996
Cassini	USA	Hardware for IBS, CAPS and LEMS instruments	Launched 1997
Space Shuttle	USA	AMS instrument	Launch 1998
Stardust	USA	CIDA instrument	Launched 1999
Mars Polar Lander	USA	Pressure instrument	Launched 1999, landing failure
Odin	SE, F, CAN	119 GHz receiver and antenna measurements	Launch 2000
EOS-Aura	USA	OMI instrument	Launch 2004
Phoenix	USA, CAN	Pressure instrument	Landed 2008
TerraSAR-X and Tamdem-X	Germany	Leaf amplifiers for the SAR-radars	Launches 2007 and 2009
TWINS	United States	Scanning mechanisms for TWINS instruments on two satellites	Launched 2007 and 2008
Mars Science Laboratory	USA, E	Pressure and humidity instruments	Launch 2009
MetNet Mars Precursor Mission	RUS, E	Novel landing station(s) to carried onboard Phobos Grunt	Launch 2009/2011
BepiColombo MMO	Japan	Participation to MEFISTO-instrument	Launch 2013
Roemer	Denmark	Central processing unit for the satellite	Cancelled
SRG	RUS	Silicon x-ray array (SiXA) for the SODART instrument	Launch TBD
Radioastron	RUS	22 GHz VLBI receiver	Launch TBD

4. Space Science

4.1. Ionospheric and Magnetospheric Research

Finnish Meteorological Institute (FMI)

The research environment at the Finnish Meteorological Institute (FMI) improved considerably after the institute moved to the Kumpula Campus hosting the University of Helsinki (UH) Faculty of Science. The joint Kumpula Space Centre with the Department of Physical Sciences (now Department of Physics) of UH was initialized at the end of 2005, and became fully operative during 2006-2007. Several space projects progressed under the auspices of the new centre, some of the most ones being the X-ray instrument for ESA's BepiColombo Mercury mission, Mars Metnet Precursor Mission, data analysis algorithm development for the Planck mission, and technological development for a new electric sail propulsion technique. Each of these will be described in their own context of this report.

The solar-terrestrial research continued to be one of the backbones of the space research at FMI. In strong collaboration with the space physics group at the UH, the research programme covers the entire chain from processes on the solar surface, through the solar wind, the magnetosphere, ionosphere, and atmosphere down to Earth's surface. While the UH group concentrates more on the solar origins and propagation in the solar wind of the geoeffective events, the FMI scientists concentrate on solar wind – magnetosphere interaction, ionospheric auroral physics and atmospheric effects of the solar energetic particles.

The research is conducted in wide international collaboration, using measurements from the best space-based and ground-based sources including ESA's Cluster, NASA's Themis, the FMI-led MIRACLE-ground-based network and the corresponding Canadian camera- and magnetometer networks. FMI scientists have represented Finland in the International Living With a Star (ILWS) initiative and been active in various European space weather activities within ESA and in two EU/ESF COST projects Cost 724: *Developing the Scientific Basis for Monitoring, Modelling and Predicting Space Weather*, and COST 296: *MIERS Mitigation of Ionospheric Effects on Radio Systems*.

In addition to observational space physics, the FMI is strongly involved in numerical modelling of the space plasma processes. Empirical modelling as well as local and large-scale simulation tools are actively developed and used in scientific research. Especially, the FMI scientists have been world leaders in developing quantitative methods for analyzing four-dimensional simulation data.

The GUMICS-4 MHD simulation is still the only European global MHD simulation tool covering the solar wind, the magnetosphere, and the ionosphere. During the period 2006-2007 special emphasis was put on examining the process of magnetic reconnection as seen in numerical simulations. A PhD thesis completed at the end of 2007 focuses on developing methods to automatically identify regions where magnetic reconnection occurs in the simulation and on the energy conversion processes associated with reconnection both at the solar wind – magnetosphere interface and in-

side the magnetotail. This study was linked to a complementary study that traces the energy flow from the solar wind through the magnetospheric boundaries and within the magnetosphere.

Magnetospheric modelling took a major step forward when the project to develop a novel empirical electromagnetic field model was completed. This model has the advantage over previous ones that it gives simultaneously and self-consistently both the electric and magnetic fields within the magnetosphere. The field model is complemented by a particle model that facilitates the tracing of the evolution of charged particle fluxes in the inner magnetosphere during magnetic storms. These models together with multi-spacecraft observations are used to distinguish processes that are most important for the space weather effects.

Collaboration with the University of Bergen intensified after one of the former FMI scientists was appointed an associate professor there. The research collaboration focussed on high-speed solar wind streams and the interaction of the stream plasma with the Earth's magnetosphere, complementing the studies on acceleration of energetic particles at the CME shocks done in collaboration with the UH group.

In 2007 a major effort was put on the proposal for a medium-class mission as a response to the first call for proposals within the Cosmic Vision 2015-2025. The FMI group led an international team from Austria, Belgium, Czech Republic, Denmark, France, Germany, Greece, Sweden, and UK. The mission was a four-spacecraft constellation called WARP (Waves and acceleration of relativistic par-

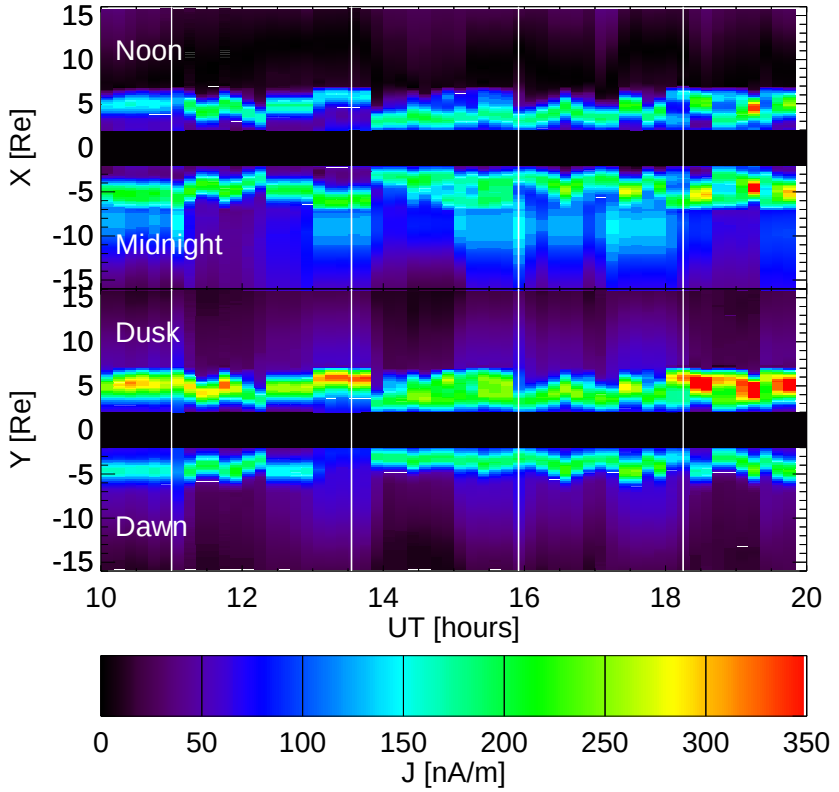


Figure 4.1. Empirical model of the ring current evolution during a magnetic storm. The two panels show two cuts of the magnetosphere, one in the noon-midnight plane (top) and the other in the dawn-dusk plane (bottom). The colour coding shows the electric current through that plane as a function of time and distance from the Earth. The figure illustrates the strong enhancement of currents in the nightside magnetotail and in the dusk-sector geosynchronous region.

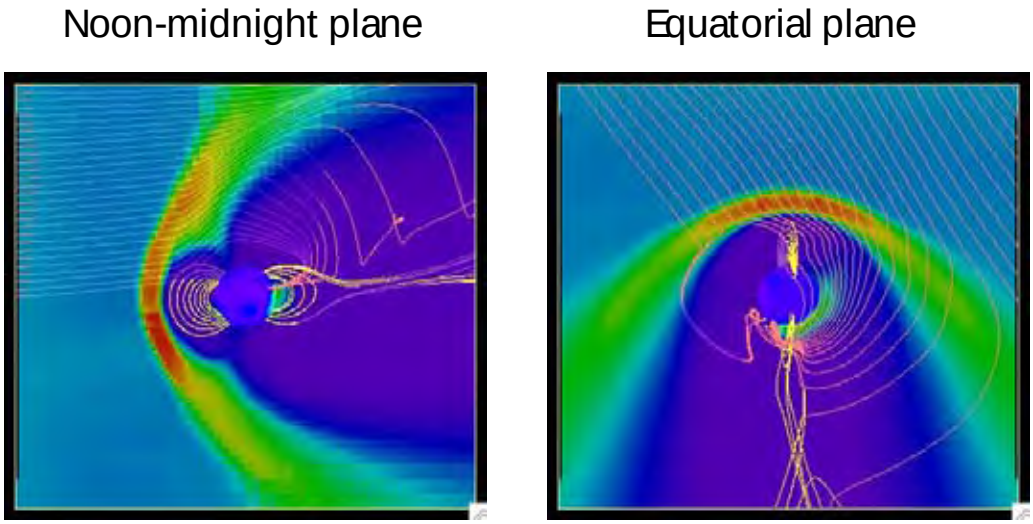


Figure 4.2. Numerical simulation results of the Earth's space environment: The white lines show Poynting flux transport from the solar wind (from left and top) into the magnetotail (shown dark blue) and into the ionosphere. The figure illustrates how the incoming energy focuses to the near-Earth region.

ticles) and its goal was to study the physical processes in the inner magnetosphere, that lead to the generation of relativistic electrons that are the most harmful particles for spacecraft on the geostationary orbit as well as the on the orbits of global positioning satellites. Although, WARP did not progress to assessment studies, the FMI scientists participated also in another near-Earth plasma physics mission proposal called Cross-Scale for studies of multiscale aspects of the solar wind magnetosphere processes. Cross-Scale is undergoing an assessment study during 2008.

The FMI team studies ionospheric currents using magnetic field measurements. While a ground-based magnetometer network, e.g., IMAGE, provides long, continuous time-series of magnetic field data in a limited region, a low-orbiting satellite, such as CHAMP, can cover the entire globe, but does not distinguish between spatial and temporal gradients in the data. The component resolvable from both ground-based and satellite-based measurements was compared during 124 passes of CHAMP over the IMAGE chain, and very good correlation was found. This connection has also made it possible to statistically determine a relation between the ground-based magnetic data and the ionospheric Hall-to-Pedersen conductance ratio. The CHAMP-IMAGE comparison studies can be considered as preparatory work for the near future ESA three-satellite SWARM mission. While the main objective of SWARM is to conduct a detailed survey of Earth's internal magnetic field structure, the SWARM constellation of three similar satellites will provide space scientists with new interesting observations of ionospheric conditions.

The FMI group has studied electromagnetic induction both as a harmful effect of ionospheric currents on ground systems, e.g., electric transmission lines and gas pipelines, as well as within the ionosphere itself. The basic principle of electromagnetic induction is simple: time varying magnetic field is associated with rotational electric field. Traditionally the role of induction effects in ionospheric dynamics has been assumed negligible, partly because temporal changes in

the ionosphere were thought to be too slow and partly because the presence of inductive electric fields would complicate the mathematics. During the last couple of years the ionospheric research group at FMI has developed a new model of ionospheric electrodynamics, where electromagnetic induction is included self-consistently. The results indicate that inductive processes are more important than previously assumed. Inductive electric field modifies the ionospheric current system and the field-aligned currents that connect the ionosphere and magnetosphere. These effects are largest during active periods, like auroral substorms. The induction studies led to a PhD thesis in the autumn 2007.

FMI has carried out systematic ground-based auroral observations in the Northern Fennoscandia since the 1950s. During the past 50 years the auroral imaging technology has moved from the black and white film cameras to the intensity calibrated digital imagers with narrow band-pass filters. In 2007 FMI and the Sodankylä Geophysical Observatory of the University of Oulu installed two new all-sky cameras that use the electron multiplying charged coupled devices for higher quality capturing of the aurora. The cameras still have filters for the three main emission lines of the aurora (blue at 427.8 nm, green at 557.7 nm and red at 630.0 nm), but in addition, filters for the background of each emission have been deployed. Important advantages of the new cameras, as compared to the previous generation CCDs, are a hugely improved signal-to-noise ratio and a much larger dynamic range. This results in capturing of greater variety of emission intensities than what have been recorded earlier.

The previous generation all-sky camera images have been used to estimate the precipitating auroral electron energy flux. In favourable observing conditions the energy flux values derived from the brightness in the all-sky images were found to be in a good agreement with satellite measurements of the particle

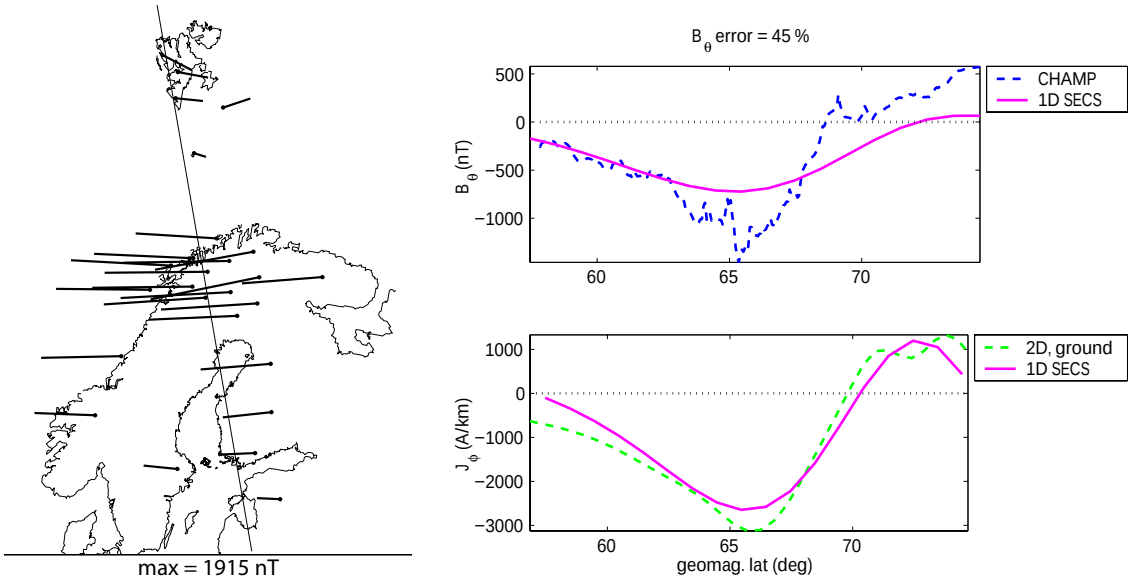


Figure 4.3. (left) Estimate of ionospheric horizontal electric current vector field as deduced from the data of IMAGE magnetometers together with the track of CHAMP satellite on 6 Nov 2001 between 05:04-05:08 UT. (right top) North-south component of magnetic field as measured by CHAMP and as deduced with the 1-D equivalent current method. (right bottom) Electrojet current intensity along the CHAMP track as estimated with the space-based and ground-based magnetometer data.

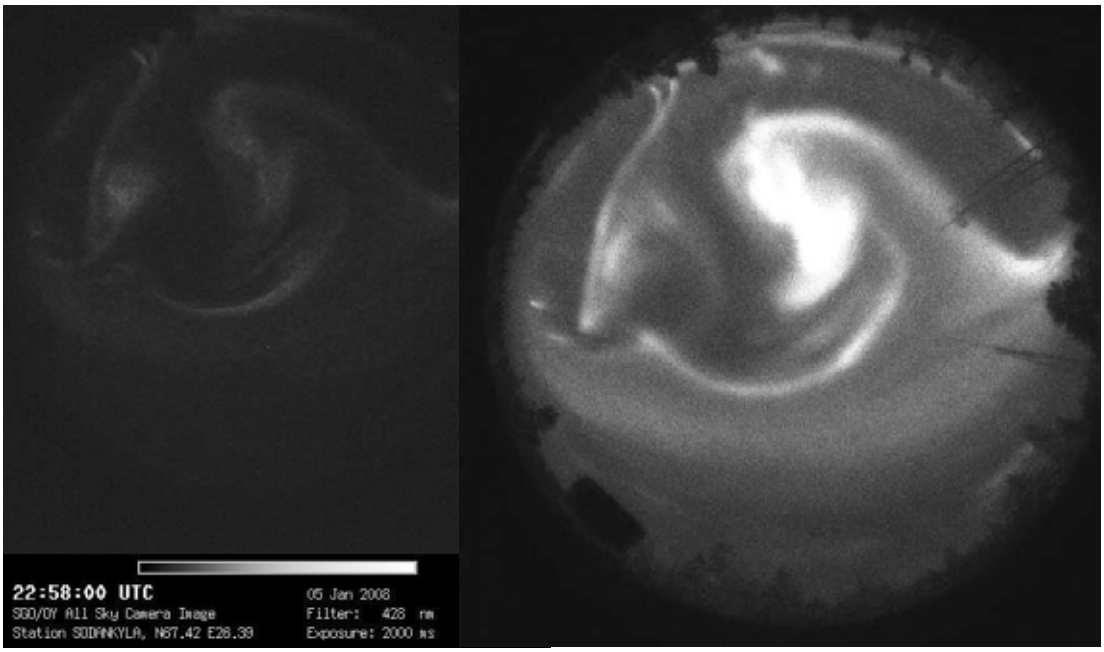


Figure 4.4. Dim blue auroras as recorded simultaneously by the old all-sky camera and by the new camera equipped with emCCD. Images were acquired during a test campaign (January 2008) in the Pittövaara station of Sodankylä Geophysical Observatory.

precipitation. The main limiting factors of the old camera system were the high noise level (due to image intensifiers), small dynamic range (bright aurora saturated the image) and poor sensitivity of the blue wavelength regime. The new imagers provide improvements in all these respects.

In 2007 FMI started investigating the feasibility of using high resolution tomography to retrieve regional ionospheric electron density maps by using global navigation satellite observations and the MIDAS (Multi-Instrument Data Analysis System) algorithm developed at the University of Bath. The observations used in the research are from the network of 86 GNSS stations in Finland operated by Geotrim Ltd. These stations provide operational Virtual Reference Station service for geodetic applications. At the same time these observations provide a novel tool for meteorological and ionospheric research.

The first results from this work were presented in the Fourth European Space Weather Workshop in November 2007 in Brussels. These results indicate that retrieval of 3D electron density maps with unprecedentedly high horizontal resolution is feasible using only ground based GPS observations, if observations from a sufficiently dense ground based GNSS observation network are available. The next steps in the research will include combining both GPS and GLONASS observations to achieve even better ionospheric sampling.

FMI participates in close collaboration with the Department of Physics in the nationwide Graduate School in Astronomy and Space Physics (described below). Most of the doctoral students are enrolled as students at the University of Helsinki or at the Helsinki University of Technology. Of the 5 PhD theses in 2006-2007 by students working at the Kumpula Space Centre two dealt with magnetospheric and ionospheric physics.

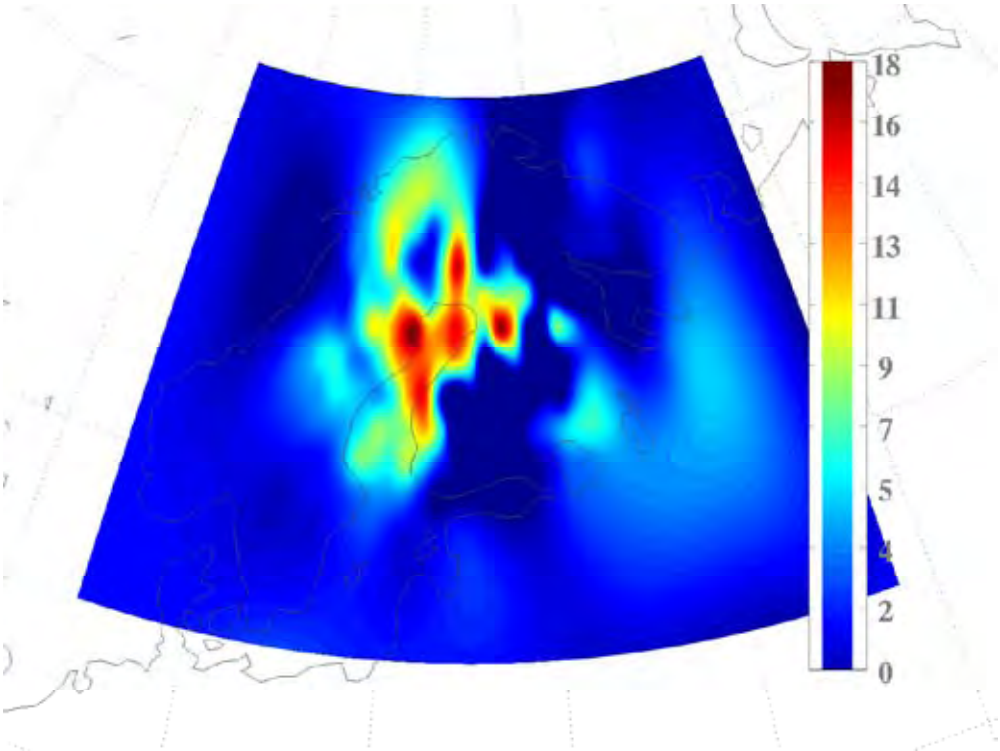


Figure 4.5. High resolution total electron content map on 15 Dec. 2007 at 02:00 retrieved with the MIDAS algorithm. The map that has been derived by integrating the retrieved electron density map vertically between 100 and 700 km heights. The increased electron density levels at that time were caused by a magnetic storm that took place on 14-15 December 2006.

University of Helsinki
Department of Physics

(note that the name of the department was in 2006-2007 Department of Physical Sciences; the new name is used throughout this report)

Magnetospheric research at the Department of Physics of the University of Helsinki (UH/PHYS) is conducted in close co-operation with the above reported activities at FMI under the Kumpula Space Centre collaboration. During 2006-2007 a special focus in magnetospheric research was in studies of energy circulation in the solar wind – magnetosphere – ionosphere system utilizing both empirical data and MHD simulations in collaboration with the FMI group as reported above.

The radiation environment of the Earth was studied within the EU COST 724 action, "Developing the scientific basis for monitoring, modelling and predicting the space weather", which lasted from November 2003 to November 2007. The UH/PHYS group had the leadership of The Radiation Environment of the Earth working group. The working group concentrated on studies of high-energy radiation in near-Earth space and its effects on the space electronics, the atmosphere of the Earth, and on human health. Theoretical modelling of the cosmic-ray penetration to the magnetosphere and the interaction of trapped electron radiation with magnetospheric plasma waves were also focus points of the group activities. The results of the COST724 action will be published as a book in 2008 and many of the models developed in the group can be accessed through the web portal of the action at www.spaceweather.eu.

The UH/PHYS and FMI have a joint education scheme in space physics that covers in addition to the magnetospheric physics, solar system science and Earth observations both in undergraduate and post-graduate levels. The Master's and Ph.D. theses are supervised jointly by the UH/PHYS and the FMI staffs. All UH/PHYS space physics graduate students, irrespective of their funding source, are enrolled in the nation-wide Graduate School in Astronomy and Space Physics led by the University of Oulu.

In autumn 2007 the Department of Physics and Department of Astronomy initiated a joint two-year Master's Degree Programme in Space Sciences. The students of the Programme are recruited internationally (see http://theory.physics.helsinki.fi/~spacemaster/).

University of Oulu, Department of Physical Sciences and Sodankylä Geophysical Observatory

The Space Physics Group of the Department of Physical Sciences and the Sodankylä Geophysical Observatory (SGO) of the University of Oulu have a broad research program in ionospheric and magnetospheric physics, including observations from both ground-based and satellite instruments. This program is conducted in extensive national and international collaboration. Note that the research activities related to the effects of cosmic rays on the atmosphere are described in Section 4.2.

National EISCAT and optical campaigns were organized in November 2006 and October 2007. In connection with radar measurements, heating experiments were carried out and auroral and VLF observations were made at various sites. EISCAT observations were used in some of the studies described below.

University of Oulu has a co-investigator status in the EFI instrument of the Polar satellite and the EFW and RAPID instruments of the Cluster mission. The group has continued using the RAPID instrument to study the dynamics of energetic particles inside the Earth's magnetosphere and at its boundary layers. Intense bursts of energetic particles have been observed in close conjunction with FTE signatures in the exterior cusp with delayed enhancements of energetic particles further away from the reconnection site deeper in the cusp. The observations support the group's earlier statistical result of the magnetospheric origin of energetic particles in the exterior cusp, whereby reconnection occurring close to the exterior cusp releases a part of energetic particles in the closed field lines of the adjacent magnetosphere into the exterior cusp. This is in contradiction with the earlier ideas of local or bow shock related acceleration of cusp energetic particles.

The satellite-based observations of Pc 1 pearl waves have been revived, and their contribution to the understanding of pearl formation has been evaluated. The study shows that the long-held paradigm of bouncing wave packets is in contradiction with satellite observations. It is argued that Pc 1 wave growth rate is successively modulated at the equator by long-period ULF waves. Furthermore, the altitude profiles of ionospheric plasma obtained by the EISCAT radar have been used to study the effect of the Ionospheric Alfvén Resonator (IAR) upon the Pc 1 signal observed on ground. Examining a multiband Pc1 wave event at a time when EISCAT observations covered an exceptionally wide altitude range, IAR model over a larger altitude range than earlier was tested, which showed that the IAR domain that affects the wave signal on the ground is essentially localized below the height of about 1200-1500 km.

The Oulu group has corrected and extended the magnetic Dst index that is used to monitor the strength of the equatorial ring current and the development of magnetic storms. The Dst

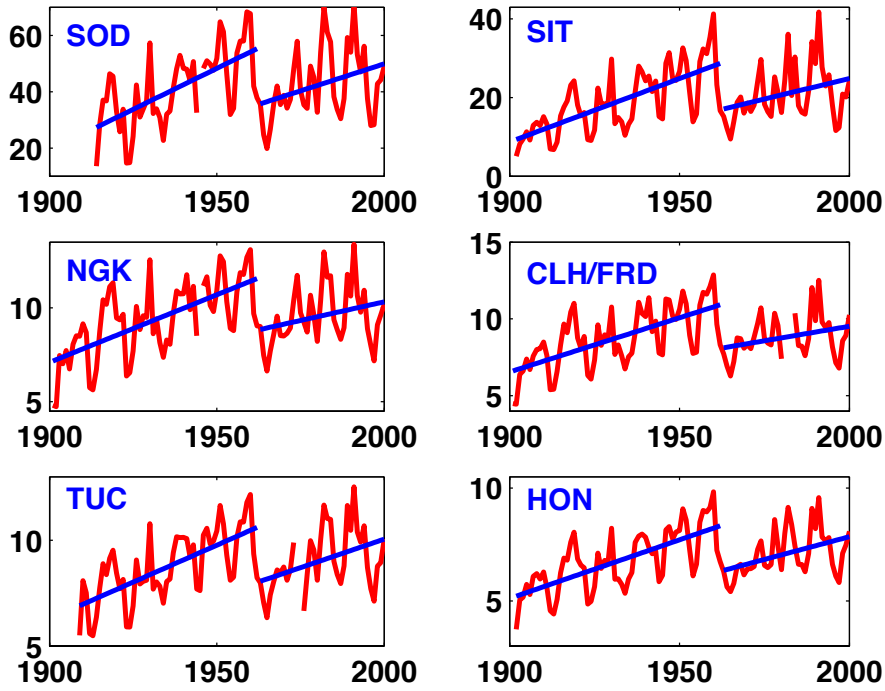


Figure 4.6. The annual Ah indices for six long-running stations. Top row: high-latitude Sodankylä and Sitka, mid-row: mid-latitude Niemegk and Cheltenham/Fredericksburg. Bottom row: low-latitude Tucson and Honolulu stations. All six stations depict a qualitatively similar centennial evolution with a rapid increase from 1900 until 1960, then a dramatic dropout and a slower increase thereafter. The stations verify the overall increase of geomagnetic activity during the last century.

index was corrected with respect to its extraneous seasonal variation by taking into account the seasonally varying level of the quiet daily curve. The absolute level can change by as much as 44 nT, leading to significant changes in studies using the Dst index. The correction has a strong seasonal variation with maxima around equinoxes, with the largest average correction in March of about 12 nT. The correction of the Dst index improves its correlation with all other disturbance measures. The group also found that the average storm was less intense and longer in the early period (1932-1956) than in the later period (1957-2002), suggesting that early storms were more typically driven by high-speed streams and the recent storms by coronal mass ejections (CME).

A new, straightforward, easily verifiable and homogeneous index, called the Ah index, was constructed. It is based on digital, hourly data and dedicated for long-term (centennial) studies. The local Ah indices were found to correlate with the local K/ak indices extremely well, much better than the IHV indices which depict a nonlinear dependence on the local K/ak values. Thus Ah yields the most accurate extension of the Kp/Ap indices typically by several decennia. The Ah index verifies that geomagnetic activity has increased during the last century. However, the amount of centennial increase varies with latitude, being largest at high latitudes, smaller at low latitudes and, unexpectedly, smallest at mid-latitudes. Also, the centennial increase in the aa index is roughly twice larger than in the Ah index at similar mid-latitudes, indicating problems in the aa index. The group has also indicated problems in the old registrations that greatly affect the homogeneity of early data and centennial scale studies. In particular, data sam-

pling was changed from hourly spot values to hourly means in the early part of the last century. Since the variability of spot values is larger, the early IHV and Ah indices, without due correction, would remain artificially large.

Global auroral images from the IMAGE satellite were used to study statistically changes of spatial distribution of the dayside aurora after an abrupt solar wind sudden impulse (SI). Contributions from IMF changes associated with an SI were also investigated. The effects of the IMF and pressure variations were separated using a multi-factor correlation analysis.

Electric fields and field-aligned currents associated with Sun-aligned polar cap auroral arcs were investigated. Detailed analysis of the observed electric field and current patterns suggests that the generation mechanism of these arcs is the interchange instability with ionospheric feedback.

A new digital VLF receiver was constructed in 2006. Its bandwidth is 39 kHz and it is capable of measuring signals with amplitudes well below 1 fT. An example of observed phenomena is a magnetospheric line radiation (MLR) event that was also seen simultaneously (even in the southern hemisphere) on board the DEMETER satellite. Thus the phenomenon filled a considerable part of the magnetosphere. This was the first observation of its kind.

An attempt was made to study the geographic and temporal variability of relativistic electron precipitation after the arrival of a CME. Data from VLF receivers, the high-altitude Miniature Spectrometer balloons, riometers, and pulsation magnetometers were combined in this study. The observations suggest that the energetic electron precipitation from the inner edge of the outer radiation belt results from pitch angle scattering due to electromagnetic ion cyclotron waves.

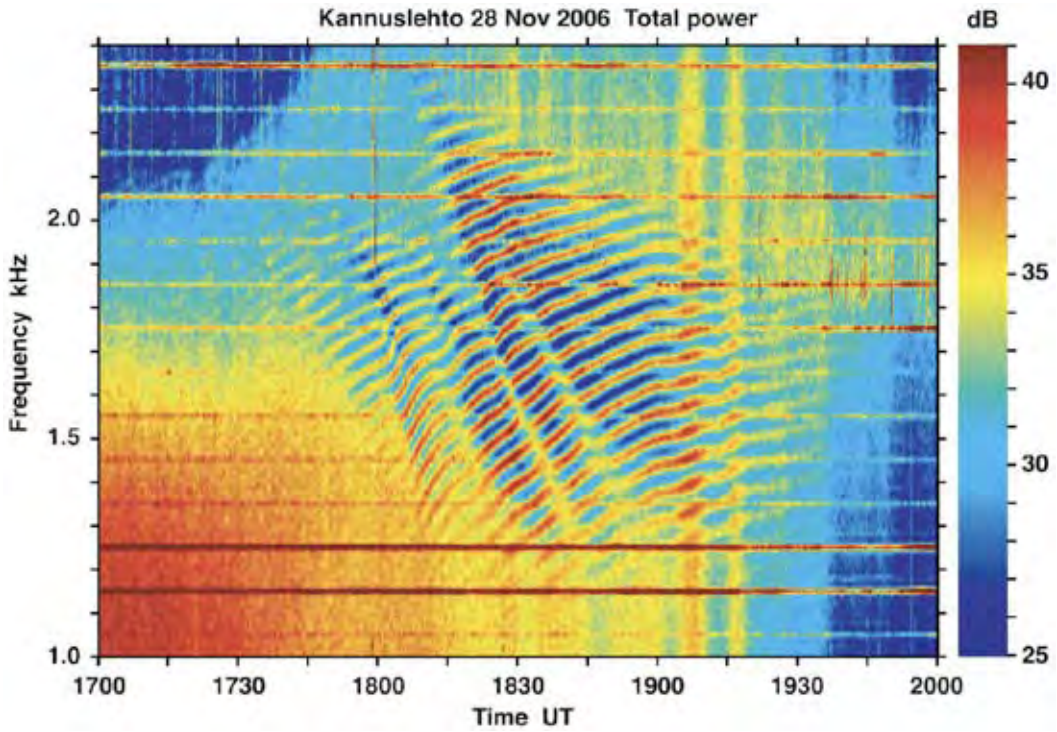


Figure 4.7.
Dynamic spectrum of magnetospheric line radiation event seen on the ground on 28 Nov 2006.

The first quantitative experimental verification of the effect of artificial ionospheric heating on D region cosmic radio noise absorption was made. A statistical study of IRIS riometer data from a selected set of heating experiments shows a clear heating effect in the antenna that intersects the EISCAT heater beam.

Changes in odd hydrogen and ozone in the mesosphere during a solar proton event was studied using a 1-D ion and neutral chemistry model and observations from the MLS/Aura and GOMOS/Envisat instruments. For the first time, the theory of HOx production and the associated complex ion chemistry could be directly tested. After the onset of a solar proton event, increases of OH concentrations by more than 100% at the stratopause and by up to an order of magnitude in the middle mesosphere were detected, together with decreases of up to 90 % in the O_3 concentration in the lower and middle mesosphere. The model predictions are in a reasonable agreement with the observations.

The role of electric field and neutral wind in the generation of polar cap sporadic E was investigated using layers observed by the ESR radar. Layer generation was calculated using model neutral winds and electric fields given by the APL model (supported by the interplanetary magnetic filed and coherent radar observations). A reasonable agreement with observations was achieved by assuming that the true electric fields are somewhat stronger than those given by the model.

The seasonal morphology of the F region trough was investigated statistically using observations from the Finnish ionospheric tomography chain. The trough latitude and width at different magnetic local times, as well as their relations to geomagnetic activity and the interplanetary magnetic field was studied. The broadest troughs were observed in winter and the narrowest in summer. The interplanetary magnetic field plays a role in the occurrence of the trough at different levels of geomagnetic activity. This is probably associated with the topology of the polar cap convection pattern, which depends on the directions of the IMF components.

A new method has been developed to determine the polar cap boundary (PCB) in the nightside ionosphere. The method is based on increased electron temperature caused by precipitating particles on closed magnetic field lines. The polar cap temperature profile is given by the ESR field-aligned measurements and the oval temperature profiles either by low-elevation EISCAT VHF or ESR 32m measurements. The new technique has been applied to several substorm events together with the 1D upward continuation method of MIRACLE magnetic measurements, which gives an estimate of ionospheric electrojets. The results show e.g. how the substorm onset takes place deep within the region of closed magnetic field lines, separated by about 6° in latitude from the PCB. In three minutes the reconnection at the near-Earth neutral line reaches the PCB and then the auroral oval starts expand poleward violently, in a form of short-lived (2-10 min) bursts, indicating that reconnection process in the tail is impulsive.

Optical auroral measurements have been made in Northern Finland, Kilpisjärvi, Kaaresuvanto and Sodankylä. In all these stations automatic multichannel photometers make measurements according to the prewritten program and timetable. They measure toward fixed direction or scan the sky back and forth. Old video cameras have been replaced in 2006 by fully digital PC-controlled CCD-cameras. A new imaging spectrometer was developed and built at the University of Oulu. The PC-controlled grating spectrometer measure the intensity of aurora from a 18° long slit in the sky. A highly sensitive CCD camera has been used as a detector. Extensive optical and campaigns have been arranged annually ion connection with EISCAT campaigns.

4.2. Solar System Research

Finnish Meteorological Institute

The solar system research at FMI includes studies of solar system plasmas, planetary magnetospheres, atmospheres and comets. The solar system plasma physics focuses on the space environments of terrestrial planets Mercury, Venus, Mars and, recently, also the Saturnian moon Titan. The planetary atmosphere studies are presently focused on Mars, Venus and Titan.

The research at FMI has provided new insights to space weather and its consequences at various sites in our Solar System. For example, the studies of plasma interactions between the solar wind and the atmospheres of Mars and Venus have direct relevance to the long-term evolution of the atmospheres of the planets. Mars represents a case where the planet has lost most of its atmosphere, whereas Venus is an example of extreme runaway greenhouse phenomenon. Furthermore, the cometary environments containing both ionized plasma and neutral dust pose interesting problems as well to space plasma physics as to cosmochemistry.

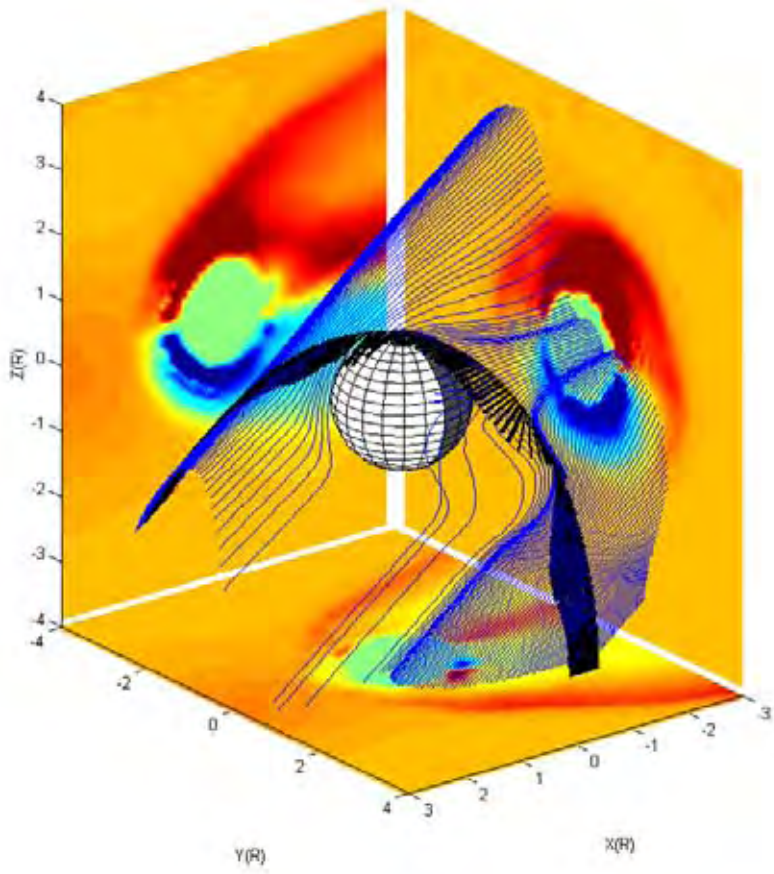


Figure 4.8. Simulation of the solar wind interaction with Venus. The blue lines are magnetic field lines calculated by the group's own hybrid plasma simulation model. The magnetic field line tracing was started along the orbit of Venus Express on June 1, 2006. The black solid line shows the orbit of VEX and the vectors superposed on the orbit show the direction of the magnetic field based on the model. The colour on the three perpendicular planes show the Sun-Mars direction magnetic field component at x = y = z = 0 planes which are moved to x = -3 R_V (radius of Venus), y = -4 R_V and z = -4 R_V so that they do not hide the field lines.

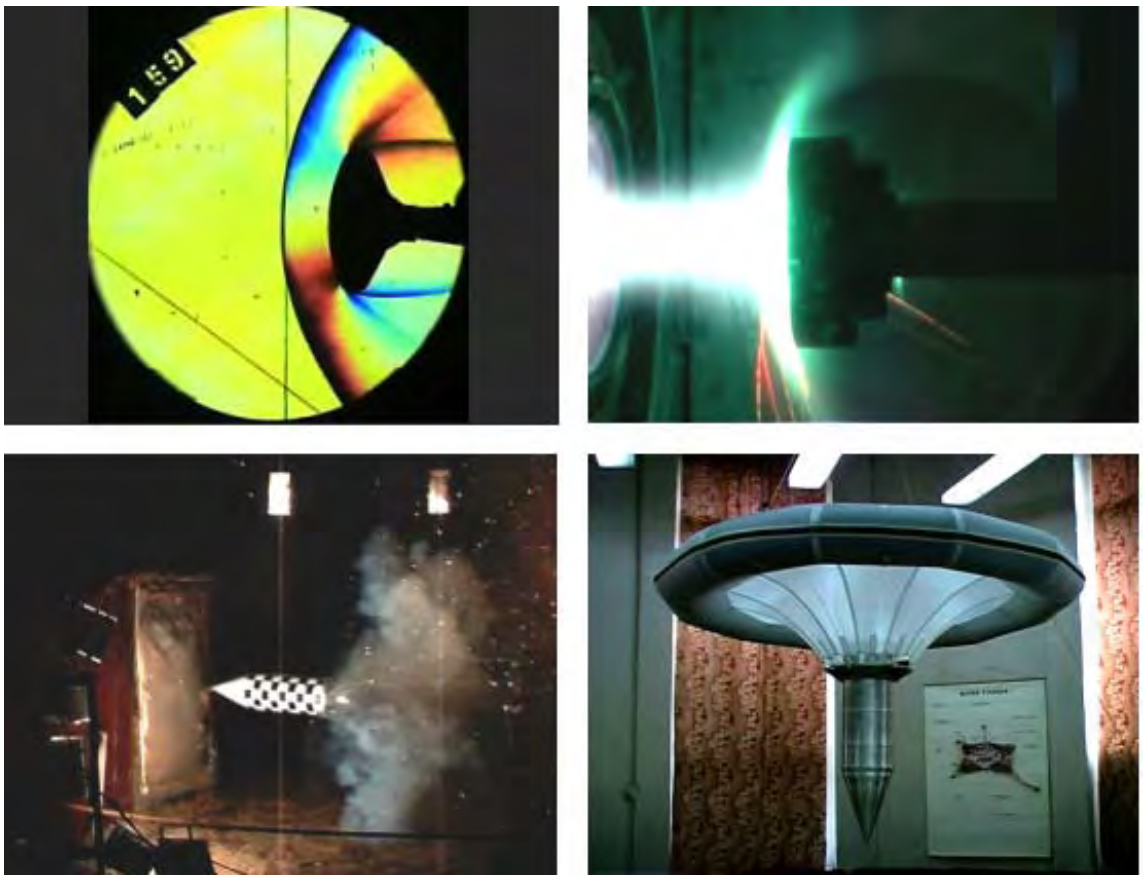


Figure 4.9. Flight unit and test photos of the MetNet entry, descent and landing device manufactured for the Mars MetNet Precursor Mission slated for launch in 2011.

Major highlight during the period 2006-2007 was the arrival of ESA's Venus Express (VEX) spacecraft at Venus in April 2006. The spacecraft carries the ASPERA-4 plasma and neutral atom instrument whose digital processing unit with its software was designed, tested and built at FMI. The ASPERA-4 instrument started its measurements successfully in the summer 2006. By the end of 2007 the instrument had provided the first ever energetic neutral atom images at Venus and measured the escape of planetary ions from the Venusian upper atmosphere.

At the same time with ASPERA-4, a similar instrument ASPERA-3 continued its measurements around Mars onboard ESA's Mars Express (MEX) spacecraft that arrived to its target in December 2003. The ASPERA-3 ion mass spectrometer and neutral particle detector have provided wealth of new exiting observations of the ion escape from the planet, the effects of the southern hemisphere magnetic anomalies, plasma neutral atom interactions and particle acceleration mechanisms. The ASPERA-3 and ASPERA-4 simultaneous measurement in 2006-2007 provided a unique data set to study the space weather effects at two different planets which identical instrumentation. Moreover, combining of these data with observations made near the Earth has made it possible, for example, to compare the response of the three terrestrial planets with atmospheres to solar disturbances.

Since 2001 FMI has been developing a new kind of planetary exploration mission for Mars - MetNet - together with the Russian space organizations. The eventual scope of the MetNet Mission is to deploy some 20 MetNet Landers on the Martian surface using inflatable descent system structures, which will be supported by observations from the orbit around Mars. Currently FMI is working on the MetNet Mars Precursor Mission (MMPM) to deploy one MetNet Lander to Mars in 2011 as a technology and science demonstration mission.

The MetNet Lander will have a versatile science payload focused on the atmospheric science of Mars. Detailed characterisation of the Martian atmospheric circulation patterns, boundary layer phenomena, and climatological cycles, as well as interior investigations, require simultaneous in-situ measurements from networks of stations on the Martian surface. The scientific payload of the MetNet Mission encompasses separate instrument packages for the atmospheric entry and descent phase and for the surface operation phase. The MetNet mission concept and key probe technologies have been developed and the critical subsystems have been qualified to meet the Martian environmental and functional conditions. The MetNet -type of mission will provide the crucial information to the understanding of the dynamics and general behaviour of the Martian atmosphere as well as the weather forecast facility for safe landings of the forthcoming large Martian landing missions. The MetNet was also proposed as a medium-class mission as a response to the first call for proposals within the Cosmic Vision 2015-2025 of ESA.

The Martian atmospheric dynamics and various phenomena are studied together with a team at the University of Helsinki. A three-dimensional Mars Local Area Model (MLAM) has been developed and installed in the computing infrastructure of FMI. MLAM is based on the local area weather forecast model HIRLAM used operationally in several European countries. The model results have been compared to NASA's Viking Lander observations and the model was used in the selection of the potential landing sites for NASA's Phoenix mission.

New kind of pressure (Digibaro) and humidity (Digihum) instruments have been developed for the NASA Mars Phoenix Lander and Mars Science Laboratory (MSL) missions to Mars in 2007 and 2009, respectively. The instruments for the Phoenix were delivered in 2007 and the landing is scheduled for May 2008.

At the end of 2006 ESA made a "Lunar impact" when its SMART-1 mission ended hitting the lunar surface. SMART-1 was ESA's technology mission to the Moon reaching the Moon orbit in 2005. Its primary objective was to test a newly developed ion propulsion engine. The spacecraft carried FMI's first PI instrument on an ESA mission, SPEDE (Spacecraft Potential, Electrons, and Dust Experiment), which monitored the outflowing gases and the effects on the spacecraft and its environment. SPEDE was actually the first instrument that was switched on after the launch and the last one operating before the impact.

Analysis of the data gained by ESA's Huygens probe during its descent through the atmosphere of Titan has been continued by the FMI Huygens team. The quality of the data of the FMI provided pressure instrument PPI measuring the vertical pressure profile of Titan has proved to be of high quality. A new method has been introduced to reconstruct the vertical temperature profile from in situ pressure measurements accompanied with rough knowledge of the atmospheric composition and the aerodynamic response properties of the descent vehicle

The FMI scientists have also participated in the studies of the interaction between Titan's atmosphere and Saturn's magnetosphere us-

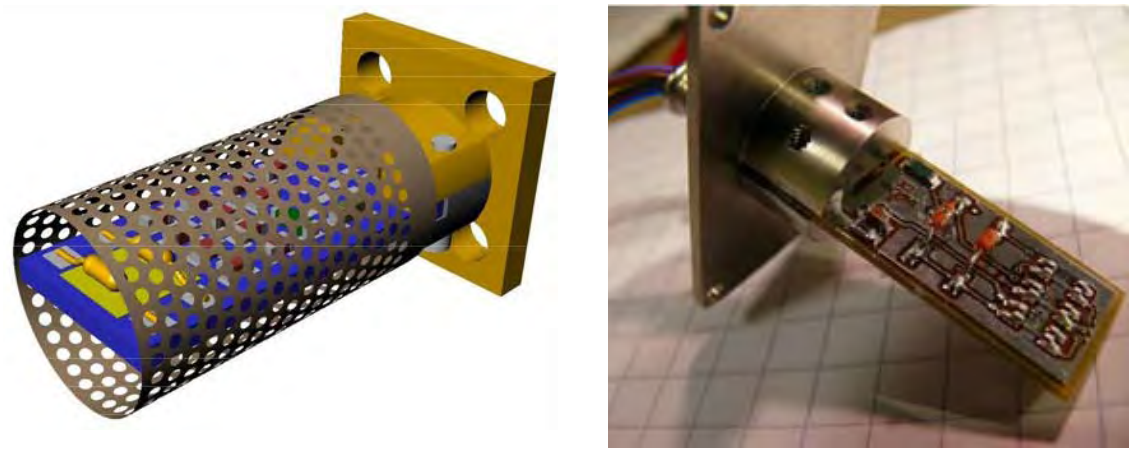


Figure 4.10. Conceptual drawing and a test unit of the DigiHUm instrument developed for the Mars Science Laboratory.

ing the quasi-neutral hybrid simulation model family that has been developed for studies of the solar wind interaction with Mercury, Venus, the Moon, Mars, asteroids, Titan and exoplanets. The input data to the Titan simulations are obtained from the magnetic field and plasma instruments onboard the Cassini spacecraft.

The longest-term space project at FMI, the participation in ESA's Rosetta mission to comet Churyumov-Gerasimenko started already in 1994 and the spacecraft was launched in 2004. In November 2007 the spacecraft made an Earth swing-by that sent it toward the outer solar system. The FMI team has participated in the check-outs of the instruments both onboard the Rosetta itself and its Philae lander before the long hibernation period until year 2014 when the spacecraft will finally approach the comet.

As a precursor for Rosetta observations the FMI team has participated in the NASA Stardust mission with the German-Finnish dust analyzer CIDA. Stardust returned in situ samples of cometary matter to Earth in January 2006. Combined analyses of CIDA observations and returned samples are still in progress. The preliminary results indicate that the molecules seen by CIDA were much larger than the returned samples, suggesting either some break-up during sampling and/or return or a different selection mechanism during the sampling. In 2007 CIDA got a new task as extended mission "Stardust-NExT" (New Exploration of Tempel) to re-visit the Deep-Impact target comet 9P/Tempel 1 in 2011 and try to answer some of the questions left open by the Deep Impact mission. After retirement of CIDA's German PI FMI got the PI role of CIDA for this part of the mission.

ESA's next planetary mission will be BepiColombo to Mercury jointly with the Japanese space agency JAXA. In 2006-2007 the Finnish consortium led by the scientists from the University of Helsinki Observatory participated in development of the UK-Finnish X-ray instrument complex MIXS/SIXS. The consortium includes scientists from the University of Helsinki, University of Turku and FMI as well as several Finnish industrial companies. In the technical project FMI is responsible for the project manager and acts also as subcontractor of some critical items to the industry. On BepiColombo FMI scientists participate also in the SERENA instrument to measure the energetic neutral atoms, the MEFISTO instrument to measure the electric fields in the Hermean magnetosphere, and the Phebus instrument to measure the Hermean exosphere.

In April 2008 the SOHO spacecraft had been operating for 12 years instead of the originally planned three. The SWAN instrument, built in cooperation between the French Service d'Aéronomie and FMI, was the first FMI contribution to the ESA Science Programme. It continues observing the solar Lyman alpha radiation scattered by interstellar hydrogen atoms inside the solar system and by comets. During one complete solar cycle the mapping of the solar wind intensity and velocity under different angles allowed to generate 3D solar wind maps as a function of the Sun's activity and to study in detail the interaction between the solar wind and the interstellar medium. SWAN also provides a novel method of identifying and monitoring solar eruptions on the far side of the Sun, offering an early warning of increased solar activity up to 10 days before they can effect the near-Earth environment. For the last 8 years this information is automatically made available to the space weather community. Additionally SWAN data have been successfully used for cometary studies, identifying new comets, deriving water production rates during the comets' trajectory around the Sun and thereby supporting the other cometary research activities at FMI.

The electric solar wind sail - or electric sail for short - is a new development for a device that can utilise the solar wind momentum flux for spacecraft propulsion. It is a technical spin-off of basic research and simulation work of solar wind interacting with different bodies, which has been carried out at FMI over the years. The electric sail deploys a set of long, thin and conducting tethers that are kept in a high

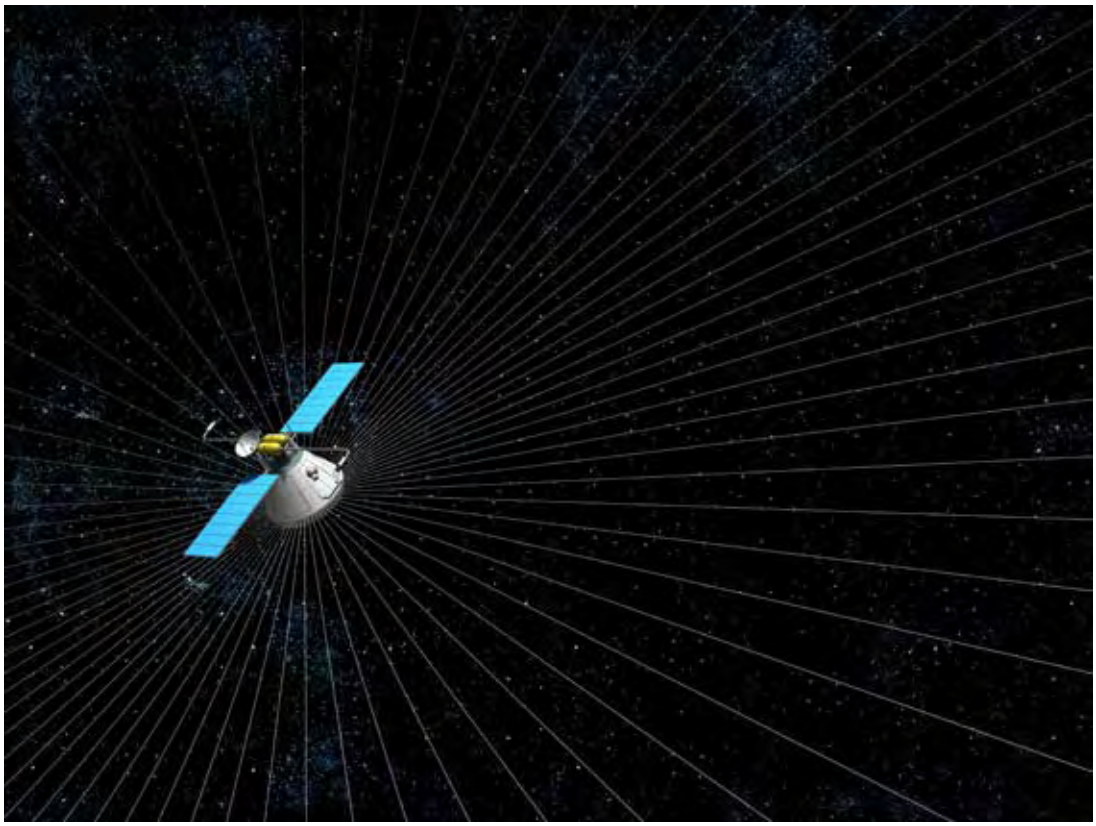


Figure 4.11. An artist's view of an electric sail in late phase of tether deployment, before jettisoning the spinup rockets and their propellant tanks. Besides the simple spinup technique shown in the figure, there are also ways to perform the spinup without auxiliary propulsion. Figure source: Allt om vetenskap, alltomvetenskap.se.

positive potential by an onboard, continuously operating electron gun. The spacecraft and the tethers spin slowly so that the centrifugal force keeps the tethers stretched. The tether spin plane can be turned by cyclically modifying the settings of potentiometers installed between each tether and the spacecraft. If the spin plane is inclined with respect to the solar wind direction, also a thrust component which is perpendicular to the solar wind can be produced, which is essential for many orbital manoeuvres. The thrust magnitude can be regulated (throttled) by changing the electron gun current and voltage.

The physical principle for the electric sail was published in 2004 and a realistic technical implementation was invented in 2006. A worldwide FMI-led consortium is developing various components of the electric sail, with the next goal of flying a test mission. If the electric sail fulfils its present promise, it may dramatically improve mankind's ability to explore the Solar System and to use its resources for solving earthly problems.

Helsinki University of Technology (TKK) Metsähovi Radio Observatory

The 14-metre Metsähovi radio telescope has been used for studying the solar millimetre-wavelength activity. During 2006-2007 the main emphasis was on using the 37 GHz frequency band and on observing solar activity maps during the summer months. Solar radio flares observed during earlier observing epochs (during higher activity) were studied in detail in order to model interacting coronal magnetic loops.

Additionally, a small (1.8-metre) telescope was used for continuous monitoring of the whole solar disk at 11.7 GHz. This telescope records a continuous data stream of the total flux for further studies, for example the studies of solar oscillations of 3-15 minutes. These data were also used to trigger observations with the 14-metre telescope as well as to alert collaborators about enhanced solar activity.

University of Helsinki Department of Physics (UH/PHYS)

The space physics group at UH/PHYS has concentrated on simulation modelling of the solar energetic particle acceleration by coronal shock waves and of the evolution of coronal mass ejection in the early phases of their development. The state-of-the-art models developed in the group for particle acceleration, in collaboration with the space research group in the University of Turku, include the back-reaction of the particle acceleration process on the coronal plasma waves responsible for the scattering of the energetic ions. This model is the first self-consistent model of coronal ion acceleration at shock waves in Europe, and it is able to explain the acceleration and the subsequent escape of protons at coronal shocks in time scales short enough to explain their detection within ten of minutes after the onset of the eruption. In another line of modelling, coronal shock waves and their radio emission have been studied in the group using MHD simulations of mass motions and magnetic field evolution in the corona. The group has concentrated in obtaining quantitative picture of the propagation of coronal phenomena related to the lift-off of coronal mass ejections, like Moreton and EIT waves, coronal dimmings and type II radio bursts. The work to integrate the particle acceleration and MHD modelling tools into a single comprehensive solar eruption model is currently ongoing.

The UH/PHYS space physics group is also involved in the studies of the solar wind interaction with Mars and Venus reported above in the section describing these activities at FMI. In 2006-2007 this was the scientifically most productive activity of the group, as the ASPERA-3 observations from Mars resulted in a large number of publications and the first results from Venus were reported.

The group participates actively in the Finnish consortium developing the solar X-ray and energetic particle instrument for ESA's Mercury mission BepiColombo. In 2006-2007 the group's focus was in the design of the miniaturized solar proton instrument that is needed for understanding the role of proton-induced X-ray emissions from the planet but that also can be used in studies of solar particle events and particles in the Hermean magnetosphere.

The meteorologists at UH/PHYS collaborate with FMI in studies of Martian meteorology. Their role has been central in the adaptation of the local area weather forecast model HIRLAM used routinely in several European countries to the Martian atmosphere as Mars Local Area Model (MLAM). Particles of variable sizes from aerosols to dust are a great concern for both robotic as well as potential future manned missions to the planet. Studies of their dynamics led to a PhD thesis in autumn 2007.

In the field of planetary geophysics low temperature magnetic properties of the Neuschwanstein EL6 meteorite as well as of mineral daubreelite ($FeCr_2S_4$), troilite (FeS) and kamacite (FeNi) were investigated. The magnetic properties of Neuschwanstein meteorite are dominated by kamacite. Unexpectedly, two magnetic features at ~ 70 K and 150 K were identified in the Neuschwanstein meteorite. Their presence was correlated to magnetic structural transition (T_m) and Curie temperature (T_c) of the ferrimagnetic daubreelite. Further the magnetic transition in the antiferromagnetic troilite at T_m ~ 60 K was identified. Its nature seems to be most likely due to change of the orientation and canting of the antiparallel spins. The low temperature magnetic data of daubreelite, troilite and kamacite can be useful for the interpretation of the low temperature magnetic measurements of various extraterrestrial materials and to identify the presence of those phases.

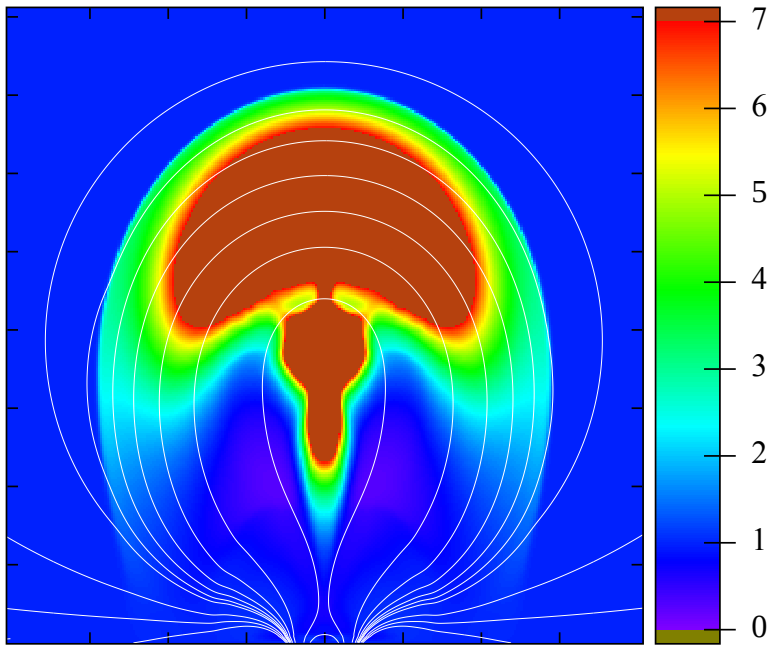


Figure 4.12. An MHD simulation of the evolution of a solar eruption, showing the density of the gas divided by the equilibrium value. A flux-rope is erupting and driving a compressive shock wave ahead. The flanks of the shock are refracted towards the solar surface, producing an observable wave-like disturbance propagating near the surface. The mass evacuated from the site of the eruption produces a dimming in the corona at the location of eruption.

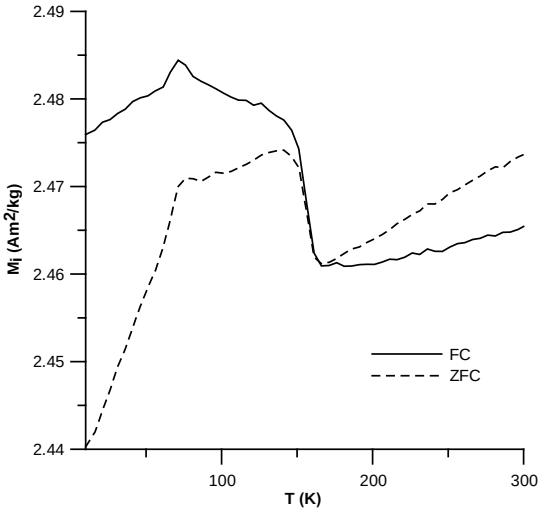


Figure 4.13. The low temperature magnetic measurements of the Neuschwanstein meteorite. The magnetic features at ~ 70 K and 150 K can be identified.

Shock-induced changes in magnetic properties of rocks, minerals, and meteorites play an important role in modelling the magnetic anomalies of impact structures, interpreting the magnetic anomalies of planetary bodies and understanding paleomagnetic data of meteorites. The group reported on results of shock experiments with synthetic fine-grained magnetite of SD (Single Domain) to PSD (Pseudo-Single Domain) magnetic behaviour.

The shock induced changes in sample properties show with increasing shock pressure decrease in magnetic susceptibility, decrease in remnant magnetization, softening of the magnetic hysteresis parameters showing more pronounced PSD characteristics, progressive shock demagnetization of the pre-shock given remanence, and reduction in bulk density and significant increase of porosity. The exception is the 45 GPa sample showing mostly out-of-the-trend change in its properties probably related to shock induced changes in mineralogy or to contamination of the sample by melted steel from the container.

Target rock samples from 29 outcrop sites in Keurusselkä area were measured in the Solid Earth Geophysics laboratory of the University of Helsinki to study shock-induced effects. Measurement consisted of petrophysical properties such as susceptibility, density and porosity. The alternating field and thermal demagnetization treatments were used to test the stability of remanence and to determine the components. Scanning electron microscope studies were performed in collaboration with the Geological Survey of Finland. Data collected from these measurements are used for comparing previous geophysical studies which include a gravity anomaly map from Finnish Geodetic Institute and aeromagnetic map from Geological Survey of Finland.

University of Helsinki Observatory (UHO)

Planetary-system research at the University of Helsinki Observatory (UHO) entails theoretical, observational, and experimental studies on key topics of solar-system exploration.

In fundamental planetary physics, UHO theoretical research is focused on light scattering by single small particles, on multiple scattering by complex media of small particles, and the celestial mechanics of the few-body problem. Experiments have been carried out to measure backscattering characteristics of particulate media (scatterometer at the Observatory) and to assess the X-ray fluorescence by planetary-regolith analogue samples (at the Department of Physics). Observations have been made using both space-based and ground-based telescopes.

The numerical method for computing coherent backscattering by complex particulate media developed at UHO has been successfully applied to polarimetric observations of transneptunian objects (TNOs). At ESO/VLT, UHO has continued to participate in polarimetric observations of TNOs. Furthermore,

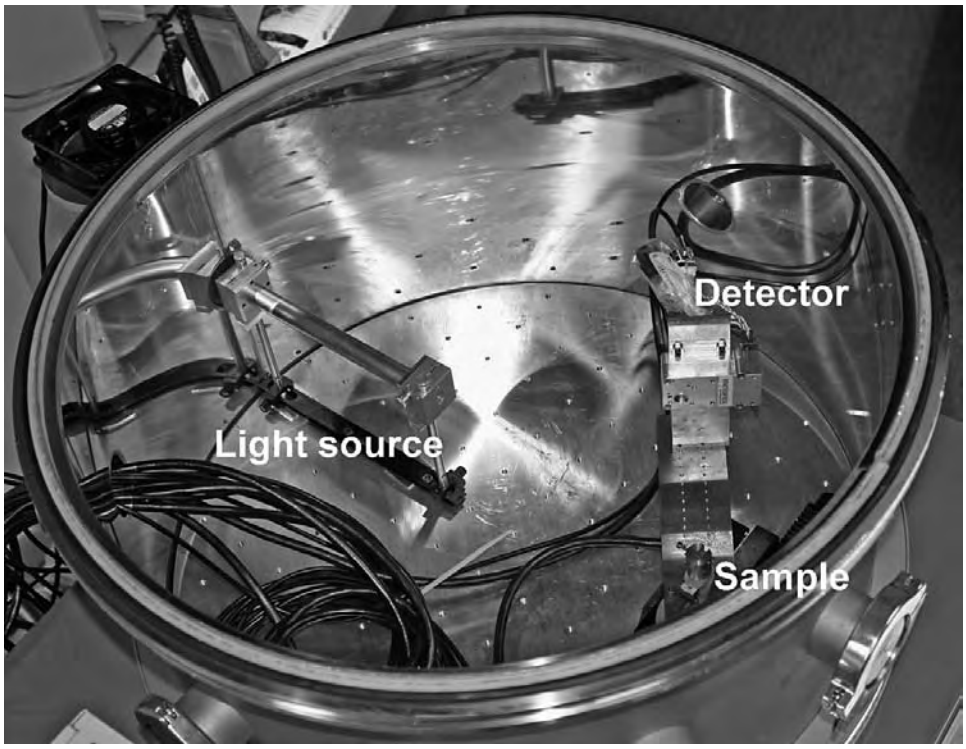


Figure 4.14. Goniometric laboratory setup used to study the regolith effects on X-ray fluorescence spectroscopy. Both emergence and incidence angles can be varied to simulate realistic observation geometries from orbiting spacecraft, e.g., ESA BepiColombo mission to Mercury. The measurements need to be performed in vacuum since air in NTP conditions is an efficient absorber and scatterer of soft X-rays.

UHO has taken part in polarimetric observations of cometary nuclei at VLT: these observations are the first-ever systematic polarimetric observations of cometary nuclei and their detailed interpretation is in progress. UHO has participated in studies of the peculiar polarization characteristics of asteroid (234) Barbara, showing an exceptionally wide negative polarization branch among the asteroids.

Systematic light-scattering simulations have been carried out for Gaussian-random-sphere particles with the Discrete-Dipole Approximation (DDA). These simulations have allowed UHO researchers to unveil the single-scattering interference mechanisms for the enhanced-intensity and negative-polarization branches of wavelength-scale scatterers. The mechanisms have been studied in detail for spherical particles by concentrating on the properties of the electromagnetic fields inside the scatterers. First steps have been taken to assess the properties of the internal fields of Gaussian particles.

In scattering of light by single small particles, UHO has studied surface-roughness effects using the DDA method and the Gaussian-random-sphere geometry, focusing on both harmonic roughness and what can be called "ragged" roughness. Scattering by thin irregularly undulating films has also been studied using DDA. In scattering of light by particulate media, surface-roughness effects are being incorporated into both scattering and X-ray fluorescence models for planetary regoliths using fractional-Brownian-motion surfaces and size distributions of spherical particles.

Detailed comparisons have been carried out between different DDA codes and optimization methods have been developed for DDA computations. Radar backscattering by shoots of scots pines have been studied using DDA. As light scattering has also direct applications in industrial processes, UHO has continued to model some industrial products like paper coatings for ideal light scattering. One of the purposes is to improve the quality of paper. Industrial applications of light scattering have further included scattering by wavelength-scale starch pigments.

UHO has continued studies of light scattering by large irregular Saharan sand particles, via Gaussian-random-sphere modelling for their shapes and assessing the significance of surface-roughness effects on scattering. Light scattering by such particles has been revisited both experimentally and theoretically: particle scattering characteristics are seen to be dictated by small-scale surface roughness.

In the field of asteroid orbital inversion using statistical methods, UHO has succeeded in finalizing orbital inverse methods for arbitrary numbers of observations and arbitrary observational time intervals. Recent developments include, e.g., the Volume-of-Variation method covering moderate numbers and time intervals of observations as well as n-body statistical ranging. A meticulous study has been carried out on how the odds for collision can be assessed for objects such as 2004 AS1 with very short observational time intervals (1-2 hours) and collision lead times (about 48 hours).

UHO has assessed the asteroid identification problem at discovery as well as across multiple apparitions and derived efficient log-linear identification methods based on augmented red-black binary trees and dimensionality-reduction techniques. The new identification methods have been successfully applied, first, to observational data obtained nearly simultaneously with the ESO/VLT and Canada-France-Hawaii Telescope ground-

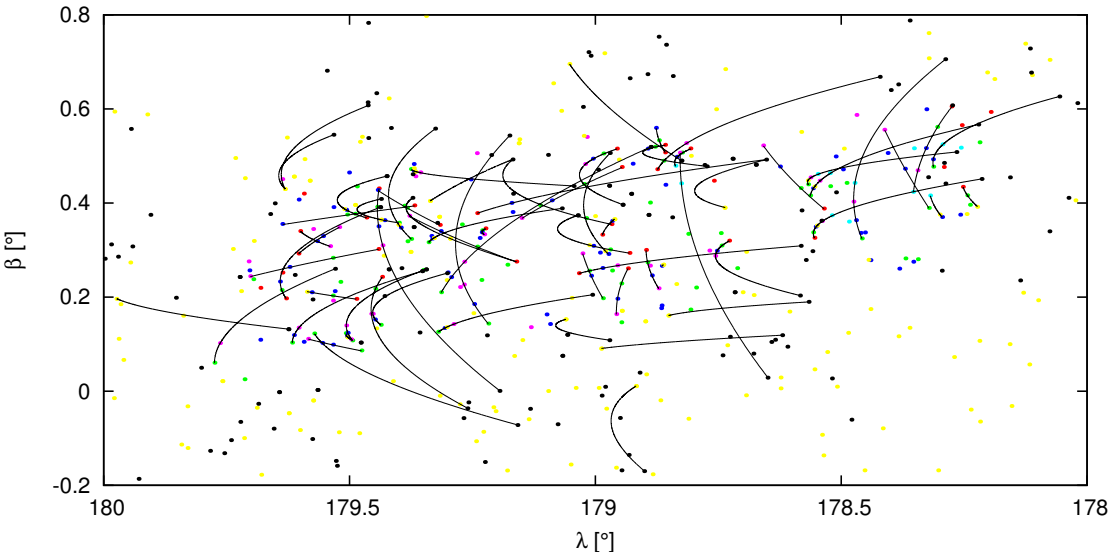


Figure 4.15. Observed topocentric positions of moving objects and selected, realistic paths linking the positions. The observations were made in 2004 with the ESO Very Large Telescope (VLT) and the Canada-France-Hawaii Telescope (CFHT). The VLT observations were made on five consecutive nights (January 20-24; red, green, blue, magenta, and aqua), whereas the CFHT observations were made on January 22 (yellow) and January 30 (black). Each dot corresponds to the first observation of an intrinsically correctly linked set of observations obtained at a single telescope during a single night.

based telescopes as well as the Spitzer space observatory and, second, to single-apparition observational data collected during the last hundred years or so.

Lightcurve inversion for asteroid spins and shapes has progressed using the convex inversion methods. At the Nordic Optical Telescope, UHO has coordinated a major Nordic Near-Earth-Object Network photometric and astrometric observing program on near-Earth objects. The observations have been interpreted using statistical convex-inversion techniques as well as analytical techniques using simple shape models such as sphere-cylinders. As an important step toward statistical asteroid spin and shape inversion methods, a downhill simplex inversion method has been established for general convex shape models.

UHO is actively participating in the interpretation of observations of the Moon with the AMIE camera onboard SMART-1. During the extended mission phase AMIE observations of the Moon were carried out close to opposition geometries. The calibration of the AMIE image data started in late 2007, providing good prospects for quantitative interpretation of the extensive lunar image data. In preparation for the interpretation, inverse shape-from-shading methods were developed for deriving lunar topography from the image data. Furthermore, methods were developed for modelling crater shapes using Gaussian random circles, in order to derive the fractal dimension for the lunar surface.

The most important experimental activity is the participation ESA's Mercury mission BepiColombo, where UHO has the PI of the SIXS instrument, and Co-PI of the MIXS instrument. The Mercury Imaging X-ray Spectrometer (MIXS) will carry out a global elemental and surface-structural mapping of Mercury, whereas the Solar Intensity X-ray and particle Spectrometer (SIXS) will provide the simultaneous calibration observations of the flux of X-rays and high energy protons and electrons, which are also valuable sources of data for independent research of the solar corona and particle radiation environment and the magnetosphere of Mercury. In preparation for BepiColombo, X-ray fluorescence measurements have been carried out at the University of Helsinki and at the University of Leicester. Another planetary system mission in preparation, where UHO has a significant role as a hardware provider is ISRO's Moon mission Chandrayaan-1 that will carry a Finnish X-ray Solar Monitor similar to that of SMART-1. The X-ray instrumentation on Chandrayaan-1 will perform studies of the X-ray fluorescence of Lunar surface and simultaneous observations of the X-ray Sun.

For the ESA Gaia mission (launch in 2012), UHO is managing and preparing the orbital-inversion work package, entailing the full solution of the orbital inverse problems for asteroids and comets. UHO has continued to carry out simulations for the discovery statistics of space-borne near-Earth-object observatories.

Finally, three-dimensional stochastic modelling has been carried out for the shapes of potato tubers. In connection to the shapes of

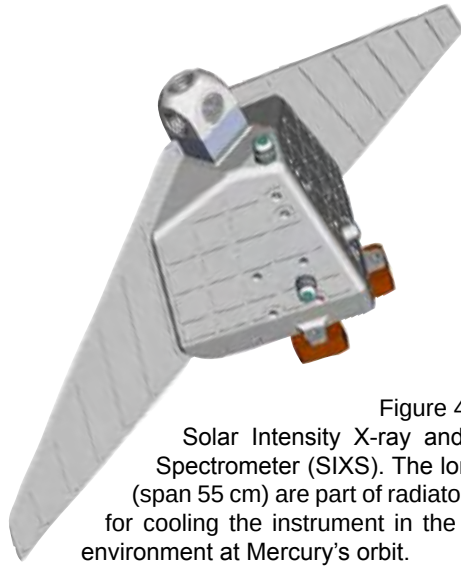


Figure 4.16. The Solar Intensity X-ray and particle Spectrometer (SIXS). The long wings (span 55 cm) are part of radiator needed for cooling the instrument in the very hot environment at Mercury's orbit.

potato tubers and lunar craters, inverse methods have been put forward for obtaining Gaussian-random-circle models from image data.

The XSM instrument onboard SMART-1 made useful X-ray observations of the solar corona. The aim of this research is to disentangle the properties of the hot solar corona by analysing solar flare associated X-ray spectra not only from XSM but also from the future Chandrayaan-1 and BepiColombo missions. In addition to own instruments, data from the RHESSI and the GOES satellites are used as complementary sources of information.

Research at UHO aims at clarifying the physical mechanism of the eruptions by examining the X-ray spectrum and its variation during flares, and by comparing different flares. Also time behaviour over longer time span is studied with the aim of studying the changes of the properties of solar corona during the 11-year sunspot cycle. The methods include developing improved theoretical models based on extensive new very high quality spectroscopic X-ray data. The data will enable obtaining a thorough new insight in understanding electromagnetic processes and X-ray emission mechanisms in hot coronal plasma of the Sun, and will also form a basis in producing a realistic model database for modelling the X-ray spectra of other stars, with the aim of understanding their coronae.

University of Oulu
Department of Physical Sciences
Division of Astronomy

The Solar System research of the Planetology Group of University of Oulu is based on the recent planetary data sets provided by ESA and NASA missions. The group has studied the Moon, Mars, Venus and Mercury as well as terrestrial and planetary impact craters and space materials found from the Earth.

A series of geology studies of the planet Venus using the Magellan and Venus Express data sets has been performed. The Magellan radar data set has the highest resolution (100 m/pixel) of all existing Venus data. The group has a long expertise in studying Venusian tectono-volcanic formations using Magellan data. This research on hot, high-pressure Venusian surface environment and geology is now added by a close collaboration with the international Venus Express VIRTIS team. The VIRTIS channels close to 1 μm provide an extremely interesting 50-to-100-km scale data set of surface properties (temperature, composition) that have to be correlated with the geology mapped from the Magellan images with much higher spatial resolution

For future Venus missions, the group has also defined the landing site characteristics required for the successful lander operations, and proposed a well-defined selection of future landing sites on Venus. The project is conducted in close collaboration with the Vernadsky Institute in Moscow and the Institut für Astronomie at Universität Wien in Austria.

ESA's Mars Express (MEX) reached Mars in 2003. Its instruments have provided wealth of new exiting observations and a huge amount of data for various Mars studies. The most productive data set for the Planetology Group has been provided by the high-resolution, colour and 3-D data set of the High Resolution Stereo Colour (HRSC) camera onboard MEX. This research on Martian geo-environment and climate-change-related geologic formations has been performed in close collaboration with the international MEX HRSC Team. The group has also utilized the extremely high-resolution image data (25 cm/pixel) obtained by the HiRISE camera of the NASA-MRO Mars orbiter. The MEX-HRSC collaboration has already materialized in several important publications that represent water-, climate- and environment-related aspects in Martian geologic history.

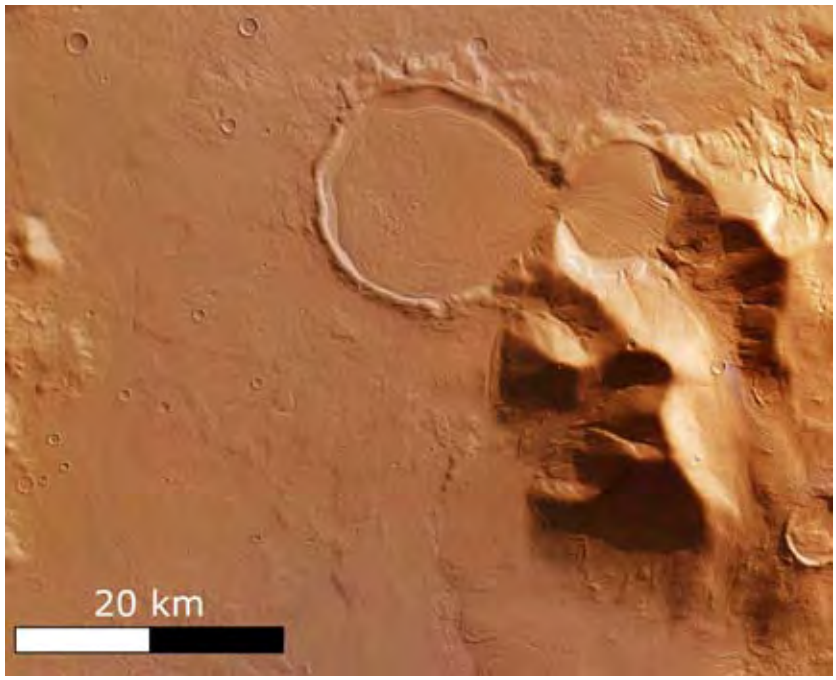


Figure 4.17. A view over two Martian craters filled with traces of a 'Hourglass' rock glacier and surrounded by a debris apron field in Promethei Terra at the eastern rim of the Hellas Basin at 38º S / 104º E. Ancient times, an amount of ice-rich material flowed from the hills into the small 9 km crater and further into the larger 16 km crater below it. The image was taken by ESA's Mars Express HRSC camera (ESA/DLR/FU Berlin: G. Neukum and the Co-I Team).

The group has also studied terrestrial impact craters by making field work, sampling and sample research on impact craters, impactites and impact-related processes. Studies on planetary impact craters have revealed the important and not so obvious result that the shape and certain morphometric characteristics of impact craters depend on the target bedrock properties. Impact craters can thus be utilized to define the importance of faults and other structural and tectonic units of the bedrock even if it is hiding below a lava field, for example.

The group has also continued the studies of space-borne spherules found from some of the terrestrial glaciers. The group participated in the first discovery of space spherules from Novaya Zemlya. This study is continued with a set of new samples that have provided several new types of undeformed and unmelted cosmic spherules. Each of these samples can be considered as a new micrometeorite. They add to our understanding of the origin of a certain meteorite groups as well as the fate of minor meteoroids approaching the terrestrial atmosphere.

The Dynamics Group of the University of Oulu has concentrated on the combined dynamical and photometric analysis of Saturn's rings. In particular, the group's model for the self gravity-induced 100-m fine-structure provides a quantitative explanation for both the azimuthal brightness variations and the longitude and elevation angle-dependent optical depth profiles. In particular, the group has participated in modelling of Cassini/VIMS A-ring stellar occultation profiles, and to modelling of Hubble Space Telescope (HST) observations of the A and B ring azimuthal asymmetry. The analysis indicates that strong gravity wakes are present nearly everywhere in the dense A and B rings. The same exten-

sive HST dataset has been used in studies of the rings' opposition brightening, both via coherent backscatter as well as mutual shadowing mechanisms. The group has also studied the rotational evolution of ring particles, and started modelling of their thermal balance, important for interpreting Cassini/CIRS observations.

The group's most important contribution has been to participate in the finding of a "moonlet belt" in Saturn's A ring, based on analysis of high resolution Cassini images. Most importantly, these ~100-m boulders are concentrated to a narrow zone in the middle of the ring. This rules out their internal origin: for example, gravitational accretion, if possible at that distance, should be even stronger outside

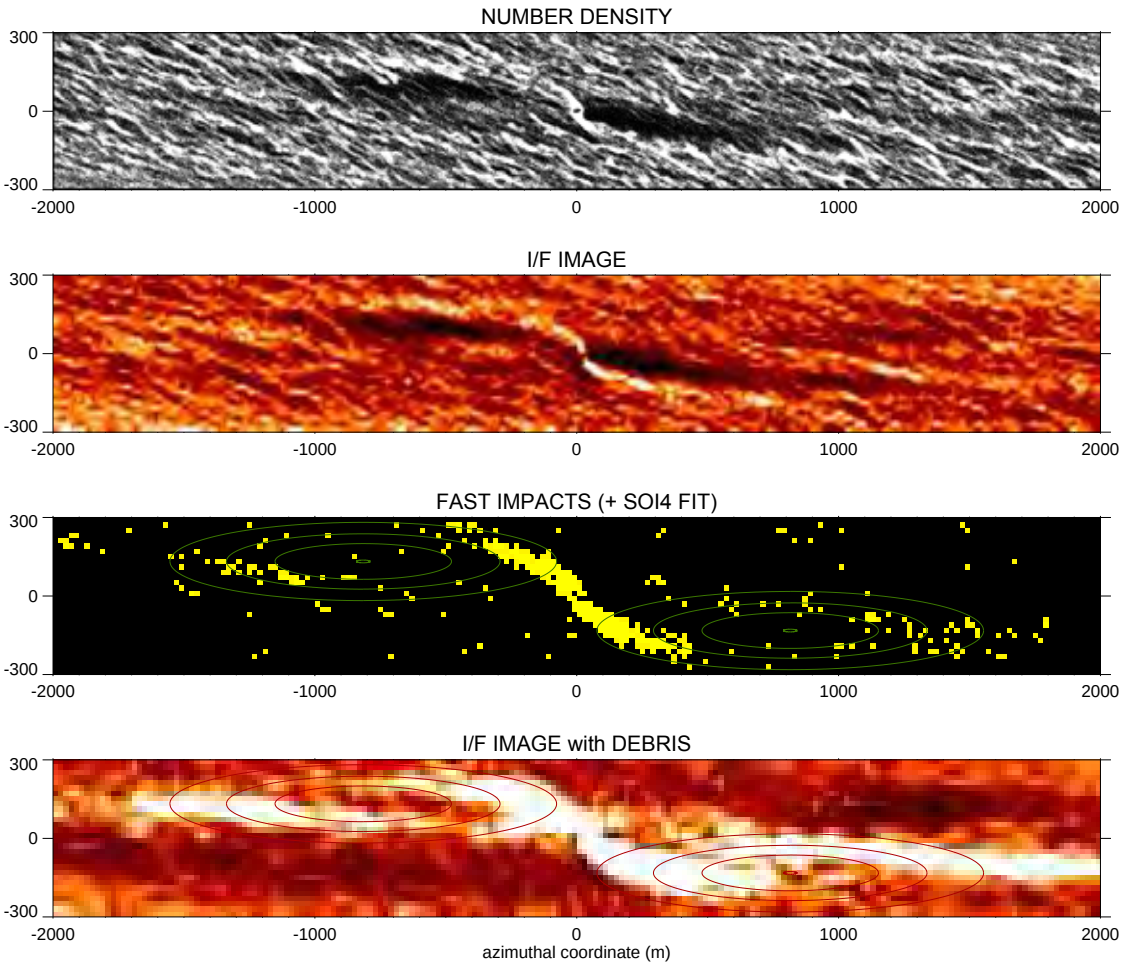


Figure 4.18. Simulation model for the effect of an embedded 40-m diameter moonlet in Saturn's A ring. The upper frame shows a 4 km by 0.6 km azimuthally elongated simulation region co-moving with the moonlet's orbital motion. The direction to the planet is downward and the orbital motion is to the right: two symmetric density enhancements are seen downstream of the moonlet, in addition to smaller scale self-gravity wakes among the small 1 meter particles themselves. The next frame shows a synthetic image corresponding to the observing geometry of the Cassini image. A good correspondence to observed propellers is obtained with the inclusion of regolith debris (lowermost frame; contours indicate a fit to one observed propeller feature), assumed to be released due to enhanced impact speeds in the vicinity of the moonlet (third frame).
Figure from Sremcevic et al. 2007 (Nature 449, 1019, suppl. online-material).

the zone. Instead, the group interpreted the boulders to represent the largest remaining fragments of a former 10-km moon shattered in a comet impact some 10-50 million years ago. The study thus suggests that such rare events may have an important effect on continuously shaping the ring system. The Oulu contribution has been to construct detailed models for the dynamical and photometric signature of such embedded moonlets.

The group's simulations suggest that the best correspondence to observed features is obtained if typical ring particles are regolith covered: the release and subsequent re-accretion of this loosely bound regolith debris can account for the high contrast of the propellers in images taken both on illuminated and unilluminated sides of the rings.

University of Oulu, Department of Physical Sciences and Sodankylä Geophysical Observatory

The Space Physics Group of the Department of Physical Sciences and the Sodankylä Geophysical Observatory of the University of Oulu are active in heliospheric and solar research. Research is mainly directed to the so-called space climate, which includes analysis of long-term solar magnetic activity, its temporal behaviour at different time scales and spatial structures, as well as its effects on the global structure and evolution of the heliosphere, the long-term properties of the solar wind and interplanetary magnetic field, geomagnetic activity, and cosmic rays. Research includes long-term satellite measurements of solar wind and interplanetary magnetic field, and ground based and underground cosmic ray measurements. Moreover, preliminary work is being carried out in the instrument design for the BepiColombo mission.

University of Oulu carries two ground-based experiments to measure cosmic rays. Oulu neutron monitor has continuously measured the cosmic ray intensity since 1964. Its data, available via an on-line database (http://cosmicrays.oulu.fi), are routinely used both for scientific and educational purposes and for a radiation hazard warning system and the calculation of radiation doses onboard trans-Atlantic jets. A muon experiment has been installed in Pyhäsalmi in co-operation within the CUPP (Centre for Underground Physics in Pyhäsalmi) project, and has been measuring the cosmic ray flux at about 20 GeV since 2003.

Galactic cosmic rays are subject to heliospheric modulation, which results in changes in the intensity and spectrum of cosmic rays detected on Earth. Thus variations of cosmic ray intensity can be used to study the large-scale changes in solar/heliospheric conditions. In order to study the modulation theoretically, a basic numerical model of cosmic ray transport in the heliosphere was developed. This model has been successfully applied to study long-term changes in the solar/heliospheric parameters. Using the model monthly averages of the heliospheric modulation parameter were reconstructed from the measured cosmic ray fluxes over more than 50 years. This also allowed estimating the evolution of the heliospheric current sheet tilt angle since 1951, i.e., 25 years before regular solar observations.

The group has also presented a quasi-steady 2D (axisymmetric) model of the heliospheric transport of galactic cosmic rays. The model is based on stochastic simulation techniques and includes all modulation mechanisms that cosmic rays experience in the heliosphere: convection, adiabatic cooling, diffusion and drifts. A special emphasis is given to the cosmic ray transport in the vicinity of the heliospheric current sheet (HCS), and a new method to calculate the wavy current sheet drift has been presented. Studies of cosmic ray modulation in different solar modulation

conditions and different levels of waviness of the current sheet have demonstrated changes in the cosmic ray spectrum and the dominant streaming patterns for different solar polarities and HCS tilt angles.

There is evidence that solar activity variations can affect the cloud cover at Earth. However, it is still unclear which solar activity dependent parameter is the most important driver of cloud formation. We have used partial correlations to distinguish between the effects of the cosmic rays and the UV irradiance on clouds. We have found that the solar influence on cloud cover is not uniquely defined by one driver, but both seem to play a role, depending on the climatic conditions and altitude. In particular, low clouds are mostly affected by UV irradiance over oceans and dry continental areas and by cosmic rays over moist lands with high aerosol concentration. High clouds respond more strongly to cosmic ray variations, especially over oceans and moist continental areas. That the results are related to the solar drivers and not induced by major ENSO events or volcano eruptions has been checked. These results provide interesting new observational constraints on climate models.

Long-term observations of the heliospheric magnetic field (HMF) at 1 AU have depicted interesting systematic hemispheric and longitudinal asymmetries that have far-reaching implications for the understanding of solar magnetism. The HMF sector that is prevalent in the northern solar hemisphere has been found to dominate the observed HMF sector occurrence for a few years in the late declining to minimum phase of the solar cycle. This leads to a persistent southward shift or coning of the HCS at these times. This result has later been verified by direct measurements of the solar magnetic field which showed that the average field intensity was smaller and the corresponding area larger in the northern (heliographic) hemisphere than in the southern hemisphere during roughly three years in the late declining to minimum phase of the cycle. Long-term observations of the geomagnetic field were used to yield information on the HMF sector structure in the pre-satellite era, showing that the ballerina was bashful since 1930s. In addition to the hemispheric asymmetries, the Sun is systematically asymmetric in longitude. It has been shown that the global HMF has persistent active longitudes whose dominance depicts an oscillation with a pe-

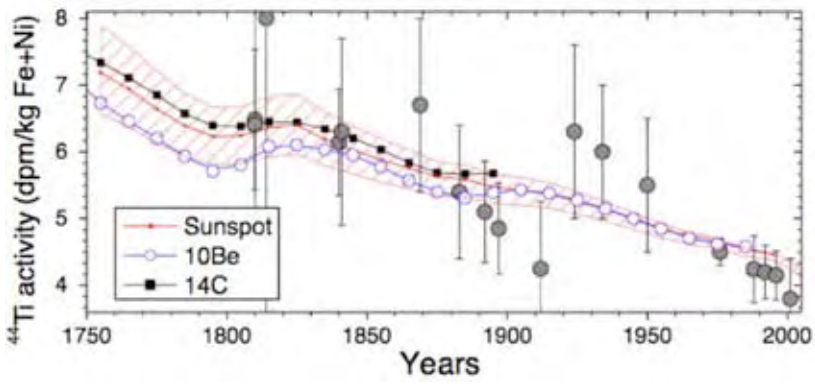


Figure 4.19. Immediate activity of cosmogenic ^{44}Ti isotope in stony meteorites as a function of time of fall. Large dots with error bars depict measurements in historical meteorites (Taricco et al. 2006), while curves correspond to the theoretically expected ^{44}Ti activity based on different models of the solar magnetic field behaviour during the last centuries (after Usoskin et al., 2006): computed from sunspot numbers (Solanki et al., 2002), reconstructed from ^{14}C data (Usoskin et al., 2007) and from ^{10}Be data (Usoskin et al., 2003).

riod of about 3.2 years. Stellar observations show that this is a general pattern for sun-like cool stars.

A full 3D numerical model of cosmic ray induced ionization of the atmosphere has been developed. The model is based on Monte-Carlo simulation of a nucleonic-electromagnetic cascade initiated by cosmic rays in the atmosphere. The model agrees well with fragmentary observations. It has been approved by CAWSES and COST international programs and recommended for practical applications.

Different models and indirect reconstructions predict different scenarios of the heliospheric magnetic field during the last few centuries – from a very strong increase in the first half of the 20-th century to a nearly constant level. Using a direct modelling, we have confronted results of different models with the measured activity of cosmogenic isotope ^{44}Ti in 19 stony meteorites fallen during the last 250 years. The results show a good agreement with the data, implying a significant change of the heliospheric magnetic field over centuries.

University of Turku Space Research Laboratory

The main focus of the Space Research Laboratory (SRL) of the University of Turku is in solar physics, particularly in phenomena related to energetic particles of solar and interplanetary origin. The main tool in conducting this research is the laboratory's own instrument, the Energetic and Relativistic Nuclei and Electron experiment (ERNE) onboard the SOHO spacecraft. Presently, SOHO is in its thirteenth year of operation observing solar phenomena in a wide range of electromagnetic and corpuscular radiation. The ERNE observations of energetic particles are complemented by other SOHO instruments and instrumentation of other ground-based and space-borne observatories.

SRL participates in national and international collaborations also outside of the SOHO context. Part of the theoretical work is conducted in collaboration with researchers from the University of Helsinki, Tuorla Observatory of the University of Turku, and Ruhr-Universität Bochum. Within this framework, studies connecting the solar wind and energetic particle energization mechanisms related to plasma turbulence have been continued. The group has also participated in the COST Action 724: Developing the Scientific Basis for Monitoring, Modelling and Predicting Space Weather.

By using the uniquely accurate angular resolution of the ERNE High Energy Detector, HED, the evolution of energetic particle transport throughout the "Interplanetary highway" event of May 2 1998 was analysed in great detail. Using Monte Carlo simulations, it was discovered that the spacecraft, while observing the event, traversed through flux tubes with extremely different energetic particle transport conditions starting with up to 20 AU scattering mean free path during the first hours of the event, and decreasing, in several steps, to just 1.5 AU, which still is long compared to average interplanetary transport conditions.

The extremely low level of particle scattering, also provides means for new insights into particle acceleration processes. The detailed analysis of the May 2, 1998, event was made possible by the exceptionally good "seeing" conditions, with the high-energy particles inside an interplanetary magnetic cloud, which resulted in smaller than usual uncertainties in determining the timings of the solar particle release. Observations clearly showed a two-component injection process for the energetic particles. The first injection, up to tens of MeV in proton energies, was rapid and energy-dependent, and well-correlated with a Moreton wave start and a radio flash, suggestive of acceleration on open field lines. This was fol-

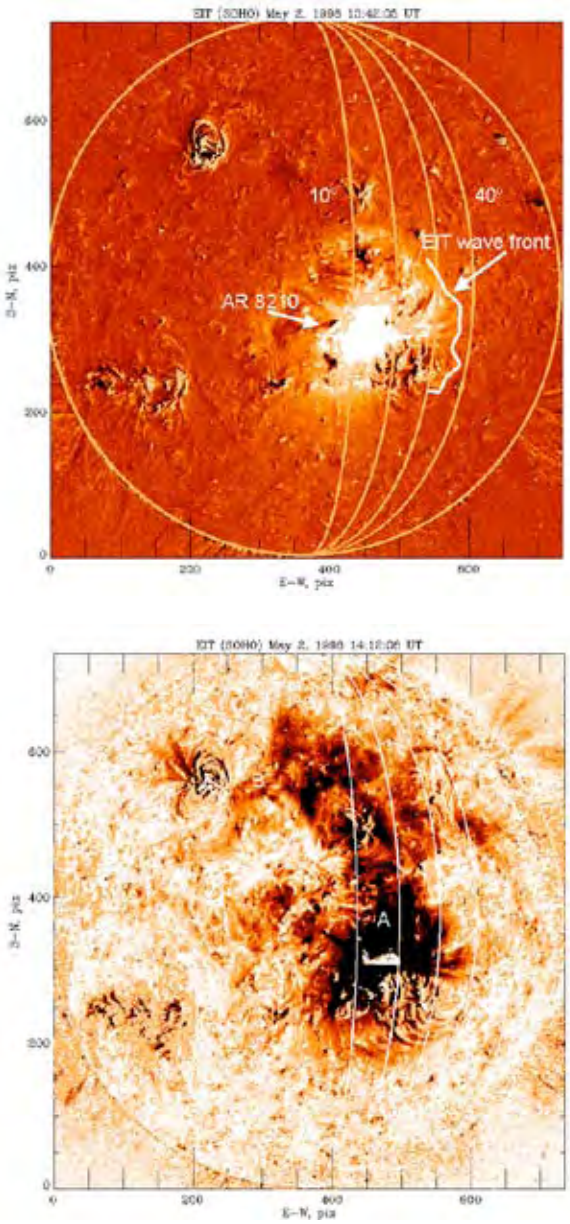


Figure 4.20. EIT 195 Å Running difference images showing the position of the coronal wave, with the associated flare (top) and the dimming region (bottom), associated with the 1998 May 2 solar energetic particle event. Letters A and B in the bottom panel indicate the footpoints of an erupted transequatorial loop.

lowed after 15 minutes by a more gradual injection, temporally associated with an EIT dimming, and occurring simultaneously at energies up to a few hundreds of MeV. The nature and temporal associations of the second injection suggest that the acceleration of these particles took place on initially closed field lines, which then opened due to coronal restructuring of the magnetic fields, allowing the particles to escape to interplanetary space.

The long-term observations of SOHO have been utilized in statistical studies of the occurrence of energetic storm particle events associated with transient interplanetary shocks and the dependence of the characteristics of the particle events on the shock properties. The goal of the investigation is to gain detailed information of not only the shock acceleration process, but also of the structure and evolution of transient shocks in interplanetary space.

SRL is the leading Finnish party within a European and U.S.-wide collaboration proposing the energetic particle instrument for the Solar Orbiter mission. Design, construction, and operation of one of the proposed sensors would be the responsibility of SRL. Within the context of the proposal preparation, the technology development of the sensor was initiated.

University of Turku, Tuorla Observatory

Tuorla researchers participate in the EU FP& Research Training Network AstroNet. Astronet brings together mathematicians, engineers and astronomers to work on innovative new methods for designing spacecraft trajectories and controlling their dynamics. Particular emphasis is being placed on optimizing trajectories and control to minimize fuel use and extend mission ranges. This will be achieved

by maximizing the use of "natural dynamics", employing sophisticated ideas and techniques from dynamical systems theory. The results will be extended to studies of the dynamics and control of novel spacecraft architectures, such as solar sails, space tethers and formations of spacecraft. In addition to the AstroNet work, studies of numerical methods and the few-body problem have continued on several areas. Among the new results are a code for black hole dynamics, algorithms for relativistic few-body motion, and the first theory for motions of quasi-satellites such as the recently discovered quasi-satellite of Venus.

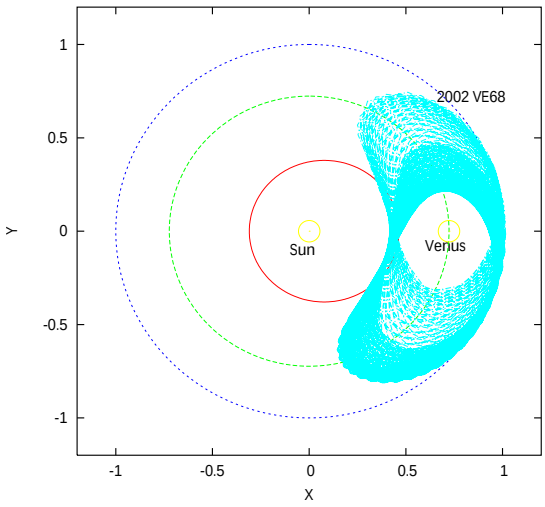


Figure 4.21. Quasi-satellite of Venus

Solar physics studies at Tuorla Observatory have focused on the studies of flares, shock waves, and the initiation of coronal mass ejections (CMEs). The main tool has been multi-wavelength analysis, with focus on signatures in radio emission. Both radio spectral and imaging observations have been utilized, and the work has been carried out in close collaboration with Paris Observatory, University of Athens, and the National Astronomical Observatory of Japan. Analyses of several metric type II bursts have shown that the radio bursts clearly have different source origins, and no single process for the shock formation can be specified. This is an important observational statement in the current debate focusing on whether metric type II burst exciters are flare blasts or coronal mass ejections – the group has found that both can be present even during the same event. Also super-Alfvénic loop expansion was found to be a good candidate for the initiation of a shock wave. Using various observational methods, the group has also traced the whole CME travel time in a few selected cases, starting from the CME lift-off and ending at the shock arrival near Earth. These results help to estimate and predict changes in CME speeds, resulting in more accurate estimates of their arrival times, and hence better space weather forecasts.

Solar energetic particles, which are observed in situ near Earth, get accelerated at or near the Sun during transient processes like solar flares and CMEs. Their origin in not known exactly, and therefore the solar groups at Tuorla Observatory and SRL of the University of Turku and the Department of Physics of the University of Helsinki have joined forces to investigate the initial conditions for particle events. The first results include evidence in support of a scenario in which electrons are accelerated low in the corona behind the CME shock front, while protons are accelerated later, possibly at the CME bow shock high in the corona. It was also found that some of the type III bursts encounter a steep density gradient as they overtake a type II shock front, resulting in an abrupt change in the frequency drift rate of the type III burst emission.

Astronomers at Tuorla Observatory have made a new, indirect measurement of the "colours" of the Sun. A longstanding problem has been to measure the colours of the Sun in the standard stellar photometric systems, since it is too bright for ordinary observations. One way around this is to find stars that are as very similar to the Sun in other properties, and from their colours to infer the colours of

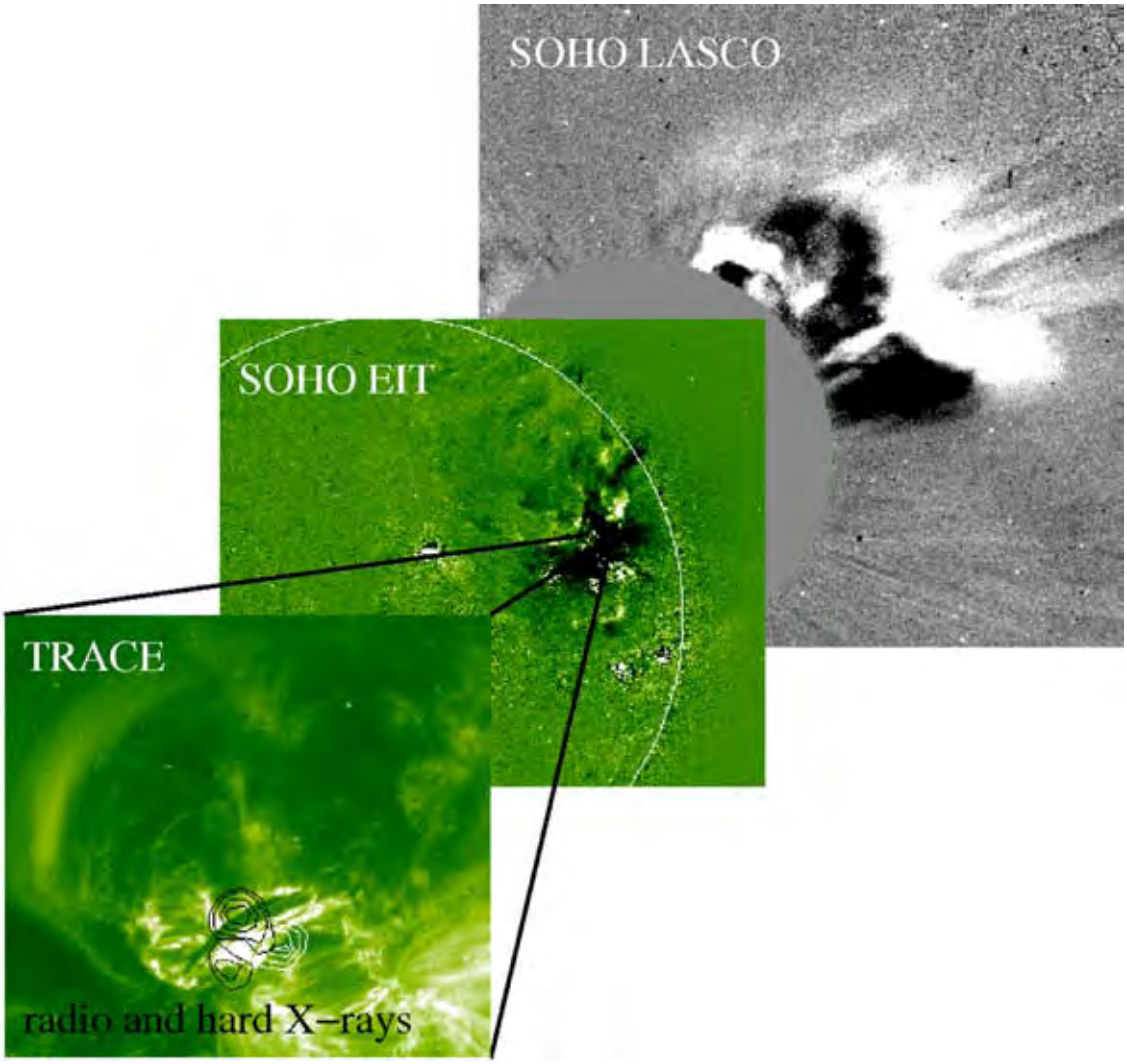


Figure 4.22. Coronal mass ejection in action: destabilized plasma loops begin to oscillate, a shock wave is formed, and plasma from the solar chromosphere and corona get ejected out from the Sun. The outward-propagating magnetic cloud creates disturbances that can be observed also at Earth.

the Sun. The problem with this technique has always been to make sure that the temperature of the stars and of the Sun are measured consistently in the same scale. To do this, the Tuorla researchers have used the tremendous advances being made in the last two years at the ESO's Very Large Telescope that has been making direct measurements of the surface temperatures of stars using interferometry. The technique shows that surface temperature can be measured consistently both for faint stars and for the Sun. This breaks through the old impasse to using this technique for measuring the Sun's colours.

4.3. Astronomy and Cosmology

Helsinki University of Technology Metsähovi Radio Observatory

The Metsähovi group studies Active Galactic Nuclei (AGNs) using the 14-metre Metsähovi telescope for long term monitoring of AGN radio variability as well as for one- to few-epoch observations of several large source samples. The data are used in connection with data gathered from other instruments, including many space-borne instruments, to study the activity of AGNs across the electromagnetic spectrum.

Several Metsähovi scientists are members of the Planck satellite's LFI consortium. The team actively participates in the core activities of the Planck Extragalactic Point Sources Working Group. The main tasks in 2006-2007 were the completion of the Planck Quick Detection System software and its installation to the Planck LFI Data Processing Centre, the construction of the a pre-launch catalogue of extragalactic point sources to be used during the Planck mission, and analysis of scientific data so far obtained for extragalactic point sources.

As part of Planck foreground studies the group has made radio observations of several subpopulations of Active Galactic Nuclei. These populations include BL Lacertae Objects, Gigahertz Peaked Spectrum (GPS) sources and other inverted-spectrum sources as well as some fainter flat-spectrum sources.

The group's studies of the inverted-spectrum source population reveal that most of the sources classified as GPS quasars in the literature are in fact ordinary, variable, flat-spectrum sources. Thus the often-quoted "general" properties of the GPS population are partly based on misidentifications. Long term multifrequency variability data for the GPS sources and candidates was published and a new "master list" of genuine GPS sources was proposed.

Recently the group carried out extensive analysis of long term (almost 30 years) data of the radio variability of ca. 80 most densely monitored AGNs. By studying the variability time scales understanding in how often the sources have flares and how long these outbursts typically last was gained. Data show that radio flares in these sources occur relatively rarely, only once in every 4-6 years. Also the duration of flares is long, of the order of 2 years at 37 GHz. The results show that even 10 years of monitoring is not long enough time to reveal the complete variability behaviour in some sources.

In collaboration with other multifrequency observers the group studied many individual AGNs across the electromagnetic spectrum, including satellites observing in the high-energy region: XMM-Newton, RXTE, INTEGRAL, AGILE, Swift. These campaigns are targeted for obtaining broadband spectral energy distributions during various activity stages in order to model the emission mechanisms.

Since the early 1990s Metsähovi has been one of the few institutes in the world where Very Long Baseline Interferometry (VLBI) data acquisition systems have been constructed and developed further. This technology accumulation has its roots in the early 1990s when VLBI research at Metsähovi was initiated in conjunction with the Radioastron project. Experience originally gained in building an own VLBA Data Acquisition Rack has enabled the group to match and surpass the traditional designs of MIT Haystack Observatory. Recently the team has focused on transforming commercially available off-the-shelf technology for VLBI data acquisition applications and on exploiting high-speed Internet protocols

for e-VLBI. The latter has already produced several "world records" in data transfer speed over the Internet.

University of Helsinki Department of Physics

The Department of Physics of the University of Helsinki has a broad research programme in cosmology reaching from the fundamental theories of Big Bang to analysis of cosmic microwave background (CMB) data. Only the activities related to ESA's Planck satellite to be launched in 2008 are discussed in this report. During the years 2006-2007 one of the most demanding tasks in the studies of cosmic microwave background (CMB) is the conversion of the huge amount of measurement data from the spacecraft into a physically meaningful form. The group participates in the development of methods for making full-sky maps of the microwave background and to determine the cosmological parameters from them. The group has written a map-making code that has been incorporated in the Planck Data Processing Centre data analysis pipeline.

The group has also participated in the testing of the 70-GHz radiometers of Planck that were developed in Finland by Millilab, VTT, and Ylinen Electronics (DA-Design Ltd.). At the beginning of 2006 the radiometers were delivered to Alcatel Alenia Space, where they were assembled together with the 30- and 44-GHz radiometers to form the Low Frequency Instrument (LFI) of Planck. Alcatel carried out tests of the combined LFI radiometer array later in 2006. The group has participated in the analysis of this test data.

The LFI was integrated to the Planck satellite in early 2007. The completed satellite will undergo final ground tests during 2008 before launch. Present activities of the group include refinement of the map-making code to take into account various realities of the actual data stream from the satellite and investigating systematic effects such as instrument pointing errors and beam profiles on the maps. The group is also developing methods to estimate the remaining pixel-to-pixel noise correlations in the maps to be utilized in the estimation of the CMB angular power spectra.

Figure 4.23. The Planck satellite in acoustic tests (courtesy of Thales Alenia Space and ESA)

University of Helsinki Observatory (UHO)

At UHO the scientific use of ESA's International Gamma-Ray Astrophysical Laboratory (INTEGRAL) has continued with new scientific papers published in 2006-2007. SMART-1/XSM made effective observations of the Sun until August 2006. Several new papers on solar coronal science with very high quality data from XSM/SMART-1 are in preparation. Observation programs with other satellites (RXTE, XMM-Newton, Chandra) and ground-based telescopes (e.g. NOT, ESO, ATCA), were also continued by UHO. Other satellite data that have been utilized by UHO are ISO and Odin. As for future plans in space

astronomy, UHO is involved in science planning of the Planck and Herschel satellites.

Investigations of interacting compact binaries aim at studying X-ray binaries in novel ways. X-ray binaries are systems in which a compact primary (black hole, neutron star, or in the case of cataclysmic variables, white dwarf) accretes matter from a non-degenerate companion. This matter swirls around the compact object in an accretion disk the accretion disk is the main source of X-ray radiation from X-ray binaries. X-ray binaries radiate at all wavelengths, from radio to hard X-rays.

One aim of this research programme is to study the numbers, structure and evolution of very short period binary systems. These systems consist of a degenerate primary star and a mass-losing secondary component that in the ultra-short period systems is either a white dwarf or a helium star. In systems with periods above about 80 minutes the donor can also be a main sequence star. These systems are also the main source of gravitational radiation to be measured for the first time by some future mission, possibly the ESA/NASA joint project LISA. These systems are crucial in verifying the theory of general relativity. The group also intends to continue developing new data modelling techniques for accretion process studies. These include combining Doppler tomography of disks with lightcurve modelling.

Another important aspect of this research program is to disentangle and thus decipher the high-energy spectra of accreting low mass X-ray binaries. This is done through a truly physical (as opposed to largely phenomenological) model and observations from, e.g., INTEGRAL, where the UHO group is a Co-I team, and major radio telescopes. The group expects to explain many of the phenomena related to the accretion disk, a corona (or plasma cloud) surrounding the central parts of the accretion disk (and hence the compact accretor that is usually a black hole), and possible outflows seen as bipolar jets in the case of microquasars.

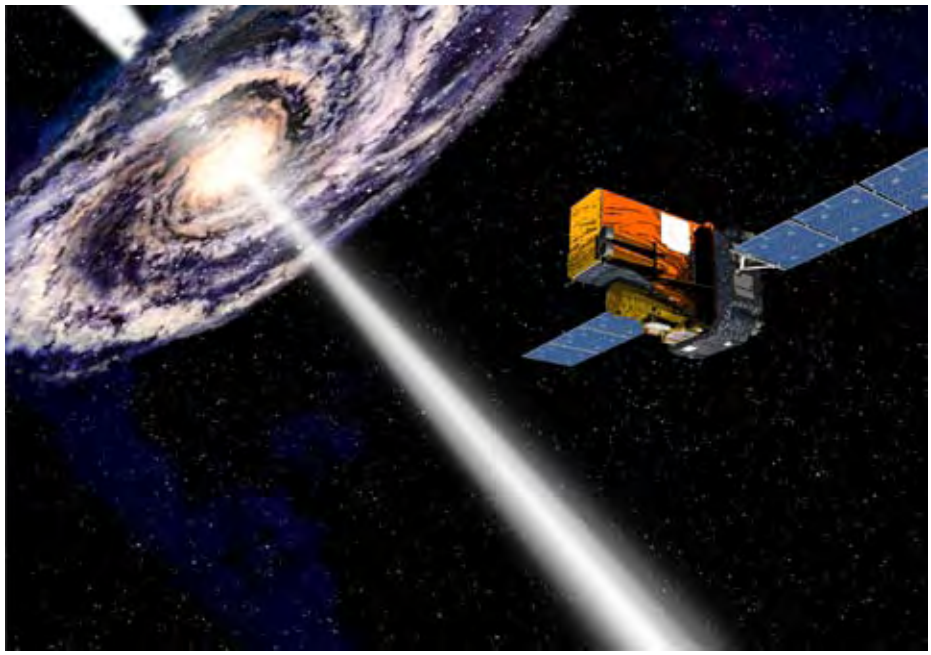


Figure 4.24. ESA's INTEGRAL is one of the workhorses of Finnish high-energy astrophysicists (photo: ESA).

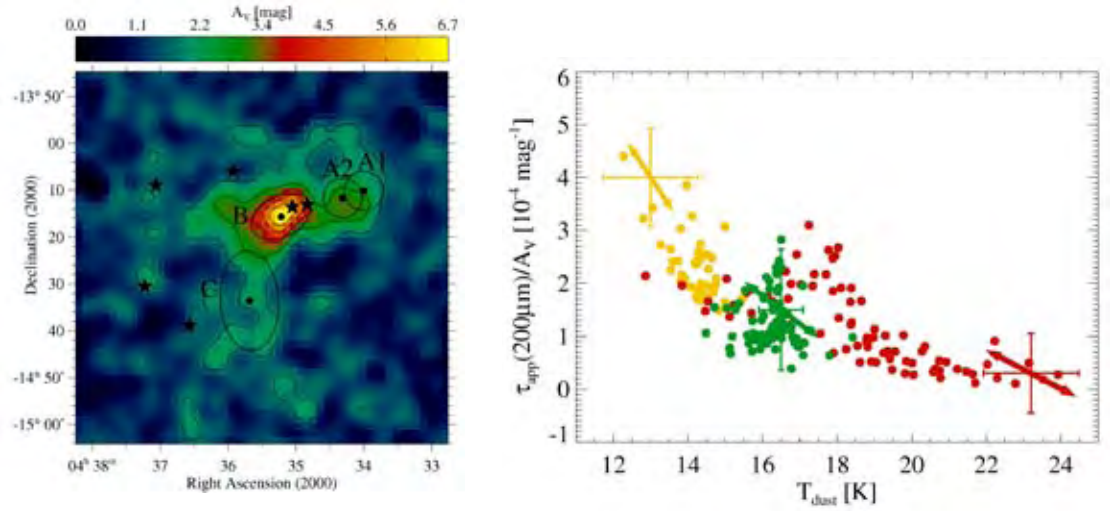


Figure 4.25. (left) Visual extinction A(V) through the dust cloud L1642, derived using near-infrared data from the 2MASS (2 Micron All Sky Survey) archive. (right) Dust emissivity, measured by the ratio of far-infrared optical depth to visual extinction, (far-IR)/A(V), increases with decreasing dust temperature in the dark cloud L1642. This phenomenon is caused by grain-grain coagulation in the denser, colder regions of the cloud. The data points of the regions A, B and C in the extinction map are marked with green, yellow, and red, respectively.

The research on clusters of galaxies aims at characterizing thermal and non-thermal processes in the clusters of galaxies. The group examines and utilizes the hydrostatic equilibrium of cluster material and uses it to derive baryonic and dark matter density distributions. This information is used to constrain cosmological parameters. Also the "soft X-ray excess" component in clusters is examined.

The main observational tools utilized by the UHO group are high-resolution imaging and spatially resolved spectroscopy of the X-ray emission of the hot intracluster gas. The group carries out analysis of the cluster data obtained with XMM-Newton and Chandra X-ray satellites. The total cluster mass determination within the virial radius is a complicated task, because the cluster brightness decreases rapidly with the radius. Both XMM-Newton and Chandra suffer from solar particle induced flaring background, which renders the background modelling uncertain. These uncertainties, if not properly accounted for, reduce the accuracy of the measurement of cluster temperature and consequently the total masses.

In order to examine the background stability, the group carried out a systematic study of a sample of XMM-Newton blank sky observations. A double-filtering method was developed, which reduces the background uncertainties significantly compared to the commonly used method. By comparing the background estimate with the blank sky data the group evaluated the involved uncertainties and presented a practical method to propagate the uncertainties when measuring cluster temperatures. The work is acknowledged by the XMM-Newton telescope team who advertise the group's background method in their web site.

UHO has completed the analysis of an extensive set of ISO data, which resulted from its successful Guaranteed and Open Time projects. ISO data are by far not exhausted

yet. ESA was supporting in 2002-2006 the so-called ISO "Active Archival Phase" during which the data, successfully collected during the 2.5 years of ISO operations, were extensively exploited.

Recent observations have indicated that the properties of dust grains change in cold, dense regions of dark clouds, probably due to grain-grain coagulation. UHO's ISOPHOT FIR study of the dark cloud L 1642 has given strong support for this. Dust emissivity increases with decreasing dust temperature in L 1642. Radiative transfer calculations show that an increase of absorption cross-section of dust at far-IR is necessary to explain the observed decrease of dust temperature towards the centre of L 1642. Furthermore, the group found that, due to temperature effects, the apparent value of optical depth derived from 100- and 200-μm intensities, is always lower than the true optical depth. This effect is not widely recognized, although it can have a profound effect on the derived far-IR optical depths. ISO observations of the cloud L1780 have revealed clear differences in the spatial distribution of different dust populations. In order to quantify these dust abundance variations, detailed radiative transfer modelling of the observations is in progress.

UHO researchers have been involved in the preparation of science projects that will be carried out using the Planck satellite of ESA. The projects are related to the study of nearby galaxies and the interstellar medium within the Milky Way. The main emphasis will be on the study of molecular clouds. In particular, UHO is coordinating a research project on compact and cold cloud cores. The population

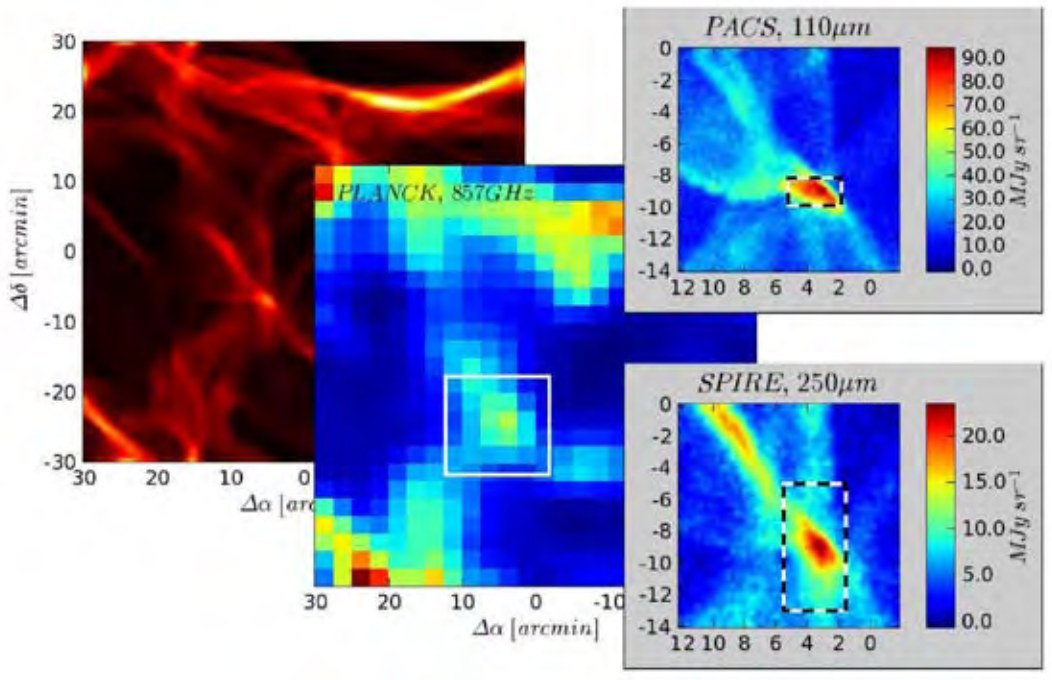


Figure 4.26. A simulation of an interstellar cloud observed with the Planck and Herschel satellites. The gas column density is shown on the left and the 857 GHz Planck map in the middle. The frames on the right show the dust emission from a cold cloud core (the area marked in the Planck map) observed in two Herschel bands. The figure illustrates the need for Herschel resolution and sensitivity for studies of the internal structure of the cores that will be identified in the Planck all-sky survey.

of cold cores is still poorly known because Planck will be the first space-borne mission that will be sensitive to their radiation. Work is in progress to develop of methods for the detection of cold cores and for the analysis of their dust emission. In this connection, simulations were carried out also of the polarized emission of dust grains aligned in interstellar magnetic fields. The efficiency of radiative torques was investigated using magnetohydrodynamic cloud simulations and radiative transfer modelling. Predictions were made for future Planck observations.

During 2007 the UHO group coordinated the creation of an open time key program proposal for the Herschel satellite. The proposal was officially accepted in early 2008. In this project the Herschel satellite will be used for follow-up observations of a number of cold cloud cores detected by Planck. The high spatial resolution provided by the Herschel instruments will be essential for the study of the internal structure of the cores.

The Odin satellite was developed by Swedish Space Corporation on behalf of the space agencies in Sweden, Canada, Finland and France. Odin was launched in 2001 and its operations have been shared between astronomy and aeronomy observations. Since 2007, Odin is working full time on studies of the Earth's atmosphere.

A major achievement of the astronomy mission was the first detection of molecular oxygen, O_2, in an interstellar molecular cloud. The very low abundance of O_2 derived from these observations is consistent with previously derived upper limits, and places a hard constraint on models of interstellar chemistry. The data analysis was extremely tedious because the 119-GHz receiver was not phase locked. The frequency calibration was, however, possible by monitoring telluric oxygen lines.

Researchers at UHO have continued Odin collaboration with the group at the Centre d'Etude Spatiale des Rayonnements, Toulouse. Odin H_2O line observations at 557 GHz towards protostellar and prestellar molecular cloud cores are analysed in conjunction with auxiliary ground-based observations and radiative transfer modelling. Detailed studies of the dense core Cha-MMS1 and the protostar IRAS 16293-2422 are underway.

University of Oulu
Department of Physical Sciences
Division of Astronomy

Main activities of the astrophysics group at the University of Oulu are concentrated on the studies of compact astrophysical objects such as black holes and neutron stars in X-ray binaries, gamma-ray bursts and the physics of relativistic jets.

Accretion-powered millisecond pulsars were studied actively using the X-ray data from NASA's Rossi X-ray Timing Explorer (RXTE) and ESA's INTEGRAL satellites. The group has shown that all of them have similar spectral energy distributions, which can be described by thermal comptonization in a shock close to magnetic poles of the neutron star where the accreting matter is channelled. The group has also developed a theory of the pulse profiles of these rapidly rotating pulsars accounting for the general and special relativity effects.

Accretion onto neutron stars with a weaker magnetic field proceeds via a boundary layer where the accretion disk decelerates to the neutron star velocity. This layer might take a form of the spreading layer where the matter, losing the angular momentum, slowly spirals up towards the stellar poles. The group has computed the spectral energy distribution expected from the spreading layer and compared it to the observations. This allowed restricting the neutron star radius to 14.8 ± 1.5 km (for a

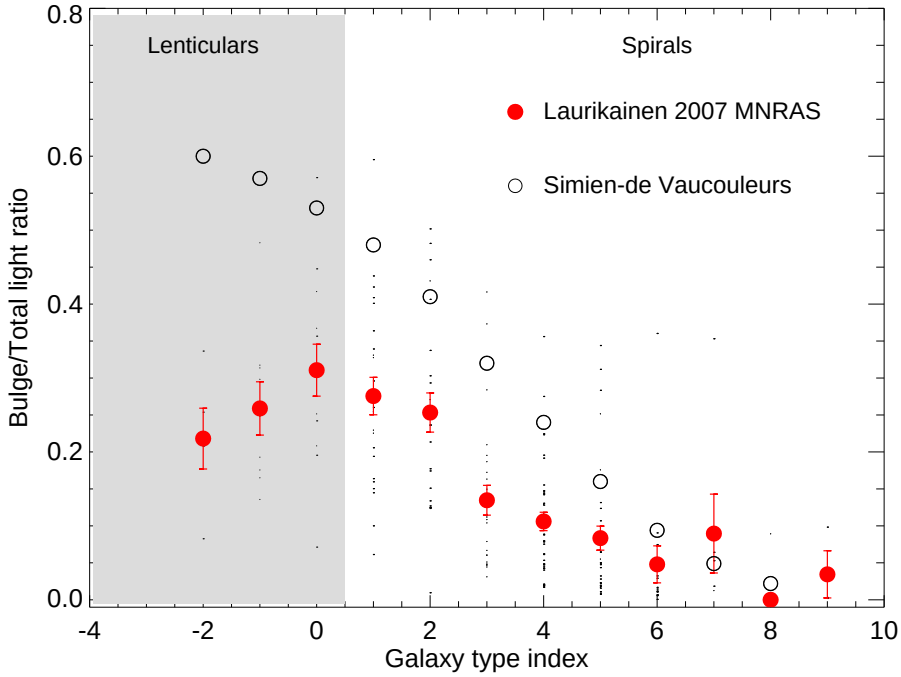


Figure 4.27. Bulge-to-total flux ratio as a function of Hubble type. Open circles denote previously estimated B/T, based on simple bulge-disk decomposition. Filled symbols are based on our multi-component decompositions, allowing the inclusion of additional bar/oval components. The bulge-to-total ratios provide important constraints for cosmological models of hierarchical galaxy formation. Figure from Laurikainen et al. 2007 (MNRAS, 381, 401).

1.4 solar mass star), which provides strong constraints on the equation of state of matter at supranuclear densities.

The group's studies of the most famous galactic black hole Cygnus X-1 using 10 years data obtained by the All Sky Monitor onboard of RXTE confirmed the existence of strong superorbital variability at 151-day period which can be modelled as a precession of the inclined disk. We have also discovered a dependence of the orbital variability on the superorbital phase, which we interpret as evidence or the absorption by the accretion bulge that is produced by the accretion stream hitting the accretion disk.

The mechanisms responsible for shaping the X-ray/gamma-ray spectra of accreting black holes are still a matter of intensive debates. The group has developed a state-of-the-art computer code to model the most important microphysical processes such as Compton scattering, synchrotron radiation, and pair production and to handle self-consistently temporal evolution of the electron and photon distributions simultaneously. The first results show that electrons can be thermalized by absorbing their own synchrotron radiation, which could be the source of incident photons for comptonization in the hard states of the black holes. The observed spectral state transitions can be associated with the increasing luminosity of the accretion disk which leads to corresponding changes in the electron and photon distributions.

A new research field of the group is the ultra-luminous X-ray sources (ULX) in nearby galaxies. These are non-nuclear sources with luminosities exceeding 1039 erg/s. There are two main competing models: intermediate-

mass black holes (IMBH) or super-critically accreting stellar-mass black holes. The group's theoretical model of the super-critical accretion disks with winds explains naturally many of the observed properties. On the observational side, the group has an ongoing program at the 8-m VLT/ESO telescopes to observe the nebulae around ULX. These nebulae are much larger than ordinary supernovae remnants and show signatures of UV/X-ray photoionization from the central source. Previous studies of the nebulae with the Russian 6-m telescope at SAO show that these nebulae also are dynamically perturbed probably by the wind/jet from the central source. This argues in favour of super-critically accreting stellar mass black holes, as the sub-critically accreting IMBH should not produce powerful winds.

The nature of the emission of relativistic jets in active galaxies such as for example in blazars is still an unsolved problem. The group has proposed a straightforward and efficient mechanism for the high-energy emission of relativistic astrophysical jets associated with an exchange of interacting high-energy photons between the jet and the external environment. This is the first self-consistent model of particle acceleration and photon emission from relativistic flows. Physical processes playing the main role in this mechanism are electron-positron pair production by photons and the inverse Compton scattering. The group has shown with the numerical simulations that a relativistic jet (with the Lorentz factor larger than about 5) moving through the sufficiently dense, soft radiation field inevitably undergoes transformation into a luminous state. The process has a supercritical character: the high-energy photons (and electron-positron pairs) breed exponentially, being fed directly by the bulk kinetic energy of the jet. As a result, a significant fraction (up to 80 per cent) of the jet bulk energy is converted into radiation mainly in the MeV-GeV energy range.

Another research field is the studies of masers. Some late-type stars show strong water maser emission lines at 22 GHz. The research was concentrated on observations and theoretical modelling of the dusty molecular disks around spectacular class of stars, so called silicate carbon stars, and its best studied representative V778 Cyg. The MERLIN data on V778 Cyg show the presence of the doubly warped disk around a companion of the carbon stars, which is a challenge to the theoretical models. The group has developed a self-consistent model of the maser emission and estimated the mass of the companion star, the distance between the stars and size of the disk.

The extragalactic research of the Dynamics Group has concentrated on barred galaxies, and the use of bars and bar-related resonance structures as a probe of galaxy evolution in the Hubble sequence. For example, bar pattern-speed measurements have been made, both with direct spectroscopic observation (using e.g. ESO 8.2-m VLT telescope), as well as by extensive simulation studies. Another central aspect has been the analysis of galactic bulges, based on the 2D photometric multi-component decomposition method developed by the group. As observational database has been the groups NIRS0S (Near-InfraRed S0-galaxy Survey) data, collected at ESO (NTT) and La Palma telescopes (NOT, WHT, TNG). Combined with similar analysis of nearly 200 spirals (using OSUBSGS; Ohio State University Bright Spiral Galaxy Survey), the group has been able to probe the bulge and bar properties of disk galaxies for all Hubble types. This study has lead to significantly revised estimates for the average bulge-to-total mass ratios, in particularly for lenticulars. The reason for the difference is the use of the group's more sophisticated decomposition method, preventing the light of bar/oval components to be erroneously attributed to bulges, as easily happens in traditional two-component bulge-disk decompositions. Another impor-

tant new result has been the finding that disc-like "pseudobulges" are quite common also in lenticulars.

University of Turku
Space Research Laboratory

SRL participates in the antimatter magnetic spectrometer (AMS) project. AMS is designed to study the fundamental cosmological questions by probing the antimatter abundance in the universe. As a particle instrument, it can also be used for investigating other astrophysical research topics, such as searching for dark matter and contributing in various aspects of cosmic ray physics by accurately measuring the elemental and isotopic composition of galactic cosmic rays. Presently, the second-generation instrument AMS-02 is in the integration and test phase. The expected launch date is in mid-2009 for the 3-year mission on the International Space Station.

University of Turku
Tuorla Observatory

Research and teaching in the new crossdisciplinary area of astrobiology has continued at Tuorla Observatory. In collaboration with the biology and geology departments at the University of Turku and the Finnish Meteorological Institute (FMI), Tuorla Observatory organized the 8th European Astrobiology Workshop. About 170 scientists and students attended the meeting. A textbook with contributions from researchers of the University of Turku researchers, "A complete course in astrobiology" (eds G Horneck and P Rettberg) was published in 2007. In 2007-2008 the group's astrobiology lectures were a part of a live streamline video course hosted by ESA/ESTEC. The course connected eleven universities and research institutes across Europe from Finland to Portugal and from Russia to UK.

Astrobiological research involved studies of the Pitch Lake in Trinidad, one of the three

Kuva 4.28. Student Riad Hosein from the University of West Indies at the Pitch Lake in Trinidad.

asphalt lakes found on Earth, in collaboration with the University of West Indies and the University of Washington. The group is investigating the life forms and chemistry found in this unique environment, which appears chemically similar to the hydrocarbon lakes found in Titan by the Cassini mission. In the proximity of Pitch Lake another unusual habitat is found. The mud volcanoes are reminiscent of some structures found in Mars at Isidia Plantita. The muddy mounts may provide a safe haven for life in the hostile environment of Mars.

Anther astrobiological research project concerns chirality. The group has investigated the factors driving towards chirality using mathematical models. And, a third direction is the interaction between the biosphere and the climate. Jointly with FMI, the Tuorla group has developed a model to describe the interdependency of the oxygenic photosynthesis, oxic atmosphere, the development and reversion of global glaciations and the evolution and proliferation of multicellular species.

The dynamical stability of extrasolar planets has been studied. The group has been searching for stable orbits of Earth-like planets, concentrating on horseshoe and other Trojan orbits and also counter-rotating planetary systems. Dynamical studies of exoplanet systems are strongly connected to the more broad research of celestial mechanics, chaos and the solar system. New observing techniques to detect these systems are also investigated with the aim of using ESO telescopes and providing input for future planet searching space missions.

The first detection of polarized, scattered light from an exoplanetary atmosphere by Tuorla researchers attracted worldwide media attention. The exoplanet circles a red dwarf star about 60 light years from the Earth. It is so close to its parent star that its atmosphere expands from the heat. The Finnish-Swiss team used the KVA telescope on La Palma to obtain polarimetric measurements of the star and its planet. Two polarization maxima were discovered near the point where the star and the planet are at maximum apparent separation. These indicate that the scattering atmosphere is considerably larger than the opaque body of the planet and most probably consists of particles smaller than half a micron, such as atoms, molecules, perhaps water vapour or even tiny dust grains.

Using circular spectropolarimetry at the ESO 3.6-m and the NOT telescope, highly magnetic white dwarf (WD) stars accreting matter from a nearby binary companion were studied. Strongly polarized optical and near infrared cyclotron emission is observed from the accretion shock above the surface of the spinning WD. Variations in circular and linear polarization over the spin cycle have been used to develop geometric and physical models of the cyclotron emission regions. Cyclotron harmonics detected in the polarized flux spectrum provide an accurate method of determining the magnetic field strength of the WD, typically 10^2 - 10^8 Gauss. Evolutionary connection between synchronized and unsynchronized systems, and the role of magnetic braking in the binary evolution have also been investigated.

Scattering of photons by free electrons in the circumstellar plasma envelopes of massive ($M > 5\text{-}10\ M_{Sun}$) interacting binaries can be efficiently studied by monitoring variations in the degree of linear polarization over the binary cycle. From observations at the NOT, and long-term monitoring with the KVA-60 telescope, the Tuorla group has, for the first time, discovered a high latitude scattering spot/jet in such a binary system. The mass gaining-component is almost completely obscured by the dense plasma envelope, and the star can only be seen via the scattered radiation in the polar directions, where the light can more easily escape from the central object.

A large ongoing stellar research effort is aimed at determining the physical parameters for low mass stars. Determining their masses, temperatures and luminosities is difficult, as much of their luminosity is released in the infrared. This situation has altered with the large area surveys in the IR region. In addition accurate parallaxes have become available from the Hipparcos observations. These data make possible an accurate temperature and luminosity calibration for stars cooler than the Sun. The group has obtained a sample of about 100 bright G and K dwarfs. An empirical effective temperature and bolometric luminosity calibration for G and K dwarfs has been derived. Despite very careful work, it has been shown that one cannot yet get temperatures and luminosities for such stars to much better than a few percent accuracy. The temperature scale has been found 100 Kelvin hotter than recent analogous determinations in the literature and angular diameters are typically 3 per cent smaller when compared to other determinations of angular diameter for such stars, but are consistent with the predictions of the latest 3D model atmospheres and the results of asteroseismology.

Efforts to measure the amount of helium in K dwarfs have led to very interesting results. A much larger sample of K dwarfs than earlier has been compiled and analyzed. Helium has been found to be produced about twice as much as metals. For stars with very low metallicities, implausibly low He content has been found, which probably reveals ma-

Figure 4.29. A luminous infrared galaxy observed as a part of search for heavily dust-obscured supernovae using the NACO adaptive optics system on the Very Large Telescope (VLT) of the European Southern Observatory (ESO) at near-infrared wavelengths. The image is a combination of the VLT near-infrared data with optical images from the Hubble Space Telescope (Credit: ESO).

jor inadequacies in current stellar models for such stars. This unfortunately prevents a reliable determination of the amount of helium produced in the Big Bang from the data, but major improvements are expected from the future comparison of stellar models with asteroseismology measurements of He content in nearby stars.

Research of supernovae has commenced at Tuorla Observatory. The group makes extensive use of both ground and space based telescopes (e.g. VLT, HST and Spitzer) for optical and infrared observations of core-collapse supernovae. Adaptive optics observations at near-infrared wavelengths are used to discover heavily dust-obscured supernovae in nuclear regions of nearby luminous infrared galaxies. At high-z, a large fraction of the massive star formation (and core-collapse supernova explosions) took place in such galaxies. The group has used radio observations at 8.4 GHz with VLA to confirm the core-collapse nature of SN 2004ip they had discovered using the NACO adaptive optics system on VLT. This is the first supernova to be discovered using adaptive optics assisted observations, and is one of the brightest and closest of all known radio SNe to a galaxy nucleus.

Together with researchers from Heidelberg and Potsdam, Tuorla scientists have analyzed the distribution of velocities and positions of about 900 carefully selected old stars of low metallicity, which are passing closed the Sun in order to identify "star streams". Such streams are composed of many stars that are on substantially similar orbits, as they move around the galaxy, and may be part of quite extended structures left over from the epoch of the Milky Way's earliest days. A special technique was developed to search for such stars, involving their angular momenta and orbital eccentricities, as a generalisation from a method that works for much more common stars in the Galaxy's disk. Besides recovering all well-known star streams in the thick disk, the group isolated four statistically significant phase space overdensities amongst halo stars. One of them is associated with a previously known halo star stream, but three of them are novel features, which are proposed to be also considered as genuine halo streams.

Galaxies can be surrounded by a "halo" of dim, red light that can extend to very large distances from the centre. With colleagues from Stockholm and Uppsala, very long exposures of a range of galaxies have been taken, discovering that they are frequently embedded in dim very red halo light. Dim red halos around galaxies have been seen in other studies, including HST observations. A possible explanation for the cause of the halo is dim, red low mass stars. If that were true the dim stars would be almost as plentiful as stars of all other types, perhaps making them a significant contributor to the total mass of galaxies. Also other ideas for what causes the red halo light have been studied, such as it being produced by stars with a high metal content or by nebulosity caused by hot gas clouds - but neither of these explanations seem to work for all the galaxies surveyed.

MAGIC is the largest Imaging Air Cerenkov Telescope in the world, located on La Palma, Canary Islands. It has been in operation since 2004. Due to its large collection area and uniquely designed camera, MAGIC has reached a lower energy threshold for cosmic gamma-ray emission than any existing terrestrial gamma-ray telescope. Tuorla Observatory is a member of the MAGIC Collaboration with the main responsibility of performing supporting optical observations with the KVA telescope. The group has provided several alerts based on optical flaring, which have proved to be useful: four new blazars were detected, two of them the most distant very high energy emitting blazars known so far, and one of them is the first quasar detected at high energies. MAGIC has also detected a very short time-scale (a few minutes) gamma-ray flare

Kuva 4.30. The MAGIC TeV telescope on La Palma, Canary Islands. MAGIC II, under construction, is in the forefront.

from Mrk 501 with indications that the higher energy photons arrived later that low-energy photons. This is highly interesting, as quantum gravity theories predict exactly this kind of effect.

In 2006-07 the Tuorla blazar group has taken part in 7 extensive Whole Earth Blazar Telescope multiwavelength campaigns combining ground-based data with satellite observations (XMM, AGILE, Swift). The observations will be tied to the Planck satellite observations coordinated jointly by the Metsähovi Observatory and Tuorla Observatory.

The Tuorla group continues to investigate the theories of gamma-ray emission. A clear connection between synchrotron-emitting shocks and gamma-ray states in 3C 279 has been found. The group found that high gamma-ray states occur during the early stages of synchrotron outbursts, and that there is a correlation between the strength of the gamma-ray flare and the distance of the gamma-emitting shock from the jet apex. These findings are in disagreement with the currently favoured External Compton mechanisms for gamma-ray emission. The analysis tools developed for quasars were also used to study the relativistic jet of the microquasar Cygnus X-3. This study suggests that there are fundamental differences between quasar and microquasar jets. An interesting result is that in the group's best model for Cyg X-3 the electron energy spectrum is very hard, in conflict with traditional relativistic shock acceleration models. In collaboration with University College, Dublin, it was found that the likely solution is turbulence in the shocks, which can cause such a hard electron energy spectrum.

A fundamental question in modelling the AGN activity is how the basic parameters such as the black hole mass, spin and accretion rate

influence the observed values such as total luminosity and jet speed, or the shape of the electromagnetic energy spectrum. It has now become possible to estimate BH masses for most of the radio-brightest AGN. In a collaboration between Tuorla, Metsähovi and University of Mexico the correlations between the BH mass and observable parameters are investigated.

The Tuorla group have used ESO VLT and ISAAC near-infrared imager to investigate the relationship between nuclear and host galaxy luminosities in high redshift quasars, over a large range of quasar luminosity function. The group has also investigated the colours of the host galaxies of low redshift BL Lac objects. Most BL Lac objects have bluer hosts than inactive ellipticals. The blue colours are likely caused by a young stellar population component, and indicate a link between star formation caused by interaction/merging and the onset of the nuclear activity.

An international group of astronomers led by Tuorla researchers has verified general relativity in strong gravitational field. The monitoring of OJ287 during the current cycle has proven correct the model of this quasar as a precessing binary black hole system that produces two major outburst peaks per 12-year orbital period. The occurrence of the latest outburst within a day of the predicted time finally clinched the model. In addition, it proved that the spacetime around the primary in OJ287 curves as predicted by Einstein's theory. As a side result, it was shown that the binary system loses energy at the correct rate as calculated for gravitational waves in general relativity. This is an important result since no gravitational waves have been directly detected so far. The discovery of the OJ287 binary black hole system is a result of an extensive monitoring program of quasars carried out both in radio (Metsähovi) and in optical (Tuorla), which started in 1980.

Tuorla cosmology group uses advanced numerical methods to study structure formation and evolution of the Universe. These theoretical results are compared with observational data (i.e. Sloan Digital Sky Survey). Questions addressed include the relation of dark matter to observed galaxies and galaxy groups, measurements of dark energy in the nearby galaxy field, the dependence of the properties of galaxy systems on their environments and the large-scale galaxy filament-void network. One of the related topics is the problem of missing baryons in the local Universe. These baryons are assumed to be located in regions with moderate over-densities (filaments connecting clusters) in a warm-hot intergalactic medium. Superclusters are expected to be rich in WHIM, and one task of the Tuorla and Tarto Observatory cosmology groups in the Planck mission is to produce an all-sky template of optical superclusters for the Planck community.

5. Applications, Earth Observations and Space Technology

5.1. Space Geodesy

Finnish Geodetic Institute (FGI)

Geodesy is becoming a major partner in studies of global change. Satellite-based methods, GPS, European Galileo in the future, gravimetric satellites, and satellite altimetry have changed the Earth research facilitating the research global phenomena and changes that are on 10^{-9} level or even below.

The Global Geodetic Observing System (GGOS) of the International Association of Geodesy (IAG) will be geodesy's central interface to the scientific community and to the society in general. With the establishment of the Group on Earth Observations (GEO) in 2005 a more permanent mechanism on geodesy contribution has become possible. A joint programme of the European Commission and ESA for Global Monitoring for Environment and Security (GMES) represents a European effort to bring data and information providers together with users. The Nordic Geodetic Observing System (NGOS) of the Nordic Geodetic Commission is the Nordic contribution to the global GGOS. FGI has participated in the steering committee of GGOS and has a leading role in NGOS.

Global and regional permanent GPS networks form nowadays the frame where local and global changes are studied. The Finnish permanent GPS network FinnRef® consists of 13 permanent GPS stations and it is the backbone of the Finnish realisation of the European-wide reference frame EUREF. Four stations in the FinnRef network belong to the EUREF permanent GPS-network, and one station belongs to the International GNSS Service. Through these stations FinnRef creates a connection to the global reference frames and the stations are used for maintaining global reference frames and global geodetic studies. All GPS stations are connected with a broadband Internet or wireless connection allowing automatic hourly downloads and automatic data transfer to international data centres.

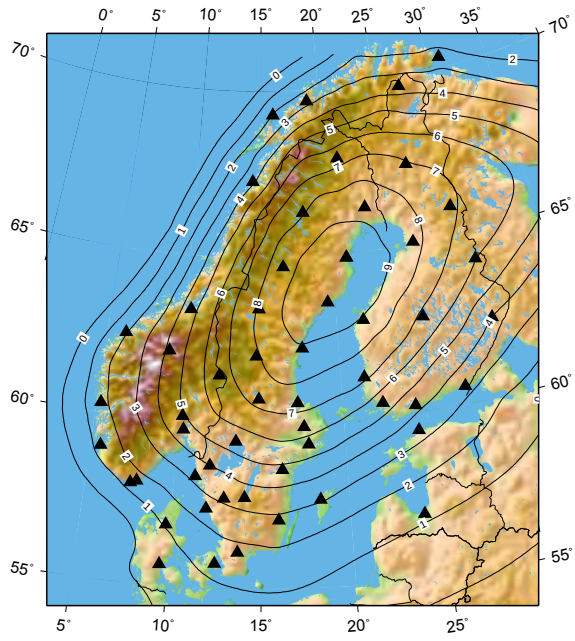


Figure 5.1. Fennoscandian land uplift and permanent GPS stations. Values are mm/year relative to the centre of the Earth. The Nordic NKG2005LU uplift model is based on levelling, tide gauges and a geophysical model and it is fitted with GPS observations made on permanent GPS stations (triangles).

Figure 5.2. EUREF-RE measurements at the point G240 Iso-Pyhätunturi (Photo: Hannu Koivula).

The FinnRef stations are also used for local studies on crustal movements as well as a reference for local and national GPS measurements. Additional information using data of Metsähovi superconducting gravimeter, and ocean and atmospheric loading were used. In a joint project with the FMI both crustal deformations and atmospheric effects on GPS signal have been studied. Significant improvement in accuracy was achieved by using the weather forecast model and computing the delay in the GPS signal due to the troposphere.
A re-measurement of the 100 EUREF-FIN points was made in 2006. As a result, an accurate regional 3-D model of contemporary crustal motion and an observation-based present day stress and strain field will be created for Finland. All new information obtained here supports the maintenance of Finland's coordinate system.

Investigation of local crustal motions contained in a contract with Posiva Oy was continued on three sites. The local networks at Olkiluoto, Kivetty and Romuvaara were measured with GPS. Olkiluoto, which is now selected as the nuclear waste deposit site, is measured twice a year, two other sites, earlier as candidate sites for the waste deposit, serve now as a reference network, and they are measured once a year. Ten-year time series allow better than 0.5 mm/yr tracking for 3D-crustal movements.

A larger network, as a part of Geo-Satakunta project was measured with GPS three times both in 2006 and 2007. Olkiluoto network is a subnet of this larger network. Other participants in Geo-Satakunta are the Geological Survey of Finland, and Cities of Pori and Rauma. The project is partly funded by EU, and its goal is to study geology and geophysics of the area, including crustal movements.

The measurements taken at FGI's Metsähovi station serve both the Institute's own research

and the international scientific community. The instrumentation in Metsähovi covers the satellite laser ranging, geodetic VLBI, GPS and GLONASS receivers, French DORIS beacon operated by CNES, superconducting gravimeter, seismometer and the fundamental absolute gravity point. Data collected by various observation instruments at the Metsähovi station are stored in several international data banks and used in international scientific projects. Metsähovi Satellite Laser Ranging (SLR) was discontinued during the year 2006. A new laser arrived in 2007 and renovation of the old telescope is under way.

The Metsähovi FinnRef GPS station data were submitted to the European permanent GPS network computation as well as to the IGS network. Also, data from Javad/Legacy GPS/GLONASS receiver were submitted to the GLONASS data center of the IAG. Based on an agreement with NASA, a GPS receiver of JPL, installed in 2006, continued its operation and it submitted real-time 1 s data in the NASA network.

In co-operation with the Metsähovi Radio Observatory of TKK, geodetic VLBI observations were continued. Eight campaigns were made in 2007, as a part of the International VLBI Service network and the European geodynamics project. VLBI data are used for determining the Earth Orientation Parameters, monitoring tectonic motions, and maintaining the global reference frame.

The GRACE satellite probes the gravity field of the Earth. Studies at FGI are related to the use of GRACE data in geodetic research and to improve local and regional geoid models. On regional scale GRACE data have been investigated over Fennoscandia. Hydrological models used in the study are the Global Land Data Assimilation System of NASA and

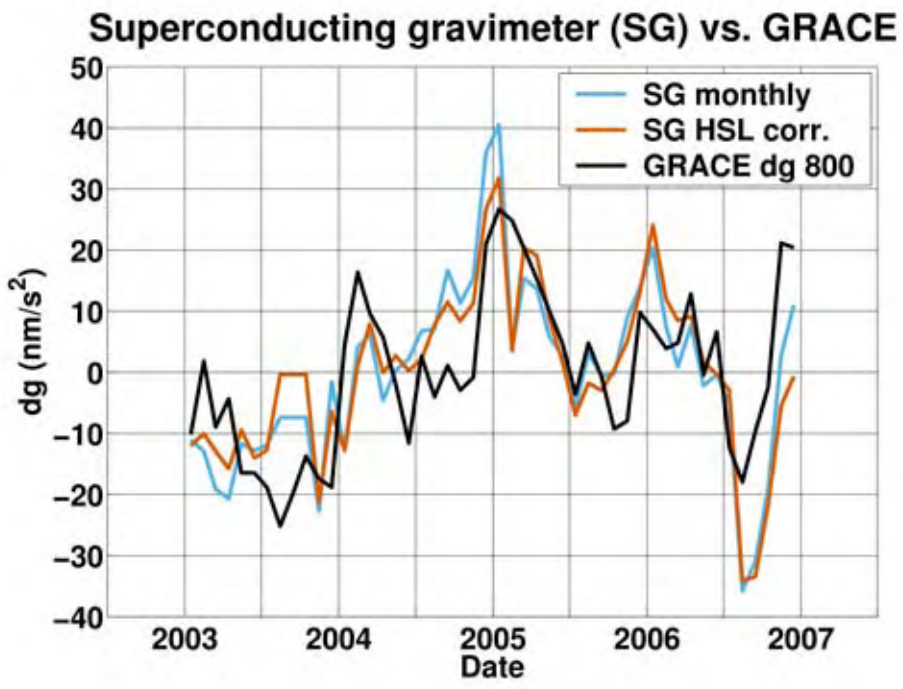


Figure 5.3. Effect of regional hydrology in gravity. Comparison of gravity variations observed by GRACE (black: computed from UT-CSR RL04 with 800 km smoothing) and superconducting gravimeter in Metsähovi (blue: monthly mean; red: corrected for the changes due to the Baltic Sea).

NOAA, the Climate Prediction Center global soil moisture data set, and the Watershed Simulation and Forecasting System (WSFS) of the Finnish Environment Institute. Water equivalent time series calculated from the GRACE data for the Finnish watershed area show that GRACE is able to correctly reproduce the main signal and scale of the water storage in the WSFS area. GRACE time series were analysed and compared with time series from the superconducting gravimeter in Metsähovi.

The variations in the level of the Baltic Sea also have a large effect on the gravity field detected by GRACE. Gravity field solutions from GRACE are corrected for ocean variability, with varying success over the Baltic Sea. An ongoing study supported by the Academy of Finland investigates how well the Baltic Sea signal can be removed from the GRACE solutions.

The Nordic NKG2004 geoid model and the EUVN-DA GPS/levelling observations were used to determine a new National geoid model, which can be used to transform the heights from the ETRS89 to the national N2000 and N60 height systems. The model, referred as to FIN2005, was obtained fitting a surface to the height differences between GPS/levelling and spirit levelling.

A permanent GPS station at the Finnish Antarctic base Aboa was established at the beginning of the year 2003. During the field expeditions the data of the whole year are retrieved. Using data from repeated absolute gravity measurements, GPS and local kinematic GPS determination of snow/ice changes, allows the determination of the direction of the vertical crustal motion and the behaviour of the surrounding glacier.

In co-operation with ESA a Ranging and Integrity Monitoring Station (RIMS) of the European Geostationary Navigation Overlay Service (EGNOS) is operational in Virolahti, Finland. The RIMS will ensure the quality of the EGNOS service in Finland.

Helsinki University of Technology (TKK) Department of Surveying

In May 2007 TKK's Surveying Department's geodesists re-measured and modernized the base network of the city of Uusikaupunki, including determination of co-ordinate transformation parameters between old and new systems. The work was done by second and third year students as part of the curriculum under Department staff leadership.

The group has a chairmanship of in the International Association of Geodesy Subcommission on Spatial and Temporal Gravity Field and Geoid Modelling and representation in IAG Commission on Gravity Field in the GGOS (Global Geodetic Observing System) Steering Committee,

5.2. Earth Observation and Atmospheric Sciences

Finnish Environment Institute (SYKE) Geoinformatics and Land Use Division

The Finnish Environment Institute (SYKE) is both a research institute and a centre for environmental expertise serving the whole of Finnish Environmental administration, local authorities, general public and private industry. The Geoinformation and Land Use Division (GEO) looks after the GIS and earth observation data, while also maintaining and developing information systems related to land use in Finland.

There is a remote sensing group of 10 people at GEO, whose task is to provide the environmental administration with the earth observa-

tion data it requires. GEO operates the daily processing of the EO data (AVHRR, MODIS, MERIS), implements the information systems required, plan and develop the methodologies required in these systems and conduct research on remote sensing technology in order to support environmental monitoring with new EO based data. This includes validation of EO products with in-situ observations in addition to theoretical and experimental research on water optics and general spectral radiance measurements. The research and development work is conducted in cooperation with national and international partners.

Presently operational, daily end-user products are

- SCA-maps (snow covered area) during snow melting season,
- Sea surface temperature maps of the Baltic Sea and the largest Finnish lakes,
- Water quality maps (chlorophyll-a and turbidity) during spring and summer
- Algae bloom maps during surface floating cyanobacteria bloom period in July-August.

Datasets on vegetation changes within yearly growing season (fenology) and lake water quality variations - currently turbidity variations - are produced on yearly basis, as well as different sets of summary datasets from the operational remote sensing data.

Production of the data is partly completed within GMES service elements. SYKE is a service provider in three ESA GMES Service Elements (GSE):

- GSE Land (fenology data for vegetation as input for drainage basin leaching models; lake water quality related services)
- MarCoast (services related to the Northern Baltic Sea)
- Polar View (snow related services)

SYKE participates in the European CORINE land cover project. At the moment CORINE

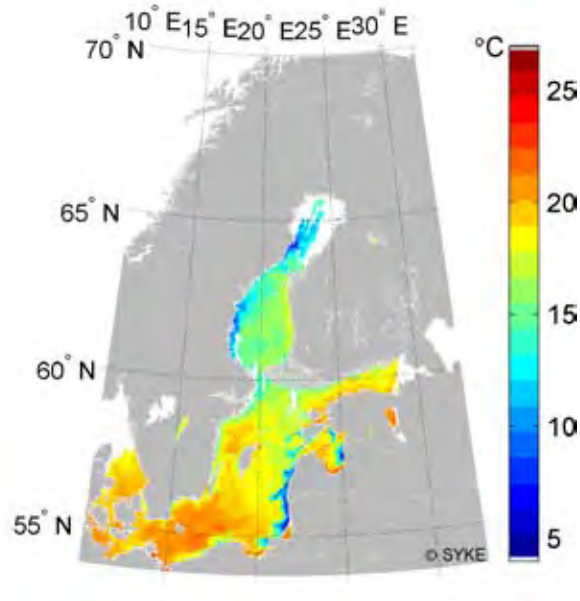


Figure 5.4. An example of the MarCoast services provided by SYKE: Sea surface temperature image for 17th July, 2006 with strong cold bottom water upwelling phenomena near the coastal areas.

Land Cover maps describing Land cover of Finland year 2000 are being updated using IRS LISS and SPOT satellite data acquired in year 2006.

In addition, SYKE is using EMSA (European Maritime Security Agency) provided SAR microwave radar satellite derived information for detecting illegal oil spills from ships in the Baltic Sea. If necessary, SYKE is able to process and use SAR data independently for these purposes.

Finnish Geodetic Institute (FGI) Department of Remote Sensing and Photogrammetry

The Department of Remote Sensing and Photogrammetry of FGI, focuses on interpretation methods and new applications of digital camera images, laser scanning, BRDF and SAR. In 2007, the group consisted of 24 researchers participating in nearly 30 international projects. The number of researchers has

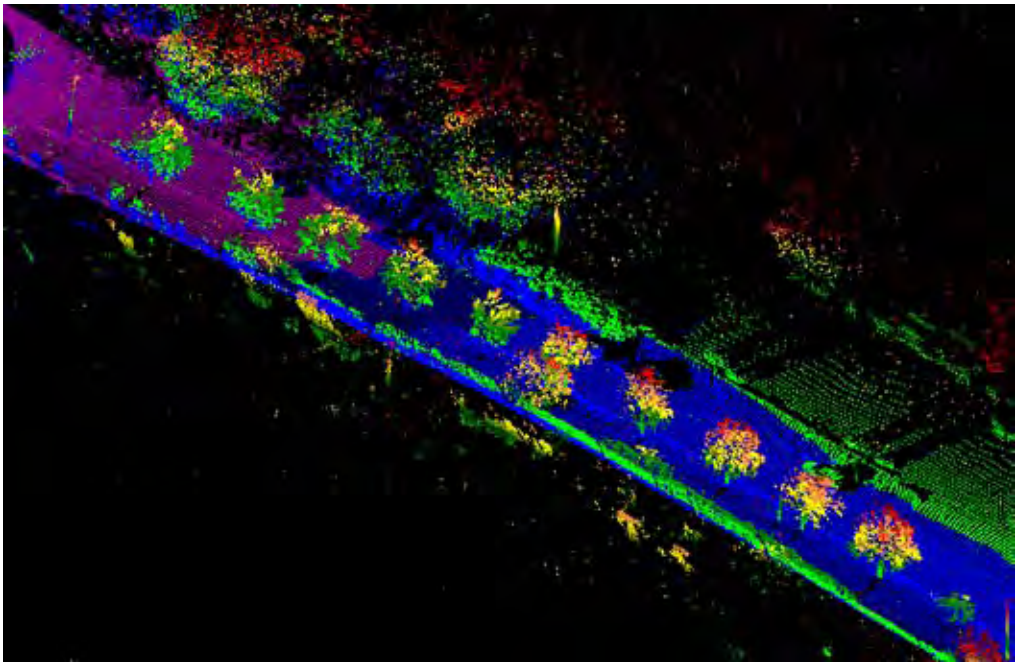


Figure 5.5 . Laser point cloud acquired using the ROAMER mobile mapping platform.

constantly increased during the last few years. In September 2007, the department organized the ISPRS Workshop on Laser Scanning 2007 and SilviLaser 2007 in cooperation with the Institute of Photogrammetry and Remote Sensing, TKK. Over 240 researchers from all around the world attended the workshop.

The backbone of the photogrammetric research is the permanent test field located in Sjökulla, Kirkkonummi. The test field contains permanent and transportable test targets for radiometric calibration, permanent ground control points for small, medium and large-scale geometric calibration and also test bar targets for spatial analysis of analogue and digital aerial cameras. The test field was used to study the geometric and radiometric quality of the first generation digital aerial photogrammetric sensors. The results of the study have shown that despite the fact that the digital photogrammetric sensors are of high quality, standardization and test field calibration are required in order to use the sensors efficiently. Additionally, a radiometric calibration method for airborne and terrestrial laser scanners has been developed in the FGI laser laboratory. In May 2007, a EuroSDR project "Radiometric Calibration of ALS intensity" in co-operation with the Technical University of Vienna was accepted.

FGI has coordinated the EuroSDR/ISPRS Tree Extraction project, in which the objective was to evaluate the quality, accuracy, and feasibility of automatic or semi-automatic tree extraction methods based on high-density laser scanner data and digital image data. The trees in these sample areas were measured from several station points using a terrestrial laser scanner. The point clouds of individual scans were georeferenced and combined, and accurate 3D-models of the trees were obtained. 3D-models were used to determine the desired tree parameters, which were then used as a reference in the evaluation of models produced by participants. The final report of the project was delivered to EuroSDR in November 2007 to be published in the EuroSDR Official Publication 53.

An integrated platform for mobile mapping, ROAMER (Road Environment Mapper), was designed and manufactured in 2007. Moreover, automatic data processing and modelling algorithms were developed and tested. The platform was manufactured of hardened aluminium plates and profile tubes. The integrated platform has been mounted on three standard off-the-self racks designed for the railings on top of the vehicle. The idea is to provide a compact and robust platform, isolated from the carrier vehicle, for the instrumentation to be mounted on. The GPS antenna is attached on top of a mast in front of the scanner. For the attitude determination an inertial measurement unit is mounted on its own rack at the front end of the platform base plate, with a suspension of four additional rubber absorbers. The ROAMER was tested in Espoonlahti, Espoo, where the first test was carried out with typical urban speeds of 10-40 km/h, and in the second test the driving speed varied in full range of 10-100 km/h.

Knowledge-based interpretation methods exploiting classification trees have been developed at the FGI. These methods are particularly useful in developing new classification applications and testing the feasibility of new remotely sensed datasets. If a suitable training dataset is available, the method could be used for the rapid construction of classification trees, which could then be directly applied to classification or used as a starting point for further development of the rules. The classification tree approach has been applied to airborne laser scanner data, aerial images, and various types of synthetic aperture radar images including fully-polarimetric images. In the context of mapping and map updating, the FGI has participated in the projects concerning the scientific exploitation of the next generation of satellite-borne SAR sensors.

Finnish Institute of Marine Research (FIMR)

Finnish Institute of Marine Research conducts Earth Observation research in order to improve and enhance monitoring of sea-ice and algae blooms in the Baltic Sea and in the Arctic Ocean. The research is mainly based on the existing satellite data and focuses on the development of the advanced retrieval algorithms to support operational oceanography activities. FIMR is also contributing to the CryoSat activity, which is a new Earth Observation mission of the ESA focusing on the climate monitoring of the cryosphere.

Finnish CryoSat CAL/VAL research has been funded by Tekes and FIMR. During the first phase in 2005-2007 FIMR conducted the BoB-2005 field experiment in the Bay of Bothnia, contributed to the CryoVEx-2006 experiment in the Lincoln Sea, validated the ASIRAS measurements, examined variations of the surface elevation of the pack ice, analyzed waveforms of the ASIRAS and developed a new method to analyze sea-ice characteristics from the RA-data. Based on the BoB-2005 measurement a relationship between the waveforms of backscattering echo signal and the ice types has been found. This method makes possible to separate of the ice classes (undeformed level ice and ridged ice) from the CryoSat-2 measurements and enables development of an advanced sea-ice retrieval algorithms.

During the first phase of the CryoSat CAL/VAL research, it has become apparent that an accurate determination of the sea-ice thickness requires that the sea-ice ridges be properly taken account in the sea-ice retrieval algorithms. The classical conversion method of freeboard to thickness assumes that the sea-ice has a constant density. However, that is not a case, as first-year ice and multi-year ice have different densities and the sea-ice ridges include open water between the ice blocks.

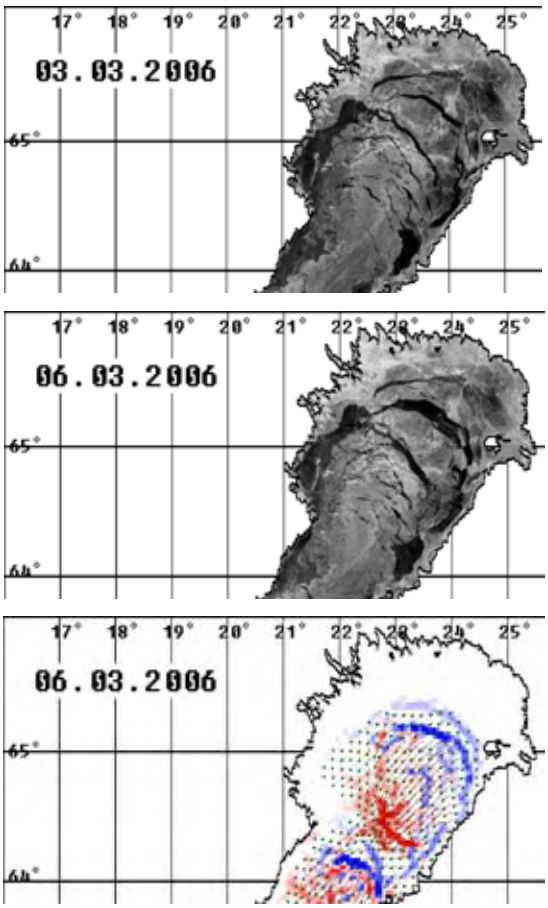


Figure 5.6. Two SAR images rectified on Mercator projection (i.e. the projection used in nautical charts), March 3rd 2006 and March 6th 2006, and the estimated motion vector field between the two images.

The major objective of the Baltic Sea ice remote sensing is to develop tools to aid the winter shipping. The most recent research project in this area was the joint Finnish-Canadian project POL-ICE "Multi-Polarisation SAR for Operational Sea Ice Monitoring" led by MacDonald Dettwiler (MDA) and Helsinki University of Technology (TKK) aimed to determine how operational sea ice monitoring could best benefit from the multi-polarization SAR. Due to the late launch of Radarsat-2 in December 2007 the dual-polarization analysis was performed using the ENVISAT APP-images with HH and HV polarizations. These two polarizations are also used by RADARSAT-2. Due to their complementary nature using two polarizations it is possible to separate ice from open water and diminish the effect of snow on the sea-ice type classification. In addition the deformed ice fields can be divided according to the magnitude of the multiple scattering.

A significant part of the POL-ICE project was to study how the high-resolution snow/sea ice thermodynamic model HIGHTSI can be used to help the interpretation of the SAR signature. It was noted that with current modelled processes HIGHTSI acted as a good indicator of the change of the backscattering strength. Examination of seasonal evolution of radar response showed that the snow layer alone could modulate the SAR response up 7 dB during the period of few days. It is evident that snow layer can effectively mask out the differences between separate ice types. This kind of situation occurred e.g. during the 2007 POL-ICE field campaign when the correlation between ice thickness, as measured by helicopter-borne sounding (HEM), and the SAR signal vanished totally. On the other hand, during the 2005 Cryosat Cal/Val field campaign collected airborne laser scanner (ALS) measurements and SAR data exhibited strong dependence. Using a nonlinear statistical model the freeboard could be predicted with a surprising accuracy (about 6 cm) in the SAR/ALS data set even if the SAR measurement angle varied from 20 to 40 degrees. Coupling this with a large set of SAR/HEM-measurements indicates that the SAR signature alone can offer in some circumstances (cold ice temperature, dry thin snow cover) much information about ice cover thickness. For the seasonal ice the major complicating reason is the snow layer that modulates the SAR signal also when the snow cover is dry with its structural properties.

Finnish Meteorological Institute (FMI)

Space-based Earth observation science strengthened significantly when a new joint professorship was initiated between the University of Helsinki and FMI. This expanded FMI's space-based atmospheric research from middle atmosphere research to observations of tropospheric phenomena including greenhouse gases, aerosols, and forest fires. Work on monitoring the surface, especially snow and ice cover, was further strengthened both in the Earth Observation Unit and at the Arctic Research Unit in Sodankylä.

The new professorship has initiated aerosol retrieval from satellite data to determine aerosol optical properties on regional and global scales and derived data such as an indication on aerosol composition, size distribution and PM2.5. Results are applied in several projects such as AMFIC (EU-STREP) to retrieve aerosol properties over China, EU-FP7 IP Megapoli on the effects of megacities on climate and air quality, a project of the Academy of Finland to study aerosol properties over Finland and EU-FP6 IP EUCAARI coordinated

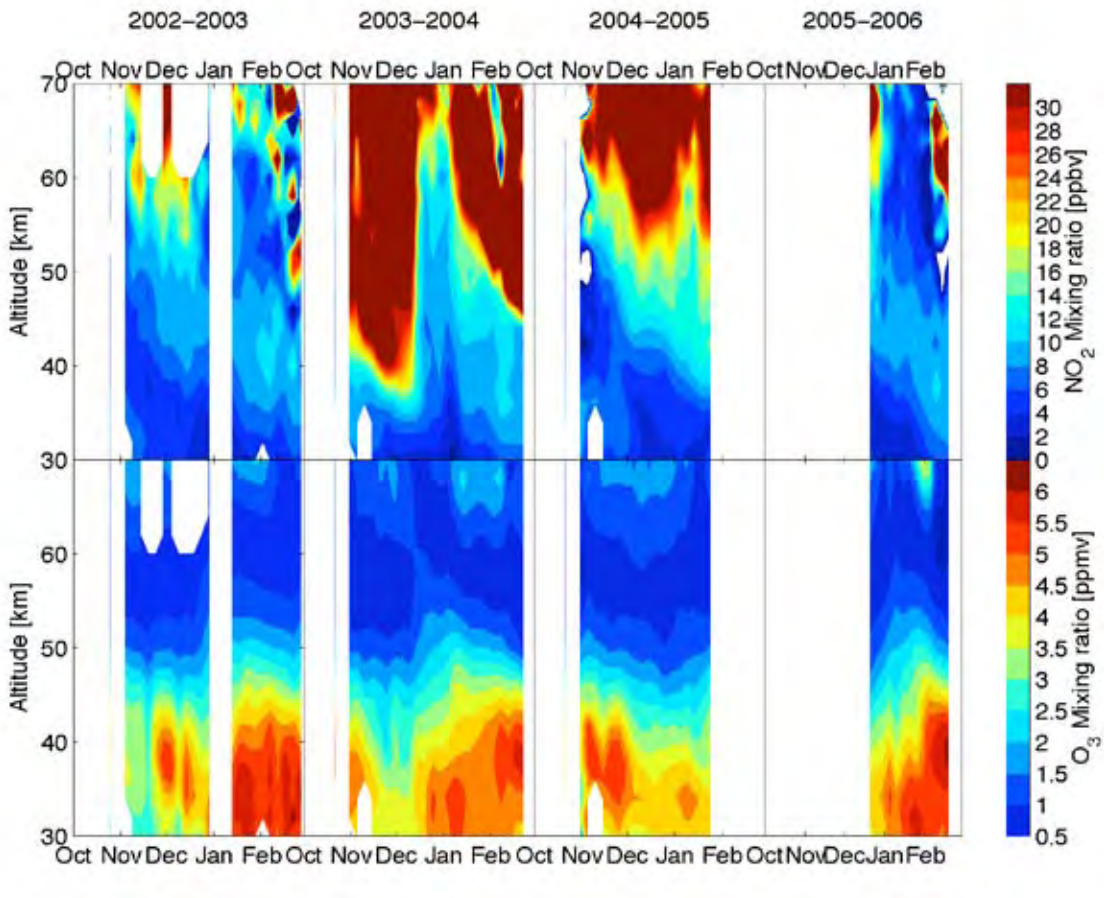


Figure 5.7. NOx enhancements due to high energy particle precipitation into the Earth's atmosphere, the descent of the NOx enhancements (top panels), and the consequent ozone loss (bottom panels) were observed during recent polar winters using the unique nighttime observations of the Global Ozone Monitoring by Occultation of Stars (GOMOS) instrument on board the Envisat satellite. The observed NOx enhancements in both the Arctic and the Antarctic were found to be highly correlated with geomagnetic activity increases. GOMOS has provided important new insights to the effects of high-energy particle precipitation on the Earth's neutral atmosphere, and the results have lead to two PhD theses in 2006-2007.

by the University of Helsinki to derive aerosol optical properties over Europe. University of Helsinki also leads Activity 3 – Aerosols – of the EU-FP6 IP GEOMON on ground based data complementary to satellite measurements, which is aimed to contribute to GEOSS. The aerosol activities aim at developing the European Network of Aerosol Networks (ENAN) in which ground-based in situ data are brought together with ground-based remote sensing. Furthermore, FMI participates in the ESA-ESRIN project PROMOTE and TEMIS to provide aerosol data from satellites in near real time. As part of the ESA project AMARSI FMI will look at the synergy between AATSR and MERIS to improve the aerosol retrieval over the ocean. AATSR and MERIS both fly on ENVISAT and similar instruments will be part of Sentinel-3 of the EU/ESA GMES programme.

The middle atmospheric research is collecting the fruit from past investments, as three instruments (Envisat/GOMOS, EOS-Aura/OMI, Odin/OSIRIS) were operative and produced excellent measurements of middle atmospheric ozone, other trace gases, and aerosols. These results were processed, distributed in part in near real time, analyzed using a variety of chemical and dynamical models of the atmosphere, and used intensively in various scientific studies.

In March 2007 the Envisat/GOMOS instrument fulfilled its nominal lifetime of 5 years. The high-resolution measurements of the atmospheric trace gas profiles and, in particular, ozone have been used to study the atmospheric composition in the middle atmosphere. GOMOS measurements of ozone and nitrogen dioxide during the polar night at high latitudes have been essential when studying the long-term impacts of solar proton events. The already relatively long time series have been used to study the impact of particle precipitation on the composition of the mesosphere in different atmospheric conditions. GOMOS fast photometer data of stellar scintillations have extensively been utilized for studying small-scale structures and turbulence in the stratosphere. These unique data have enabled research on parameterization of the turbulence and the gravity waves.

The OSIRIS instrument on-board the Swedish-Canadian small satellite Odin had originally 2 years nominal life-time but it is still in operation after more than 6 years since the launch. At FMI the OSIRIS Level 2 processor has been updated during 2006-07 and all data is being re-processed.

The Dutch-Finnish Ozone Monitoring Instrument (OMI) that was launched onboard NASA's EOS-Aura satellite in 2004 has worked excellently. OMI data have been used in WMO's assessments on ozone depletion and climate change. FMI is responsible for processing OMI global UV data. UV-data have been validated and made available to science community in 2007. FMI's Very Fast Delivery (VFD) processing system of OMI data is based on receiving EOS-Aura Direct Broadcast data at Sodankylä and processing these data immediately. The OMI VFD service was opened through internet in March 2006 and it provides almost real time ozone and UV maps of the Northern Europe (omivfd.fmi.fi). The OMI multi-wavelengths aerosol retrieval algorithm, OMAERO, which has been developed in cooperation between the Dutch organizations KNMI and TNO has been implemented in FMI's Kuopio unit.

The middle atmospheric group is also involved in the development and use of atmospheric models. The chemistry-transport model FinROSE, the ion and neutral chemistry model SIC, the climate-chemistry model HAMMONIA and the assimilation model FASP together with the enormous satellite data sets provide excellent possibilities for doing atmospheric science. The results will make it possible to get more accurate estimates of the

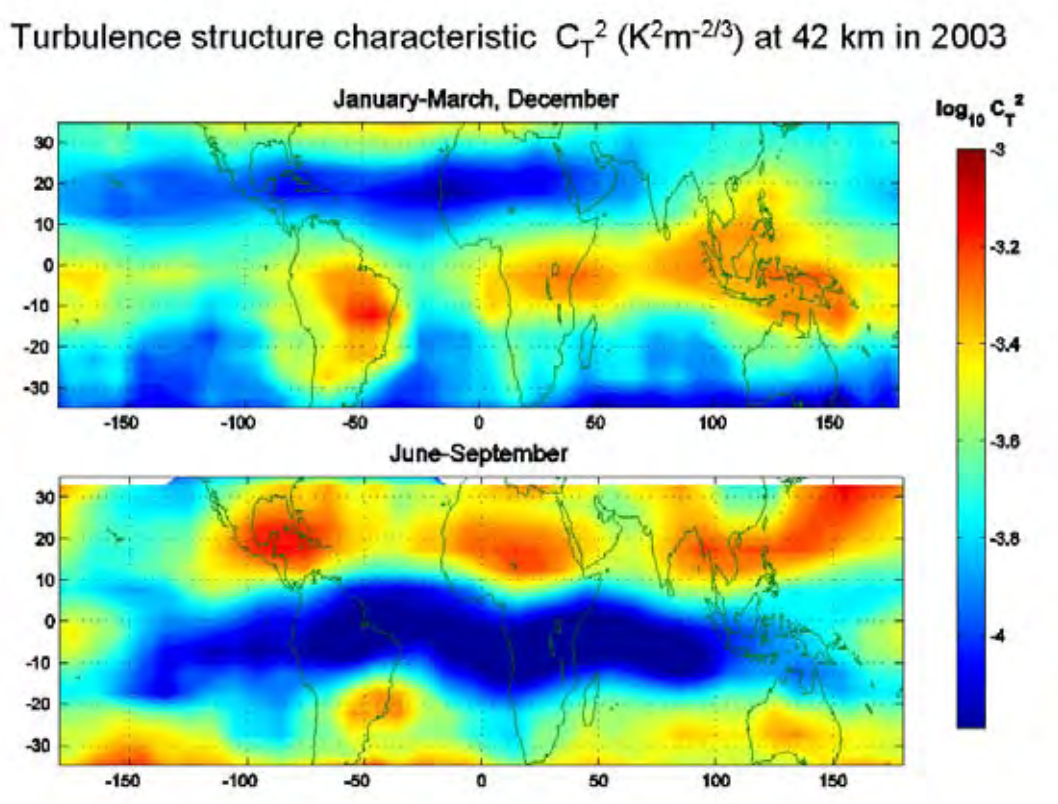


Figure 5.8. Intensity of turbulence in the upper stratosphere quantified by the turbulence structure characteristic, as obtained from analysis of GOMOS scintillation measurements (adapted from Gurvich et al., 2007).

climate change development in the middle atmosphere and in the upper troposphere lower stratosphere region.

FMI continued its active involvement also in development of next-generation of atmospheric instrumentation. In wide international collaboration, the group actively participated in the preparations for next-generation ozone, water and greenhouse gas monitors that could reach tropospheric altitudes and in planning a mission to measure high-altitude winds in the polar regions from a Molnyia-type orbit.

Metop-A, the first of three satellites of the EUMETSAT Polar System, was launched in October 2006. FMI is leading the international Satellite Application Facility for ozone and atmospheric chemistry (O3M-SAF) –project where the aim is to process, validate, archive and distribute the ozone and atmospheric chemistry data from Metop satellite and especially from the GOME-2 instrument. At the end of 2007 first O3M-SAF products were in pre-operational phase.

FMI is coordinating the WMO's theme office on Integrated Global Atmospheric Chemistry Observations for ozone and UV-radiation (IGACO-O3/UV). Here the long-term objective is to combine satellite and ground-based ozone data, as well as other constituents participating in ozone depleting processes, so that they can be used efficiently for different purposes including protocol monitoring and atmospheric research.

FMI also participates in three other Satellite Application Facilities aiming at estimation of various properties of the earth surface using satellite data. FMI continues developing the surface albedo product of Climate-SAF. Monthly and weekly mean surface albedo values are derived operationally for the full MSG/SEVIRI disc area and for Europe with Arctic extension using NOAA/AVHRR data. Deutsche Wetterdienst is responsible for the operational processing. The METOP/AVHRR based surface albedo products are being developed to cover the whole Arctic area. Recently the surface albedos of sea ice and open water have been included in the operational processing chain.

In the Land Monitoring SAF and Hydro-SAF the snow cover, fractional snow cover, snow status and snow water equivalent products are being developed in co-operation with the Finnish Environment Institute (SYKE) and TKK. Currently the MSG/SEVIRI snow cover product is operational.

For the snow and albedo product development also validation campaigns are important. Thus a major effort has been the planning of the SNORTEX campaign to take place in spring 2008, 2009 and 2010. Besides Finnish partners (FGI, SYKE, University of Helsinki and TKK) also Météo-France will have a major contribution in the campaign by producing BRDF data with the airborne OSIRIS instrument.

Algorithms for estimating the leaf area index (LAI) using both optical and microwave data have been developed in co-operation with the University of Helsinki (formerly the Department of Forest Ecology, currently the Department of Forest Resource Management) in the NorSEN project financially supported by the EU interreg funding. Related EM modelling has been carried out in co-operation with the University of Helsinki, Department of Astronomy. Also participation in the international VALERI network has been one activity in the research of canopy remote sensing.

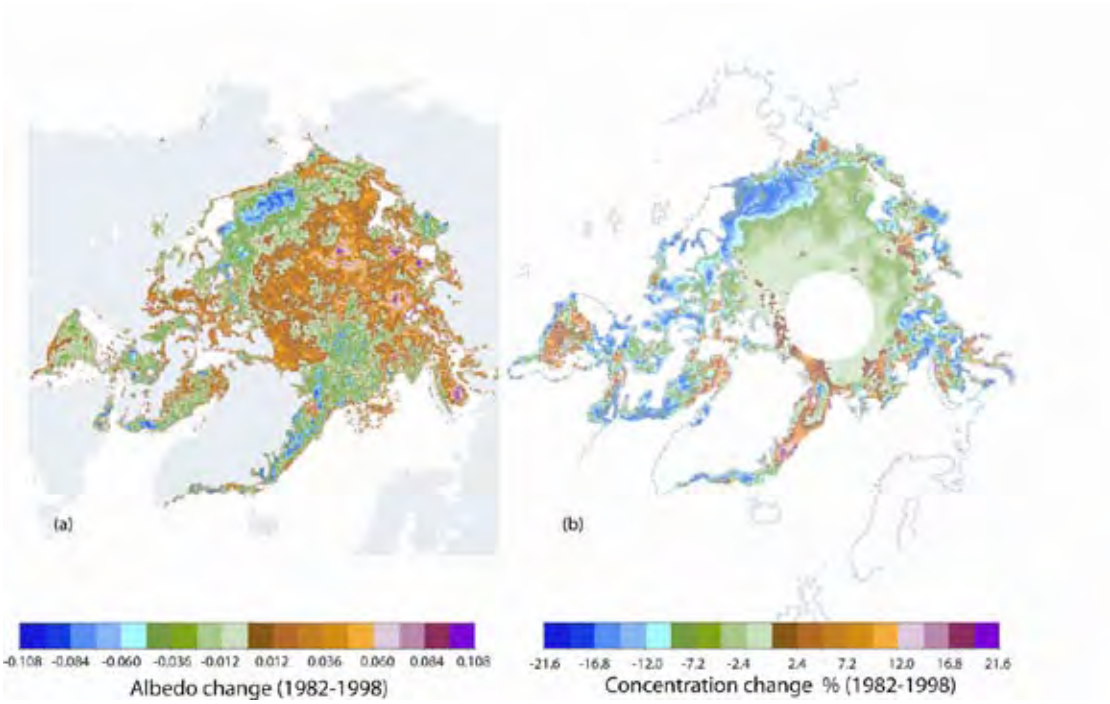


Figure 5.9. The 17-year trends in the summer sea ice albedo (a) and in the sea ice concentration (b).

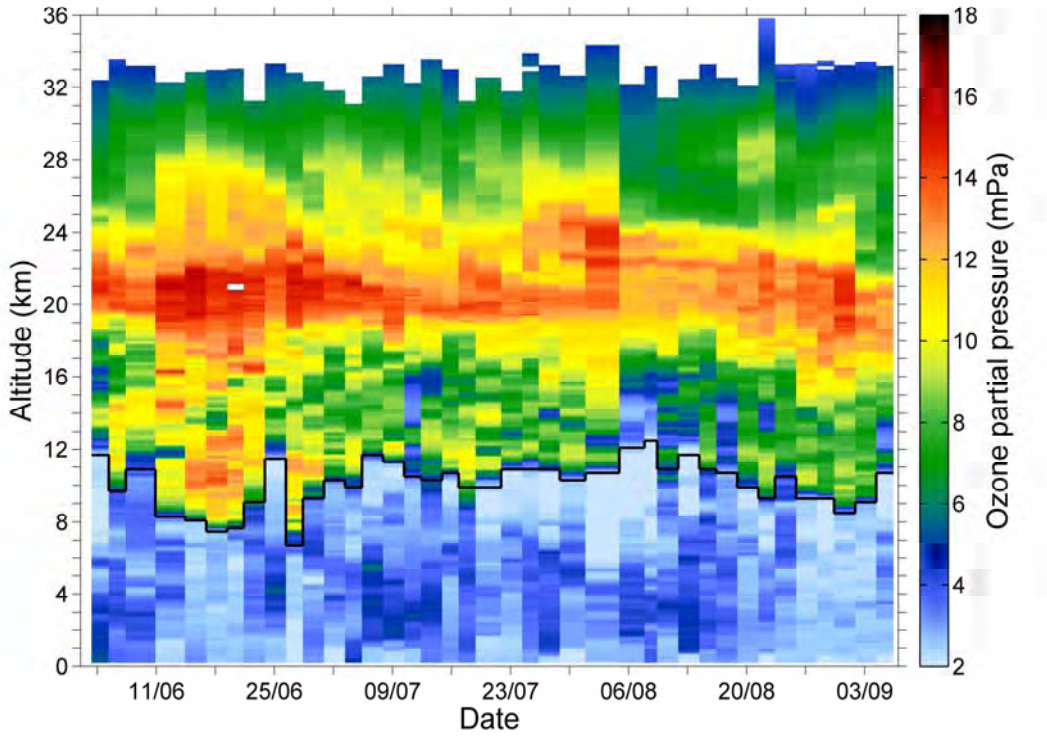


Figure 5.10. Ozonesonde profiles measured during the EPS campaign in Sodankylä in summer 2007. The black line corresponds to the altitude of tropopause.

A new three-yearly research project called "An integrated monitoring and modelling system for wildland fires - IS4FIRES" was started, funded by the Academy of Finland. Wildland fires have many serious negative impacts on human safety, health, regional economies and global climate change. In particular, peat and forest fires in Western Russia can cause transportation of toxic fine particles to EU that is a serious health risk for the population.

The project is designed (i) to detect major wildland, such as peat and forest, fires, using satellite remote sensing, (ii) to model both the spread of the fires in the terrain and the atmospheric dispersion of the fire plumes in the atmosphere, and (iii) to detect the fire plumes, and to find out the source areas using a combination of ground-based air quality measurements and a long-range transport modelling system. The project will also organize a controlled forest fire dispersion measurement campaign in the vicinity of a national supersite (SMEAR2), and utilize novel data that has been measured during the TROICA (TRans-Siberian Observations Into the Chemistry of the Atmosphere) campaign.

Two major field campaigns, related to satellite validation activities, have recently taken place in Sodankylä (67.4° N, 26.6° E) at the Arctic Research Centre of FMI. The first of the campaigns, the Sodankylä Total Ozone Intercomparison and Validation Campaign, focussed on satellite borne and ground based ozone observations during late winter/spring season. This campaign had two deployments: first in March-April 2006 and the second one in February-March 2007. The campaign was led by the NASA Goddard Space Flight Center, FMI and ESA. The campaign involved 40 scientist from Canada, Belgium, Italy, Fin-

land, France, Norway, Spain, Sweden and the United States. A wide variety of ground-based instruments participated. Instruments included six Brewer spectrophotometers, two Dobson instruments, two DOAS, a SAOZ, and the NDSC travelling standard stratospheric ozone LIDAR. Daily ozonesonde launches gave the ozone vertical distribution. As a result of the two deployments, the campaign has contributed to the improved knowledge of the accuracy of ground based ozone observations at very high solar zenith angles and secondly, has helped to improve satellite based ozone retrievals. The findings of the campaign will also lead to better understanding of the processes that contribute to the eventual recovery of the ozone layer.

FMI participated in validation activities of Metop-A measurements during the summer of 2007 in Sodankylä, soon after the beginning of the satellite's operational phase. In Sodankylä the newest radiosonde techniques were used to obtain accurate profiles of atmospheric water vapour, temperature and ozone, the sonde launches being timed to the satellite overpasses. In addition, data from continuous ground based measurements were obtained. These measurements included continuous profiling of temperature and humidity of the lower atmosphere, total column measurements of atmospheric water vapour, ozone and aerosol optical properties, cloud measurements using ceilometers and automated observations of surface meteorological parameters. Accurate measurements of water vapour in the upper troposphere and lower stratosphere is a technological challenge. FMI's Arctic Research Centre has participated in several field campaigns related to the improvement of the in situ measurement techniques. Some of these initiatives are on-going in cooperation with Vaisala Oy in Finland, the University of Colorado in the United States, the Central Aerological Observatory in Russia and other participating institutes.

FMI has purchased four CIMEL sun photometers which are implemented in Finland as part of the NASA AERONET network. These measurements are complementary to the WMO-GAW PFR (Precision Filter Radiometer) network and provide the ground segment for the validation of satellite retrieval algorithms.

Furthermore, FMI leads tasks in the ESA-ESTEC sponsored projects CAMELOT and ONTRAQ, in which future scenarios (aerosol, trace gases, dynamics) are provided using the global climate model (GCM) ECHAM5-HAM). The results are used to determine requirements for future missions and retrieval algorithms.

Helsinki University of Technology (TKK) Institute of Photogrammetry and Remote Sensing

Photogrammetry and remote sensing are technologies of measurement, observation and monitoring within the science of surveying and mapping. Basically all activity within the institute is focused on acquiring and managing 2D or 3D geoinformation of our environment. The applications include environmental monitoring with satellite imagery, large-scale urban mapping with aerial imagery, 3D virtual modelling of buildings, and analysing of quality and accuracy of 3D models. The institute is also internationally recognized for the research in the field of laser scanning of rural and urban environment.

Advances in laser scanning technology have challenged the conventional measurements in urban and rural environments. In addition to geometrical information, laser scanning provides also radiometric information, which is not yet efficiently used because of lack of radiometric calibration. Radiometric calibration methods for airborne and terrestrial laser

scanners have been investigated and developed in co-operation with the Finnish Geodetic Institute (FGI) laser laboratory. The concept is based on calibrated brightness targets (tarps and commercially available gravels) for airborne and laboratory use. The major goal is the development of a practical calibration method.

Laser scanning has entered also into civil engineering where it has been developed as the response to the need of a wide range of users for up-to-date models. The detailed 3D models of the transport systems are needed for traffic and highway modelling and traffic simulation systems. A modern mobile mapping system (MMS) is a multi-sensor system that integrates various navigation and data acquisition sensors on a rigid, moving platform for determining shapes and positions of the objects remotely. The navigation sensors typically include GPS receivers and IMU, while as the data acquisition sensors some of the most sophisticated systems use both terrestrial laser scanners and digital cameras. During the year 2007, system integration platform ROAMER (Road Environment Mapper) for mobile mapping was designed and manufactured in co-operation with FGI and TKK. Automatic data processing and modelling algorithms were developed and tested.

In differential SAR interferometry the goal is to separate phase contributions due to topography and displacement in order to detect deformations. Objective of the project was to demonstrate a novel EO-based method to determine surface deformations. Time series comprising of both ERS and ENVISAT data acquisitions has been processed with a persistent scatterer interferometry (PSI) algorithm from the Turku study area, where subsidence of buildings is a known problem. The technique provides a tool for city area monitoring with millimetre level accuracy. The technique is ideal for mapping large areas and finding possible problem sites. Damages due to subsidence require expensive renovations, and thus, there is a need for wide area subsidence data, which can assist in monitoring and planning. This project was completed in co-operation with FGI

The TKK group has participated in archaeological survey of Jebel Bishri mountain area in Syria by processing and interpreting satellite images (Landsat, Spot, Aster). Research concerning interpretation methods has been concentrated on decision based data fusion methods. Photogrammetry has also been applied for multi-temporal as well as multi-scale documentation during another archaeological study the Finnish Jabal Haroun Project in

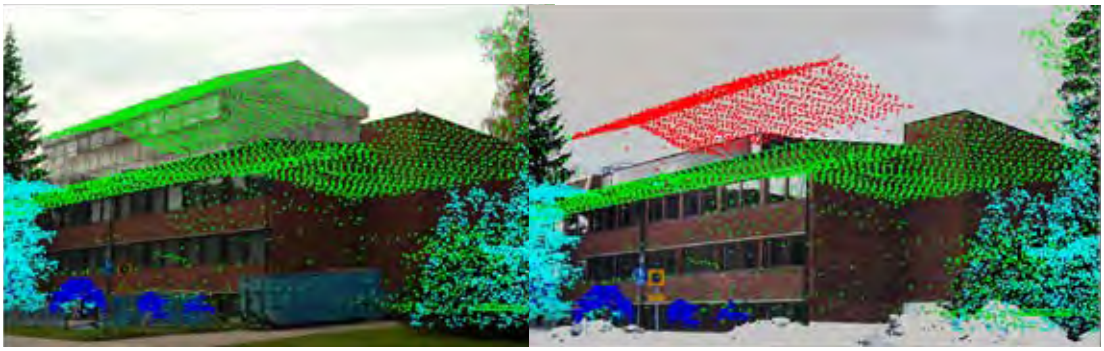


Figure 5.11. Integration of a laser point cloud and digital terrestrial images in Otaniemi. Airborne laser scanning data describes well the roof structures of a building. In the right image, terrestrial image reveal how the temporary construction shelter was removed after half a year from laser data acquisition. (Courtesy of Petri Rönnholm)

Petra. An economic and feasible approach to georeference multi-scale imagery to the common coordinate system using photogrammetry was developed.

Helsinki University of Technology (TKK) Research Institute of Modeling and Measuring for the Built Environment

The Research Institute of Modeling and Measuring for the Built Environment was founded 2007 at the Department of Surveying at TKK. The Institute consists partners from the TKK and the Finnish Geodetic Institute (http://www.foto.hut.fi/instituutti/index.html)

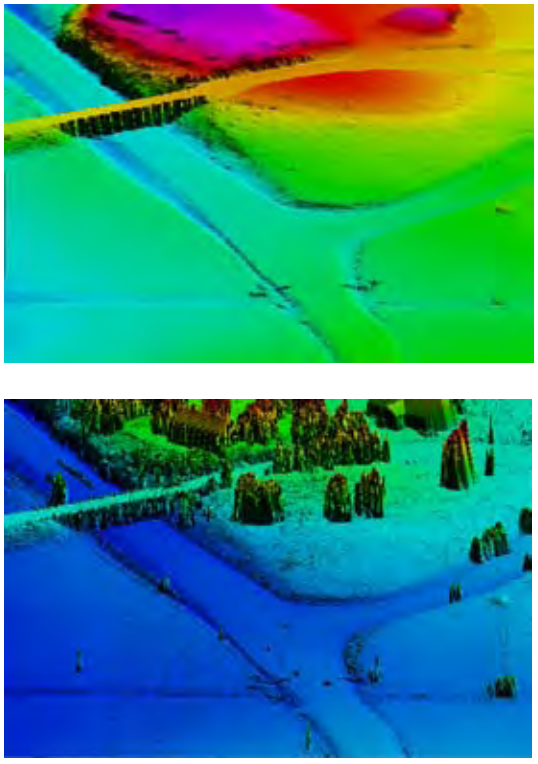


Figure 5.12. Digital terrain model (DTM, upper picture) and digital surface model (DSM) using airborne laser scanning
(Courtesy of Hannu Hyyppä).

The institute is built from the growing needs of close co-operation between the Civil Engineering and Surveying groups. The research topics initiated so far includes

1) comparison of the quality of airborne laser for Digital Terrain Model
2) development of modelling methods for terrestrial laser scanning
3) generate the digital city concept
4) integrate laser scanning in flood hazard mapping
5) development of algorithms for mobile mapping

University of Helsinki Department of Geography

Remote sensing research at the Department of Geography of the University of Helsinki started in 2002. It falls within Geoinformatics, one of the focus areas of the Department and the Faculty of Science. Recent research has concentrated on the applied use of remote sensing in environmental studies. The applications include land cover mapping and change analysis, assessment of biological diversity using optical remote sensing, glacier monitoring and utilising GI techniques in urban studies. Basic remote sensing research has also been carried out, concentrating on data calibration and validation, and development of biophysical parameters, such as LAI (leaf area index), from the imagery. Geographically, the research has concentrated mostly on Northern Europe, East Africa, Canada and South America.

The main current research project is the TAITA project, which focuses on the development of land use change detection methodologies using remote sensing and GIS, and applying the created databases for conservation and development. In the first 3-year phase remote sensing data from 1955 to 2004 were compiled, processed and analysed, while in the second 4-year phase the database will be applied for

studies related to soil erosion modelling, forest fragmentation and connectivity studies, and for the development of participatory rural appraisal methods. Mapping of the landscape through remote sensing techniques has utilised both multi-temporal SPOT XS satellite imagery and detailed 0.5-m resolution digital aerial photo mosaics. Extensive field work has been conducted to gather training areas and ground reference test data, and remote sensing research has focused on the methodological development of calibration, classification and change detection techniques to enhance the accuracy of land cover mapping in this complex heterogeneous environment. A comprehensive GIS database covering the socio-economic as well as the environmental aspects of the study area in South-Eastern Kenya is being constructed and the results made available to Kenyan and international partners via an ArcIMS powered web service. Also other tropical regions, namely Amazonian forests have been studied in collaboration with the University of Turku Amazon Research Team.

The research on northern boreal forests of Finland has been carried out using ASTER, MODIS and MISR data. The suitability of visible to shortwave infrared ASTER data for estimating forest biophysical variables, aboveground tree biomass and the LAI in the tree line mountain birch forests has been tested in a set of studies in northernmost Finland. The results indicate significant relationships between the biomass, LAI and ASTER data. The best models were applied for biomass and LAI mapping, and to calculate biomass and LAI statistics for the most widespread subalpine mountain birch forest types. The

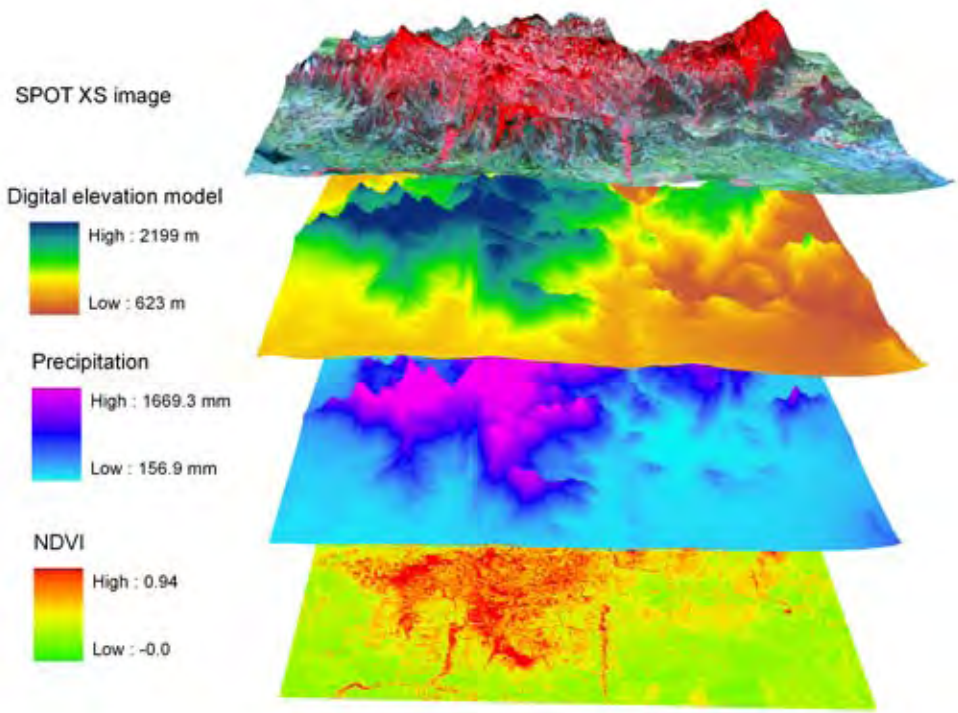


Figure 5.13. Examples of compiled GIS/RS layers for Taita Hills, South-east Kenya. The layers are used for ecological modelling and environmental research.

ASTER data have also been used together with stand wise forest inventory data for estimating the biomass of boreal forest stands in mineral soils. Non-linear regression analysis and neural networks were applied to develop models for predicting biomass according to stand wise ASTER reflectance. In addition, the potential of multiangular MISR data at 275 m and 1.1 km resolutions to estimate tree cover and height in northernmost Finland have been studied. The tree cover and height were estimated using neural networks, which were trained and assessed by high-resolution biotope inventory data. All the spectral-angular data together produced lower estimation errors than single band nadir, multispectral nadir or single band multiangular data alone. The results suggest that directional information has potential in improving tree cover and height estimates in the tundra-taiga transition zone.

Ongoing research on monitoring forest damage, structure, health and succession following the ice storm of 1998 is being conducted using optical remote sensing in temperate Canadian forest in cooperation with Carleton University. The research mainly focuses on the calibration of airborne remote sensing imagery, studying forest biophysical, ecological and structural reaction to ice storm, forest health monitoring and change studies using airborne and satellite remote sensing. Extensive work has already been made and results of mapping and modelling forest damage, LAI validation studies from high and moderate resolution optical remote sensing data have been produced. Improved and parameter independent LAI inversion algorithms are developed.

A new research field for the group has been hyperspectral remote sensing through an EC-funded SSA project HYRESSA (Hyperspectral remote sensing in Europe). The project has studied the user requirements and data providers of hyperspectral remote sensing data within EU member states.

University of Helsinki
Department of Physics

The geophysics laboratory of the Department of Physics uses space-borne remote sensing methods in the investigations of the cryosphere and natural water bodies. The principal research questions are sea ice, surface of glaciers and ice sheets, seasonal snow cover, surface temperature of water bodies and the ecological state of lakes and coastal waters. The main satellites and instruments used are NOAA/AVHRR, MODIS, SSM/I, ERS-1/2 and Envisat.

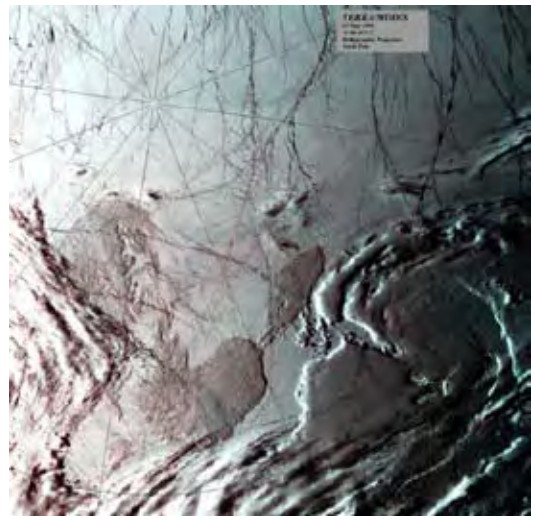


Figure 5.14. Observation of linear kinematic features (LKFs) in sea ice. Terra/MODIS true color image of the North Pole region on 5 May 2000, sea ice appears white, and areas of open water and thin ice appear black.

Sea ice thickness mapping from space is the main unsolved question in sea ice remote sensing. The group has examined the feasibility of the thermal infrared method for this purpose in the Baltic Sea, based on satellite data and helicopter-borne scanner. The method is good up to ice thicknesses of about half a meter, but the use of the method needs special consideration with respect to time of the day

Figure 5.15.
Surface truth observations of snow in the Dronning Maud Land from shallow and deep snow pits.

and weather conditions. Also high spatial resolution is required, which is still a limitation for space-borne instruments. An algorithm for data inversion and methodology analysis was developed. In sea ice dynamics research MODIS and Envisat imagery were used for model calibration and validation for ice kinematics and for analysis of geometric features for mechanical processes.

Similar ice work as in freezing seas is ongoing in lakes, but due to the spatial resolution problems the research is limited to large lakes, in particular Lake Peipsi. The temperature vs. ice thickness question has been investigated and the work is ongoing. Lake ice kinematics has also been examined from MODIS images and used in the development of lake ice dynamics model.

Glacier and ice sheet remote sensing has involved mainly the Dronning Maud Land, Antarctica, and Nordaustlandet, Svalbard. The work is done with microwave methods, first of all Envisat ASAR, and the principal goal is to observe the dynamics of the melting front in summer and also to obtain properties of the surface layer snow. Surface truth data has been collected in the Dronning Maud Land and Nordaustlandet for the calibration of methods. The Nordaustlandet research is part of the IPY Kinnvika programme.

Remote sensing of lakes and coastal waters in summertime has focused on the optical window, and has long-term collaborative roots with Tartu University, Estonia. This method provides information of the transport and dispersion of pollutants and other contaminants in the water and of the ecological state of natural water bodies. But most lakes and coastal waters are optically multi-componential, with the backscatter signal coming from coloured dissolved organic matter, chlorophyll and suspended matter, and the inversion of backscatter spectra is difficult and not yet well solved. The research work has consequently involved mainly the relation between backscatter and optically active substances in the water body.

University of Joensuu
Faculty of Forest Sciences

The main focus on research on remote sensing at the University of Joensuu, Faculty of Forest Sciences concentrates on forestry applications that utilize airborne laser scanning (ALS) data.

During this report period the most important project dealing with ALS was "The use of airborne laser scanning in the estimation of accurate forest resources 2005-2007" funded by Tekes. The main aim of the project was to develop a forest inventory method that produces tree species specific stand characteristics information by combining ALS and digital aerial photographs. The area based height and density characteristics of low pulse density ALS data as well as textural variables of photographs were used to predict volume, basal area, stem number and mean height and diameter at the plot level. The ground truth data consisted of accurately measured fixed area circular plots. The applied estimation method was non-parametric nearest neighbour approach. The results were generalized to stand and large-area level by using systematic grid. The accuracy of the results was found to be better than visual field assessment of stand variables, especially in the case of dominating tree species.

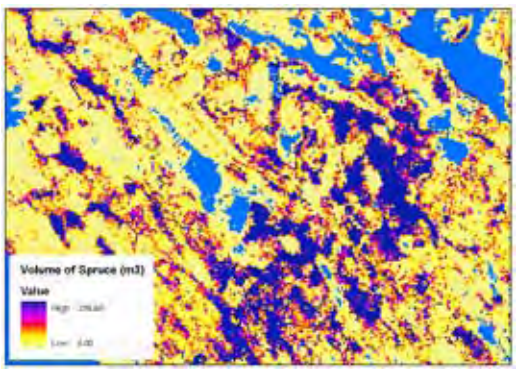


Figure 5.16. Large-scale prediction map of the volume of Norway spruce.

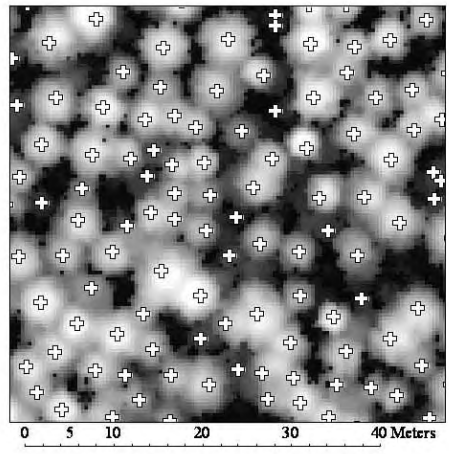


Figure 5.17. Recognition of individual trees by using local maxima of canopy height model of ALS data.

Related to the topic of the above mentioned project it was also examined if the field plot data of National Forest Inventory (NFI) could be used as ground truth data for ALS inventory. This would cause considerable savings in inventory costs. The corresponding project "Combining of NFI plot data and laser scanning data for forest management planning 2006-2007" was funded by the Ministry of Agriculture and Forestry of Finland and led by The Finnish Forest Research Institute. The specific point of NFI data is that sampling proportional to tree size (angle count sampling) is used in field measurements. The results of the project indicated that the accuracy of the use of angle count sample plots is close to that of fixed plots but the GPS location accuracy and sampling scheme of NFI plots may cause additional inaccuracy on the results.

In the project "Estimation of stand characteristics of marked stand using laser scanning and harvester data 2005-2006" funded by Metsämiesten säätiö the high pulse density ALS data was used at tree level to predict timber sortiments. The approach included recognition of individual trees, the prediction of tree characteristics, and calculation of timber

sortiments. The results were compared to accurately measured stand harvester data. The accuracy of the method was excellent in the example stand.

The possibility to produce biodiversity information by using ALS data and digital aerial photographs was examined in the project "Monitoring system based on modern remote sensing imagery for natural forests and restored forests of conservational areas 2005-2007" funded by the Ministry of Environment of Finland. The Finnish Forest research Institute and the Finnish Geodetic Institute also participated in this project. The research area of the project was Koli National park in eastern Finland. The data sets included also some measurements of terrestrial laser scanner. The main topics of the project were recognition of individual large aspen trees, prediction of downed dead wood and classification of herb rich forests by using remote sensing data sets. The other topics included characterization of gap dynamics and forest structure in the study area.

Multi-Source National Forest Inventory of Finland (NFI) at the Finnish Forest Research Institute (METLA)

The Finnish Forest Research Institute, Metla, is an impartial state research organization founded in 1917. The National Forest Inventory (NFI) is one example of official duties of Metla. NFI has produced large-area forest resource information for 85 years. Since late 1980s, the NFI has applied the multi-source forest inventory method that combines information from field measurements with satellite images and other numeric data sources (multi-source national forest inventory, MS-NFI). The method produces forest resource information for smaller areas than what is possible using sparse field data only, like for municipalities, and also thematic maps about forest resources. MS-NFI products are employed as input information in small area forest management planning by forestry authorities and for timber procurement planning by forest industries. Furthermore, the results have been applied in ecological studies and in other research purposes.

The MS-NFI method is under continuous development. Recently, a method to utilise large area variation of forests as additional information and genetic algorithm based optimization in feature weighting were introduced. Updating of NFI field plot data based on multi-temporal satellite images and growth model has been developed and applied. Model based approaches have been developed for error estimation and for an alternative to k-NN estimation.

Figure 5.18.
Map depicting the volume of growing stock, produced in the Finnish multisource national forest inventory. Note that the classification is done for the visual image. The unit in the original digital data is 1 m³/ha.

The MS-NFI team is firmly established in the field of forest remote sensing. The MS-NFI method has been successfully tested or applied also outside of Finland, and its further development work is going on. Examples are Austria, China, Germany, Ireland, Italy, New Zealand, Norway, Poland, Sweden and USA.

The current research activities of the MS-NFI team include:

- Maintaining Multi-Source Finnish forest resource information
- Developing of advanced multi-source estimation methods, examples are Bayesian methods, regression methods and improved k-NN methods
- Developing model-based error estimation methods.
- Updating of NFI -information by means of remote sensing data (an operative method has been developed and applied at regional level)
- Utilisation airborne lidar data and aerial photographs in large area forest inventories
- Estimating carbon balance of forests.

5.3. Space Technology

Helsinki University of Technology (TKK) Laboratory of Space Technology

The development of remote sensing methods for boreal forest snowmelt monitoring has continued at TKK/LST during the last years. The synthetic aperture radar (SAR) based snow-covered area (SCA) estimation method has been further enhanced in regard with operational, reliability and accuracy aspects. The major accomplishment during the last two years has been the creation of an enhanced SCA estimation method for boreal forest zone that incorporates assimilation of spaceborne data with ground-based weather station measurements and the development of a new method for reference image selection that functions in a computational unit scale. The new enhancements improve the accuracy and reliability of SCA estimates during and near the end of the snowmelt season. The new method is intended for operational use by the Finnish Environment Institute (SYKE), and will enhance their current SCA estimation methodology that relies on optical and radar-based satellite data. The new enhanced method has been designed to be fully compatible with SYKE's Watershed Simulation and Forecasting System that is operationally used to provide river discharge information and flood forecasts for the land areas of Finland.

Large scale mapping of snow water equivalent (SWE) and snow depth has been developed in LST together with the Finnish Meteorological Institute (FMI). The estimation method uses microwave radiometer data together with ground-based snow depth measurements us-

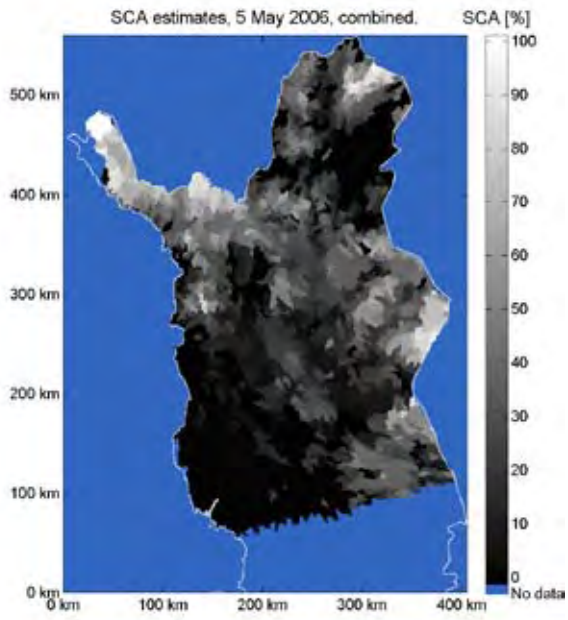


Figure 5.19. An estimate for Snow Covered Area (SCA) (%) for northern Finland on 5 May 2006, generated from a Radarsat image.

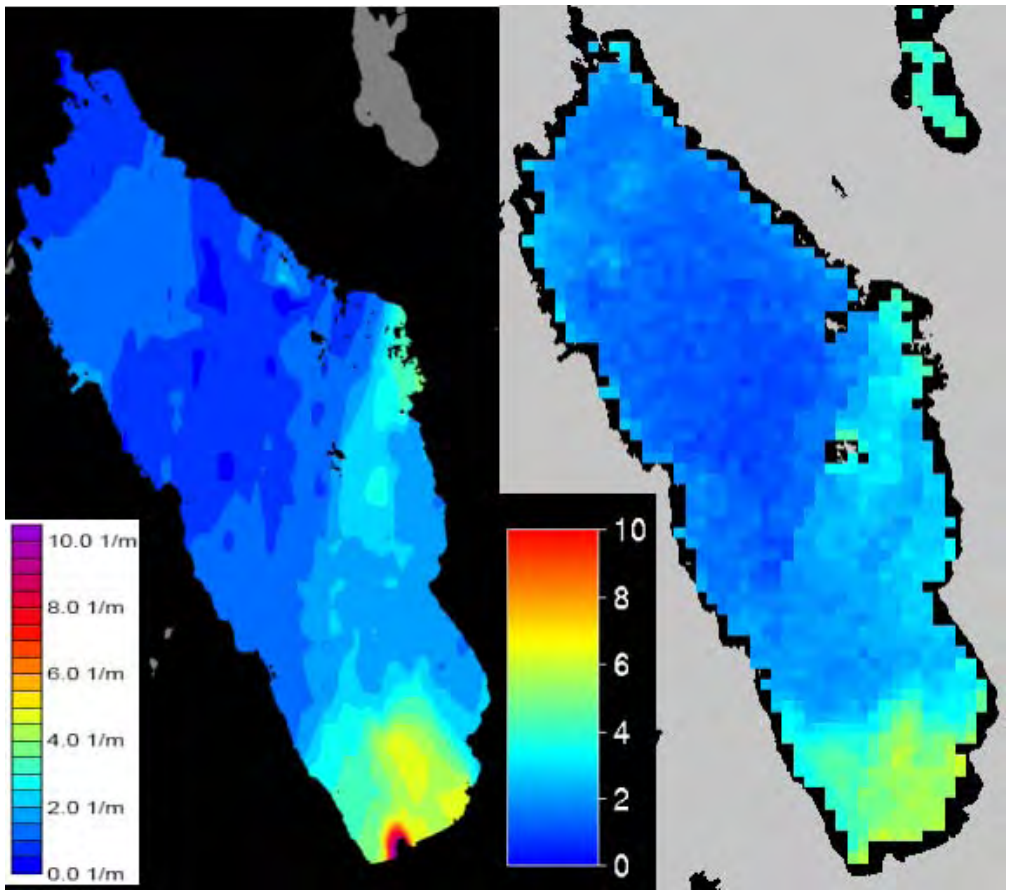


Figure 5.20. Estimation of absorption by humic substances (at 400 nm) in Lake Pyhäjärvi, Southern Finland on 9.5.2006 using (left) interpolated transect data measured from a moving boat, and (right) Envisat/MERIS satellite observations (ratio of channels 665nm/490nm).

ing Bayesian inversion techniques. In ESA funded PolarView project, this method is used to estimate SWE over Northern Eurasia. In the EUMETSAT funded Hydro-SAF project the area of interest is Europe, for which snow status (dry/wet/no snow) and snow water equivalent products are developed.

LST and Finnish Institute of Marine Research (FIMR) conducted a study where a time series of C-band HH-polarization backscattering coefficient for the Baltic Sea landfast level ice was compared to a 1-D thermodynamic sea-ice model (HIGHTSI). The main goal was to investigate how significant changes in time series coincide with major changes in the sea-ice thermodynamic parameters. In general, the HIGHTSI results greatly helped to interpret the behaviour with changing ice and weather conditions. Very interesting observation was the large variation of level ice with changing weather conditions, which complicates automatic classification of the SAR images, and, thus, the algorithms must be tuned for different ice conditions.

TKK/LST was active in several projects concerning polarimetric synthetic aperture radar (SAR) utilization. The VTT-led NewSAR project investigated utilization possibilities of

new generation space-borne SAR instruments. TKK/LST was responsible in the project for image calibration and made research on new polarimetric interferometric techniques and their applicability. For technology demonstration, airborne E-SAR imagery from FINSAR campaign was used. Project showed that new space-borne sensors are well calibrated and give high quality data for many new applications. However, some of most promising new techniques like polarimetric interferometry have to wait for upcoming tandem missions to show their full capability.

During 2006-2007 TKK/LST participated in several national and international projects related to research on remote sensing of water quality. The main research partners were SYKE, FIMR and FMI. The research has moved towards developing and using analytical retrieval methods. For example, in the ESA funded project "Development of MERIS lake water algorithms" that is coordinated by TKK, the goal is to develop a processor that converts radiance values measured by the Envisat/MERIS instrument to data about water quality by using bio-optical and atmospheric models. The portable spectrometers acquired in 2004 have been used during several in situ measurement campaigns. These data are used for testing and developing the analytical retrieval methods.

LST operates HUTRAD radiometer system mounted onboard a twin-engine Short SC-7 Skyvan aircraft owned by TKK. HUTRAD has vertically and horizontally polarized channels at frequencies 6.8, 10.65, 18.7, 23.8 and 94 GHz. In addition, there is a fully polarimetric 36.5 GHz radiometer. The main technical characteristics of HUTRAD are close to those of AMSR-E radiometer onboard NASA's Terra satellite. HUTRAD data has been used in the development of snow water equivalent and soil moisture retrieval algorithms. Polarimetric 36.5 GHz data has been used to investigate the retrieval of wind speed and direction over the Baltic Sea.

LST has developed a novel L-band airborne radiometer using two-dimensional aperture synthesis (HUT-2D) for remote sensing purposes. The instrument is similar to that onboard the ESA's SMOS (Soil Moisture and Ocean Salinity) satellite. The HUT-2D instrument is accommodated underneath the TKK research aircraft fuselage. The instrument consists of total 36 L-band receivers in U-shape geometry. The receiver outputs are digitally sampled and correlated to achieve an image of the target without any mechanical scanning with good geometric resolution. The maiden flight was in conducted in spring 2006. Since then HUT-2D has been operational in ESA's soil moisture and sea surface salinity monitoring campaigns as a part of SMOS calibration and validation activities. The project has been funded by TKK, TEKES and ESA and in the early phase of the project Ylinen Electronics Ltd was participating in receiver development.

After delivering the calibration subsystem (CAS) and the reference noise injection radiometer (NIR) to ESA's SMOS satellite in 2006 together with Elektrobit Microwave Ltd, LST continued to analyse and develop of their calibration procedures throughout 2007. The effect of the calibration uncertainties of CAS on the SMOS image retrieval were analysed and simulated. The calibration procedures of NIR were updated based on new analyses and payload level characterisation and thermal vacuum test results. Especially, the use of the reference radiometers as part of the interferometer array has been consolidated, which is their additional function besides working as a reference for the instrument calibration

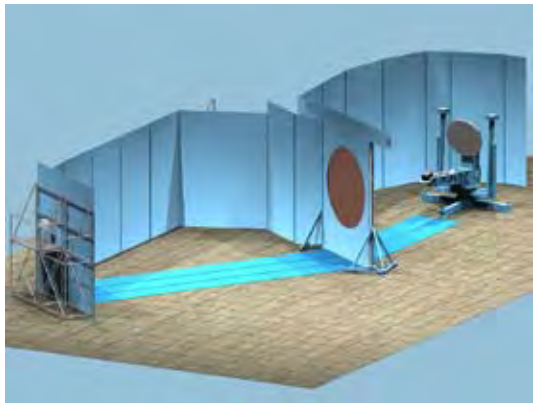
Figure 5.21. HUT-2D radiometer mounted underneath the TKK research aircraft fuselage.

Helsinki University of Technology (TKK) Radio Laboratory

The TKK Radio Laboratory has carried out research in satellite application oriented antenna measurement techniques and instrumentation development at millimetre and submillimetre wavelengths. This work has been done together with MilliLab. The main focus has been in developing the hologram based compact antenna test range (CATR) for 650 GHz and in antenna pattern correction techniques.

Testing of electrically large reflector antennas at sub-mm wavelengths is an extremely challenging task. Far-field measurements are ruled out because of atmospheric effects, near-field measurements are technically very complicated and expensive, and conventional compact antenna test range measurements are difficult due to high surface accuracy requirement of the reflectors. A CATR based on a binarized amplitude hologram overcomes the problems found in conventional techniques. The hologram pattern is realized on a metal layer that is on top of a dielectric substrate.

During 2006-2007 TKK Radio Laboratory carried out an ESA project, where a sub-mm



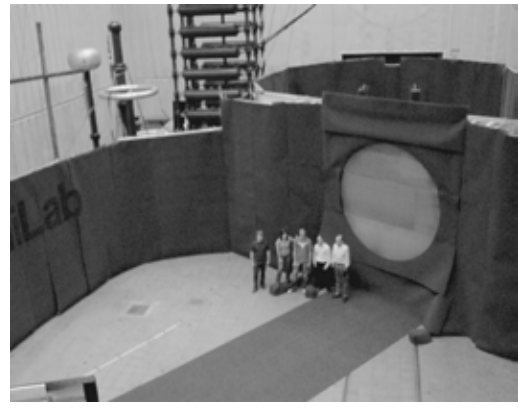


Figure 5.22. Constructed hologram-based CATR for 650 GHz.

wave hologram CATR based on a 3-m hologram for 650 GHz was developed and constructed. The radiation pattern of a 1.5-m reflector antenna, the ADMIRALS Representative Test Object by EADS Astrium, was measured at 650 GHz. For this measurement, the hologram-based CATR was improved and the CATR instrumentation was upgraded. Synthetic fibre floor mats were investigated and used as low-cost but efficient sub-mm wave absorbers. The measured reflectivity of the mats used was below –50 dB at 650 GHz.

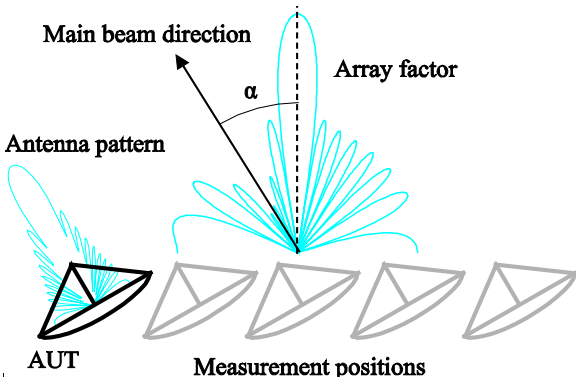


Figure 5.23. A linear virtual antenna array is formed when the antenna pattern is measured at several locations in the quiet-zone.

The measurement accuracy of a compact antenna test range (CATR) is limited, e.g., by the level of the spurious signals. Measurement accuracy can be improved using antenna pattern correction techniques. A feed scanning based antenna pattern comparison technique is especially suitable antenna pattern correction technique at sub-mm wavelengths. Also another pattern correction technique has been introduced for hologram based CATRs. This is the frequency shift technique in which the antenna pattern is measured several times at different frequencies. The feasibility of the methods has been studied and experimentally tested in the hologram based CATR at 310 GHz.

Furthermore, two new antenna pattern correction techniques have been proposed and demonstrated: one based on an adaptive array algorithm and another, which maximizes the signal-to-interference ratio in the antenna pattern measurement. In these techniques, antenna pattern measurements form a virtual antenna array at each rotation angle of the AUT. Both methods are verified in a hologram based CATR. The accuracies provided by the methods are found to be much better than that of the conventional antenna pattern comparison technique.

Millimetre Wave Laboratory of Finland (MilliLab)

Millimetre Wave Laboratory of Finland – MilliLab is a joint laboratory between VTT, Technical Research Centre of Finland and TKK, Helsinki University of Technology. MilliLab is also a European Space Agency Centre of Competence called ESA External Laboratory on Millimetre Wave Technology. MilliLab was established in 1995. Its main purpose is to support European space industry to meet the demands of future ESA missions, which will include an increasing number of millimetre wave instruments for astronomical and remote sensing applications.

MilliLab supplies services at millimetre wavelengths in the field of device modelling, device characterisation, measurements, testing, research, and development. The parent organisations of MilliLab, VTT, and TKK have a substantial amount of experience and expertise in the field of microwave and millimetre wave technology.

A low noise receiver for the ESA Planck-mission and an antenna test method for future mm-wave space telescopes are the main development projects in MilliLab, related to space applications. In the Planck Low Frequency Instrument (LFI) MilliLab's respon-

sibility together with DA-Design Ltd. is to design and construct the 70 GHz receivers. In order to obtain maximum sensitivity, the receiver is divided into a front-end cooled to 20 K and a 300 K back-end. The most vital parts of the receiver are the Low Noise Amplifiers to be realised by utilising the InP MMIC technology. The use of integrated circuits is important due to the large number of receivers in the LFI.

The six 70 GHz flight receivers were delivered to Italy for integration into the LFI in February 2006. In addition, two 70 GHz Flight Spare receivers were completed in August 2006. With the 70 GHz flight receivers, extremely low noise temperatures were obtained. A system noise temperatures between 26 and 36 K were measured over the required 63-77 GHz band for the six 70 GHz full Radiometer Chain Assemblies. The LFI system level tests took place in Italy in 2006. The LFI was integrated with the other spacecraft subsystems early 2007 in France, where room temperature tests of the various subsystems were carried out during rest of year 2007. The launch is scheduled for the end of 2008 from Kourou together with the Herschel spacecraft.

University of Jyväskylä Radiation Effects Facility RADEF

The RADiation Effects Facility, RADEF, is located in the Accelerator Laboratory at the University of Jyväskylä. The facility includes beam lines dedicated to proton and heavy ion irradiation studies of semiconductor materials and devices. The heavy ion line consists of a vacuum chamber with component movement apparatus inside and ion diagnostic equipment for real-time analysis of beam quality and intensity. In the proton line irradiations are performed in air and the line includes a dosimeter setup and movement apparatus similar to that in the heavy ion line. Both irradiation lines are located in the same cave.

Since its inauguration in 2005 RADEF has served more than 20 biggest European satellite companies, national institutes, space organisations and universities from eight different countries. It is annually visited by about 60 test engineers and has become one of the most known radiation test sites among the RADECS community (Radiation Effects on Components and Systems).

As a high light the community has authorized the RADEF team to organize the next RADECS workshop in September 2008, for a first time in The Nordic countries during the community's 20 years history: www.radecs2008.jyu.fi.

Figure 5.24. ECIF logo describing the locations of the European irradiation test laboratories: HIF in Belgium, PIF in Switzerland, ECF in ESTEC, Holland, and RADEF.

VTT Technical Research Centre of Finland

VTT is the largest contract research organisation in Northern Europe. VTT provides high-end technology solutions and innovation services. With its about 2700 employees, VTT can combine different technologies, create new innovations and a substantial range of world class technologies and applied research services, thus improving its clients' competitive-

ness and competence. In the field of Remote Sensing the annual volume of the research work in the years 2006–2007 has been 15 person-years.

VTT develops advanced image interpretation methods for analysing the information content of digital satellite images. The field of expertise is remote sensing of the natural environment, particularly forestry applications, including the whole value-adding chain from geometric and radiometric processing up to the delivery of versatile mobile and fixed platforms. VTT also does research in the fields of data fusion, sensor webs and GIS (Geographic Information Systems). VTT is involved in the research network that comprises key actors in Earth observation in Europe, North America and Japan. International co-operation is mostly connected to ESA and EU projects and to the exchange of personnel.

Three new space borne SAR sensors, ALOS PALSAR (Phased Array type L-band Synthetic Aperture Radar), TerraSAR-X and Radarsat 2 provide fully polarimetric images. These satellites have high spatial resolution, even as high as 1 m and they are capable of day-and-night, all weather observation. In a project called NewSAR, VTT has been developing new ways to utilise polarimetric and non-polarimetric SAR data from the new SAR sensors. Other organisations, which have been contributing to the project, are FGI and TKK/LST.

Pre-processing methods were developed for ALOS Palsar and TerraSAR-X data. Polarimetric, dual-polarized, and single-polarized data can be ortho-rectified. Stokes matrix format is used in resampling of fully polarimetric data. Scattering area effects due to topographic variation are corrected during the ortho-rectification process. Main application areas have been forest parameter estimation, change detection, and land cover classification. In forest stem volume mapping, good predictors were HV-polarized data, HH-polarized data, circular co-polarized data, and various polarimetric features computed from fully polarimetric data. Also land cover classification benefit from fully polarimetric imagery, and the best classification accuracy was achieved with multitemporal polarimetric features.

The ENVIMON project (Environment monitoring using earth observation) started in 2004 and ended in 2006. Environmental monitoring

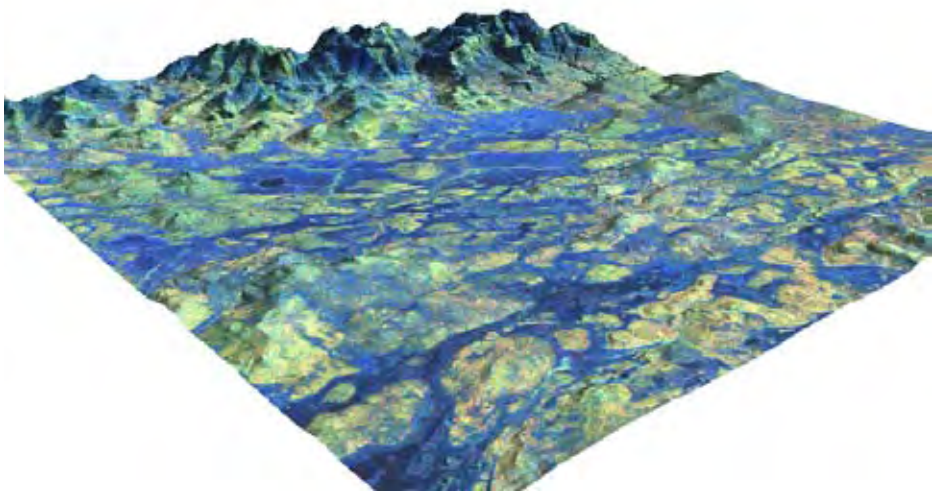


Figure 5.25. An example of ortho-rectified polarimetric radar image mosaic. The data is from northern Finland. ALOS/Palsar data © JAXA, METI 2007

Figure 5.26. Trees from SPOT satellite image integrated to a hybrid 3D city model.

systems provide information on the state of the earth by analysing satellite images and other remote sensing data. Within ENVIMON, tools for a wide variety of environmental monitoring needs were produced. These applications were developed on top of in-house platform called EOFrame. The applications included disaster monitoring, forestry, maritime routing, traffic monitoring, repository site, and season monitoring.

In 3D terrain project new tools were developed for the mapping of buildings, vegetation and trees from aerial and satellite images. Security and military simulations, architectural planning and navigation, as well as training simulators use 3D models and topographic visualisations of the built environment. The 3D models, or maps, are produced from aerial and terrestrial images, laser scanning data, and existing databases. In this project, a mapping and viewer demonstrator was constructed to demonstrate the new tools and a direct flow from remote sensing data to 3D visualisation. 3D Terrain project was a two-year project, which was carried out in co-operation with TKK and the University of Helsinki.

The on-going Forest and Season Monitoring project (ForSe) concentrates on developing new satellite image processing methods for forest resource mapping and seasonal monitoring of the nature. In the part of the study that concentrates on the forest resources, a new image segmentation method and a method for separating tree species in mixed boreal forest conditions have been developed. The image segmentation method will be used for delineating forest stands and will be utilised in producing forest variable estimates with different levels of spatial detail, thus giving information on forest resources for different purposes. The tree species recognition method utilises very high resolution satellite images as input data, and produces classification of detected trees into pine, spruce and broad-leaved classes. The target is to develop a tree species classification method that is accurate enough for operative use. The beneficiaries of the forestry study are forest industry and forest management companies. The focus of the seasonal monitoring part of the study is on monitoring the vegetation cover of the landscape, especially the colour change of deciduous tree leaves in autumn, and on the snow water equivalent measurement.

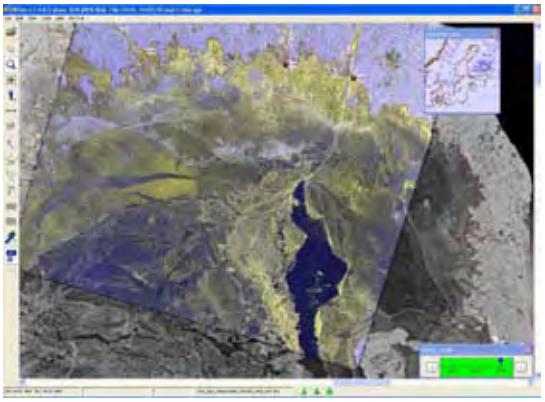


Figure 5.27. An image mosaic consisting of Envisat false-colour dual-polarized image in 100 m resolution presented on top of a Radarsat image subsampled to 400 m resolution. Ice can be seen in yellow, open water as dark blue.

An automatic method for analysing web-camera images of nature has been developed in the study of seasonal colour change monitoring. The image analysis produces a numerical index that indicates the seasonal development stage of the observed trees (e.g. degree of autumn colour of deciduous trees). The future target of this part of the study is a service for the tourists, and for the tourist industry. The service is planned to provide information about the conditions in the environment to help planning of the recreation activities in nature.

In the snow water content measurement part of the study, the objective is to create methods to produce snow water equivalent maps for several candidate end-users (including water power plant companies, environmental authorities, rescue authorities, defence forces). A prototype product (thematic maps) that indicates the water equivalent of snow by assimilating satellite data and in-situ measurement data is being developed.

VTT has participated in GSE Forest Monitoring project of ESA in French Guiana. The aim of the activity is to map and monitor forest area using SAR data of the ERS and Envisat satellites. SAR data are especially important in tropics where frequent cloud cover makes the acquisition of optical data difficult. The user of the results is CITEPA (Centre Interprofessionnel Technique d'Etudes de la Pollution Atmosphérique) of France, which uses the information to support the implementation of the Kyoto Protocol. Three SAR ortho-rectified mosaics using C band radar data from 1992/1993, 2003/2004, and 2006/2007 were compiled and a land cover / land cover change map was produced.

In the Fire2007 project, a fully automatic fire detection system was operated through fire season 2007. The system has been developed in a series of national projects and the ESA-funded project FF-Operat. In 2007, Modis data were integrated into the fire detection system to augment NOAA/AVHRR data and to fill gaps in temporal coverage of NOAA/AVHRR data. During the fire season (May to October), a daily fire map of the fires has been available on the internet for public use. The automatic fire detection system has been operated in every fire season since 1994. The number of detected fires in 2007 (488) was close to the 10-year median.

In co-operation with TKK and FIMR, VTT developed tools as a preparation for the use of new Synthetic Aperture Radar products by the Canadian Radarsat-2 satellite. The tools were developed focusing on the needs of winter navigation. VTT prototyped new ways of presenting dual-polarimetric images for operational use by the icebreaker fleet. An image portal was also prototyped as a way of bringing the extended image offering to the end-users. The services and products were evaluated during annual interactive seminars with the end users. As a result of the project, VTT can now offer tools for an automatic production of dual-pol SAR images processed according to the needs of the end users.

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