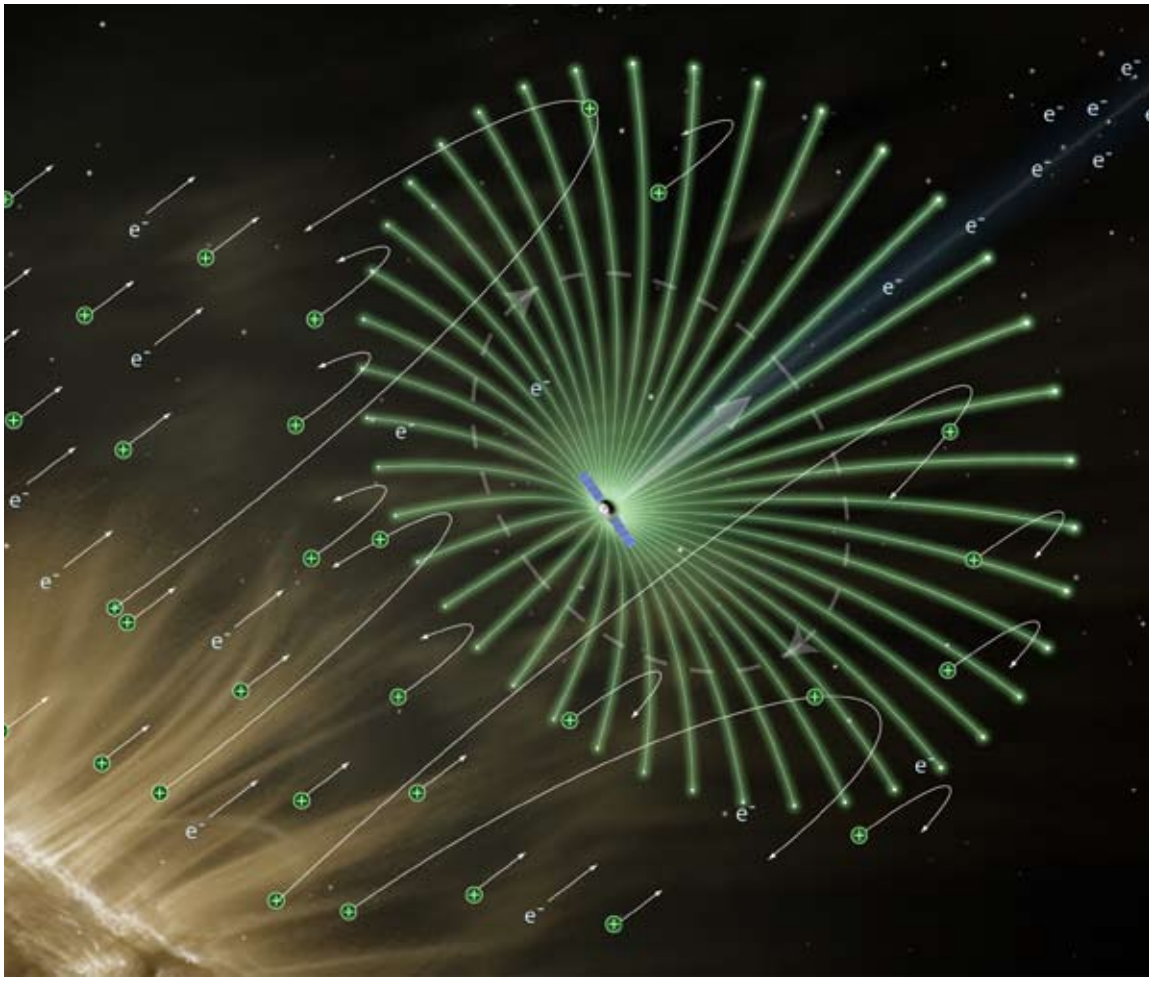
Space Research in Finland

Report to COSPAR 2010



COSPAR
Finnish National Committee

Tekes

Academy of Finland

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Space Research in Finland

Report to COSPAR 2010

Editors

Hannu Koskinen
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COSPAR
Finnish National Committee

Tekes

ACADEMY
OF FINLAND

Helsinki 2010

Front cover:

An artist's view of the principle of the electric solar wind sail. The positively charged wires repel the solar wind protons and thus transfer their momentum to the spacecraft (Figure courtesy: Alexandre Szames, Antigravité, Paris). More on page 87.

Back cover:

The new national geoid model FIN2005N00 is used in connection of GPS observations to transform GPS-based ellipsoidal heights to the national height system. For further info see page 64.

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 and the progress during 2008–2009 in pure and applied space sciences within the domain of COSPAR activities.

One of the highlights of Finnish space science during 2008–2009 was the launch of the Herschel and Planck satellites of ESA on May 14, 2009. The main mirror of Herschel was polished by a Finnish company and Planck carried a number of Finnish radiometers to measure the cosmic microwave background. Another spacecraft involving scientific hardware contribution from Finland was the Lunar mission Chandrayaan-1 of India with a Finnish solar X-ray instrument onboard. The satellite was launched on October 22, 2008, and continued observations until August 2009. Finland also contributed to two satellites in ESA's Earth Observation Programme, which were launched in 2009: Gravity field and steady-state Ocean Circulation Explorer (GOCE, launched March 17, 2009) and Soil Moisture and Ocean Salinity (SMOS, launched November 2, 2009) satellite November 2.

During the two-year period the largest technological effort in space research in Finland was invested in the Finnish PI-instrument Solar Intensity X-ray and particle Spectrometer (SIXS), which is a part of the X-ray instrument complex MIXS/SIXS onboard ESA's Mercury mission BepiColombo. While the BepiColombo mission itself went through a complicated redesign phase in 2008–2009 and was even threatened to be cancelled, the technical work with SIXS proceeded with full speed and the Instrument Preliminary Design Review was successfully completed in 2009.

A list of Finnish peer-reviewed articles in space research in 2008–2009 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

Ariane 5 flight V194. ESA

Table of Contents


Aurora Borealis by Jouni Jussila.

1. Overview of Finnish Space Activity

1.1 Finnish space research at the beginning of the new decade.

From the very modest beginning a quarter of century ago, the Finnish space research activities have grown to a good European level. In 2010 Finnish scientists and industry participate in practically all present and future ESA science and Earth observation missions in various roles (Principal Investigator, Co-Investigator, hardware supplier, system level contractor, etc.). We have been able to educate a new generation of space scientists and have today a healthy 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 25 years.

The beginning was not, however, easy. Finland joined the Committee on Space Research (COSPAR) already 1964. The members of the early Finnish National Committees of COSPAR were active in pushing the Finnish space activities toward international co-operation, including scientific instrument participation. After more than 20 years of efforts the first Finnish instrument contributions to spacecraft started in 1985 within the Russian Phobos-mission. Two spacecraft were launched toward Mars and its moon Phobos in 1988 and one of them performed observations on an orbit around Mars during the first few months of 1989. Meanwhile Finland had in 1987 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. In addition to the Science Programme the second main pillar of Finland's ESA activities has been 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.

Figure 1.1. Herschel/Planck launch on May 14th 2009

While COSPAR as an organization has strong focus in space-borne observations, the Finnish space research community has close ties to the various ground-based means of observing space from the immediate Earth environment to as far as it is possible to see with modern instruments. Finland has been an active member in the European Incoherent Scatter Radar Facility (EISCAT) and the Nordic Optical Telescope (NOT), and since 2004 in the European Southern Observatory (ESO). Today the ESA and ESO activities provide the main international context in space sciences whereas within Earth observations also EUMETSAT is another central organisation.

During the years 2008 and 2009 a number of changes in the Finnish space research organizations took place. The most notable was the creation of the new Aalto University in 2009, within which the former Helsinki University of Technology now forms the School of Science and Engineering. In this report we use new name of the University along with the old abbreviation (TKK). Another major organizational change was the reorganization of Finnish marine research from 1.1.2009. A part of the former Finnish Institute of Marine Research was merged with the Finnish Meteorological Institute (FMI) and another with the Finnish Environment Institute (SYKE).

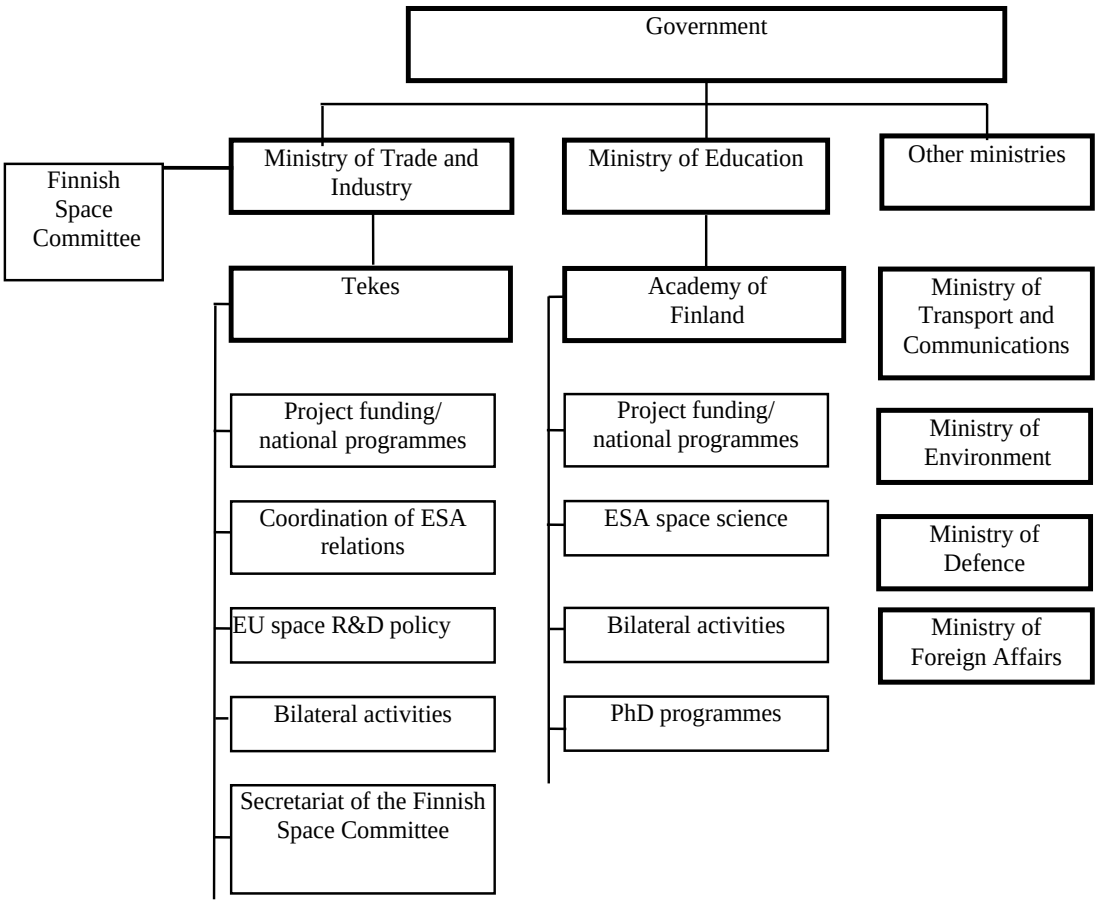

Figure 1.2 Organisation for administration of space activities in Finland

Figure 1.2. The Soil Moisture and Ocean Salinity (SMOS) mission makes global observations of soil moisture over Earth's landmasses and salinity over the oceans. Variations in soil moisture and ocean salinity are a consequence of the continuous exchange of water between the oceans, the atmosphere and the land – Earth's water cycle. ESA - AOES Medialab

We report the marine research-related Earth observation activities within the new organization. From 1.1.2010 also the Department of Astronomy (Observatory) of the University of Helsinki was merged with the Department of Physics. However, this report covering the activities 2008–2009 is organized according to the old Department structure.

1.2 Summary of the Finnish space policy

Publicly funded space activities in Finland are administered in decentralised way mainly involving Tekes (Finnish Funding Agency for Technology and Innovation), Academy of Finland and ministries of Employment and the Economy, Education, and Transport and Communications.

Finnish Space Committee (established in 1983) acts as the overall coordinating body for the Finnish space activities. It makes 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 Finnish Government nominates the Space Committee on a proposal by the Ministry of Employment and the Economy for a period of three years. The committee has members from relevant ministries and main actors. The Committee has met on average six times per year. Finnish Space Committee's members and advisors from 1 April 2007 to 30 March 2010 are listed on the next page.

Finnish Space Committee from 1 April 2007 to 30 March 2010

Chairman

Mr. Petri Peltonen	Ministry of Employment and the Economy

Vice Chairman

Mr. Markku Suvanen	Ministry of Education

Members

Ms. Katja Pehrman	Ministry of Foreign Affairs
Mr. Kari T. Ojala	Ministry of Transport and Communications
Mr. Juha Vuorimies	Ministry of Environment
Gen. Veli-Pekka Valtonen	Finnish Defence Forces
Prof. Tuija Pulkkinen	Finnish Meteorological Institute
Prof. Eeva-Liisa Poutanen	Finnish Institute of Marine Research (until 31.12.2008)
Dr. Susan Linko	Academy of Finland
Dr. Kari Tilli	Tekes
Mr. Topi Miettinen	Patria Systems

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)

Secretaries

Dr. Kati Sulonen	Academy of Finland
Mr. Pauli Stigell	Tekes

In spring 2010 the new Finnish Space Committee was nominated for the next three years. It is organized in a somewhat different way. The high-level Committee is expected meet less regularly and the role of the secretariat will be strengthened

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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

EARSeL
Helsinki University of Technology

SARSAT/COSPAT
Frontier Guard of Finland

Figure 1.3. Two of the ESO Atacama Large Millimeter/submillimeter Array (ALMA) antennas on the Chajnantor plain of the Chilean Andes, 5000 m above sea level. ALMA is the largest ground-based astronomy project in existence. Construction of ALMA started in 2003 and will be completed in 2012. The ALMA project is an international collaboration between Europe, East Asia and North America in cooperation with the Republic of Chile.

Figure 1.3. Image of Earth taken by Rosetta from a distance of 633 000 km on Nov. 12. 2009. ESA

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 development 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 accumulation of human capital, improvement of international competitiveness of companies, and more effective public services and improvements in the quality of life.

2.2. Strategy for Finnish space activities

The national space strategy for years 2009-2011 is outlined in The Space Activities in Finland, National Strategy and Development Objectives that was published (in Finnish) on the 3rd of March 2009. Strategic areas of the public sector investment are space science, satellite Earth observations, satellite telecommunications, satellite navigation and the industrial production of equipment for space vehicles.

The strategy for the development of space science lists main goals:

- The high standard of Finnish space science and remote sensing research 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. Information for the needs of environmental monitoring, protection and sustainable development will be generated.
- Technological competitiveness of industry and service sector will be improved thus supporting economical growth.
- 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.

2.3 Funding sources

The main public space activities' funding is divided between the Ministry of Employment and the Economy, Tekes and Academy of Finland, and several universities and research institutes.

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

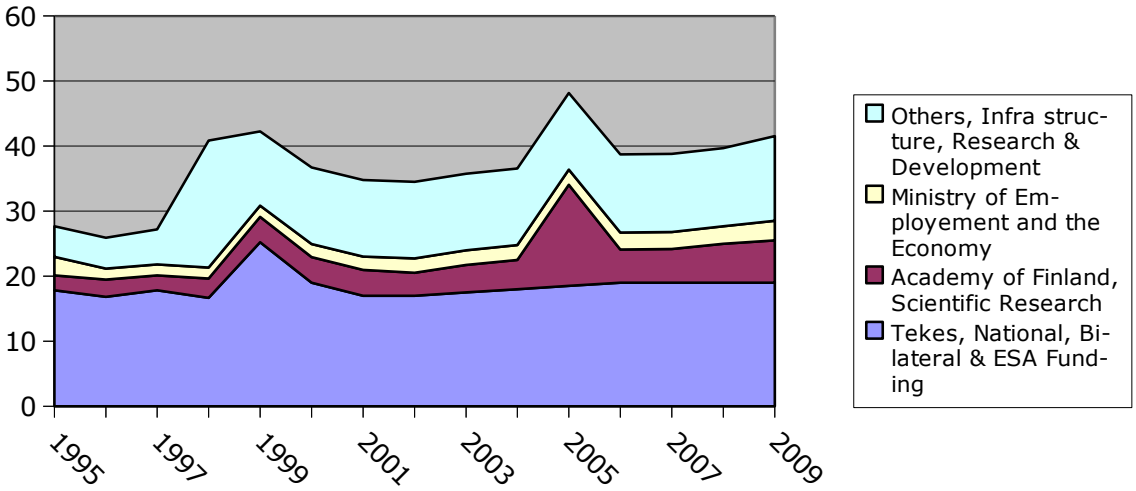

Figure 2.1. Funding of Finnish space activities 1995-2009 (million euros). Note that the strong peak in the funding from the Academy of Finland in 2005 was due to the entrance fee of ESO. The total fee was 12.8 M€ of which 10.5 M€ was paid cash and the rest as in-kind contributions.

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 2009 Tekes had 25 national technology programmes.

In 2009 Tekes total financing for national and international R&D-projects was 579 million euros. From this 19 million euros was provided for national and ESA space activities.

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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 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 projects, and personal 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 somewhat above 3 million euros annually (2009: 3.4 M€), excluding membership fees to international organizations (ESO, NOT, EISCAT), which make about 3.1 M€ in 2009.

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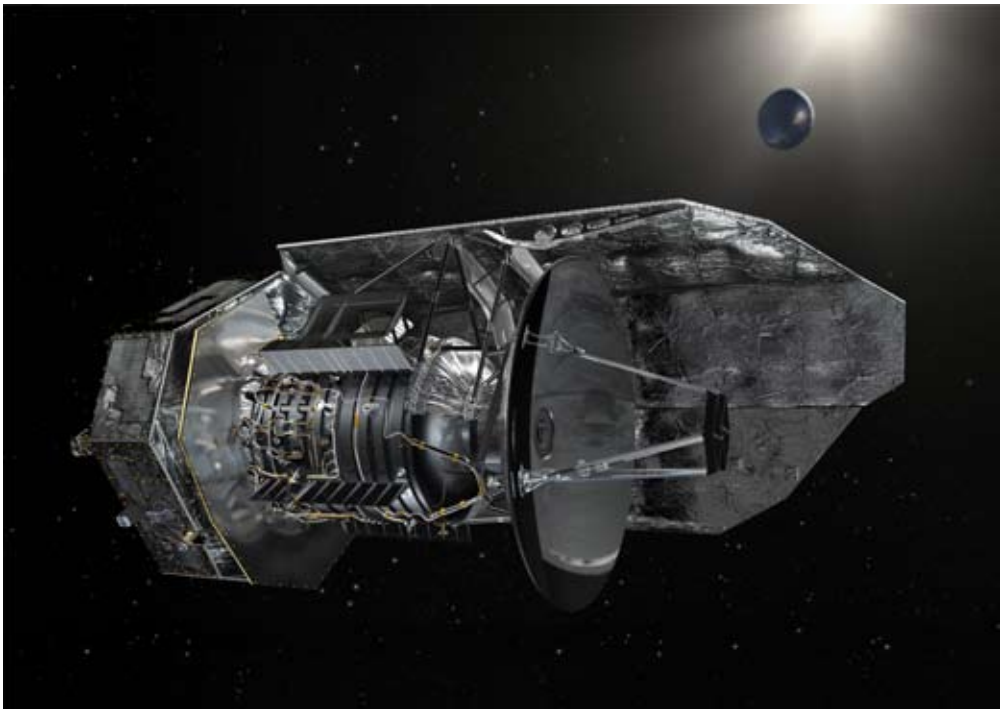

Figure 2.1 Artists impression on Herschel. ESA

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. 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."

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. In addition to these biannual reports the Committee has organized national FinCOSPAR Meetings roughly biannually since 1987, the most previous one in September 2009.

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. By the end of 2008 two long-time members, Professors Martti Tiuri and Pekka Tanskanen resigned from the National Committee. Prof. Tiuri had been active in COSPAR for 44.5 years, from the summer of 1964. The membership during 2008–2009 was

Chairman	Hannu Koskinen	University of Helsinki
Members	Martti Hallikainen	Helsinki University of Technology
	Juhani Huovelin	University of Helsinki
	Kalevi Mursula	University of Oulu (from 2009)
	Tuomo Nygrén	University of Oulu
	Petri Pellikka	University of Helsinki
	Juri Poutanen	University of Oulu
	Markku Poutanen	Finnish Geodetic Institute
	Tuija Pulkkinen	Finnish Meteorological Institute
	Jouni Pulliainen	Finnish Meteorological Institute (from 2009)
	Pekka Tanskanen	University of Oulu (until 2008)
	Erkki Tomppo	Finnish Forest Research Institute
	Merja Tornikoski	Metsähovi Radio Observatory
	Martti Tiuri	Parliament of Finland (until 2008)
	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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Figure 2.2. Finnish National Committee of COSPAR meeting January 15th 2010 at the Finnish Meteorological Institute: Martti Hallikainen, Erkki Tomppo, Martin Vermeer, Markku Poutanen, Juhani Huovelin, Hannu Koskinen, Merja Tornikoski, Jouni Pulliainen ja Sini Merikallio.

Figure 2.2. Finnish National Committee of COSPAR meeting January 8th 2009 at the Finnish Meteorological Institute: Erkki Tomppo, Juhani Huovelin, Tuomo Nygren, Tuija Pulkkinen, Hannu Koskinen, Merja Tornikoski, Martti Hallikainen, Martin Vermeer ja Markku Poutanen.
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.

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 is a summary of the ESA telecommunication and navigation programmes in which Finland participates.

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.

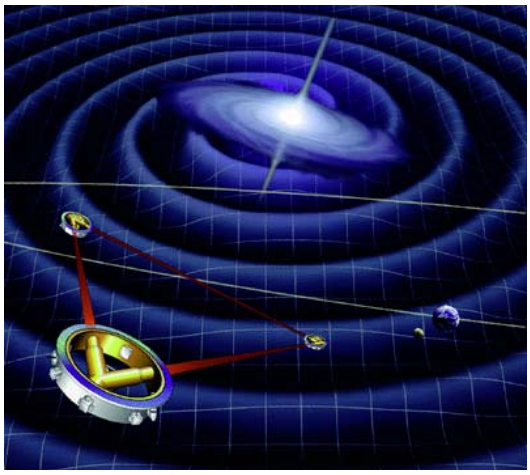


Figure 3.1. LISA will be the first space-based mission to attempt detection of gravitational waves. ESA

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

Programme	Finnish participation	Schedule
SOHO, ESA Solar and Heliospheric Observatory	SWAN and ERNE instruments	Launched 1995
Cluster / Cluster-2, ESA 4-spacecraft magnetospheric mission	EFW instruments; satellite power system electronics units	Launch failure 1996, launched 2000
Huygens, ESA descent module to Titan in the NASA/ ESA Cassini/Huygens mission	HASI instrument; ESA funded radar altimeter	Launched 1997, descent 2005
XMM-Newton, ESA X-ray mission	Telescope structure and satellite electronics	Launched 1999
Integral , ESA gamma-ray mission	JEM-X instrument	Launched 2002
SMART-1 , ESA Moon mission	XSM and SPEDE instruments	Launched 2002
Mars Express , ESA Mars mission	ASPERA-3 instrument, participation in Beagle-2-lander; satellite power electronics	Launched 2003
Rosetta , ESA cometary mission	COSIMA, PP, MIP instruments and lander CDMS; satellite structure and power electronics	Launched 2004
Venus Express , ESA Venus mission	ASPERA-4 instrument participation; power distribution units for spacecraft	Launched 2005
Herschel/Planck, ESA infrared and cosmic	LFI microwave receivers onboard Planck; mirror polishing for Herschel, onboard software for both	Launched 2009
LISA Pathfinder , ESA test mission for gravity wave observations	Solar array structures	Launch 2012
BepiColombo, ESA/ JAXA mission to Mercury	PI of SIXS , participation in MIXS (X-ray instruments), participation in SERENA particle instrument.	Launch 2014

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, ESA environment mission	Software and hardware for GOMOS observation instrument.	Launched 2002
Meteosat Second Generation (MSG-1)	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, ESA Gravity Field and Steady-State Ocean Circulation Mission	Onboard software	Launched 2009
SMOS , ESA Soil Moisture and Ocean Salinity	Radiometer modules, aircraft campaigns for reference measurements	Launched 2009
Cryosat-2, ESA Radar altimetry mission	Secondary structures	Launched 2010
ADM-Aeolus, ESA Atmospheric Dynamics Mission	Instrument electronics	Launch 2011
SWARM , ESA Earth magnetic field measurement mission	Power distribution unit	Launch 2012

Figure 3.2. ADM-Aeolus will provide global observations of wind profiles.

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-

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 operative bilateral programmes is given in table 3.4.

In addition Finnish groups also participated with instrument contributions for the Danish Roemer satellite and the Soviet/Russian Spectrum-X-Gamma, which were cancelled before the end of development. □

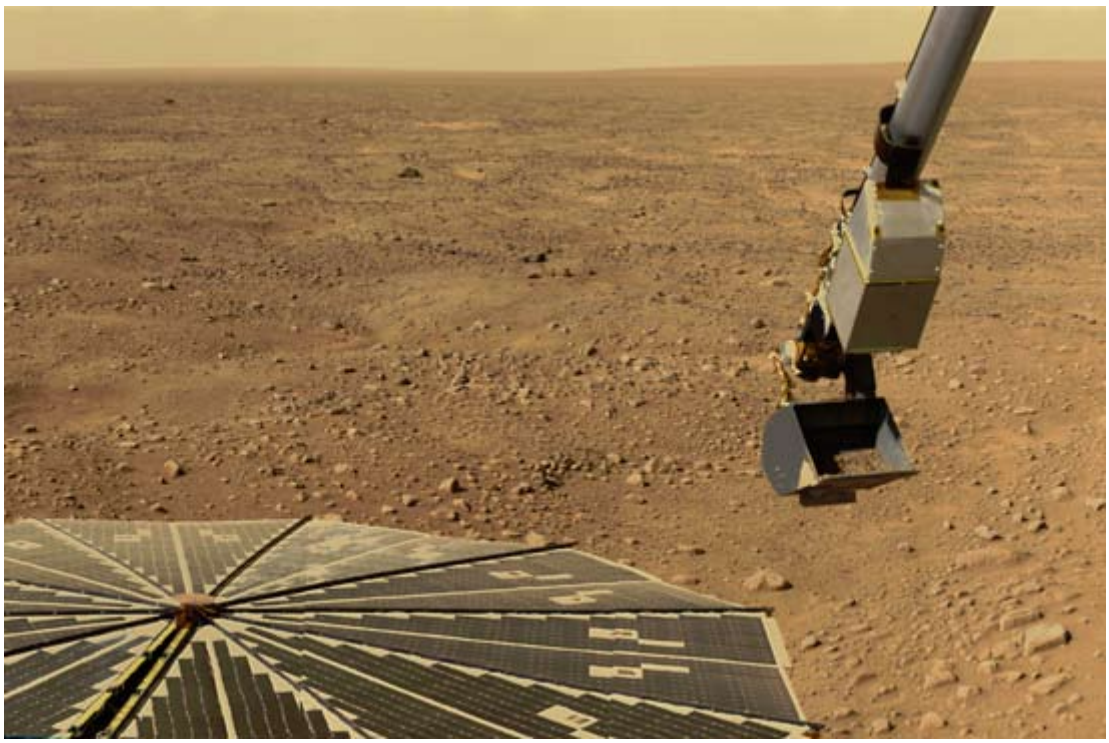


Figure 3.3.The Phoenix Mars lander's robotic arm and solar panel on Mars. Phoenix survived five months on the harsh martian environment. NASA/JPL-Calech/University of Arizona

Table 3.4. The main Finnish operative bilateral space programmes.

Programme	Main Partners	Finnish participation	Schedule
Phobos, Soviet mission to Mars and Phobos	USSR, SE, D	Electronics for ASPERA instrument and test system for LIMA-D instrument	Launched 1988, mission ended
Freja , Swedish magnetosphere mission	SE	Plasma and wave instruments	Launched 1992, mission ended
Astrid-1, Swedish microsatellite	SE	Instrument electronics	Launched 1995 mission ended
Interball , Soviet/Russian m'sphere mission	USSR/ RUS, SE	Electronics for Promics-3 instrument	Launched in 1995 and 1996, mission ended
Polar , NASA magnetosphere mission	USA	Mechanisms for EFI instrument	Launched 1996
Mars-96 , Russian Mars mission	RUS	Central electronics units, sensors and software for two landers	Launch failure in 1996
Cassini , NASA Saturn mission	USA	Hardware for IBS, CAPS and LEMS instruments	Launched 1997
Space Shuttle	USA	AMS instrument	Launch 1998
Stardust, NASA heliospheric mission	USA	CIDA instrument	Launched 1999
Mars Polar Lander, NASA Mars mission	USA	Pressure instrument	Launched 1999, landing failure
Odin , Swedish-led atmos-pheric and astronomy mission	SE, F, CAN	119 GHz receiver and antenna measurements	Launched 2000
EOS-Aura, NASA EO mission	USA	OMI instrument	Launched 2004
Phoenix , NASA Mars lander	USA, CAN	Pressure instrument	Landed 2008
TWINS, NASA magneto-sphere mission	USA	Scanning mechanisms for TWINS instruments	Launched 2007 and 2008
TerraSAR-X and Tamdem-X, German EO mission	Germany	Leaf amplifiers for the SAR-radars	Launches 2007 and 2010
Chandrayaan-1, Indian Moon mission	India, UK	XSM-insturment	Launched 2008
Mars Science Laboratory	USA, E	Pressure and humidity instruments	Launch 2009
Mars MetNet Precursor Mis-sion	RUS, E	Novel landing station(s) to carried onboard Phobos Grunt	Launch 2011
BepiColombo MMO, JAXA part of the ESA/JAXA Mercury mission	Japan	Participation to MEFISTO-instrument	Launch 2014

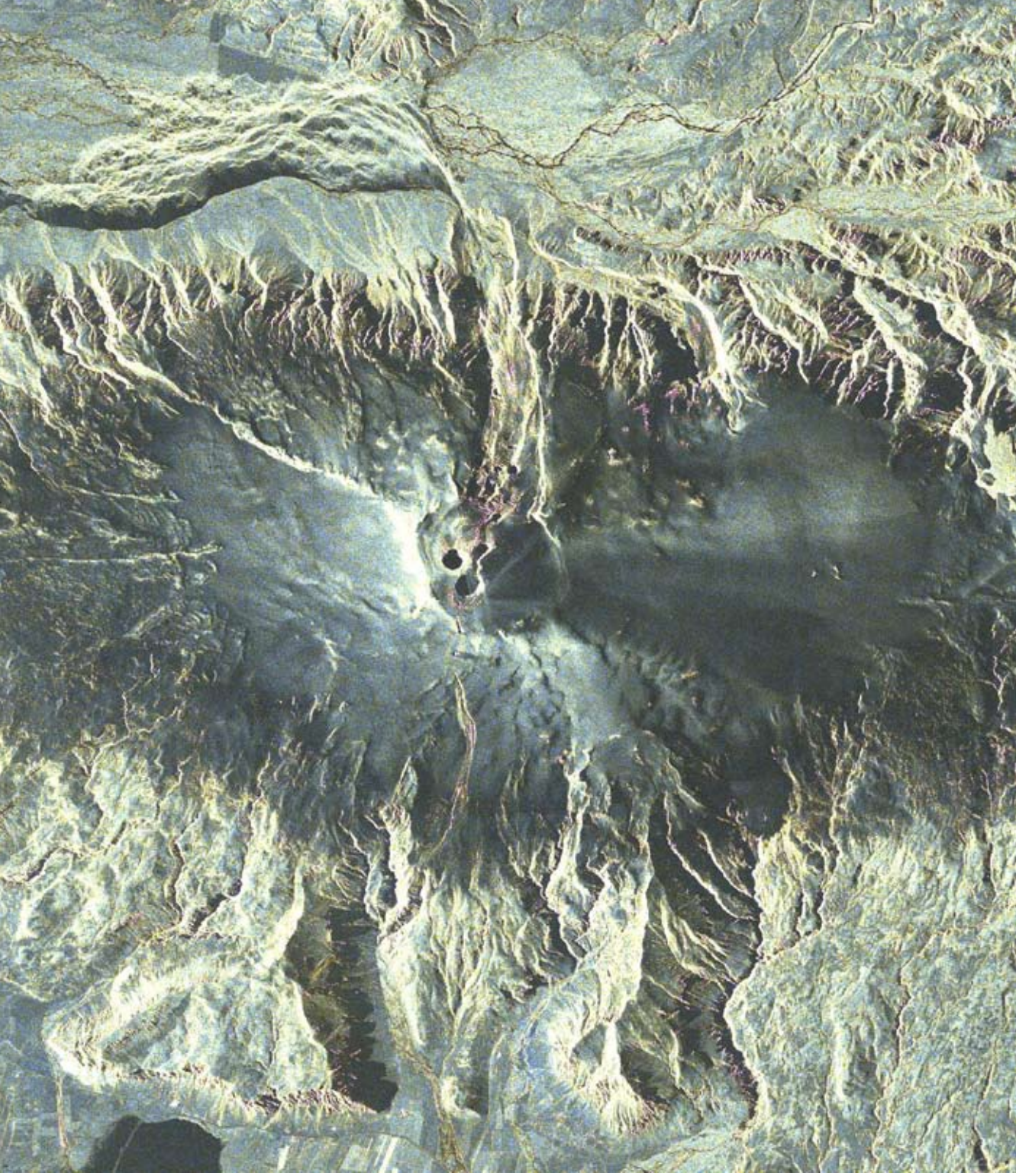


Figure 3.4. While aircraft cannot fly over the active volcano, the TerraSAR-X satellite looks down safely from space at the eruption site and its surroundings. The image, acquired on the evening of 15 April 2010 (19:04 local time), clearly shows three black craters. Previously, the caldera was covered with about 200 metres of ice. The fine ash from the eruption was caught by the wind and carried to the East, where it was deposited on the ice as a dense and smooth surface coating. In these areas, the microwave radiation from the radar satellite is only weakly reflected, and they appear dark in the image. DLR

4. Space Science

4.1. Ionospheric and magnetospheric research

Finnish Meteorological Institute (FMI)

The Solar–Terrestrial research strengthened considerably during 2008 – 2009 at FMI, due to both enhanced collaboration with the University of Helsinki Department of Physics (UH/PHYS) and due to increased funding from both domestic and European sources. The Kumpula Space Centre acts as an umbrella organization for several long-term space projects, and during 2008 – 2009 also more remote sensing space projects have been taken into the menu of the Centre. These projects will be described in their own context elsewhere in this report. The FMI research groups were active participants in the functions of the Graduate School on Astronomy and Space Physics, as host of graduate students as well as in teaching at the University and the GS summer schools. All together, five doctoral students at FMI worked in the field of magnetospheric research.

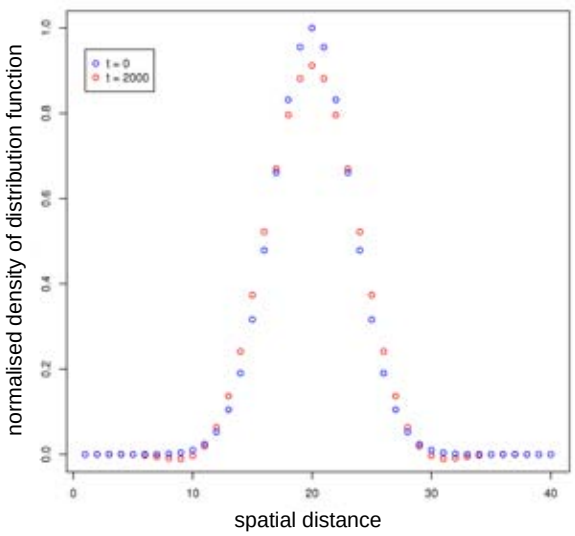


Figure 4.1. Initial (red) and simulated (blue) solution of the distribution function after 2000 timesteps in the Vlasov–hybrid simulation. The reproduction of the distribution function is remarkably good while keeping the numerical diffusion to minimum.

The solar-terrestrial research and especially development of global numerical simulations got a large boost in 2008 with the highly competitive Starting Grant for young scientists from the European Research Council (ERC) and a 5-year position as Academy Research Fellow from the Academy of Finland. The QuESpace-project aims to investigate fundamental plasma processes in the Earth's magnetosphere using multipoint space measurements and to develop a new self-consistent global simulation for the magnetosphere-ionosphere system. The research has already led to a breakthrough in understanding how the dynamic state of the magnetosphere itself affects the entry of solar wind energy through the boundary; this result followed from joint analysis of observations and simulation results, and could not have been obtained without either component. One of the major QuESpace challenges is to develop a 6-dimensional Vlasov-hybrid plasma simulation that will be extremely demanding on computation speed and memory. The group has developed solvers that represent cutting edge science in computational physics, for instance the numerical diffusion in the solver is among the smallest ever achieved. The high demand on the speed has led the group to become involved in the development of parallel algorithms for graphics processor units (GPU) in collaboration

with CSC, the national IT Center for Science. Although the GPU computing has recently emerged, the parallel algorithms for a set of GPUs are not known, and hence the group efforts will be among the first in the GPU computing as well.

Collaboration with (UH/PHYS) has strengthened especially in the studies concerning the outer boundaries of the magnetosphere and

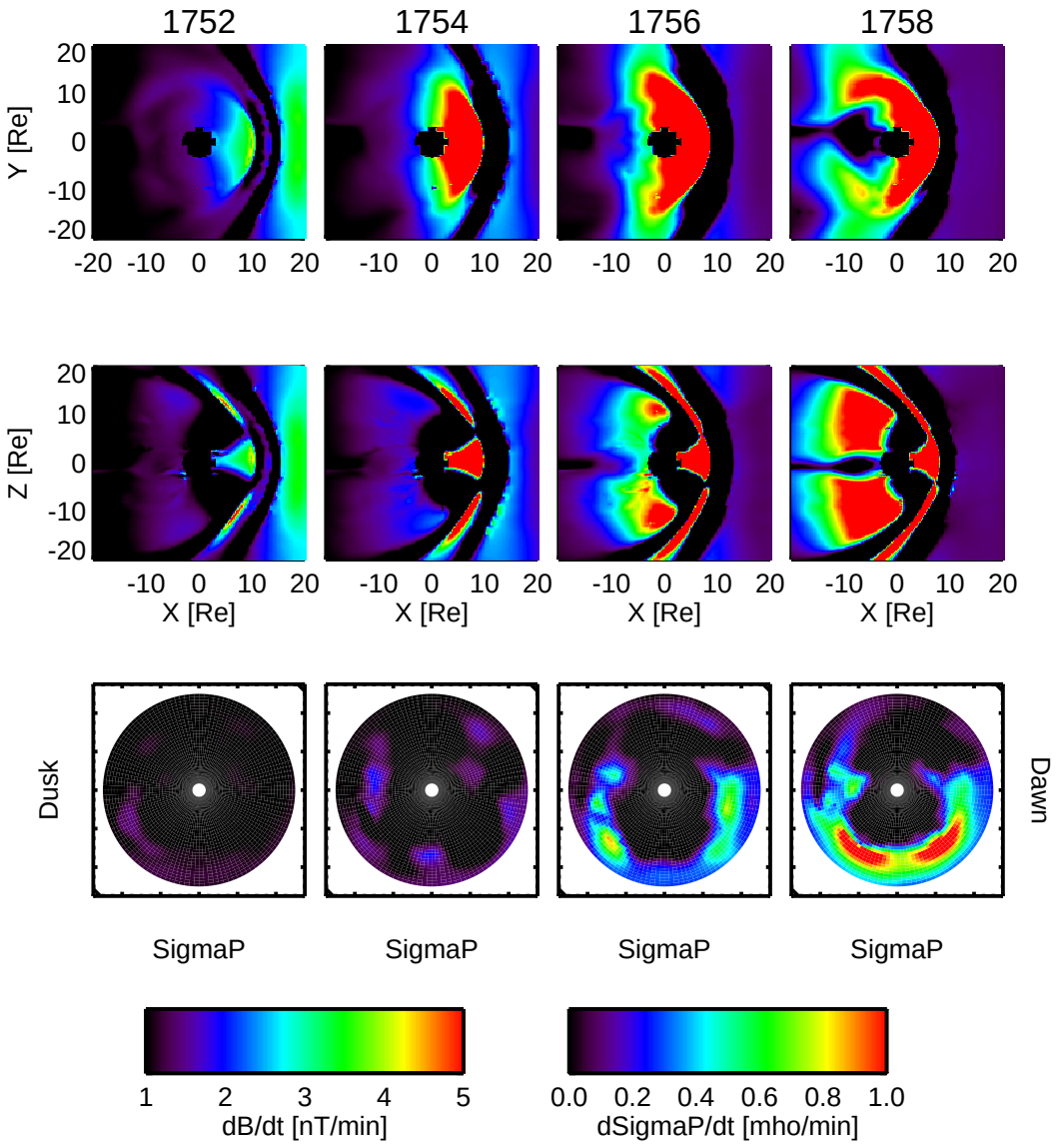


Figure 4.2. Solar wind shock propagation through the magnetosphere. The four time steps from a numerical simulation illustrate how a solar wind shock impacts the magnetosphere and how the disturbance propagates inside the magnetosphere. The top row shows the magnetosphere in the equatorial plane, with the Sun to the right. The middle row shows a cut in north–south direction at the midnight meridian. The bottom row shows the expansion of the disturbance in the ionosphere, with noon to the top and midnight to the bottom of the figure. Note that even if the solar wind shock arrives from the sunward direction and impacts first the dayside magnetosphere, the signatures in the ionosphere are first seen near midnight and later propagate along the auroral region towards the dusk and dawn.

the interaction of the solar wind with the magnetosphere. The magnetosheath is a turbulent region limited by the bow shock forming in the supersonic solar wind and the actual magnetospheric boundary, and controls many of the processes related to energy transfer from the solar wind into the near-Earth space. Joint research topics included propagation of solar wind disturbances into the magnetosphere as well as solar wind-induced dynamics at the boundary itself; the latter led to a publication by a young graduate student in the high-impact Physical Review Letters.

Joint studies with the University of Bergen on high speed streams and their interaction with the magnetosphere continued with a joint position at FMI and the University of Bergen. The period 2008–2009 was an especially interesting time to study such effects, as the solar activity remained at record-low levels since the minimum was reached in mid-2007. The impact of strong solar wind drivers in the magnetosphere was continued by observational and empirical modelling studies of specific classes of activity, magnetic storms, sawtooth events, and steady convection periods.

Collaboration with the University of Michigan in the magnetospheric modelling enhanced during 2008–2009 with a one-year visit from FMI. The Michigan group is known for its Sun–Earth simulation framework as well as its work on ring current modelling. The research targeted understanding how the energetic particles deform the inner magnetosphere, and how those effects could be embedded within the MHD simulations, which in principle cannot explicitly account for the effects of this distinct population.

A major research opportunity was provided by the EU in 2009, when the first call within the 7th Framework Programme concerning space science and space weather were opened. The FMI scientists were internationally active in forming consortia and formulating tasks for both scientific and application-oriented proposals. The heavy workload finally paid off when several of the applications were highly evaluated and proceeded to negotiation phase in 2010.

The ionospheric research group of FMI has continued in 2008 – 2009 the development of advanced data-analysis tools for meso-scale electrodynamics with ground-based instrumentation (magnetometers, radars and auroral cameras). These tools, which so far have been used mainly for the analysis of the Fennoscandian MIRACLE network data, have now been adopted to wider international usage: Scientists in the NASA THEMIS-mission have been guided to use the SECS-method (Spherical Elementary Current Systems) for investigating ionospheric signatures of huge magnetospheric plasma vortices ("space tornadoes") whose existence was for the first time evidenced with the configuration of the five THEMIS spacecraft. In collaboration with the community maintaining the network of SuperDARN radars a variant of the SECS-method has been developed, which enables a purely observational way to deduce regional electric field maps also when radar data are available only sporadically.

FMI research in auroral physics has progressed in quantitative utilization of optical observations. This means better estimates for auroral precipitation energies and of auroral dimensions than previously. Supporting observations from the EISCAT radars and riometers have been used in a study that demonstrates the use of optical data for estimating precipitation fluxes and, consequently, ionospheric conductances. Once the conductances are available, they open together with magnetic field data an opportunity to make regional maps of ionospheric currents and electric fields. For the first time it was demonstrated that this way calculated electric fields are consistent with plasma convection velocities as measured with SuperDARN radars. Whether a mysterious gap around 1-km scales in the distribution of auroral arc widths is a real physical feature or just an instrument artifact has been debated among the auroral

research community during the recent years. Recent FMI-led analysis of camera data from the Canadian Dense Array Imaging SYstem (DAISY) shows that the latter option is true and thus the gap at 1 km cannot be used as a test for qualifying different theoretical arc models.

Although the solar activity has been extremely low during the minimum between solar cycles 23 and 24, FMI has continued the development of the AurorasNow! space weather services that were launched in 2005 as part of an ESA Space Weather Pilot project. The service has modules for spotting auroras (AurorasNow!) and for monitoring Geomagnetically Induced Currents in natural gas pipelines (GICNow!). More auroral camera and magnetometer stations have been integrated to the near-real-time displays and the method for short-term magnetic activity forecasts have been improved. As a new opening in international collaboration FMI is participating in a

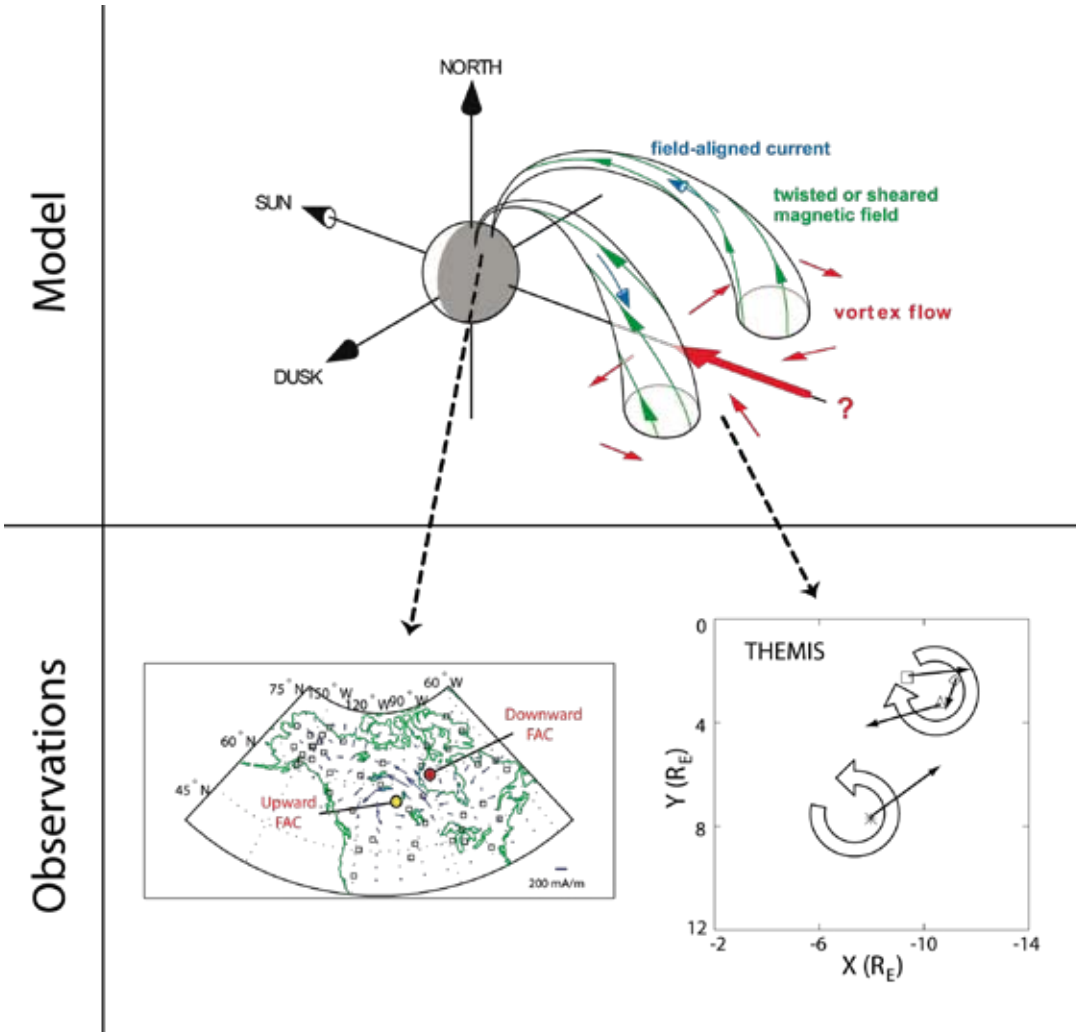


Figure 4.3. Ionospheric equivalent currents as deduced from ground magnetic field observations (lower left) supporting the NASA THEMIS mission. The ionospheric current vortices as calculated with FMI's SECS-method (for more details, see text) are associated with a pair of huge magnetospheric plasma vortices ("space tornadoes") whose rotational speeds in the magnetotail at magnetic equator (lower right) are estimated to be above one million km/h. The top figure illustrates how the tornadoes and the ionospheric vortices are coupled together through magnetic field-aligned current systems.

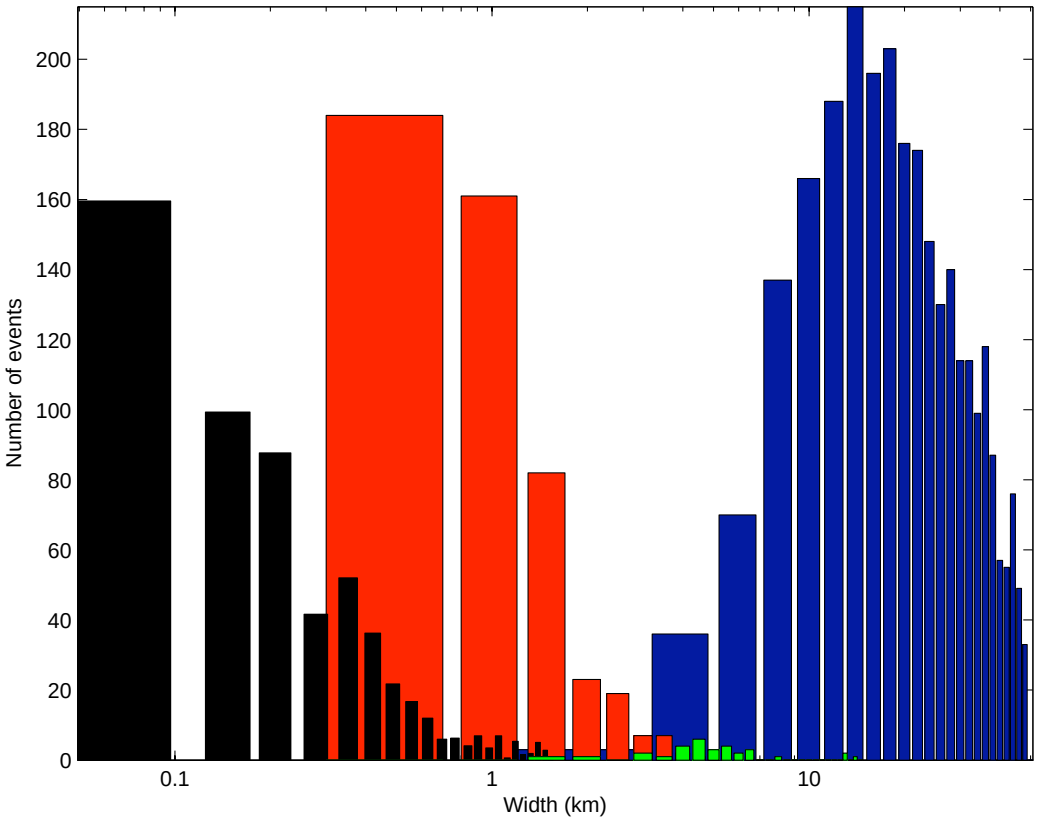


Figure 4.4. The distribution of auroral arc widths as deduced from high-resolution TV-camera data (black bars) and all-sky imager data (blue bars). The widths observed with the DAISY system and analysed by FMI scientists (green and red bars) reveal that the gap at 1 km widths appearing in the combined distributions of previous studies is not a physical feature but an instrument artifact.

research project where the GIC intensities in the Chinese power transmission grid is investigated by using recent space weather storms as test cases and from this basis the future risks in the power transmission activities are being analysed.

The fourth International Polar Year campaign was finished in March 2009. FMI coordinated one of the IPY core projects (Project #63: Heliosphere impact on geospace) under the space research theme. Scientists from 22 countries participated to this IPY project that paid special attention to interhemispheric relationships in polar aeronomy and solar–terrestrial linkages. One of the IPY projects used the data from the one-year long EISCAT Svalbard Radar run in atmospheric gravity wave research and another has resulted in a new statistical model for Northern and Southern hemispheric auroral currents as deduced from five year magnetic field measurements by the CHAMP satellite. The latter project contributed to a PhD thesis defended in spring 2009.

An international conference gathering about 50 scientists for discussions on inner magnetosphere physics was organized by FMI scientists near Helsinki in 2008. FMI also participated in the symposium “From the Core of the Earth to Space” organized in celebration of the 100 year anniversary of the Finnish Academy of Sciences and Letters in the organizing of Exhibition of Geoscientific Expeditions at the University of Helsinki Museum.

University of Helsinki
Department of Physics

Magnetospheric research at the Department of Physics of the University of Helsinki is conducted in close co-operation with the above reported activities at FMI under the Kumpula Space Centre collaboration. In 2008 - 2009 the group was involved in studies of energy circulation in the solar wind–magnetosphere–ionosphere system utilizing both empirical data and MHD simulations at FMI. In addition to simulations, Cluster observations of shock waves near the Earth's bow shock have been analysed to obtain better understanding of the temporal and spatial variations of shocks in collisionless plasmas. These studies have established that the plasma flow behind the shock can, under relatively general circumstances, be filamented into fast jets and slower streams because of rippling of the shock front. This finding has immediate consequences to the physics of collisionless shocks in general. It also introduces a novel mechanism to solar wind–magnetosphere coupling, as the fast jets forming during relatively quiet solar wind conditions may drive geomagnetic activity that other models cannot account for.

Space weather and space storms very much motivate the research space physics research at UH and FMI. A large project to produce a comprehensive text-book on physics of space storms was underway during 2008 – 2009 continuing to 2010. The book is expected to be published the autumn 2010 by Springer/ Praxis.

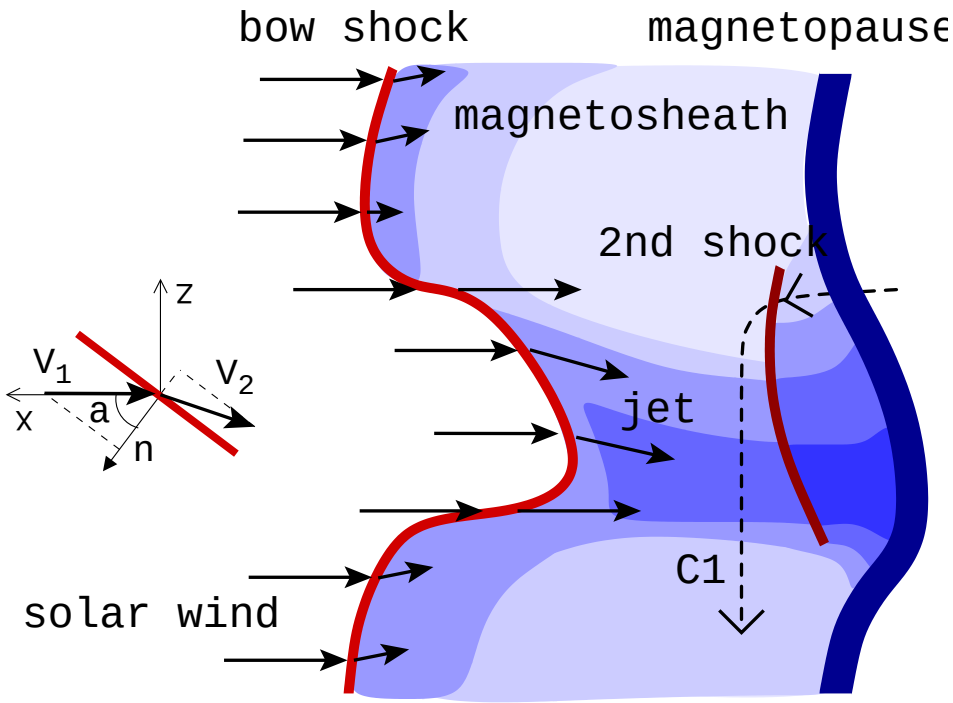


Figure 4.5. Illustration of the effect of local bow shock curvature. The variation of the plasma number density in the downstream region is illustrated by the shading: dark blue indicates density enhancement, light blue indicates density depletion. The trajectory of Cluster sc 1 in the reference frame moving with the ripple is sketched with the dashed line. The inset details the flow deflection when upstream velocity is not parallel to the shock normal.

University of Oulu
Department of Physics and Sodankylä Geophysical Observatory

The Space Physics Group (SPG) of the Department of Physics and the Sodankylä Geophysical Observatory (SGO) of the University of Oulu have a broad research programme in ionospheric and magnetospheric physics, including observations from both ground-based and satellite instruments. This programme is conducted in extensive national and international collaboration with several foreign institutes. Note that the research activities related to the effects of cosmic rays on the atmosphere are described in the Solar System Research section.

SPG and SGO organized the Third Space Climate Symposium in Saariselkä in March 18-22, 2009, as well as the First Space Climate School in the same place before the Symposium in March 15-18, 2009. Moreover, the SOTERIA project meeting was organized after the Space Climate Symposium in Saariselkä in 23-24.3.2009. There were altogether about 125 participants in these three meetings.

SPG has a co-investigator sta¬tus in the EFI instrument of the Polar satel¬lite and the EFW and RAPID instruments of the Cluster mission. Cluster satellite data was used to study the outflow of ionospheric H+ and O+ ions, which took place within the plasma sheet boundary layer (PSBL) and was associated with increased electron temperature in the ionospheric F region, as observed by the EISCAT radar. Polar satellite UV imagers were used to study the appearance of auroral poleward boundary intensifications (PBIs), transient localized auroral forms near the polar cap boundary. EISCAT radar observations showed simultaneous enhancements in the reconnection electric field, suggesting that PBIs

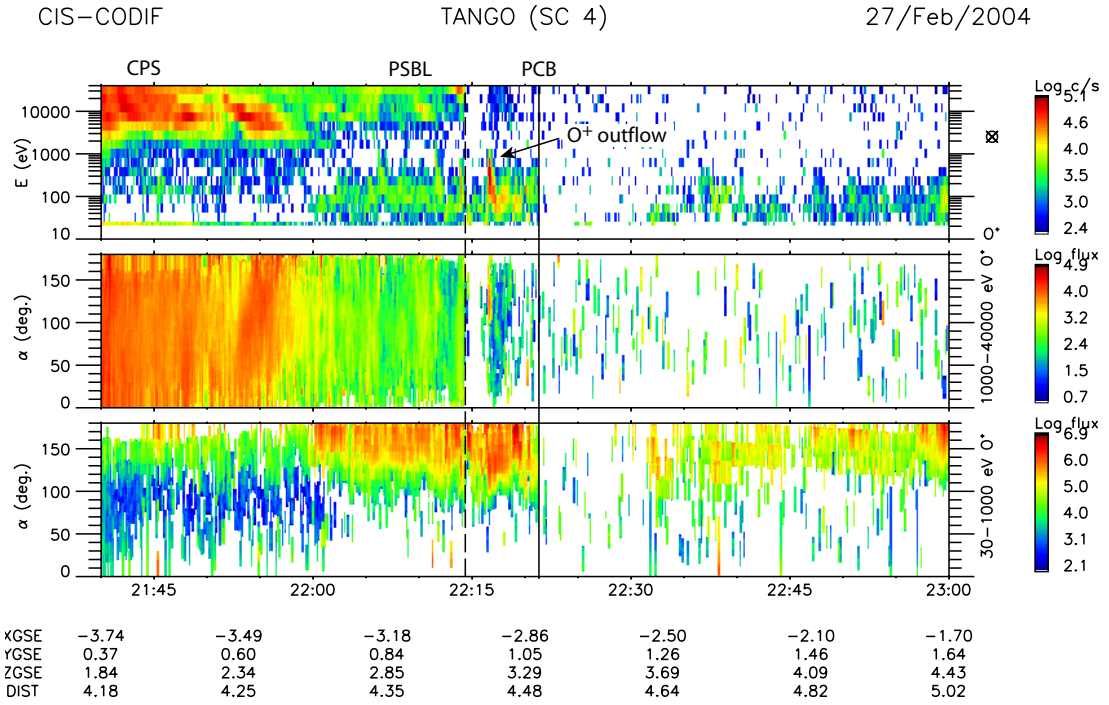


Figure 4.6. Spectrogram of O+ ions (in counts per sec) observed by the Cluster-4 CIS instrument (top), pitch angle distribution of the upper energy population (1 – 40 keV) (middle) and of the lower energy population (30 eV – 1 keV) (bottom). Low-energy O+ ions are flowing away from the ionosphere (180° pitch angle in bottom panel). Cluster-4 satellite is at the distance of about 4.5 Earth radii.

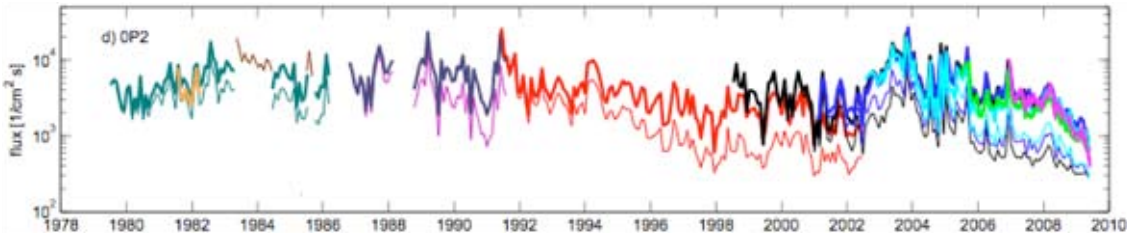


Figure 4.7. Calibrated (thick lines) and uncalibrated (thin lines) fluxes of protons above 80 keV (P2 channel) of NOAA/POES MEPED instrument's 0-detector. Calibration raises fluxes and unifies measurements from the different satellites. Fluxes have reduced to an exceptionally low level in recent years.

are a consequence of longitudinally localized magnetic flux closure in the Earth's magnetotail, lasting for 5-12 min.

An extensive study of the radiation damage to the MEPED energetic particle instruments onboard NOAA/POES satellites was conducted. The study involved the entire energetic particle dataset spanning from 1978 to 2010 from all the 13 POES satellites. The level of damage was quantified by assessing how much the energy thresholds of the instruments have increased. The corresponding calibration factors were produced and the entire dataset was calibrated. Calibration greatly improved the coherence and continuity between the measurements from different satellites. The calibrated fluxes were found to be exceptionally low since 2008, reflecting the uniquely low solar minimum.

SPG is participating in the EU FP7 Collaborative project called SOTERIA (Solar–Terrestrial Investigations and Archives). SPG develops a corrected and enlarged version of the magnetic Dst index, the measure of the ring current intensity. We have shown that the contributions of the four stations used in the Dst index are systematically different. This was corrected in the new Dcx index. A data server is under construction to serve the global Dcx index as well as the local indices for an enlarged network of stations. SPG has also studied the effect of other magnetospheric currents, in particular the magnetopause current and tail current, to the Dcx index. Using the NOAA/POES observations to estimate the intensity of the tail current we were able to separate the contributions of ring current, tail current and magnetopause current to the Dcx index for all storms in several years.

SPG has used EISCAT radar observations during a nearly continuous one-month interval in a statistical study of ionospheric Joule heating, which was found to have clear evening and morning maxima and a local minimum near the Harang discontinuity region in the pre-midnight sector. It was found that the response of conductances to increased magnetic activity is stronger in the morning sector than in the evening. In the midnight and evening sectors, a statistical anticorrelation between electric field and conductance was found so that intense electric fields were associated with low conductances, as expected for the return current regions adjacent to auroral arcs as a result of ionosphere–magnetosphere coupling.

SGO has installed recording systems of raw data on EISCAT mainland radars. These systems record voltage samples of the transmitted and received signals, from which the scattering spectra at different altitudes are solved by means of statistical inversion. The data can be analysed with almost arbitrary height and time resolution, which has allowed, e.g., to study Polar Mesospheric Winter Echoes (PMWE) at optimal resolution in height and time. Statistical inversion-based analysis has also allowed completely new transmission modulations, so-called multi-purpose experiments, to be developed, which provide truly

Figure 4.8. An unfocused delay-Doppler image of the Lunar surface obtained with the EISCAT UHF system. The range resolution is approximately 600 m. Because the image is unfocused, Doppler smearing can be seen on the edges.

simultaneous measurements of all height regions of the ionosphere. In addition to incoherent scatter analysis, the voltage data has been used for other purposes. A feasibility study of Lunar radar mapping was completed using the EISCAT UHF system. The conclusion of this study is that such mapping is possible, although a better clock would increase sensitivity.

SGO has observed space debris and meteors. Both dedicated and piggy-back measurements of the current space debris situation have been performed. These measurements are currently being used to calibrate the ESA MASTER model. The sensitivity of meteor head echo measurements has been improved, and significantly more meteors are now detected than previously. Such an analysis can also be used in piggy-back mode for routine ionospheric measurements, allowing a secondary analysis of meteor head echoes from EISCAT common programs.

4.2. Solar system research

Finnish Meteorological Institute (FMI)

FMI has been actively involved in the analysis of plasma observations from the ESA Venus Express and Mars Express missions. The focus of the research is on interpretation of in situ plasma and magnetic field observations from Venus using a hybrid simulation model adapted to Venus (HYB-Venus) and plasma observations from Mars using a hybrid model adapted to Mars (HYB-Mars). The HYB models belong to a global modelling platform developed at FMI during the last ten years. In addition the platform is being used in studies of several solar system objects.

FMI participates in several investigations of the ESA Rosetta mission currently on its way to come Churyumov–Gerasimenko. The configuration of the flight software of the mass-spectrometer COSIMA onboard Rosetta, originally developed at FMI, was configured

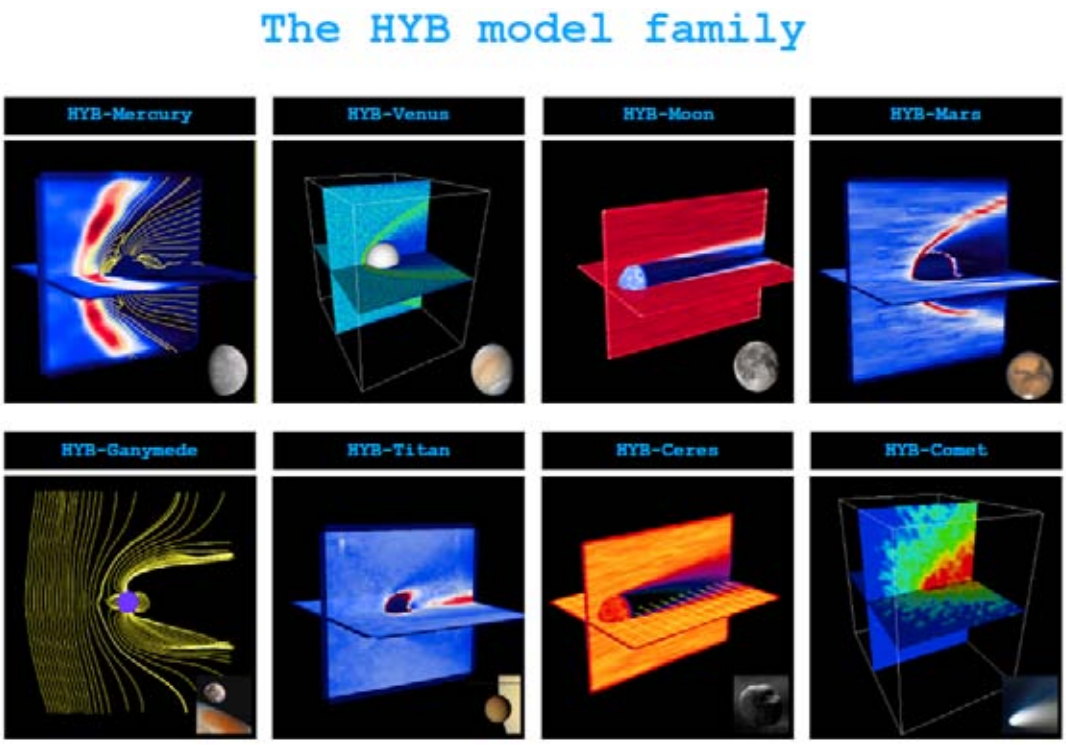


Figure 4.9. FMI has developed a HYB plasma model platform to study various plasma environments in the solar system and beyond: (top, from left to right) Mercury, Venus, the Moon, Mars (bottom. From left to right) Jupiter's moon Ganymede, Saturn's moon Titan, asteroid Ceres and a comet.

in autumn 2009 for the July 2010 fly-by of the asteroid Lutetia and for the operations at the comet in 2014. The Rosetta plasma instruments ICA and LAP with FMI-built control electronics participated successfully in the 2009 Earth fly-by observations. FMI has also started to build a global modeling tool (HYB-comet) to interpret Rosetta's forthcoming plasma observations.

FMI participates in an instrument proposed for the Jupiter Ganymede Orbiter (JGO) mission under competition for the first large-scale mission flight opportunity in ESA's Cosmic Vision 2015–2025 programme. The goals of the mission are to study Jupiter and its moons Ganymede and Callisto. FMI has developed a first model version (HYB-Ganymede) to study how the Jovian magnetospheric plasma interacts with Jupiter's moon Ganymede, the only moon in the solar system known to have a global intrinsic magnetic field. The model will be used both in basic research and in JGO instrument design.

FMI has continued exoplanet research within an international team. New observations have become available, especially, from the ESA–France Corot mission and NASA's Kepler mission. FMI's contribution in the exoplanet research has been to model how stellar wind interacts with exoplanets, especially, with their upper atmospheres. The model is another extension of the HYB model family.

FMI has extended the numerical planetary plasma simulations by developing a fully kinetic model. In the model both positively charged particles and electrons are modeled as particles and it includes electromagnetic waves. The model is developed to study plasma instablities and propagation of electromagnetic waves in a plasma, for example, at Mars generated by MARSIS instrument on Mars Express.

FMI is an active partner in EU funded Europlanet collaboration. The Europlanet Research Infrastructure is a four-year project launched in 2009 and supported by the European Union under the 7th Framework Programme. FMI participates in development IDIS (Integrated and Distributed Information Service), development of a modeling infrastructure, and in planet and exoplanet research.

Aalto University School of Science and Techonology (TKK) Metsähovi Radio Observatory

The 14-metre Metsähovi radio telescope has been used for studying the solar millimetre-wavelength activity. During 2008–2009, period of the solar minimum, the main emphasis was on using the 37 GHz frequency band and on observing solar activity maps and tracking objects on solar disk during the summer months. These data were used for studying quasi-periodic solar and differential rotation of the Sun together with data that were obtained from our collaborators (Nobeyama Radio Heliograph). Also some preliminary results at 86 GHz frequency band were obtained during 2008–2009.

In collaboration with the RATAN-600 telescope in Russia we carried a multifrequency observing campaign in September 2009. The campaign was targeted to study polar faculae. Additionally, some first sunspots of the new solar cycle were observed during this campaign.

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 quasi-periodic solar oscillations of 3–60 minutes. These data were also used to trigger observations with the 14-metre telescope as well as to alert collaborators about enhanced solar activity.

Campaigns on spacecraft observations with the Metsähovi radio telescope coordinated by

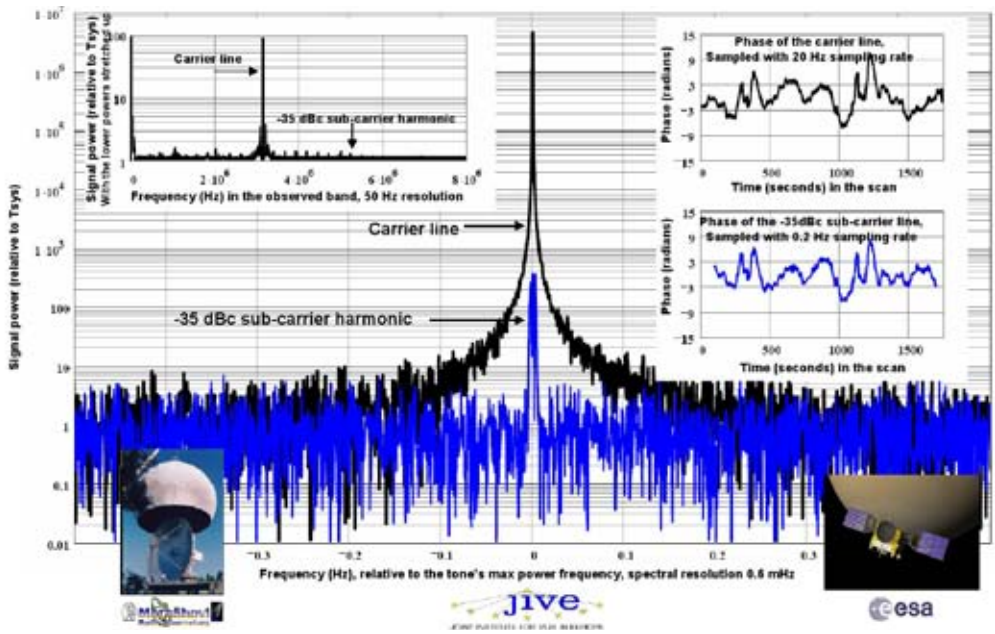


Figure 4.10. Summary plot for VEX observations with the Metsähovi telescope. The top left corner insert shows a preview spectrum with 50 Hz resolution over 8 MHz video band, with more than 40 dB dynamic range. The top right inserts show the detected phases of the carrier line and sub-carrier harmonic at the -35 dBc level. The central part of the plot shows the final spectra of the carrier line and one of sub-carriers with 0.6 milli Hz resolution and SNR of 5 million.

the JIVE institute (Joint Institute for VLBI in Europe) started in 2008 as a part of development and test activity in preparation for future involvement of European VLBI Network (EVN), Metsähovi and JIVE in planned ESA/NASA/JAXA deep space missions. The ESA Venus Express (VEX) spacecraft was first observed with the Metsähovi radio telescope at X-band in June 2008 using tools developed at Metsähovi. Successful detection of the spacecraft when it was 1.5 AU away from Earth, allows us to estimate that VEX-class transmitters can be detected by Metsähovi-class telescopes from a distance of more than 50 AU. This is a very encouraging step in preparation for EVN participation in Deep Space Gravity Theory Test missions (Pioneer-anomaly), like The Odyssey mission, proposed for the ESA Cosmic Vision program.

The ESA/NASA Ulysses spacecraft was observed simultaneous by Medicina and Metsähovi telescopes on S-band in 2008. Two hours of captured data were electronically transferred from Medicina to Metsähovi for high performance processing, while intermediate data were sent from Metsähovi to JIVE for post-processing and analysis. At the time of observations Ulysses was 4.5 AU away from Earth, and its signal power was a factor of more than 1000 weaker than that from Venus Express.

The presence of water has long been seen as a key condition for life in planetary environments. The Cassini spacecraft discovered water vapour in the Saturnian system by detecting absorption of UV emission from a background star. Investigating other possible manifestations of water is essential, one of which, provided physical conditions are suitable, is maser emission. We searched for water maser emission in the Saturnian system in an observing campaign using the Metsähovi and Medicina radio telescopes. Spectral data were Doppler-corrected over orbital phase for the Saturnian satellites,

yielding detections of water maser emission associated with the moons Hyperion, Titan, Enceladus, and Atlas.

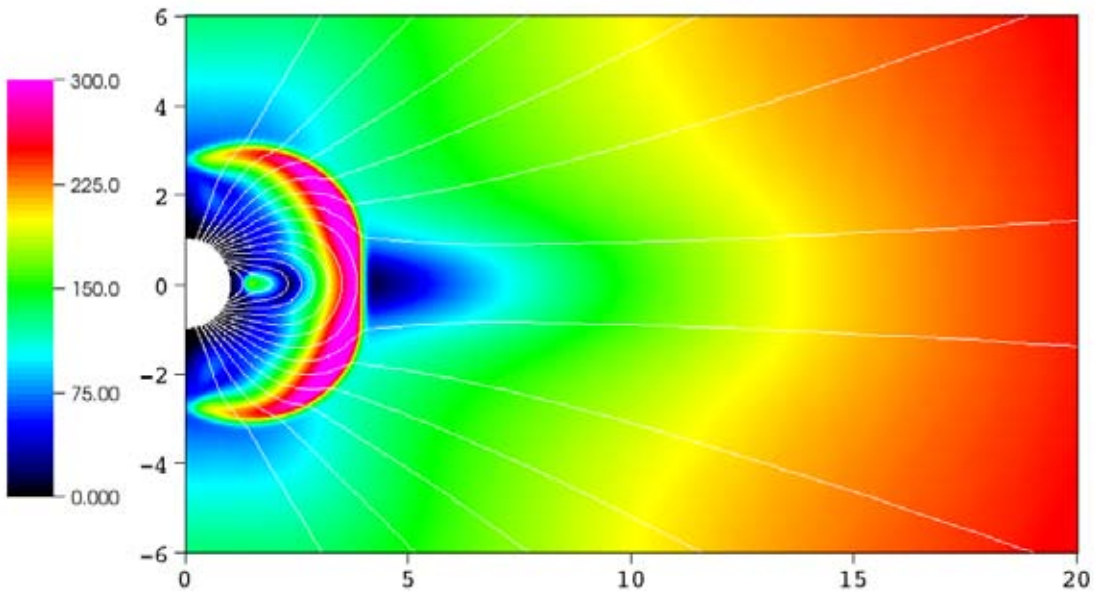


Figure 4.11. Snapshot from a MHD simulation of a coronal mass ejection propagating in a corona mimicking solar minimum conditions. The image depicts the speed of the plasma in units of kilometers per second together with magnetic field lines drawn as white lines. The shock driven by the eruption is clearly visible.

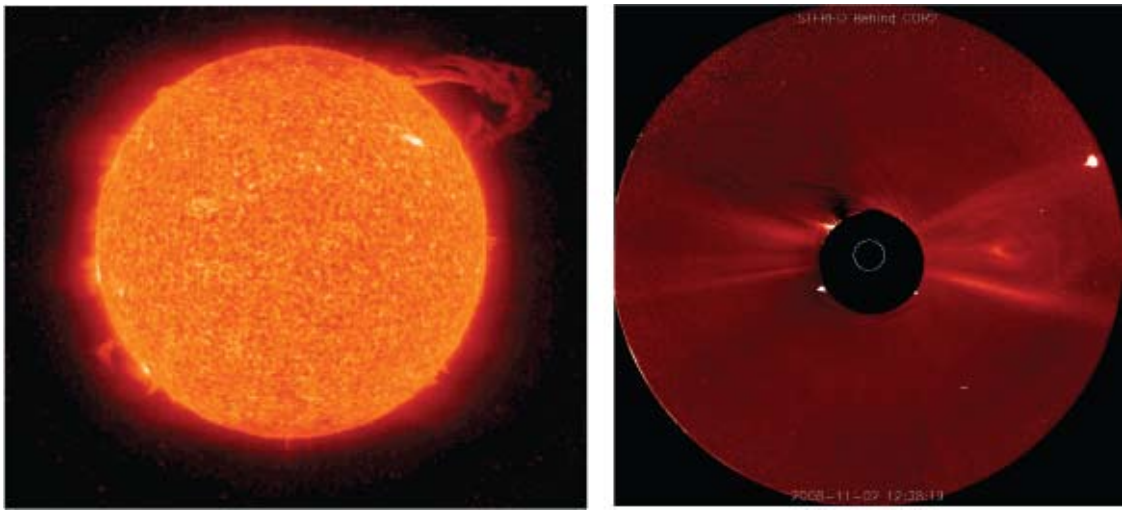


Figure 4.12. Left: STEREO B/SECCHI/EIT image captured the eruption of a huge polar crown filament on 2 November, 2008. The prominence originated from a high-latitude source region. Right: The outer coronagraph of STEREO B/SECCHI shows that the CME associated with the prominence eruption was quickly deflected to the ecliptic plane. STEREO A spacecraft, 90 degrees away from STEREO B, detected in-situ counterpart of this CME four days later.

University of Helsinki
Department of Physics

Solar, interplanetary and planetary shock physics is one of the main topics of research of the UH space physics group. In 2008–2009, the work concentrated on computer simulations simulations of coronal shock waves launched during the lift-off of fast coronal mass ejections, which are responsible for example for large solar energetic particle events filling the heliosphere with charged-particle radiation. The group has adopted a multi-physics approach to the simulation studies, employing magnetohydrodynamic simulations to study the thermal plasma evolution during the eruptions as well as test-particle simulations modelling the acceleration and propagation of ions in the erupting solar electromagnetic fields. Results of these simulation studies have established that coronal shock waves can indeed explain the observational characteristics of the large energetic particle events including those that lead to the ground-level enhancements of cosmic rays, requiring particle acceleration up to relativistic energies.

The characteristics of coronal mass ejections (CMEs) and the structure of the solar wind has been studied taking advantage of the multi-spacecraft measurements provided by the NASA STEREO twin observatory that was launched in October 2006. Multipoint solar and in situ observations enable connecting solar and in situ CME observations in an effective way. For example, observations by two STEREO spacecraft when they were separated by almost 90 degrees allowed following a deflection of a high latitude polar crown filament and its consequences in the interplanetary medium. Observations from multiple well-separated vantage points have demonstrated that even at the time of deep solar minimum CME related material comprises a significant fraction of the slow solar wind. White-light coronagraph images have revealed a continuous outflow of small blobs from the tips of the helmet streamer. The interplanetary counterparts of these streamer blobs have been identified and their characteristics can help to understand the formation of the slow solar wind component.

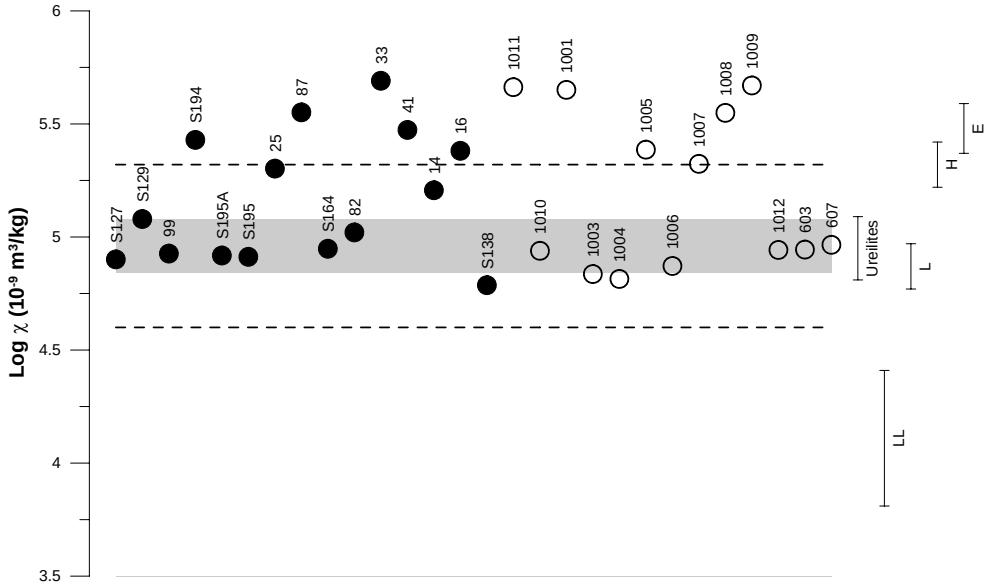


Figure 4.13. Magnetic susceptibility of Almahata Sitta meteorites compared to average of different meteorite types from our database. Magnetic susceptibility reveals presence of anomalous compositions (some of them are confirmed to be H and E chondrites) mixed together with ureilites in the asteroid 2008 TC3.

The group also participates in the design and testing of the Solar Intensity X-ray and particle Spectrometer (SIXS) built under the leadership of UH for ESA's BepiColombo mission (see solar system research at the University of Helsinki Observatory below). The group is responsible for the definition and monitoring of the scientific performance of the particle detector of the instrument. In addition, simulation studies of charged-particle propagation inside the Hermean magnetosphere have been conducted to reveal the most interesting regions of precipitation of energetic particles originating at the Sun and in the magnetospheric particle acceleration processes.

The UH space physics group is also involved in the studies of the solar wind interaction with within the ESA Mars Express, Venus express and Rosetta missions reported above in the section describing these activities at FMI. During 2009–2013 the International Steering Committee of the Rosetta Lander Philae is being chaired by the UH.

The Rosetta mission will also have an important role in the studies of Solid Earth Geophysics group in their studies of magnetic properties of extraterrestrial materials. Because iron, chromium and manganese bearing sulfides have been reported to be abundant in interplanetary dust particles (IDP's) and in cometary dust, an extensive magnetic properties study of these sulfides at low temperatures was done and the results were used to model magnetic properties of cometary body. Results indicate that besides FeNi alloys mainly daubreelite and monoclinic pyrrhotite with its strong induced and remanent magnetizations may be a significant magnetic mineral in cold environment. Modelling revealed that interactions of a comet with interplanetary magnetic fields will result in weak, but detectable signal.

On October 6, 2008 a small asteroid called 2008 TC3 was discovered in space 20 hours prior to its impact on Earth. This was the first Near Earth Object (NEO) asteroid that was detected in space before its encounter with the Earth and subsequently meteorite fragments (named Almahata Sitta) were collected from the impact site in Sudan. Most recovered Almahata Sitta meteorites are polymict ureilites

– highly differentiated mantle rocks. However, magnetic susceptibility measurements of Almahata Sitta meteorites performed in-situ in Sudan and compared to our database revealed presence of high number of compositionally anomalous various chondritic types mixed within recovered ureilites. This was independently confirmed by mineralogical analysis. The physical properties investigations determined micro-porosity of the Almahata Sitta material around 10%. The porosity estimates of the whole 2008 TC3 asteroid predict significant additional macro-porosity within the asteroid. The high porosity, low mechanical strength and diverse composition reveal true rubble pile structure of the 2008 TC3. While low density fragmented rubble piles are common, this is for the first time when such also compositionally diverse rubble pile asteroid was observed.

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. We have continued to investigate these shocked magnetite pellets in co-operation with the Humbold University and University of Münster in order to model the shock event with numerical hydrocodes. The results show that the role of porosity is vital in the modelling. A new project was initiated in 2009 where the target rocks from the Vredefort and Jänisjärvi impact structures were artificially "shocked" using explosive methods in the facilities provided by the FORCIT Explosives.

Microscopic observations on petrographic thin sections from the in-situ shatter cones of the Keurusselkä meteorite impact structure continued in 2009 in co-operation with the University of Western Ontario. The discoveries of planar fractures (PFs) as well as planar deformation features (PDFs) in quartz and feldspar grains, and their shock indicative histograms prove the impact origin of the Keurusselkä structure and also solve the long continued debate of whether the shatter cone-like features are tectonic or extraterrestrial. Keurusselkä is undoubtedly the 11th proven meteorite impact structure in Finland.

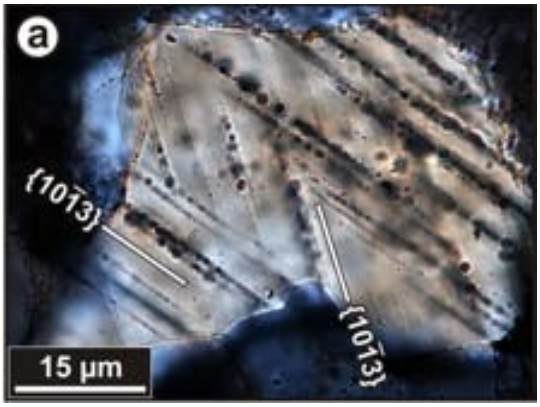


Figure 4.14. Photomicrographs showing quartz grain (sample VN3) containing decorated PDF sets with ω{10$\bar{1}$3} equivalent orientations.

The paleomagnetic dating of the Keurusselkä impact structure was one of the main research objects in 2009. Preliminary paleomagnetic data reveal several remanence components in the rocks within the structure. One of the components is probably the characteristic remanent magnetization (ChRM) and reveals an age of ca. 1150 Ma which is strikingly similar to the recently obtained direction of the Salla diabase dyke (1120 Ma), thus suggesting a late Mesoproterozoic age for this impact event.

Asteroid and meteorite reflectance spectra can be used to establish links between them. It may then be possible to infer physical properties from looking at meteorite reflectance spectra. The grouping of ordinary chondrite and achondrite meteorites is evident using physical properties together with spectral features. The correlation between the meteorite types is complicated however due to shock effects during the impact event. Magnetic sus-

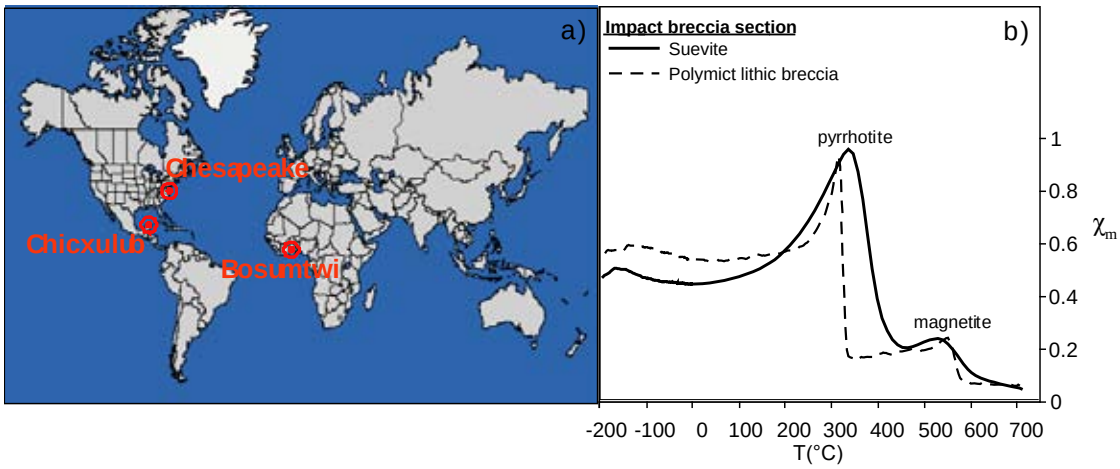


Figure 4.15. (a) ICDP drilling sites. (b). The magnetic susceptibility versus temperature for impactites.

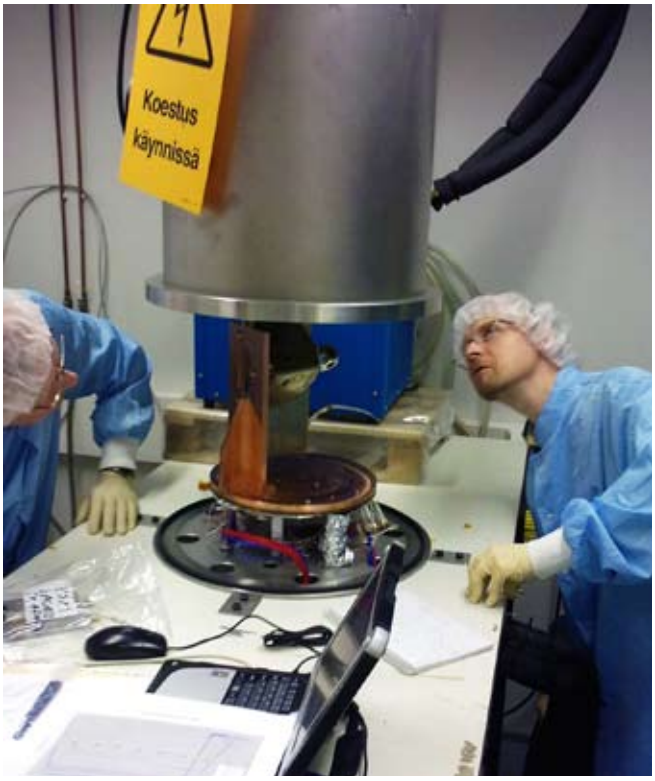
ceptibility was found to be also correlated to spectral features such as the band area. PCA analysis of spectral features has demonstrated reflectance spectra as a possible non-destructive tool for classifying meteorites being able to distinguish the main groups of meteorites from each other.

Majority of meteorite impact structures are not exposed and subsurface information is only available from geophysical surveys and deep drill holes. Thus, the scientific deep drilling is essential for providing ground truth data of the subsurface properties of important structures. The group of Solid Earth Geophysics is investigating the physical properties of samples from three deep drillings through large impact structures: (i) Chicxulub (Mexico), (ii) Bosumtwi (Ghana) and (iii) Chesapeake (USA).

During the past years the petrophysical as well as of rock-magnetic and paleomagnetic properties were carried out. Results of Bosumtwi studies revealed distinct lithological patterns but no depth dependence. Magnetic data indicated that magnetic parameters are related to inhomogeneously distributed ferrimagnetic pyrrhotite. In 2009, the results of Chesapeake drilling were published. Those results indicate a complex behavior of physical properties of the lithologies due to shock-induced changes. The data suggest that pyrrhotite and magnetite carry the magnetic properties in most of the core samples and are strongly fractured or show brittle deformation, thus provide an extraordinary opportunity to study the effect of impact on these two main magnetic minerals creating crustal magnetic anomalies.

University of Helsinki Observatory (UHO)

The Solar system research at the University of Helsinki Observatory included studies of the Sun and the planetary system. These two lines are also strongly linked in the X-ray-instrument suite MIXS/SIXS that is under development for the ESA BepiColombo mission to be launched to Mercury in 2014. The SIXS instrument led by the University of Helsinki measures the primary X-ray signal from solar flares and MIXS instrument led by the University of Leicester measures the X-ray fluorescence from Mercury to determine the elemental composition of the planetary surface. As the planet also emits solar particle induced X-rays, SIXS contains a small particle instrument. MIXS/SIXS is presently the biggest Finnish contribution to the ESA Science Programme and involves also scientists



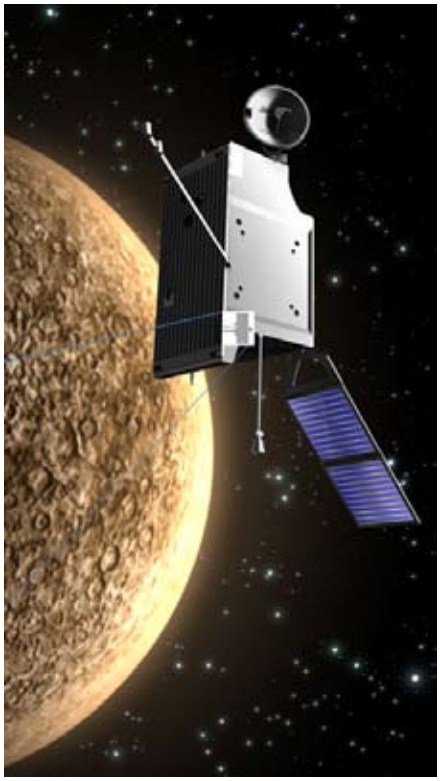


Figure 4.16. The Oxford Instrument Analytical OY engineers prepare the SIXS Sensor Unit for a laboratory test at VTT (Photo: VTT) . A structrural and thermal model as well as an engineering model will be delivered to ESA for spacecraft level tests in autumn, 2010 (drawing: ESA).

from the Finnish Meteorological Institute and a large industrial consortium. Similar solar X-ray (XSM) instruments were earlier provided for two Lunar missions SMART-1 of ESA and Chandrayaan-1 of India, the latter of which was launched in October 2008 and operated until August 2009.

In addition to contributing to the studies of the Moon and Mercury the XSM and SIXS instruments are used in studies of the Sun. Our research aims at clarifying the physical mechanism of the eruptions by examining the X-ray spectra and their variations during solar flares, and by comparing different flares. The observations are supplemented by data from the U.S. RHESSI and GOES satellites. These studies are also discussed in the section of astronomy as the X-ray instrument projects are closely related to our activities in high-energy astrophysics. The same applies to the studies of solar activity and dynamo, as those are also studied in their astrophysical context.

Planetary research at UHO was strengthened with a new professorship in planetary astronomy and geodesy funded jointly by the University and the Finnish Geodetic Institute. The research entails theoretical, observational, and experimental studies on key topics of solar-system exploration. In fundamental planetary physics, 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, to assess the X-ray fluorescence by planetary-regolith analog samples, and to measure meteorite spectra in visible and near-infrared wavelength. Observations have been made using both space-

based and ground-based telescopes and orbiting spacecraft (SMART-1).

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 the research group has continued to participate in polarimetric observations of TNOs. Furthermore, the group has taken part in polarimetric observations of cometary nuclei at VLT. These observations are the first-ever systematic polarimetric observations of cometary nuclei. Among the highlights of the TNO studies was the discovery of two distinct polarimetric behaviours of transneptunian objects.

Figure 4.17. Comet 17P/Holmes

Radar-scattering computations from spherical and spheroidal particles, as well as clusters of spherical particles in the C-band using DDA have been compared to those from exact methods. Light scattering by agglomerated debris particles composed of highly absorbing material, and the applicability of DDA to conductive particles has been studied. Diffuse scatterers have been introduced to the ray-optics treatment for light scattering by particles large compared to wavelength.

In studies of orbit computation a new method was presented for the previously unsolved problem of linking scarce sets of astrometry of solar system objects over apparitions. The new method is based on statistical orbital inversion. An open-source orbit-computation package called OpenOrb was published. In addition to the well-known least-squares method, OpenOrb contains both Monte-Carlo and Markov-Chain Monte-Carlo versions of the statistical orbital ranging method based on well-established Bayesian inversion theory.

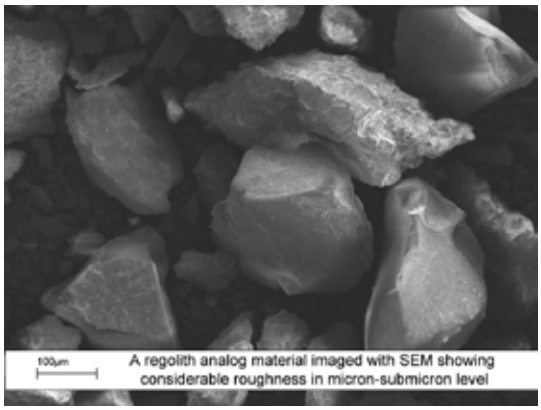


Figure 4.18. A regolith analog material imaged with scanning electron microscope.

The group contributed to the preparation of the ESA astrometric cornerstone mission Gaia (launch in 2012): this entailed orbital-inversion software delivery to the Gaia Data Processing and Analysis Pipeline and further development of Markov-Chain Monte Carlo methods for inversion of forthcoming Gaia photometry for asteroid spin and shape characteristics. The group also participated in the assessment study of the Marco Polo near-Earth-object sample return mission within the ESA Cosmic Vision Programme.

Laboratory measurements of the effect of the physical properties of the planetary regolith on soft X-ray fluorescence spectroscopy were performed both at the University of Helsinki (in collaboration with the Department of Physics) and at the University of Leicester

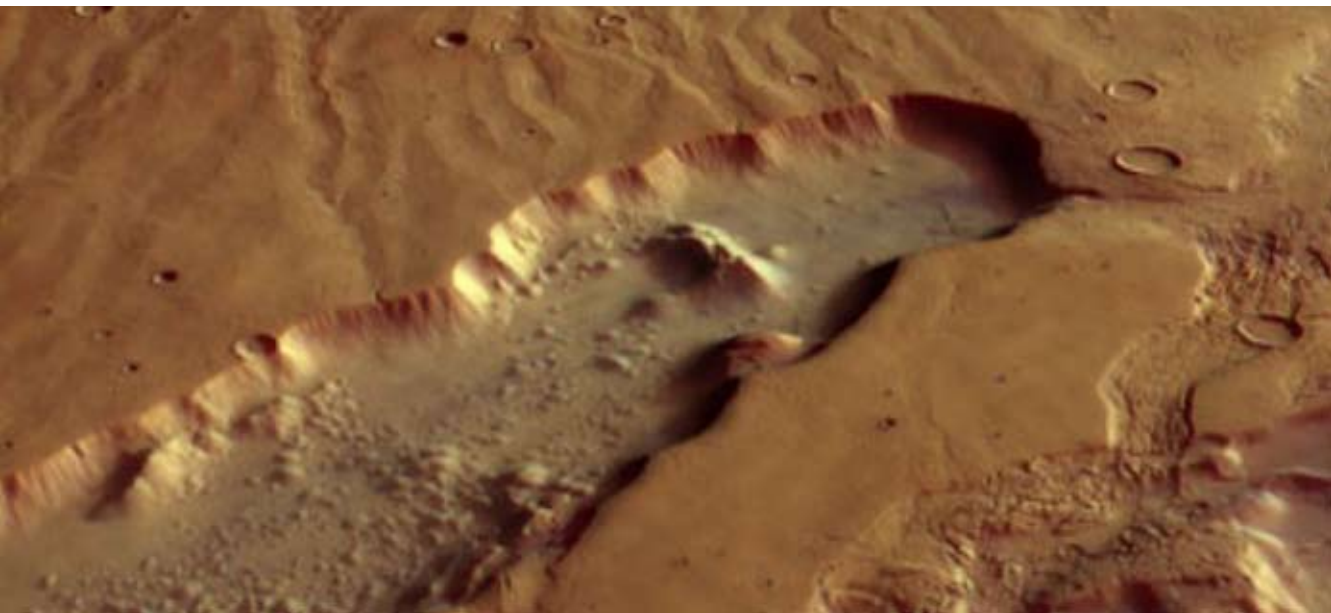
(UK) Space Research Centre. A hardening of the fluorescent spectrum was observed for our simulated regolith sample that is a function of growing phase angle. The hardening is also larger for rougher surfaces. Understanding this effect will be important for the analyses of present and future X-ray spectrometer data from orbiting platforms (e.g., BepiColombo at Mercury and Chandrayaan-1 at Moon).

University of Oulu
Department of Physics
Division of Astronomy

The Solar System research of the Planetology Group of University of Oulu is based on the still-cumulating planetary data provided by ESA and NASA missions. The group has studied the Moon, Mars and Venus. The studies on the Martian and Venusian geology provide straightforward clues to the evolution of the Earth and other terrestrial bodies. We have also incorporated comparative observations, space-borne measurements and planetary image studies when making research on the effects of impact events on the planets. A part of the studies are connected to the development and importance of target bedrock properties in the final impact crater formation. This has been added with geochemical analyses of meteorite matter and cosmic spheres found to be mixed in impactite rocks and be part of the samples collected from glaciers of Severnaya Zemlya and from the peat of the Tungushka area, respectively.

Our recent research on hot, high-pressure Venusian surface environment and geology has concentrated on the landing site selection for the European Venus Explorer (EVE) mission proposed to ESA by an international team. For these studies, the group has made comparative research on Venusian geological structures and proposed the landing site candidates for the new Venus mission. We have made a well-defined selection of future landing sites on Venus and defined the landing site characteristics required for the successful landing and lander operations. The Venus Express VIRTIS data, supported by the Magellan ra-

Figure 4.19. The Mars Express HRSC image of Dao Vallis (upper channel) which begins from a source depression that is located close to the Hadriaca Patera volcano on the NE rim of the Hellas Basin. The channel runs to the SW direction parallel to Niger Vallis (lower channel). There are a few tributary channels connecting Niger Vallis to the much deeper channel of Dao Vallis. The ancient water flow was disturbed by cataracts where the water was broken white by water falls, islets and boulders on the channel floor. ESA/DLR/FU Berlin/G.Neukum



dar images, provides important information for the Venusian research and helps to correlate the geology mapped from the Magellan high-resolution images with the thermal data that reveals possible endogenic activity.

Mars makes an excellent case to study climate phases and occasional dry and wet periods on an Earth-like planet. The high-resolution, color and 3D images of the High Resolution Stereo Color (HRSC) camera of the Mars Express spacecraft have been used for research on Martian geo-environment and climate-change-related geologic formations in close co-work with the Mars Express HRSC Co-I Team. The group has also utilized the MRO-CTX data and the extremely high-resolution HiRISE images.

The Planetology Group has studied ice-cumulating periods in the history of the Hellas basin. The most recent ice accumulation has resulted in debris aprons, viscous flows and braided on-surface channels. There are also a few flat-topped mesas with alternating layers of ice and dust/pyroclastics that were largely eroded to carve smallish flow channels. Older massive ice deposits were accumulated and covered episodically by lava flows and pyroclastic deposits originating from eruptions of the two large near-by volcanoes. Major flow channels that begin from chaotic areas were formed when subsurface ice melted and released water. The deepest chaos locations indicate the deepest icy horizons and the oldest ice accumulation phases, while the shallower chaos depressions correspond to higher ice layers accumulated later during or between the volcanic events. The very oldest ice-related phase consisted of a massive erosion of the whole east rim of Hellas It also carved the

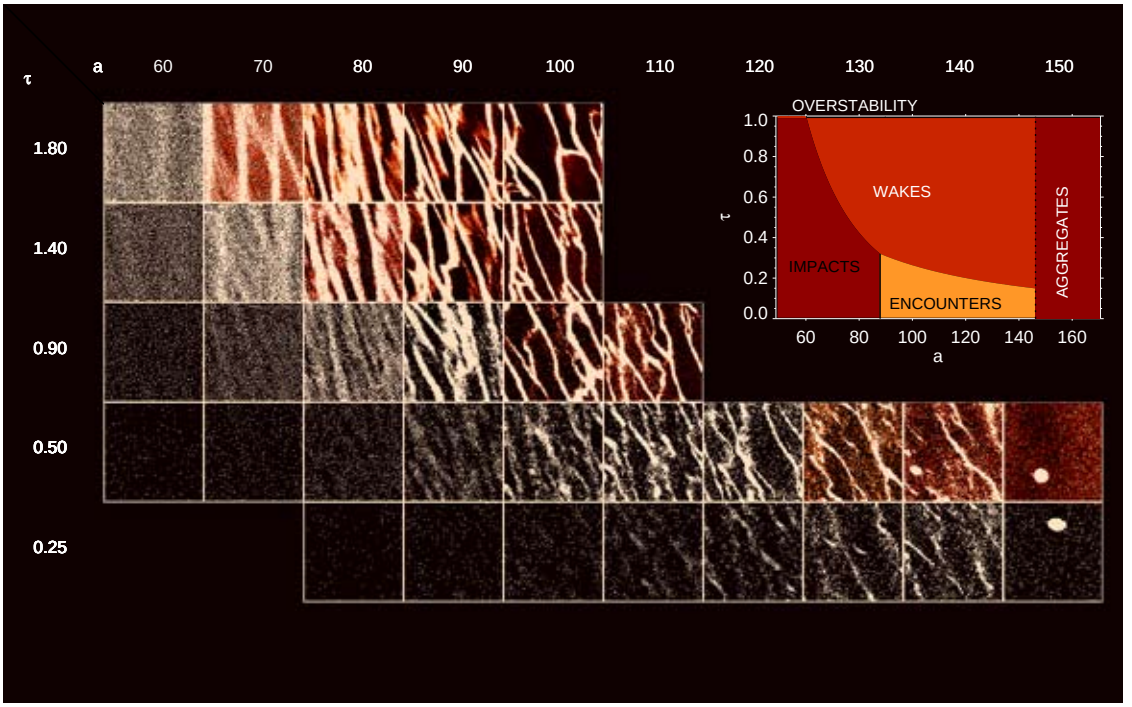


Figure 4.20 Examples of self-gravitating simulation surveys conducted in Oulu. Snapshots from simulations for different Saturnocentric distances a and optical depths τ are shown. Identical particles with solid ice internal density are assumed, and the coefficient of restitution ε=0.5. The insert shows schematically the dynamical regimes where physical impacts, pairwise gravity, and collective gravity dominate. Note also the regime in the upper left (high density and weak self-gravity) where inclined self-gravity wakes are superposed on axisymmetric overstable oscillations.

Hesperia basin that was subsequently filled with ice and covered by lavas.

The group has also studied terrestrial impact craters and made field work and sampling on impact craters as well as impactite sample research and studies on impact processes. Our studies on planetary impact craters have revealed the important result that certain morphometric characteristics of impact craters depend on the target bedrock properties. Impact craters can thus be utilized to find the importance of tectonic faults and other structural units in the bedrock even if covered by lavas or regolith.

The group has continued studies on cosmic spherules found from certain terrestrial glaciers. Following our discovery of cosmic spherules from the icy pools of northern Severnaya Zemlya we have both deepened and widened our approach. The second field season on Severnaya Zemlya provided new cosmic samples that have provided several previously unknown types of undeformed and unmelted cosmic spherules. Each of these tiny samples can be considered as a new micrometeorite. This experience was utilized when studying samples collected from the cosmic Tunguska explosion (CTE) area in Siberia.

The Dynamics Group has continued the dynamical and photometric analysis of Saturn's dense rings. For example, we have conducted N-body surveys of the self-gravity wake structures at various distances and optical depths, currently utilized in the theoretical interpretation of Cassini observations. We have also suggested a novel type of size-dependent selective viscous instability mechanism, which in principle allows bimodal density variations between adjacent high-density regions. Our future studies will address the possible role of both viscous instabilities and overstabilities in explaining the A and B ring structures.

University of Oulu Department of Physics and Sodankylä Geophysical Observatory

SGO maintains 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 used both for scientific and educational purposes, as well as for monitoring the radiation environment of the crew members of commercial jets. In 2008 the Oulu cosmic ray station joined, within the framework of an EU FP7 Infrastructure project, a pan-European database server for cosmic ray data (**http://www.nmdb.eu**), which combines 12 cosmic ray stations. A scintillator muon experiment, operated jointly with the CUPP (Centre for Underground Physics in Pyhäsalmi) project since 2000, has been moved to Oulu in 2009.

The SGO model of cosmic ray induced ionization (CRII) of the atmosphere has been compared to other models and directly measured fragmentary data. The model has been shown to correctly (within 10% accuracy) simulate the ionization rate in the lower-middle atmosphere in a wide range of parameters. This CRII model has been applied in many studies by the research community worldwide. SGO has developed a method to trace atmospheric dynamics using the short-living cosmogenic 7Be isotope. It has been shown that a General Circulation Model of atmospheric dynamics correctly reproduce the observed data of 7Be concentrations in near-surface air at the time scale of longer than a week.

SPG and SGO have continued collaborative studies of long-term solar activity. We showed that, contrary to recent claims, the geomagnetic declination data do not imply that the early (mid to late 19th century) Zurich sunspot numbers should be significantly corrected. This is because the relation of these data with solar activity is strongly seasonally dependent, which makes their annual averages rather unreliable proxies of solar activity in early times. We used the newly recovered

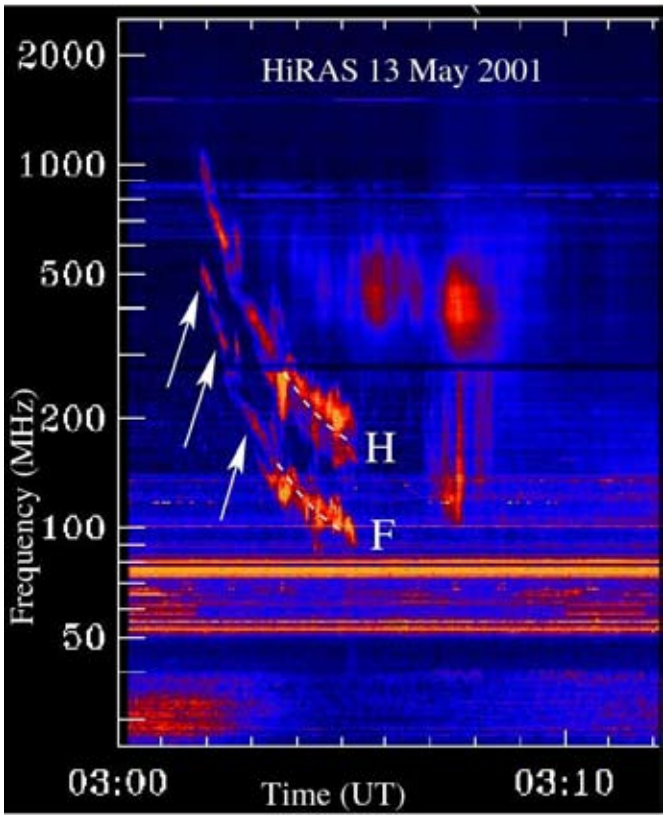


Figure 4.21. Radio emission created by a shock wave that propagates in the solar atmosphere. The curved and fragmented emission lanes, visible in the dynamic spectrum from Hiraiso Solar Observatory (Japan), reveal the passage of the shock through high-density active region loops. Radio emission is formed at the fundamental plasma frequency (F) and its harmonic (H).

solar drawings to construct the solar butterfly diagram in the 1790s. We found a sudden, systematic occurrence of sunspots at high solar latitudes in 1793–1796, proving that a new cycle, which was lost in the Zurich sunspot series, started in 1793. This confirms the existence of the lost cycle and resolves an old mystery. The reconstruction on long-term solar activity made by SGO earlier has been analyzed in terms of solar dynamo models in cooperation with the University of Manchester and University of Moscow. It has been shown that the standard solar dynamo model with an essential stochastic component is able to explain the occurrence rate of Grand minima of solar activity in the multi-millennial time scale.

University of Turku
Department of Physics and Astronomy
Tuorla Observatory and Space Research Laboratory (SRL)

Tuorla researchers participate in the EU 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 is achieved by maximizing the use of natural dynamics, employing sophisticated ideas and techniques from dynamical systems theory. The results

are applied to novel spacecraft architectures, such as solar sails, space tethers and formations of spacecraft. A new simple and accurate method for computing the altitude dynamics has been developed. In addition, a universal formulation of the quasi-Keplerian motion (which has an 1/r2-type extra potential term) has been formulated and applied to obtain simple approximations that include the secular perturbations in artificial satellite orbits.

Solar physics at Tuorla Observatory is directed to studies of transients like flares and coronal mass ejections (CMEs), but also solar structures are investigated. Multi-wavelength data are used for comparison, and the Tuorla researchers are especially interested in radio observations. Radio dynamic spectra and flux density data are used together with radio imaging, that are then compared to white-light, EUV, and X-ray data, obtained from solar data archives around the world. The main collaborating radio groups are from Nobeyama Radio Observatory (Japan) and Paris Observatory (France). Solar energetic particles are often detected during solar eruptions, which are being using data from the ERNE instrument of SRL. Numerical MHD studies of shock structures associated with erupting CMEs are done in collaboration with the University of Helsinki. Solar radio astronomy studies have been continued in the longstanding collaboration with the Metsähovi Radio Observatory. The main focus has been on quasiperiodic oscillations from various solar radio structures, analyzed with traditional Fourier and modern wavelet methods.

A Finnish–Australian collaboration has reached an apparently trivial result: There is nothing special about our Sun. This is an important conclusion for astrobiology, since scientists have long argued whether or not the Earth has some special characteristics that led to the evolution of life. The researchers looked at 11 properties that could plausibly be connected with life and did an analysis of these properties. It was found that the Sun's mass is the most anomalous of its properties; the Sun is more massive than 95 per cent of stars. The Sun's orbit around the centre of the galaxy is also more circular than the orbits of 93 per cent of its peers. However, when analysing the 11 properties together the Sun appears to be a random star that was blindly pulled out of the bag of all stars, rather than one selected for some life-enhancing property. This comprehensive study of the Sun with other stars thus adds weight to the idea that life could be common in the universe.

The period 2008–2009 covers the 13th and 14th year of the flight of the Solar and Heliospheric Observatory. This collaborative mission between ESA and NASA is considered to be the most significant and successful solar mission in the history of space research. The Space Research Laboratory (SRL) has had the fortunate opportunity to participate in the SOHO mission as the PI institute of ERNE, one of the twelve instruments onboard SOHO.

During 2008–2009 the activity of the Sun was very low. Only two solar energetic particle (SEP) events of any significance were observed: one at the beginning of 2008 and another one at the end of 2009. During this period solar modulation of galactic cosmic rays has steadily decreased leading correspondingly to increasing background of galactic protons and helium nuclei. Low solar activity has also provided a good opportunity to investigate anomalous cosmic rays.

The exceptionally accurate directional sensitivity of ERNE has been employed in studying the acceleration and propagation of solar energetic particles. Particle flux anisotropy data have proved to be essential in identifying particle sources and in modelling the observations. In studying the double SEP event of October 19–21, 2001, strong evidence was found that the high-energy particles were accelerated within 0.2 AU from the Sun and then temporarily confined in the interplanetary space. These observations once again call into question the common view that in all gradual

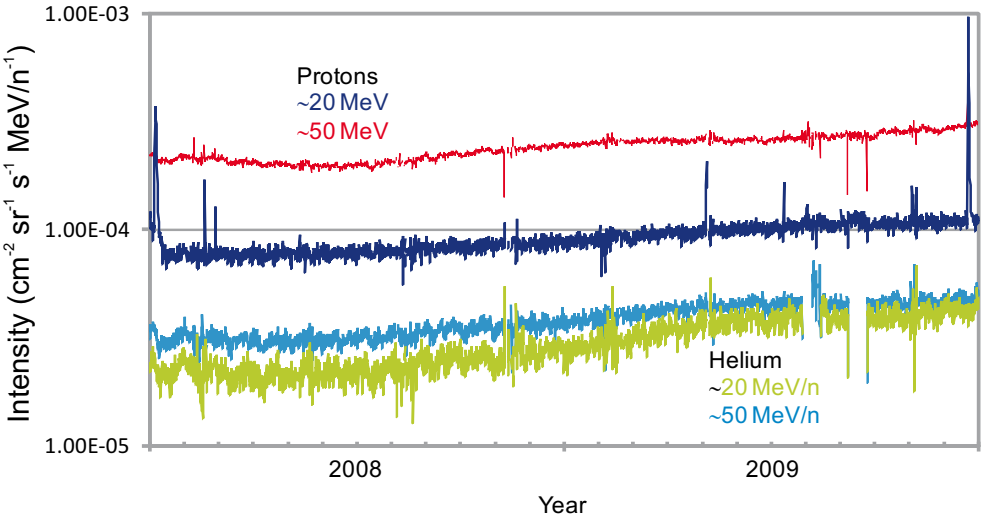


Figure 4.22. Proton and helium intensities measured by SOHO/ERNE in 2008–2009. These measurements reflect the very quiet Sun with only minor SEP events visible mainly at 20 MeV proton intensities.

events the >10 MeV protons are continuously accelerated at a CME bow shock.

A simulation model of particle acceleration in coronal shock waves has been developed. In the model particles are traced in prescribed large-scale electromagnetic fields utilizing the guiding center approximation. The particles are scattered in the turbulence according to quasi-linear theory, with the scattering amplitude directly proportional to the intensity of Alfvén waves at gyro-resonant wavenumbers. In the model the Alfvén waves responsible for the diffusive acceleration of particles are generated by the accelerated particles themselves.

SRL is the lead institute of one of the particle instruments selected for flight on ESA's Solar Orbiter mission. Although the mission is still in competition with some other Cosmic Vision missions, the instrument development has been started and the Instrument Design Status Review was successfully held in November 2009.

The Alpha Magnetic Spectrometer (AMS) is scheduled for launch on July 29, 2010, and subsequently installed on the International Space Station for a period of three years data taking. SRL has participated in the launch preparations through contribution to the AMS ground support system. As well, preparations have been carried out for the data analysis. While the primary goal of AMS is to search for anti matter and dark matter, SRL also intends to employ AMS in measurements of solar and galactic cosmic rays. AMS will provide for the first time the opportunity to directly measure solar energetic particles above 1 GeV, which by now has only been possible at ground level with very limited accuracy by using neutron monitors.

4.3. Astronomy and Cosmology

Aalto University School of Science and Technology (TKK) Metsähovi Radio Observatory

The Metsähovi group studies Active Galactic Nuclei (AGN) 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

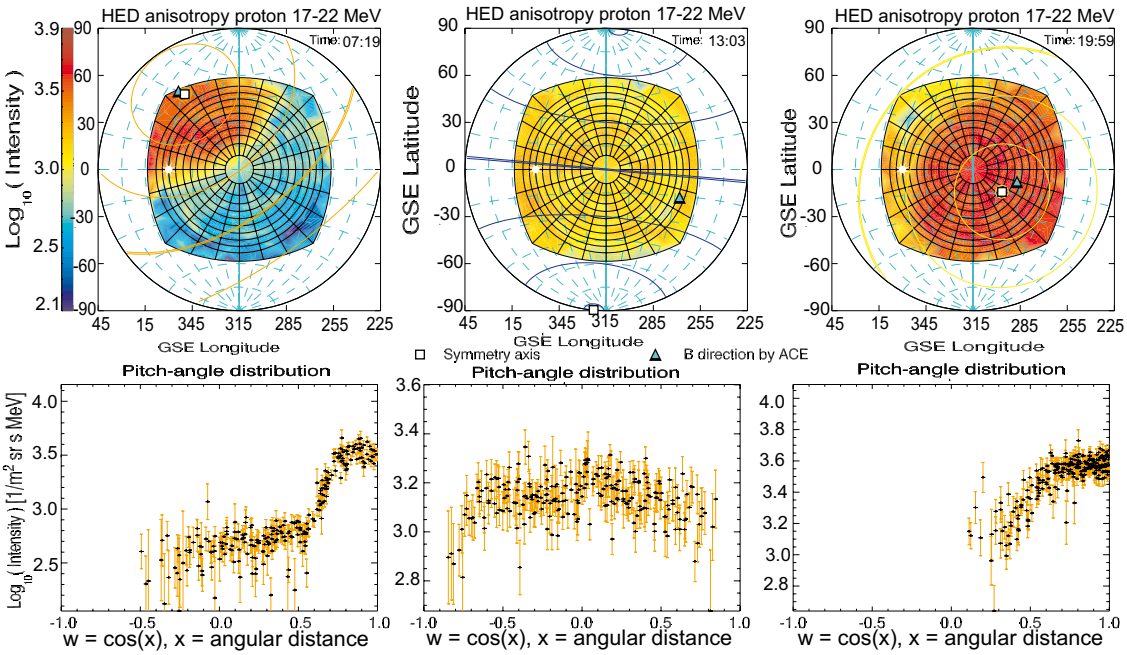


Figure 4.23. Angular distribution of 16.9–22.4 MeV protons measured by ERNE/HED and the derived pitch angle distribution (lower panels) during the October 19–21, 2001 SEP event. These anisotropy measurements were used in interpreting this complex SEP event and the results refute the current paradigm that all energetic particles in gradual events are continuously produced at CME bow shocks during their transit from the Sun to the Earth's orbit.

samples. The data are used in connection with data gathered from other instruments – including many space borne instruments – to study the activity behaviour of AGNs across the electromagnetic spectrum.

Several Metsähovi scientists are members of the Planck satellite's LFI consortium. Planck was successfully launched on May 14th, 2009. Our team actively participates in the core activities of the Planck Extragalactic Point Sources Working Group. Our main tasks just before the launch were the completion of the Planck Quick Detection System (QDS) software and its installation to the Planck LFI Data Processing Centre, as well as the construction of a pre-launch catalog of extragalactic point sources to be used during the Planck mission. We also prepared for multi-frequency support observations during the mission, by applying for observing time, or establishing Planck-related collaboration with several ground-based and satellite facilities. After the launch we coordinated the multi-frequency support observations and distributed information about the QDS alerts on flaring or otherwise interesting sources.

As part of our Planck foreground studies we have 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.

We have already shown earlier that a vast majority of the GPS sources and candidates are highly variable flat-spectrum sources that show convex spectra only during active states. And contrary to earlier assumptions, even the ones whose spectra remain somewhat convex during the various states of activity can be highly variable especially in the high-frequency domain. We studied the properties of GPS sources by using a self-organized map,

an unsupervised neural network that uses no a priori assumption of the cluster memberships. We used a sample of 206 GPS and high frequency peaker sources for this detailed study of the underlying populations of various source types. Our results confirm the contamination of GPS samples by small, beamed blazar-type sources. More than one quarter of the map is populated by variable flat-spectrum sources and variable sources that have inverted spectra only during outbursts. Sources with confirmed GPS-type spectra form various separate clusters, and it seems likely that there are diverse subpopulations of GPS sources in addition to the quasar vs. galaxy dualism that was also seen in the analysis.

From our extensive data sets of BL Lacertae Objects and flat-spectrum radio quasars we were able to study the so called “Blazar Sequence” in detail. The Blazar Sequence refers to the much debated anticorrelation between the luminosity and the frequency of the synchrotron radiation energy peak of blazars. It has been proved and disproved with samples of varying size and composition over the years. To get to the root of the problem, the Metsähovi team used the calculated Doppler factors to derive the de-boosted luminosities and synchrotron peak frequencies for a sample of 135 blazars. This revealed that the alleged blazar sequence is not viable when using the source frame values. In fact, due to the very strong correlation between the Doppler factor and the synchrotron peak frequency, the anticorrelation turns positive when only BLOs are considered.

We also continued our work on long-term variability of AGNs. Our study of long-term variability timescales using the wavelet analysis method showed that the variability behaviour of AGNs is complex and timescales in these sources change over a long time.

Based on these analyses we consider it appropriate to use wavelets when quasi-periodicities in AGNs are studied. We also used the long-term data obtained at Metsähovi at 22

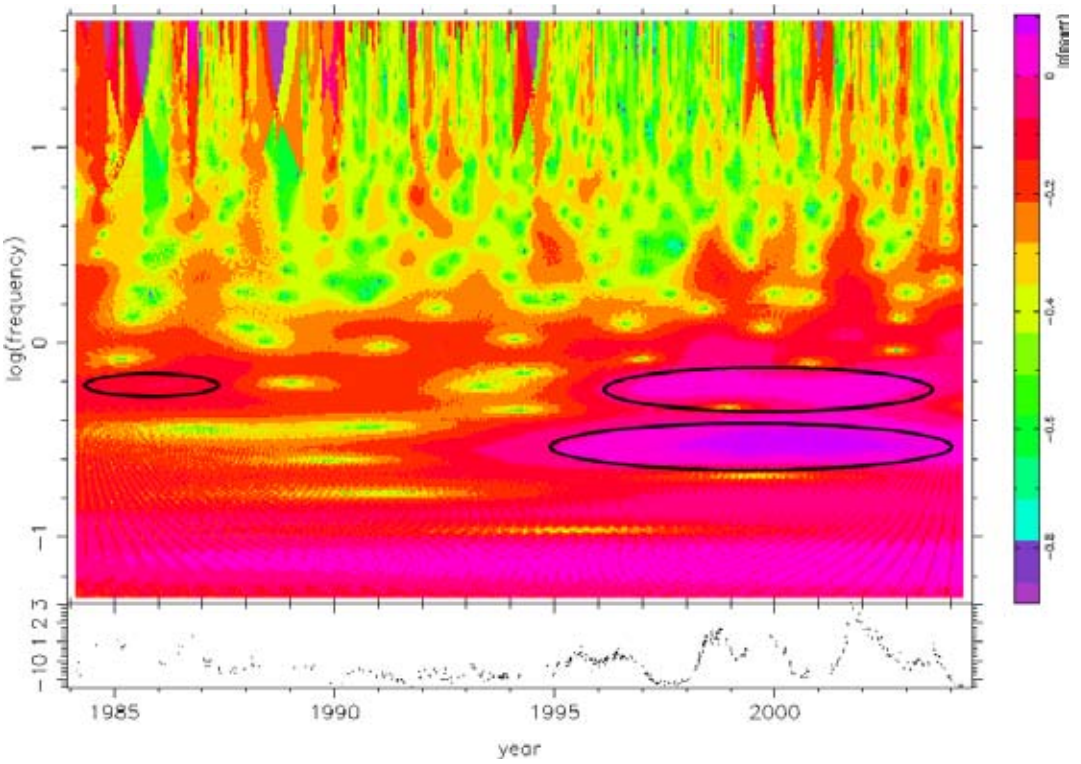


Figure 4.24: Wavelet transform of the quasar 1156+295 at 22 GHz (Hovatta et al. 2008).

and 37 GHz to calculate various jet parameters. By decomposing the flux curves into exponential flares we were able to determine the Doppler boosting factors for 87 sources. In addition, we obtained apparent speeds of the jets from the Monitoring Of Jets in Active galactic nuclei with the VLBA Experiments project. Using these values and the Doppler boosting factors, we were able to calculate the Lorentz factors and viewing angles for 67 sources. We found that Flat Spectrum Radio Quasars are more Doppler boosted and have faster jets than BL Lacertae Objects. Additionally, almost all the sources in our sample are seen at a small viewing angle of less than 20 degrees.

In collaboration with other multi-frequency observers we have 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.

Metsähovi is one of the few institutes in the world where Very Long Baseline Interferometry (VLBI) data acquisition systems are being constructed and developed further. Experience originally gained in building our own VLBA Data Acquisition Rack has enabled us to match and surpass the traditional designs of MIT Haystack Observatory. Recently our 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. Our team is also working on the digital post-processing of VLBI data.

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 are discussed in this report. 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 has participated 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 analysis pipeline.

The correction for instrumental effects in the data and possible biases in data analysis, as well as obtaining error estimates, require construction of multiple realizations of simulated data. The data analysis is then repeated on this simulated data. For this purpose the group has constructed a simulation plus map-making pipeline at the Finnish supercomputing centre CSC.

Planck was launched on May 14, 2009, and reached its final orbit around the Sun–Earth L2 point on July 3. The following calibration and performance verification phase lasted until August 12, after which Planck began to operate in survey mode. The first two weeks, during which a 15 degree wide strip of the sky was observed, constitute the First Light Survey (FLS). From this data, the group calculated the frequency maps for the three lowest Planck frequencies, 30, 44, and 70 GHz, using their map-making code at the Planck Low Frequency Instrument Data Processing Center. Preliminary analysis of the FLS data indicated that the quality of data was excellent, and FLS data will thus be considered as part of the first full-sky survey. After FLS, Planck has continued operating in survey mode, and

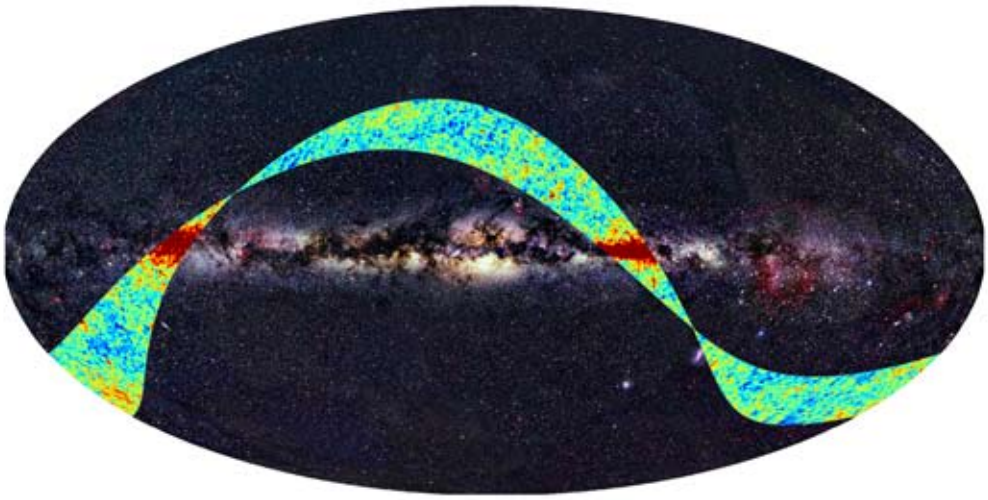


Figure 4.25. The Planck First Light Survey 70 GHz frequency map (the temperature, i.e., Stokes I, component) superimposed on an optical map of the sky. (ESA, LFI & HFI Consortia (Planck), Background image: Axel Mellinger).

at the time of writing this report it is already performing its second sky survey.

University of Helsinki Observatory (UHO)

Research in Astronomy at UHO, besides planetary astronomy reported in the previous section, had two main lines: 1) Interstellar medium, star formation and magnetic activity of stars and 2) High-energy astrophysics.

The activities of the research group of interstellar medium, star formation and magnetic activity of stars were directed to the following fields: (1) the formation of protostars in dense molecular cloud cores; (2) the properties and evolution of dust and molecular gas in interstellar clouds; (3) radiative transfer and magnetohydrodynamic (MHD) modelling of interstellar clouds and protostellar accretion discs; (4) MHD-modelling of solar and active late-type star convection and turbulent dynamos and related optical spectropolarimetric observations using inversion methods; (5) the optical and infrared extragalactic background radiation. The group uses ground-based and space-borne optical/infrared, (sub)millimetre, and radio telescopes.

In recent years the use of ESO facilities has been of growing importance. The group has successfully performed several ESO/VLT observing programs and special attention is paid to the 12-m Atacama Pathfinder Experiment (APEX) and to the Atacama Large Millimetre Array (ALMA). APEX became publicly available in 2006 and ALMA will begin its commissioning phase in 2010. During the past several years the data from ESA's Infrared Space Observatory (ISO) has been intensively exploited, often in combination with near-IR and (sub)mm data from ESO and other ground based telescopes such as the Australian Telescope Compact Array, the Effelsberg and Onsala radiotelescopes, and the Nordic Optical Telescope (NOT).

Based on its ISO experience the group has been participating in scientific studies related to ESA's Planck satellite. Among the other ESA missions the group is particularly

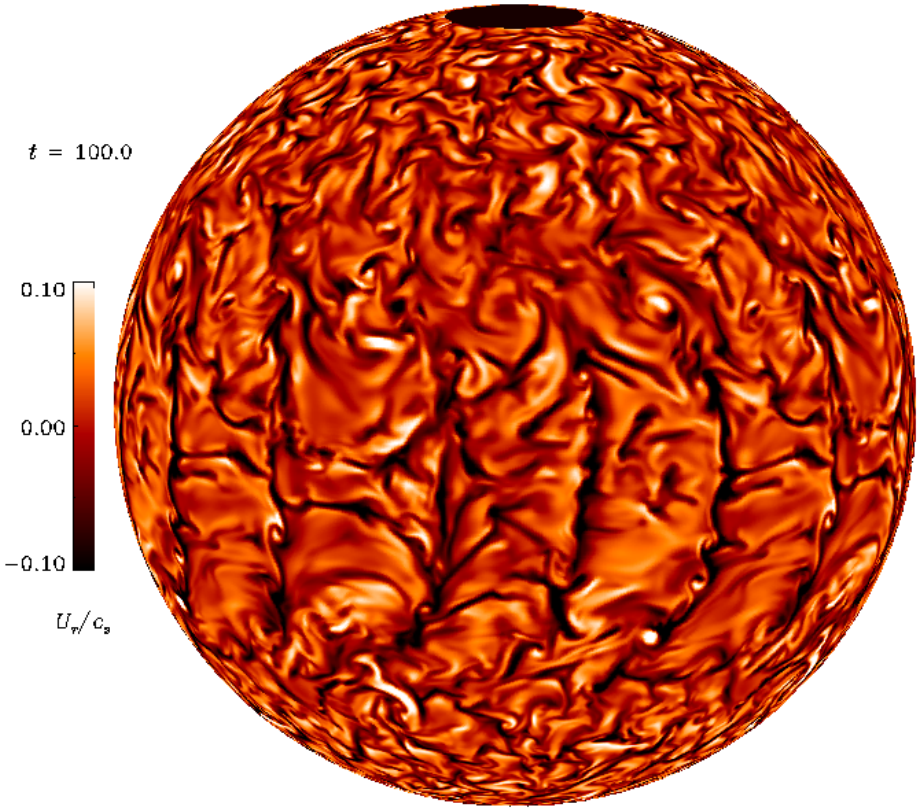


Figure 4.26. Radial velocity near the stellar surface from a convection simulation in a spherical wedge extending over the latitude range of ±80 degrees and longitude 90 degrees. The image has been replicated four times over the longitude. Such models have been used to study solar and stellar differential rotation and magnetic field generation.

well-prepared to make use of the Herschel Space Observatory launched together with Planck in 2009. Our plans also include expanding and emphasizing our theoretical research of star formation and interstellar cloud physics.

Spectropolarimetric observations of active late-type stars using the high resolution Echelle spectrograph SOFIN at NOT have continued successfully. The time series of spectroscopic observations for surface temperature maps already extend over 19 years. Simultaneous local and global MHD modelling and model development has been actively carried out, applications ranging from the solar dynamo activity to the active rapid rotators followed up by the observational programme, also including MHD turbulence in accretion disks around prestellar or protostellar cores, and molecular clouds and star-forming regions in galaxies.

We have successfully continued the investigation of the magnetic field structure, especially the polarity of the field in spots of two active longitudes, in active late-type stars (detected earlier by the group using surface temperature maps and named as ”active star Hale rule”). Spectroscopic observations were started in 1991 with the SOFIN spectrograph. The time series collected since then is one of the few most extensive and complete existing data sets to study long-term variability (cycles) in active late-type stars. An important development is the magnetic inversion based on new spectropolarimetric data with upgraded spectropolarimeter and reduction software, giving

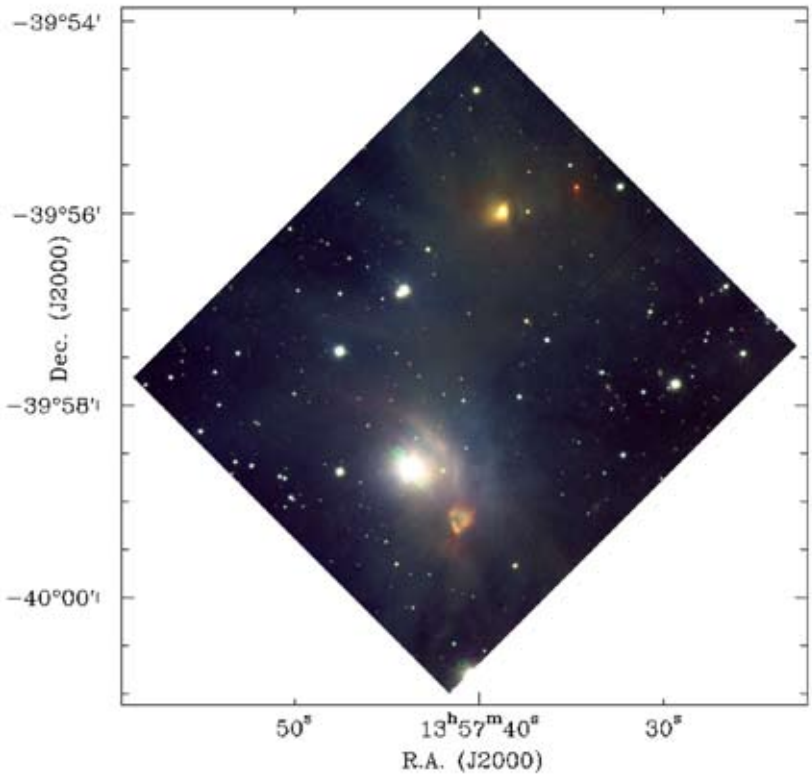


Figure 4.27. Colour coded SOFI image of CG 12. The J, H, and Ks bands are coded in blue, green and red, respectively. Square root scaling has been used to better bring out the faint surface brightness structures

the first observational proof for the theoretical prediction of the magnetic field polarity.

Simultaneously to the observations, local and global MHD models have been developed and utilized, to be able to investigate the transformation from solar-like dynamo activity to the activity seen in the active rapid rotators. Numerical modelling has yielded new results in a variety of systems: local turbulence models have been utilized to study the turbulent transport of angular momentum and numerical studies of convection have, for the first time, revealed a large-scale dynamo.

Low and intermediate mass star formation takes mostly place in isolated clusters and in low mass star forming regions. The structure of one of these regions (CG12) in molecular line emission has been extensively studied by us at SEST. CG12 is an active formation site but only the brightest stars in the associated stellar cluster are known. We have conducted near-infrared imaging of CG12 with SOFI at the ESO/NTT telescope. The imaging reveals several new deeply embedded member stars.

Most stars form in clusters and smaller groups in the densest parts of giant molecular clouds. By studying their physical and chemical characteristics, we hope to learn the conditions leading to protostellar collapse and the timescale related to this process. We have carried out studies of the Ori B9 cloud the APEX and IRAM telescopes. Together with our previous results these were used to derive the degree of deuteration and other chemical characteristics. Using additional information from far-infrared Spitzer/MIPS maps, prestellar and protostellar cores were identified, and

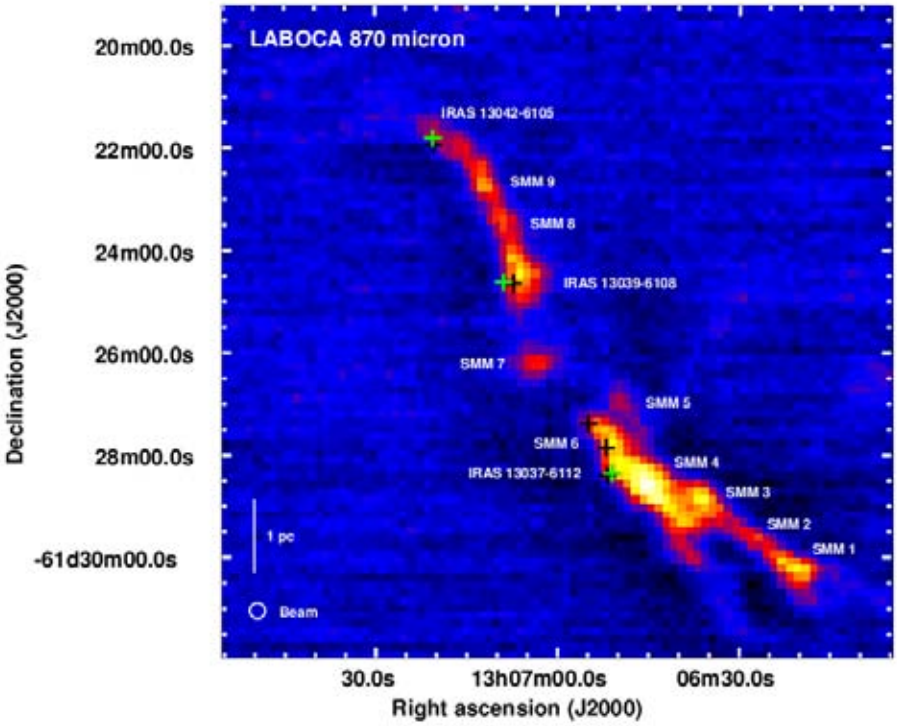


Figure 4.28. LABOCA map of the 870 ¹m dust continuum emission from the IRDC G304.74. The green and black plus signs mark the positions of the IRAS and MSX point sources, respectively.

the evolutionary stages of the protostars were estimated.

Near-infrared scattered light was observed towards several interstellar clouds using ESO/NTT and UKIRT telescopes. Near-infrared observations and the role of dust scattering was investigated also in connection with external galaxies. We performed a radiative transfer simulation study where the near-infrared reddening signatures of extragalactic dust clouds were examined in a simple plane-parallel model mimicking a face-on spiral galaxy.

Studies were completed of the polarized submillimeter emission from dust grains in interstellar clouds. In a magnetic field, dust grains remain aligned as long as their rotation speed is significantly larger than their thermal rotation speed. The grains are believed to be spinned up mainly by radiative torques. The efficiency of radiative torques was investigated using magnetohydrodynamic cloud simulations and detailed radiative transfer modelling. Results indicate large spatial variations in the polarization efficiency. Through Zeeman effect, magnetic fields cause splitting of some radio lines. With radiative transfer modelling three-dimensional magnetohydrodynamic simulations could be compared with existing measurements of the Zeeman effect in cloud cores. Good agreement was found between models of super-Alfvénic turbulence combined with self-gravity and available observations of OH molecule lines. This suggests that the average magnetic field of molecular clouds may be low and supports the idea of turbulence as a central factor behind the formation of self-gravitating cloud cores.

The Planck and Herschel satellites were launched successfully in May 2009. By the end of 2009 the first data were received from both satellites. We participate in several science projects within the Planck consortium.

The main emphasis is on studies of dense interstellar clouds and especially their cold and compact cloud cores. Planck is the first space mission that has the sensitivity and the resolution necessary for the study of the cold core population over the whole sky. We are coordinating a Herschel Open Time Key Programme, where a sample of the Planck-detected cores are investigated in more detail using the Herschel PACS and SPIRE instruments. Herschel can observe wavelengths close to the peak of dust emission. Compared to Planck Herschel has much higher spatial resolution. This makes it possible to study the internal structure of the selected cores and to determine their evolutionary stages and their relation to future star formation. We also participate in several other Planck science projects, including the study of nearby galaxies. We are also involved in the Herschel key programme to map a large fraction of the plane of our Galaxy.

Using data from the ISOPHOT instrument of the ISO satellite, we have completed a study of the extragalactic far-infrared background light. The signal represents a significant fraction of the cosmic energy output from stars that has been reprocessed by interstellar dust and is redshifted to far-infrared wavelengths. Our study is the first independent test of the results obtained with the COBE satellite some ten years earlier. Our values are in agreement with the published COBE results. As a follow-up of the far-infrared extragalactic background light we have performed observations of the far-infrared (FIR) sources detected as part of that project.

The activities in high energy astrophysics research of the HESA (High Energy Space Astronomy) group are divided into three areas: (1) fundamental science, (2) developing of new instruments for space research, and (3) developing of data analysis software. The first part consists of scientific return from the instrument projects (INTEGRAL, SMART-1, Chandrayaan-1) complemented by data from other satellites (e.g. XMM-Newton, HST, RXTE, Chandra, Suzaku). The second part is a continuation of the ongoing hardware projects.

The science topics addressed include coronae and flaring in active stars and the Sun, and studies of clusters of galaxies and related questions in cosmology. In particular, the very broad spectral coverage (INTEGRAL) and the possibility for a long monitoring (SMART-1, Chandrayaan-1) coupled to the sophisticated modelling are the key ingredients of the research. Our research aims at characterising the thermal and nonthermal processes in clusters of galaxies. We use this information to derive the distribution of baryonic and dark matter in clusters and to constrain the cosmological parameters. We also derive properties of the relativistic electron populations and magnetic fields in clusters. The main analysis tools utilized by us are high resolution imaging and spatially resolved spectroscopy of the hot intracluster gas. For this work we use X-ray and gamma-ray data of clusters of galaxies obtained with XMM-Newton, Suzaku and INTEGRAL satellites. We have obtained observation time via our own proposals which we combine with the available archival data. Since clusters of galaxies are massive and hot, they interact with the Cosmic Microwave background via the Sunyaev- Zeldovich effect. In a working group of Planck satellite, we are planning the usage of this effect based on the Planck data. We are participating in a international project IACHEC which aims at studying the cross-calibration of high energy satellites. Comparison of X-ray measurements of clusters of galaxies allows us to estimate the calibration accuracy of different instruments. We are currently developing cluster-based calibration tools for the future X-ray missions.

The aim of the new instrument development is to utilise the advances in instrument performances carried along with bigger telescopes, larger field-of-view and decreased noise of new systems in the future plans of ESA, NASA and JAXA (IXO, International X-ray

Observatory, and Lobster). The systems under development are: (1) The SIXS instrument for BepiColombo (2) common DPU and onboard software of SIXS and MIXS instruments for BepiColombo, and (3) SQUID readout electronics for the X-ray Spectrometer (XRS) for IXO.

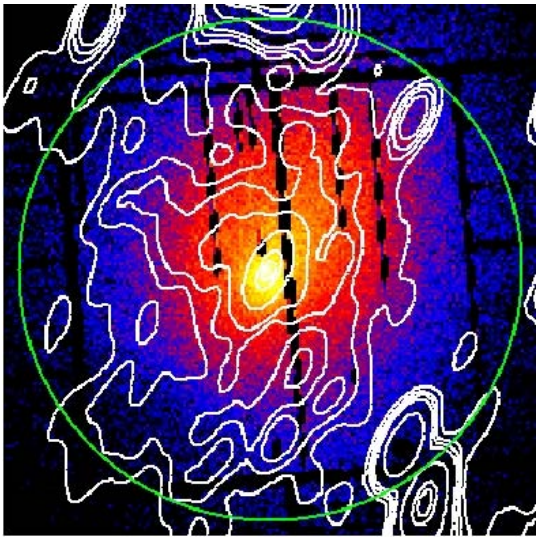


Figure 4.29. The X-ray brightness of Ophiuchus cluster of galaxies obtained with XMM-Newton PN instrument. The white contours show the radio brightness obtained with VLA

The activities have also evolved to a higher level of collaboration with new plans for instruments and satellites, which combine the expertise and experience of the group and its collaborators. The wide scientific and technological expertise within this framework have made it possible to start planning bigger contributions in international space science programs, e.g. participation at PI level in the next ESA cornerstone mission to Mercury (BepiColombo). We are also involved at Co-PI level in the India-ESA collaborative Moon mission Chandaryaan-1 (launched in 2008) with an XSM similar to that of SMART-1.

ESO-connected data analysis activities have also grown significantly since the beginning of Finland's ESO-membership in 2004. The project, called ESO-Sampo, conducted development of science data analysis environment for ESO. The main result of the project is the ESO Reflex workflow engine, an advanced science analysis environment that ESO plans to implement as standard ESO software for the reduction of VLT and other ESO data. HESA team has also participated actively in the preparation for national technology return from ESO.

University of Oulu
Department of Physics
Division of Astronomy

Main activities of the Astrophysics group are concentrated on the studies of compact astrophysical objects such as black holes and neutron stars in X-ray binaries, ultra-luminous X-ray sources in nearby galaxies, 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) satellite. Our detailed studies of the 2002 outburst of SAX J1808.4−3658 showed that the pulse profile and spectral evolution is consistent with the picture where the accretion disk recedes when the flux drops because of the growth of the magnetospheric radius. This allowed us to measure the neutron star magnetic field as well as some geometrical parameters.

Accretion onto neutron stars with a weaker magnetic field proceeds via a boundary layer where the accretion disk decelerates to the neutron star angular velocity. The layer is strongly radiation pressure dominated and numerical simulations are challenging. For the first time we were able to make 2D radiation-hydrodynamical simulations of the disk-boundary layer interface. Understanding the physics of the boundary layer will give a clue on the origin of the mysterious kHz quasi-periodic oscillations observed from these sources.

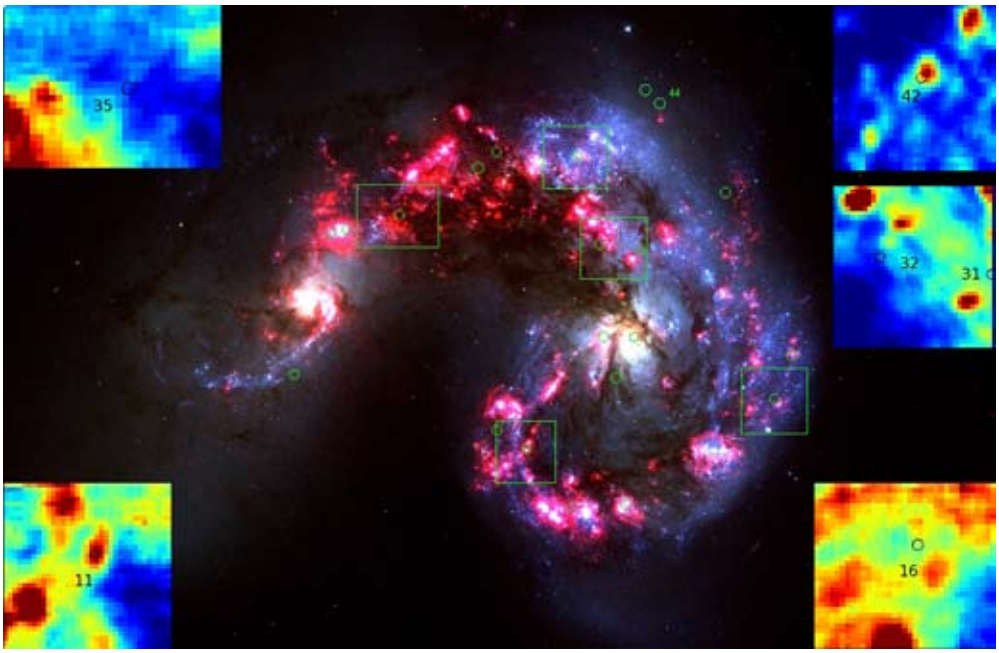


Figure 4.30. The Antennae galaxy NGC4038/NGC4039. Large image is from the Hubble Space Telescope. The insets are our VIMOS/VLT images (red – H_2 line, green – V band, blue – B band) of the stellar clusters in the vicinity of the bright X-ray sources marked by circles.

Our 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 modeled as a precession of the inclined disk. We have also discovered a dependence of the orbital modulation and spectral hardness on the superorbital phase, which we interpret as an evidence of the absorption by the accretion bulge, which 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. We have 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. Our 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.

Ultra-luminous X-ray sources (ULX) in nearby galaxies were targets of our investigations with the X-ray as well as optical telescopes. We have analyzed all ULX observed with XMM-Newton and Chandra observatories more than 5 times with the aim to detect spectral variability and study the evolution of the accretion disk temperature with luminosity. Our results show that the evolution is not consistent with that expected from the standard disks around intermediate-mass black holes. The super-Eddington accretion on to stellar-mass black holes is more consistent with the data. We have also studied with Very Large Telescopes (ESO) the environment of the ULX in the Antennae galaxies. We found

that ULX are connected with very young star clusters, which gives us strong constraints on the mass of the progenitor.

The nature of the emission of relativistic jets in active galaxies such as for example in blazars is still an unsolved problem. We have 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 via electron–positron pair production and Compton scattering. We have shown with the numerical simulations that a significant fraction (up to 80%) of the jet bulk energy can be converted into radiation mainly in the MeV–GeV energy range. As a result of the interaction the jet becomes decelerated at outer edges and the emission becomes less beamed. The mechanism produces significantly broader angular distribution of radiation than that predicted by a simple model assuming the isotropic emission in the jet frame. This helps to reconcile the observed statistics and luminosity ratio of Fanaroff–Riley type I and BL Lac objects with the large Lorentz factors of the jets as well as to explain the high level of the TeV emission in radio galaxies.

The extragalactic research of the Dynamics group concentrates on secular evolution of galaxies. We use both ground-based (optical and IR-imaging and spectroscopy) and IR data from satellite space missions. We have analyzed a statistically significant Near-IR S0 galaxy Survey (NIRS0S) of nearly 200 lenticular galaxies, based on our observations collected during the last 5 years at ESO and La Palma telescopes. Using this data we have completed the first systematic multi-component (bulge/disk/bar/oval) 2D decomposition study of S0s, combined with our previous similar analysis of spirals. The scaling relations we find for the bulge and the disk parameters fit to the picture where 1) the formative processes of bulges and disks in S0s are coupled in a similar manner as in spiral galaxies, and 2) stripping of disk gas, with subsequent cessation of star formation, may have transformed bright spirals directly into featureless S0s. Our findings thus emphasize the role of internal secular evolution of galaxies in addition to early merger processes, which current galaxy formation paradigm concentrates on. Driving force in this slow ongoing process of galaxy evolution can be bars, which are efficient in redistributing material in galactic disks. Our work with NIRS0S has currently expanded via our participation to the Spitzer S4G project, where deep 3.6 and 4.5 micron images are obtained for 2300 nearby galaxies. Oulu group is leading one of the project's data analysis pipelines (multi-component structure analysis). Additionally, we participate on an international training collaboration on the origin of dwarf galaxies. Oulu currently has a joint PhD student with Heidelberg, working on dwarf S0s.

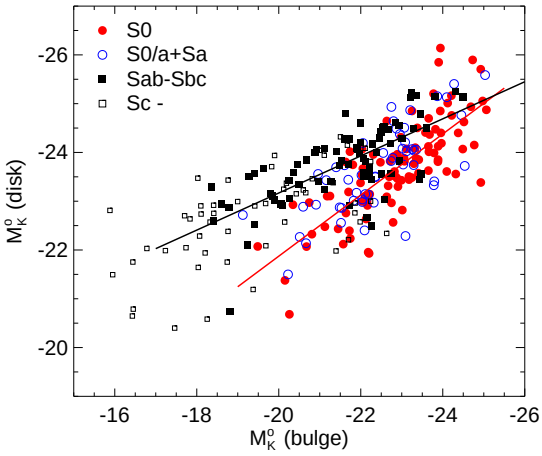


Figure 4.31. The absolute brightnesses of bulge and disk correlate, both for S0s (lenticular galaxies) and for spirals, suggesting a common formative process for these basic galactic building blocks. In particular for bright galaxies, these correlations are fairly similar for all morphological types, supporting the view that a variety of spiral types can evolve into S0s (e.g. by disk gas stripping and/or secular internal growth of bulges). The data from NIRS0S survey is combined with our previous analysis of OSUBSG spirals.

University of Turku
Tuorla Observatory

Research and teaching in the interdisciplinary field of astrobiology has continued at Tuorla Observatory in collaboration with the Biology Department at the University of Turku. A related text-book "The evolving Universe and the origin of life: The search of our cosmic roots" by Teerikorpi, Valtonen, Lehto, Lehto, Byrd and Chernin) was published in 2009. In 2009–2010 the group's astrobiology lectures were a part of the live stream video course hosted by ESA/ESTEC. The course connected eleven universities and research institutes across Europe from Finland to Italy and from Russia to UK. This Astrobiology Course Network ran for the third time. Astrobiology is a minor subject the University of Turku, and a variety of other astrobiological courses have been taught in various Departments of the University.

Astrobiological research involved studies of the Pitch Lake in Trinidad, one of the three asphalt lakes found on Earth, in collaboration with the University of Washington, the University of the West Indies and several other institutes. The chemical composition and life forms found in this unique habitat have been characterized with analogies to possible life in Titan. Several dozen mud volcanoes have been found in Southern using Google Earth images. Our active phase of investigating life in extreme conditions has shifted now to studying these muddy mounts with analogies on Mars and Titan. This collaboration includes also the Department of Geology at the University of Turku. In collaboration with the Finnish Meteorological Institute we are the studying the chemistry of comets.

The cyanobactrium Spirulina is suitable for human consumption as food. It is also a viable source of oxygen both during space travel and in human bases at Mars. We have been studying the survival of Spirulina in atmospheric conditions analogous to Mars in collaboration with the Biology Department at the University of Turku.

Thus far nearly 500 exoplanetary systems have been detected, yet the analysis tools for combining e.g. radial Doppler measurements and eclipse light curves or taking stellar jitter properly into account remain mathematically at a rather poor level. We have been developing tools for analysing such data by using Bayesian analysis methods. These have resulted e.g. in a detection of a new planet around the star HD 11506.

One of the main topics of stellar research in Tuorla is the programme to study the behaviour of accretion discs in compact interacting binaries consisting of a compact star (white dwarf, neutron star or a black hole) and a normal companion star donating matter to the former. These systems are generally known as Cataclysmic Variables and X-ray binaries. One such system is UW CrB, which was discovered in 1990 with the Einstein X-ray satellite. The most likely scenario at present is that it consists of a neutron star and a low mass main sequence star, an M dwarf. Most of the optical light from the system does not come from either of the two stars, but instead from the accretion disc of hot gas which forms around the neutron star, as material is transferred from the M dwarf. The system rotates every 111 minutes, and shows a strong eclipse of the light each time it makes a full rotation. The eclipse is probably caused by the M dwarf regularly blocking light from the accretion disc, so that the system temporarily looks fainter. We have followed intensively the eclipsing behaviour of the system over a period of many months with the Nordic Optical Telescope, finding that eclipsed light from the system changes in a regular manner with a period of about 5 days. The simplest explanation of this unusual behaviour is that the accretion disc is not symmetric around the neutron star. Furthermore, it appears that some part of the accretion disc is self-eclipsed at all times, so that the whole light curve is affected by the geometry of the disc and the secondary. The changes in the light curve shape in these systems happen without any change in the overall optical or

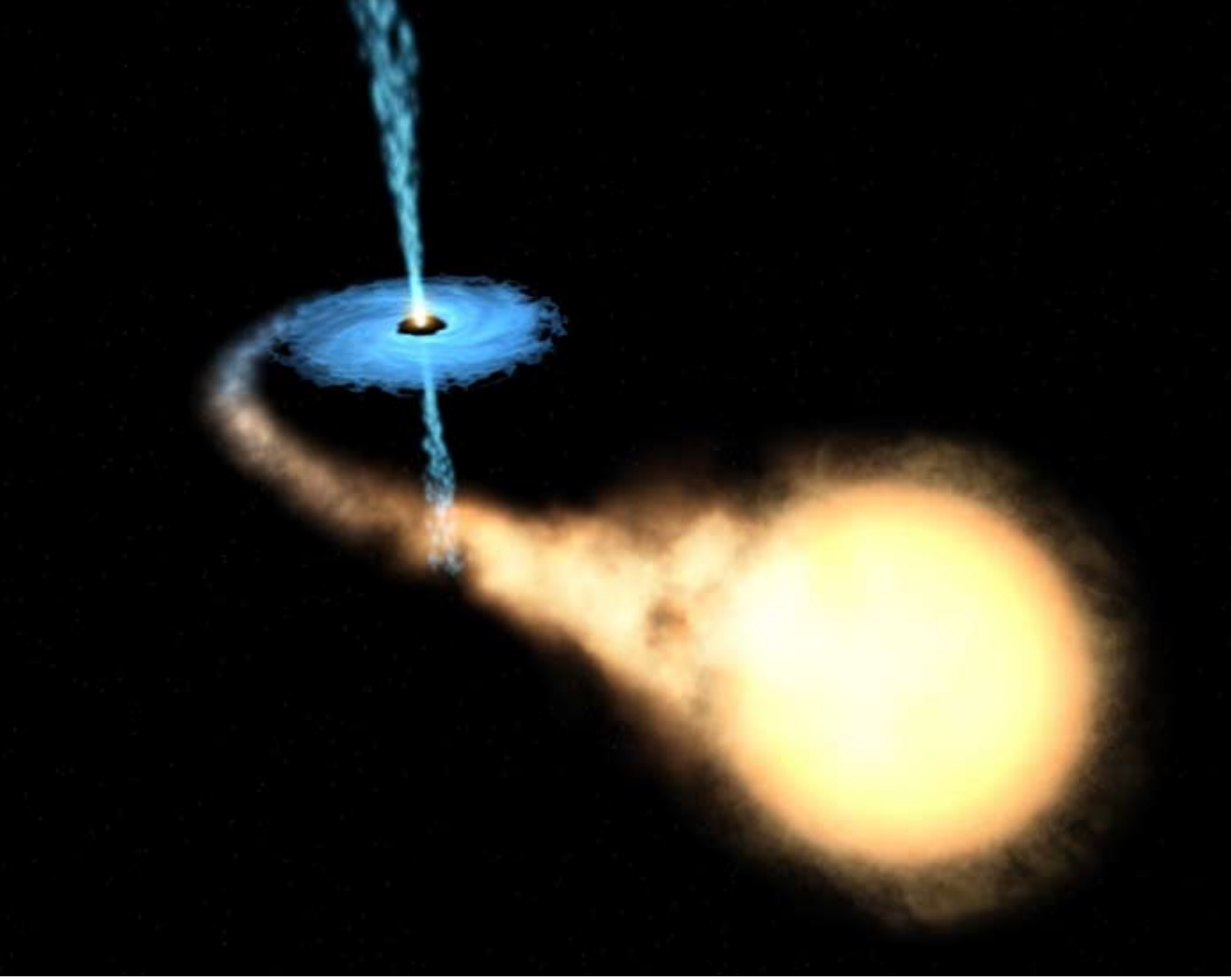


Figure 4.32. Artist's impression of binary star with an accretion disk and the secondary star.

X-ray luminosity, so it is strongly suspected that the changes are caused by the geometry of the disc.

The Milky Way galaxy consists of a flat disk of stars and gas, surrounded by a spherical and very tenuous system of stars, the halo. These stars were among the first born in the Milky Way, and their motions tell us about the conditions under which they were born, long before the Milky Way resembled the disc galaxy it is today. A Finnish–German collaboration has studied the Milky Way halo, using the enormous new database of stars created by the Seventh Sloan Digital Sky Survey, and found 22 000 halo stars. Motions through space of the stars were computed and Galactic orbits for the stars determined. Five streams of stars in the halo were found – stars sharing the same orbits around the Galactic center, of which two are previously unknown. Streams have a range of applications, including their use to reconstruct the mass distribution in the Galaxy. Many such streams are expected to be discovered by the ESA satellite Gaia scheduled for launch in 2012, and this study is a useful precursor to how one might go about isolating stellar streams in the enormous dataset Gaia will produce.

The Milky Way galaxy has a so-called bar in its central regions, a long, thin system of stars that may contain up to ten percent of the total matter in the Galaxy's disc. Recent observations of stars in the inner Galaxy have shown that there may actually be two bars.

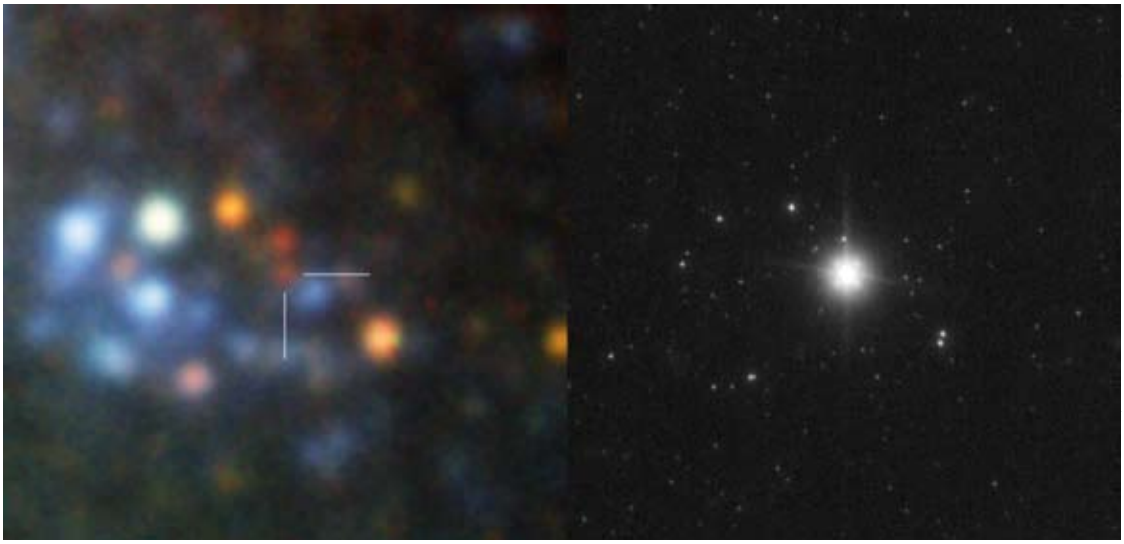


Figure 4.33. The site of Supernova 2008bk in the spiral galaxy NGC 7793 as observed with the Very Large Telescope (VLT) of the European Southern Observatory (ESO) shortly before (left) and after (right) the explosion (Credit: ESO). The star that later exploded as SN 2008bk was identified in the images (left) and was shown to be a red supergiant that had initially a mass of about eight times the mass of the Sun.

researchers have speculated that the Arcturus stream is the remnant of a small galaxy that has been broken up by approaching the Milky Way too closely: this new research indicates that it could have a different origin entirely, having been stirred up from certain stars in the disk of the galaxy through short-range gravitational interactions with the "long bar".

Measurements of how many stars have formed in galaxies as a function of time is an important factor in understanding how galaxies form and evolve. A new method to trace backward the star formation history of the Milky Way disk, using a sample of M dwarfs, has been developed by the group. Such stars are used because they show hydrogen emission until a particular age, which is a function of their absolute magnitudes, permitting us to reconstruct the rate at which disk stars have been born over about half the disk's lifetime, or about 5 Gyr. The principal result of this study is to show that a relation between star formation rate and gas content of the Schmidt–Kennicut type has been found in the Milky Way disk during the last 5 Gyr: in other words, it is the same as is seen in other galaxies.

central results are that it may be necessary to revise theoretical models for the low Main Sequence, and to recalibrate also the previous results. A revision of low Main Sequence stellar models, suggested from nearby stars, could significantly

reduce the helium content inferred for the subpopulations of globular clusters. Using our local data for the recalibration, we find that the estimated helium content for those super helium-rich populations could decrease from 40% to as low as 30%, a value which is well within reach of our present understanding of stellar nucleosynthesis and chemical evolution.

Research of supernovae continued at Tuorla Observatory. The group makes extensive use of both ground- (e.g., NOT, ESO VLT, Gemini-N) and space-based (HST and Spitzer) telescopes for optical and infrared observations of core-collapse supernovae, the end points of massive stars. Adaptive optics observations at near-infrared wavelengths are used by the group to discover heavily dust-obscured supernovae in the nuclear regions of nearby luminous infrared galaxies. At high redshifts, a large fraction of massive star formation took

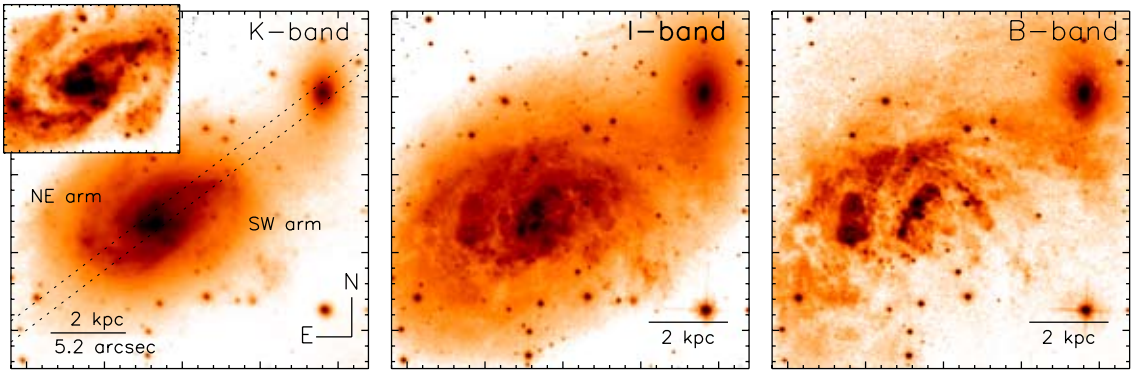


Figure 4.34. Near-infrared image of the galaxy with leading spiral arms is shown in the left panel, while the inset highlights the arms in better contrast. The HST + ACS optical images are shown in the middle and right panels.

place in such galaxies. Recently, members of the group became involved in the whole northern sky supernova search making use of the newly commissioned Pan-STARRS1 survey telescope on Hawaii. Adaptive optics assisted observations are also very powerful in pinpointing the progenitor stars of nearby core-collapse supernovae in images obtained before the explosion in which the group is working together with colleagues from Belfast. Using observations from the ESO VLT the progenitor star of the core-collapse supernova, SN 2008bk, was shown to be a red supergiant, initially of about eight solar masses, which is thought to be the minimum mass needed to produce such explosions.

We have obtained near-infrared imaging with ESO VLT plus ISAAC and NACO of the host galaxies of high redshift quasars to investigate the connection between galaxy evolution and nuclear activity. The cosmological luminosity evolution of the quasar hosts resembles that of massive inactive galaxies, suggesting a similar star formation history. In particular, quasar host galaxies appear fully assembled already at the peak epoch of quasar activity, as early as 2 billion years after the Big Bang. We have also detected a rare case of a galaxy with leading spiral arms, i.e. spiral arms opening in the rotational direction of the galaxy disk, based on near-infrared adaptive optics imaging with ESO VLT plus NACO and near-infrared spectroscopy with AAT plus IRIS2. The arms are not easily traceable in optical images, suggesting that high-quality near-infrared imaging of interacting galaxies may uncover further cases of leading arms, placing constraints on spiral arm theories, and on the relationship between disk and dark matter halo masses.

OJ 287 is an active galactic nucleus thought harbor a supermassive binary black hole. Every twelve years a two-peaked optical outburst is observed in this object, possibly caused by the passage of the secondary black hole near the primary. Two new peaks were predicted to occur in 2005-07, so we started photometric and polarimetric monitoring programs which lasted 4 years and involved 18 telescopes from 13 counties all over the world. Two major flares were indeed detected in fall 2005 and 2007, together with a dozen of minor flares. The polarization state of OJ 287 was changing rapidly and apparently chaotically during and between the two major flares. However, several minor flares showed consistent behavior in polarization, pointing to a common mechanism in these flares. We also detected a dip in polarization degree at the beginning of the second major flare. This dip was predicted to occur precisely at the observed epoch by a model which connects the major flares with impacts of the secondary black hole to the accretion disk of the primary. We also studied long-term behaviour of the polarization by collecting literature data from the past 30 years. There was a 90 degree

change in the position angle of the polarization in 1994, which shows that large changes in the jet configuration occur in time scales of several tens of years. We also used the VLT-UT2 with FORS2 to monitor the H_2 line of OJ 287 in 2005–2008. The aim was to detect changes in the velocity field of the gas clouds orbiting the primary black hole during the proposed passage of the secondary. Unfortunately the H_2 line luminosity was a factor of 10 lower than previously, and we could detect the line only during 2 out of 7 epochs. No changes in the H_2 line were seen.

MAGIC-I is the first large atmospheric imaging Cherenkov telescope with a mirror surface of 236 m2, and equipped with photomultiplier tubes of optimal efficiency. In 2009, a second telescope MAGIC-II of essentially the same characteristics was installed. With the advent of these instruments, cosmic gamma-rays at an energy threshold lower than any existing or planned terrestrial gamma-ray telescope have become accessible. So far achieved has been a threshold of 25 GeV. 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 has proved useful: five new blazars were detected, one of them the most distant very high energy emitting blazar known so far. MAGIC has also detected the first pulsed gamma-ray emission above 25 GeV. The pulsed emission was detected from the Crab pulsar, which sheds light to the longstanding question about the emission region, as it rules out the possibility that the emission region would be located close to the pulsar surface. With the new stereoscopic system (MAGIC-I + MAGIC-II), a new extragalactic very high energy gamma-ray source was discovered, the position of the source being consistent with the head-tail radio galaxy IC310 in the Perseus cluster of galaxies.

Tuorla Observatory has continued its participation in the Planck satellite project. The satellite is now operating well, with a total of at least four full-sky mappings at numerous radio frequencies to be done between 2009

and 2012. Among other things, Planck will be used to study active galactic nuclei in collaboration with the Metsähovi Radio Observatory and the Planck Working Group 6 (Extragalactic point sources). Another part of Planck research is done by the Tuorla and Tartu observatory cosmology groups with the aim to produce an all-sky template of optical superclusters for the Planck community. Supercluster templates will be part of the scientific goal to explore the supercluster regions for the warm–hot intergalactic medium and to study the problem of missing baryons in the local universe.

Tuorla cosmology group also continues the studies of the large scale structure of the universe in order to investigate galaxy distribution and properties in different environments and scales: groups, clusters, superclusters and global galaxy density field. In one of our recent projects we studied formation, properties and evolutionary paths of isolated field elliptical galaxies which represent deviant class of objects in the typical galaxy environmental morphology–density relation. For that purpose we used observational data and detail analysis of merger trees of field elliptical galaxies in numerical cosmological simulations. Our analysis highlighted three typical formations mechanisms for field elliptical galaxies. Our results also predict a previously unobserved population of blue, dim and light galaxies that fulfils observational criteria to be classified as isolated field elliptical galaxies.

Together with new deep and wide galaxy redshift surveys (especially the final release of the Sloan Digital Sky Survey, SDSS-DR7 and its extensions) the luminosity density field method provides new applications to analyse and study the galaxy universe. One such an application is to use the large-scale density field to characterise the environments of a certain type objects. Our recent results demonstrate that nearby quasars clearly avoid rich superclusters and that they tend to be located in the outskirts of superclusters or in filaments connecting those. This provides a new and interesting scope in the study of evolution and formation of active galactic nuclei (AGN) addressing the question how global and local density field affects the poorly known evolution and formation of the AGN? □

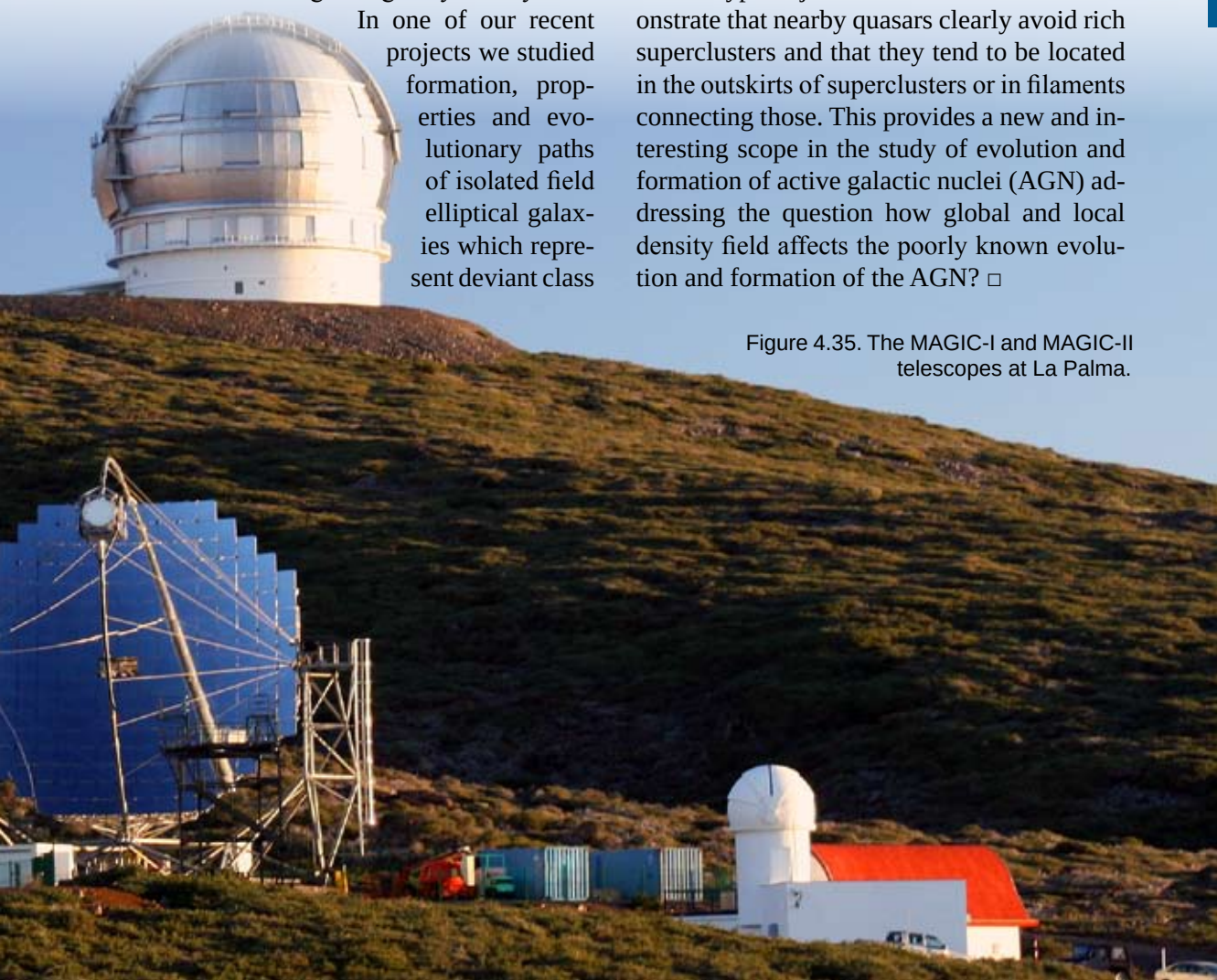


Figure 4.35. The MAGIC-I and MAGIC-II telescopes at La Palma.

5. Applications, Earth Observations and Space Technology

5.1. Space geodesy

Aalto University School of Science and Technology (TKK) Department of Surveying

The geodesy research group participates in COST Action ES0701 “Improved constraints on models of glacial isostatic adjustment”. Two of the graduate students of the group participated in the COST ES0701 GIA Training School in Gävle, Sweden, June 2009.

In 2008 the geodesy research group was commissioned to write a plan, including extensive GPS measurements, for the renewal of the municipal co-ordinate systems for a consortium of 24 municipalities in the Turku area.

Finnish Geodetic Institute (FGI)

Space geodetic techniques have a key role in studying and monitoring the dynamic Earth. The mass transportation within the solid Earth is an enormous phenomenon. Waxing and waning of the Northern hemisphere glaciers in about 100-kyear cycles cause up to 135 m of global sea level rise and fall. In addition to the sea level and gravity changes, the mass transportation has its effect in the Earth Orientation Parameters, especially on the long-term Earth rotation variability and the polar motion. The mass transportation causes cyclic variation on the surface load resulting in the viscoelastic mantle flow and elastic effects on the upper crust, e.g., is the Fennoscandian land uplift due to the postglacial rebound.

Only precise space geodetic observations can perceive these changes.

GNSS (Global Navigation Satellite Systems, including GPS and European Galileo), gravimetric satellites (especially GRACE and GOCE), VLBI (Very Long Baseline Interferometry) and SLR (Satellite Laser Ranging) are the main instruments in this study. All these are needed to reach the accuracy of 10–9 on the global scale, and to support the three pillars of geodesy: geometry and crustal changes, orientation of the Earth in the inertial space and measuring the gravity field and its temporal changes. There are several ongoing initiatives for an integrated observing system; one can mention the GGOS (Global Geodetic Observing System), ECGN (European Combined Geodetic Network), and the NGOS (Nordic Geodetic Observing System). Finnish Geodetic Institute participated in the work on these observing systems.

The Metsähovi research station has become an essential part of the activities of the FGI. The measurements taken at the station serve both the Institute's own research and the international scientific community, and the station forms the basis of the national geodetic infrastructure. The Metsähovi station is one of the fundamental geodetic stations in the world due to the variety of different observation techniques used there. The instrumentation covers the satellite laser ranging, geodetic VLBI, GPS and GLONASS receivers, DORIS beacon, superconducting gravimeter, seismometer and the fundamental absolute gravity point. Data collected by various observation instruments are transferred in several international data banks and used in several international scientific projects.

In co-operation with the Metsähovi Radio Observatory of the Aalto University geodetic VLBI observations are conducted as a part of 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. Metsähovi participated in a world-wide VLBI campaign in November 2009 as a special event of the International Year of Astronomy.

For the ties between space geodetic instruments in fundamental stations 1-mm positioning accuracy is anticipated. The accuracy should be site-independent, consistent, reliably controlled, and traceable over long time periods. A new model was developed to meas-

Figure 5.1. All major space geodetic techniques are used at the Metsähovi fundamental station and it is one of the fundamental stations in the world. Data are used e.g. in maintaining global reference frames and computing precise orbits of GPS satellites. Photo: Jyri Näränen

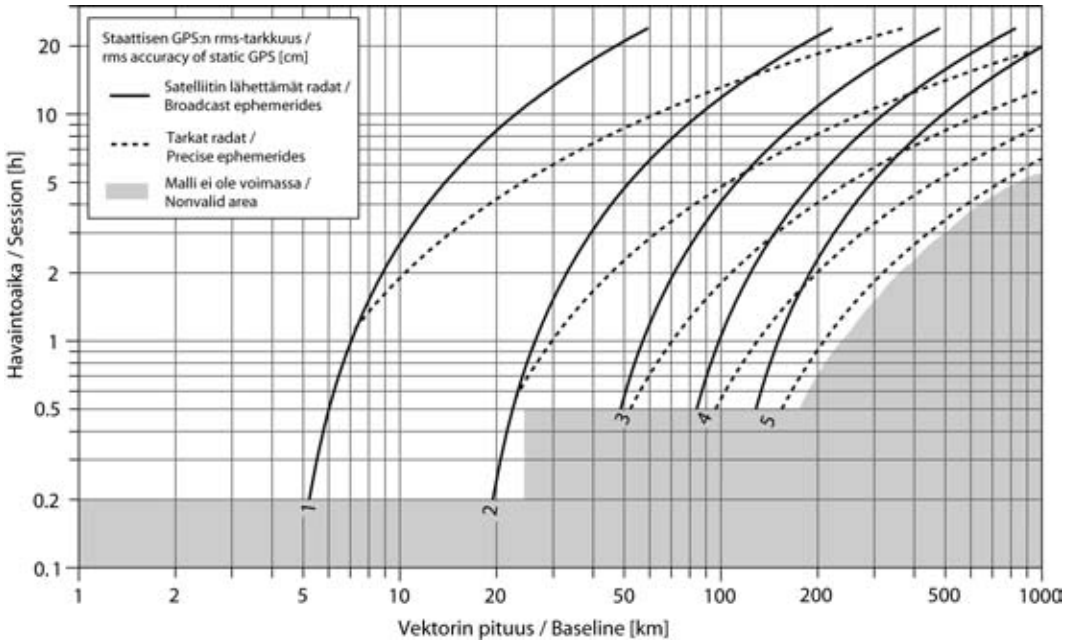


Figure 5.2. Dependence of baseline length, observation time and 3-D accuracy of static GPS surveying. Regression lines show rms accuracies between 1-5 cm (broadcast ephemerides with solid, precise ephemerides with dotted lines) as a function of vector length and the observing time.

ure the local ties, together with developing a GPS-based technique for the measurements on mm-level. The tests of the model show that 1-mm precision is possible to achieve in the local tie with kinematic GPS technique. Based on our experience, we propose that GPS tracking should be done permanently during VLBI sessions.

The Finnish permanent GPS network FinnRef® is a part of the global GNSS network structure. It consists of 13 permanent GPS stations and is the backbone of the Finnish realisation of the European-wide reference frame EUREF. Temporal variations on the time series of FinnRef® were studied using additional information from the Metsähovi superconducting gravimeter, and ocean and atmospheric loading. The goal is to improve our modelling both for crustal deformations and atmospheric effects on GPS signal. Significant improvement in accuracy was achieved by using the weather forecast model and computing the delay in the GPS signal due to the troposphere.

For practical applications the web-based FGI Coordinate Transformation Service http://coordtrans.fgi.fi/ was released in late 2008. It consists of all nationwide transformations, geoid models and height transformations recommended by the public administration prepared as a joint project of the FGI and the National Land Survey of Finland. The transformation service is also an information forum for reference frames and transformations and there are hundreds of visits monthly.

A study of static GPS accuracy was conducted covering observing sessions between 10 minutes to 24 hours and baselines between 0.6 km and 1069 km. Over 10000 baselines were processed using broadcast and precise ephemerides. Using the graph one may optimize the observation times and thus increase productivity of static GPS surveying.

FGI has been researching postglacial rebound for decades and published several land uplift maps that have been used in connection with defining new height systems. However, only recently has it been possible to construct the

first model that accurately takes into account the horizontal component. The model, created as a Nordic co-operation and based on more than 10-year continuous time series of GPS observations, greatly improves transformation accuracy compared to the results obtained from global models.

FGI has performed GPS observations at the crustal deformation network in Olkiluoto since 1995 in a contract with Posiva Oy, at a proposed disposal site for nuclear waste in Finland. Our fifteen-year time series allow better than 0.2 mm/yr tracking for crustal movements. Since 2002, a 511-m GPS baseline has been simultaneously measured using the most accurate electronic distance measurement (EDM) instrument available in order to control the scale of the network. A difference between GPS solutions and traceable EDM results has been found in semi-annually repeated measurement campaigns, which led to the assumption that the GPS solution is biased.

To study the problem, the GPS antennas used in Olkiluoto were sent for individual absolute antenna calibration and additional EDM+GPS measurements were carried out at another length standard, Kyviškės calibration baseline and test field in Lithuania. In Kyviškės, we were able to compare several lengths 20 – 1320 m in ideal conditions for GPS measurements instead of only the single distance that can be measured in Olkiluoto. True lengths with traceable uncertainties between the observation pillars were measured.

A larger network has been measured with GPS three times per year in 2003–2008 followed by the analysis of observations in 2009. Other participants in this Geo-Satakunta project were the Geological Survey of Finland, and Cities of Pori and Rauma. The project was partly funded by EU, and its goal is to study geology and geophysics of the area, including crustal movements. In five years we have reached such an accuracy in the 13-point GPS network that any large movements (> 0.5 mm/y) can be excluded. There is, however, a possibility for 0.2–0.5 mm/yr inter-station movements which can remain unobserved in the current data.

A project DynaQlim (Upper Mantle Dynamics and Quaternary Climate in Cratonic Areas)

Figure 5.3. Comparison of a precise electronic distance measurement instrument and GPS measurements were carried out at Kyviškės calibration baseline and test field in Lithuania where several lengths between 20…1320 m can be compared in ideal conditions. True lengths with traceable uncertainties between the observation pillars were measured using a Kern ME5000 Mekometer as a scale transfer standard. Photo: Jorma Jokela.

continued as a regional coordination committee of the International Lithosphere Program, whose goal is to improve our understanding on the relations between upper mantle dynamics, mantle composition, its physical properties, temperature and rheology. It is also meant to study Glacial Isostatic Adjustment and ice thickness models, Quaternary climate variations and Weichselian glaciations during the late Quaternary. FGI is the coordinator of the project. An international workshop was arranged in Finland in 2009 and a special issue in a peer-review magazine was prepared.

The GRACE satellite probes the gravity field of the Earth. Studies at FGI are related to the use of the GRACE satellite data in geodetic research and to improve local and regional geoid models. GRACE time series were analysed and compared with time series from the superconducting gravimeter in Metsähovi. Due to major developments in measuring technology and modelling capabilities, observations on the time-variable gravity field of the Earth have rapidly become a major tool studying variations in continental water masses.

Surface mass variations were studied using data from the GRACE satellite mission and hydrological models. GRACE solutions from different sources have been investigated over Fennoscandia and especially over Finland. Different smoothing algorithms have been tested on the GRACE gravity field models when calculating changes in continental mass storage from variations in the gravity field over the area. 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.

The variations in the level of the Baltic Sea also have a large effect on the gravity field detected by GRACE. Mass changes in the Baltic Sea as observed by GRACE have been compared with tide gauge data. Global and regional GRACE solutions were also investigated and the GRACE gravity field solutions were corrected for ocean and Baltic Sea variability. On monthly level GRACE is able to quite well detect mass changes in the Baltic Sea.

Methods for geoid determination were studied and the new national geoid model, referred as to FIN2005N00, was published in the series of the FGI and implemented in the FGI Coordinate Service (see picture in the back cover). Finnish gravity data bank data were checked and prepared for reanalysis and use in geoid computation.

5.2. Earth observation and atmospheric sciences

Aalto University School of Science and 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. Institute's research areas are focused on acquisition and processing of 2D and 3D spatial data, specifically related to photogrammetric, remote sensing and laser scanning techniques. Laser scanning has a major role in many of the institute's projects. However, also aerial and satellite imagery, as well as other data acquisition methods are widely in use. The application areas cover various modelling methods of the environment, monitoring large areas from satellite images, questions related to quality and accuracy of 3D models, and the development of new devices and techniques for measuring and modelling tasks.

In the field of remote sensing and large scale mapping, our research projects in 2008 and 2009 have included among others following topics:

We have studied the combination of laser scanning point clouds and aerial imagery and the use of tomographic methods in forest applications. Among others, the 3D structure and semantic properties has been determined from the wooded areas.

A measuring system for the water quality of lakes has been developed based on LED spectrometry. The work has been conducted in co-operation with the Finnish Environment Institute and the Department of Radio Science and Engineering in Aalto University, School of Science and Technology.

Large scale environmental mapping as part of an archaeological project (Finnish Jabal Haroun Project) has been active since 1997. Various satellite and aerial imagery have been utilized in order to create an extensive control point network and a reliable coordinate system, digital elevation models, and other representations from the area of interests.

The development of reference measuring methods from satellite imagery has been in progress. The task has been to measure biomass of vegetation from both the laser scanning data set and aerial imagery.

Finnish Environment Institute (SYKE), Geoinformatics 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 Geoinformatics Division (GEO) looks after the GIS and Earth observation data.

There is a remote sensing group of 15 people at GEO, whose task is to provide the environmental administration with the Earth observation data it requires. Data are also delivered to the international research community in collaborative projects and upon requests. Most of the operative production of EO services at SYKE is part of the European network of service providers in GMES (Global Monitoring of Environment and Security) programme funded by EU and ESA.

GEO operates the automated daily processing of the EO data (AVHRR, MODIS, MERIS, AMSR-E), 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. Additionally theoretical and experimental research on water optics and general spectral radiance measurements are completed in cooperation with national and international partners.

Figure 5.4. The site of the Finnish Jabal Haroun project

Operational, near real time EO products include daily:

- SCA-maps (snow covered area) and snow cover over lakes during snow melting season,
- SWE-maps (snow-water equivalent) during winter
- 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.

Off-line services includes

- Time series of lake water quality (currently turbidity)
- Summary datasets derived using the daily remote sensing products
- Times series of seasonal vegetation status within growing season (fenology)

SYKE has been responsible for the land cover mapping of Finnish territory within the European CORINE programme. The work has been completed in cooperation with several national organisations responsible for the collection and maintenance of land use and land cover information in Finland. The Finnish land cover and land cover changes has been mapped year 2000 and 2006. Also national version of the data has been provided, where the spatial resolution and nomenclature fulfil also national requirements. See **http://www.ymparisto.fi/syke/clc2000**

Produced data are delivered to the end-users as thematic maps and numerical data using

- Internet, see:

http://www.ymparisto.fi/syke/remotesensing

- Desktop and Web map user interfaces
- FTP

SYKE participates and has participated in several European projects aiming at operational environmental monitoring. These include:

- GMES service elements like PolarView, MarCoast and GSE-Land, where EO based servives are produced and delivered
- EU FP7 GMES projects like GEO-LAND2, where European land monitoring is under development
- ESA Data User Element (DUE) funded GlobSnow
- Remote sensing data is produced for two EU Life+ projects. SNOWCARBO-project aims at enhancing the current carbon dioxide net exchange modelling and estimates by using remote sensing data. VACCIA is providing dedicated datasets, derived using remote sensing methodologies, for the participants in the FinLTER- network (Long-Term Socio-Ecological Research Network).

Figure 5.5. The land cover of Finland produced in CORINE programme at SYKE.

Figure 5.6. The snow covered area (SCA) of Finland and surroundings produced in PolarView project at SYKE

Finnish Forest Research Institute (Metla)
Multi-Source National Forest Inventory of Finland (NFI)

The Finnish Forest Research Institute, Metla, is a 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 about 90 years. Since late 1980s, NFI has utilised 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). An important feature of the method is that it produces forest resource statistics for smaller areas than what is possible using sparse field plot data only, like for municipalities, in addition to thematic maps about forest resources. MS-NFI products are employed as input information in forest management planning by forestry authorities and for timber procurement planning by forest industries. Furthermore, the results have been used in ecological studies, e.g., in analysing the quality of the habitats of key-stone species, for assessing the habitat and landscape values for nature conservation planning, and for other research purposes.

The MS-NFI method is under continuous development as a goal to decrease the estimation errors at different spatial levels. New features have been introduced regularly. Recently, optional methods have been presented for analytical error estimation for the k-NN method. Updating of NFI field plot data based on multi-temporal satellite images and growth model has been developed and used for making the up-dated estimates. The team has employed low point density airborne laser

scanner data for developing methods for forest management inventories. Methods to use that data in MS-NFI, or optionally high point density data, are under development.

The MS-NFI team has worked with and assisted United Nations Forest Monitoring and Assessment Programme of Food and Agricultural Organization (FAO) for developing methods to create forest inventory sampling designs. A sampling design was made for Tanzania forest inventory late 2009 and early 2010.

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. Its variation is in use Sweden and USA. Examples of other countries with collaborative work are Austria, China, Germany, Ireland, Italy, New Zealand, Norway, and Poland.

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 laser scanner data and aerial photographs in large area forest inventories and in management inventories
- Estimating carbon balance of forests
- Developing forest inventory sampling designs for countries using remote sensing, GIS and statistical sampling methods

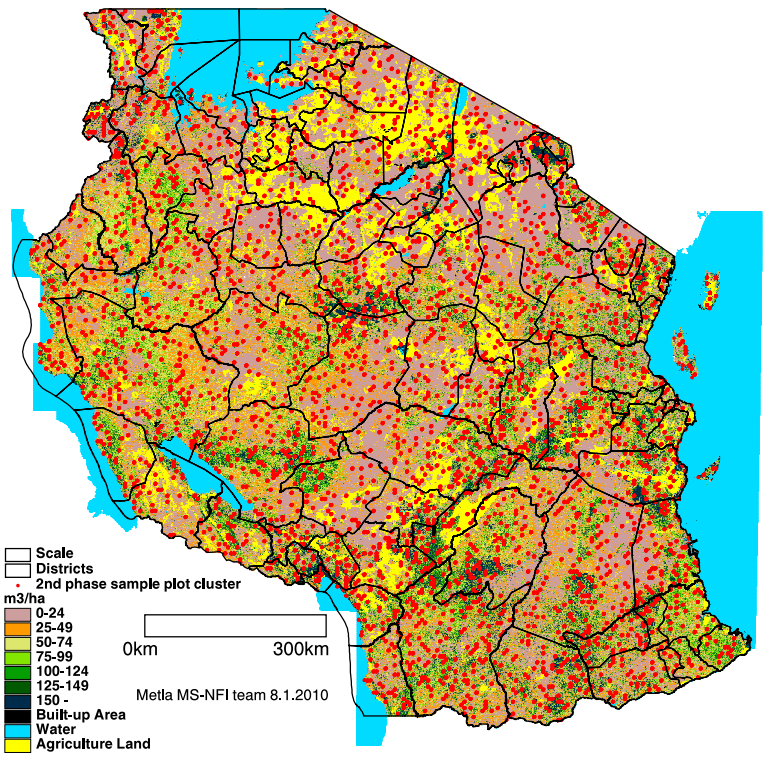


Figure 5.7. The location of the clusters and plots using double sampling for stratification, 32,551 plots on land displayed on the predicted volume of the growing stock.

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

The Department of Remote Sensing and Photogrammetry of FGI focuses on laser scanning (airborne, mobile and terrestrial), aerial photogrammetric imaging, and other remote sensing (SAR, airborne, UAV). Its strategy is to turn fundamental research into practices benefiting the Finnish society. Currently, there are 26 researchers in five research teams, publishing about 35 refereed papers per year. More than 10 international projects have been coordinated by the department during 2000–2010. The department is well linked to International Society for Photogrammetry and Remote Sensing (Vice-president of Remote Sensing Commission (VII) and one chair in the same commission and President of EuroSDR remote sensing commission (II)).

Today, the standwise forest inventory in Finland is based on airborne laser scanning. As a result of this co-operation with Forestry Development Centre Tapio, Arbonaut Oy, Blom-Kartta Oy, University of Joensuu, Aalto Univeristy and the University of Helsinki, the new technology is now applied in Finland by forestry centers outsourcing the Airborne Laser Scanning (ALS) data acquisitions and value adding to companies. Currently FGI is developing further techniques beyond the operational one.

Department of remote sensing and photogrammetry has transferred and helped in the transfer of ALS-based technology on elevation modeling to the Finnish National Land Survey, which currently makes a new elevation model of the whole of Finland entirely with ALS. Compared to the old photogrammetry-based technology, the new technology is cheaper, 5-times more accurate and it needs 1/3 of the personnel for data processing. Currently 51 000 km2 of Finland has been surveyed with ALS (started in spring 2008), but the rest of Finland is in process (in total 338 000 km2). The new model and data are increasingly used by companies for other value-added works (planning, forest inventory, environmental impact assessment, to name but a few application areas). Currently, there is also need to develop 3D environment model of the whole Finland, the research of which is tackled by the department.

The department also provides information on specifications of national photogrammetry and laser scanning processes. Aerial photogrammetric cameras in Finland are yearly calibrated in FGI test field in Sjökulla.

Other current research activities include:

- interpretation methods and new applications of digital camera images and laser scanning
- use of BRF together with aerial photogrammetric images
- UAV-based remote sensing (laser scanning, aerial imaging, spectrometer imaging)
- Mobile mapping (car- or boat-based laser scanning and imaging)
- Environmental applications
- VHR SAR-based method and applications.

Finnish Meteorological Institute (FMI)

The atmospheric remote sensing research group has continued its strong involvement in four presently operational satellite instruments, Envisat/GOMOS, EOS-Aura/OMI, Odin/OSIRIS and MetOp-A/GOME-2. Data from these instruments has made it possible to create trace gas climatologies and time series. The research group has started to create global climatologies and long time series combining data from past and presently operating satellite instruments. These efforts, which aim for understanding small changes and variability in the atmosphere, are in line with the resent research plans of ESA, SPARC (Stratospheric

Processes and their Role in Climate) and IGACO (WMO's Integrated Global Atmospheric Chemistry Observations). An important component of this activity is the quality analysis of the data retrievals, the activity where the group has a strong experience and know-how from the long Markov chain Monte Carlo retrieval development.

The Envisat/GOMOS instrument has worked 8 years since the launch in 2002. 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 9 years since the launch in 2001. FMI's OSIRIS Level 2 processor has been used as a starting point to build a new processor for GOMOS bright limb measurements.

The Dutch-Finnish Ozone Monitoring Instrument (OMI) that was launched onboard NASA's EOS-Aura satellite in 2004 has since then provided global measurements of ozone, UV, aerosols, SO2 and NO2. AURA is one of the seven satellites which are flying within less than 12 min separation at the same orbit in the International A-Train satellite constellation. The atmospheric research group at FMI's Kuopio Unit has started to utilize this unique possibility to combine data from different missions by using aerosol measurements of MODIS and CALIOP to improve OMI UV-radiation measurements. The OMI Very Fast Delivery service, based on receiving AURA Direct Broadcast data at Sodankylä, provides almost real time ozone and UV maps of the Northern Europe (omivfd.fmi.fi). The OMI type of measurements of the atmosphere will be continued in the EU GMES programme. The Netherlands is together with ESA building a successor instrument to OMI called TROPOMI with planned to be launched in 2014 as GMES Sentinel 5 Precursor mission. In 2009 FMI started a nationally funded project to scientifically contribute to the TROPOMI mission by developing the ozone, aerosol and UV-radiation retrieval algorithms.

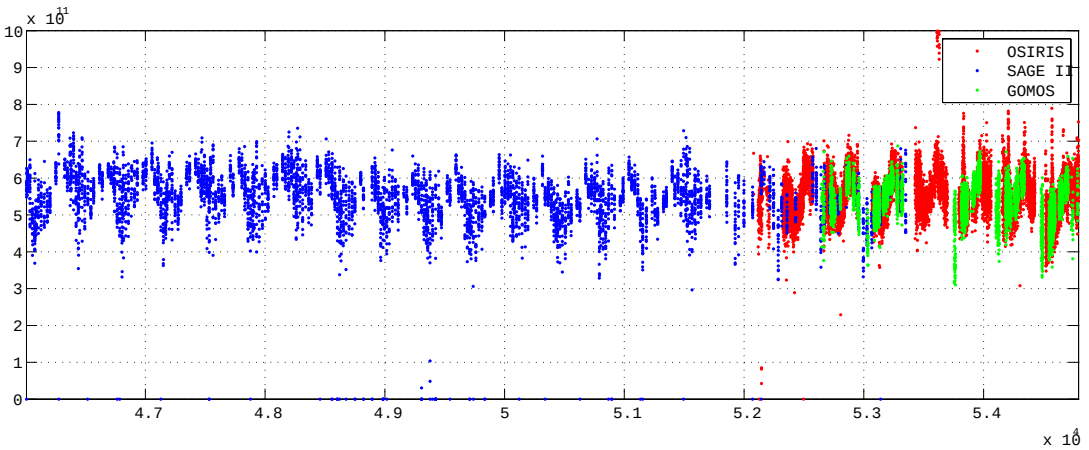


Figure 5.8. Ozone time series constructed from GOMOS, OSIRIS and SAGE II measurements.

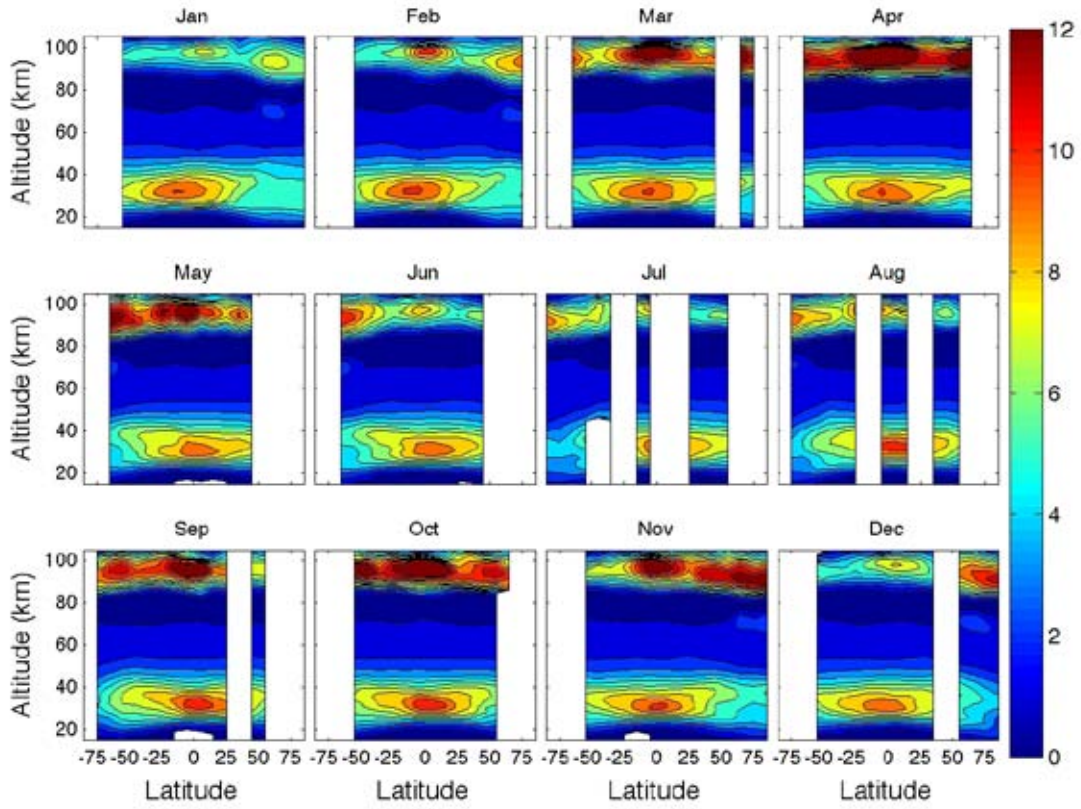


Figure 5.9. Ozone mixing ratio (ppm) at altitudes of 15 – 105 km from the GOMOS measurements in 2004. Figure shows the main ozone layer around 30 km, the second ozone peak around 95 km and in the spring months the weak third ozone peak at 72 km.

FMI is the leading entity of the EUMETSAT's Satellite Application Facility on Ozone and Atmospheric Chemistry Monitoring (O3M-SAF). The main objective of the O3M SAF is to process, archive, validate and disseminate atmospheric composition products, aerosols and surface ultraviolet radiation utilising the satellites of EUMETSAT. The majority of the current O3M SAF products are based on the measurements of the GOME-2 spectrometer onboard the MetOp-A satellite, launched in October 2006. FMI is responsible for the surface UV products. Preliminary results indicate that the UV products derived from the Metop-A data are consistent with corresponding products based on the NASA TOMS data. The current Metop-A will be followed by two similar satellites, B and C, providing data up to 2020.

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 improve the combined use of 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, atmospheric composition and climate research. In 2009 a new activity was started related to IGACO-O3/UV to evaluate the impact of the uncertainty in the absorption cross sections of ozone in the UV region.

FMI also participates in three other EUMETSAT Satellite Application Facilities aiming at estimation of various properties of the Earth surface using satellite data. FMI continues developing the surface albedo product of Cli-

Figure 5.10. International A-Train constellation consists of seven international Earth Science satellites that fly within approximately ten minutes of each other to enable concurrent science.

mate-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 a special product covering the Arctic area with the North pole as the centre has been developed.

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 and Aalto University. Currently the MSG/SEVIRI snow cover product is operational. Its quality is comparable to that of the corresponding product of NOAA/NESDIS, and in some cases it works even better.

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 University of Eastern Finland) also Météo-France and Laboratoire de Glaciologie et Géophysique de l'Environnement (LGGE) contributed in the campaign. The surface albedo and its bidirectional reflection distribution function (BRDF) were measured both from a helicopter and at ground level. In addition, various snow parameters were measured.

The long term co-operation in remote sensing of the leaf area index (LAI) continued with the University of Helsinki (Department of Forest Resource Management) and the University of Eastern Finland. A new method to measure LAI from airborne wide optics images was developed. The land surface research of FMI joined also the Northern Eurasia Earth Science Partnership Initiative (NEESPI) network.

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 cryospheric parameters

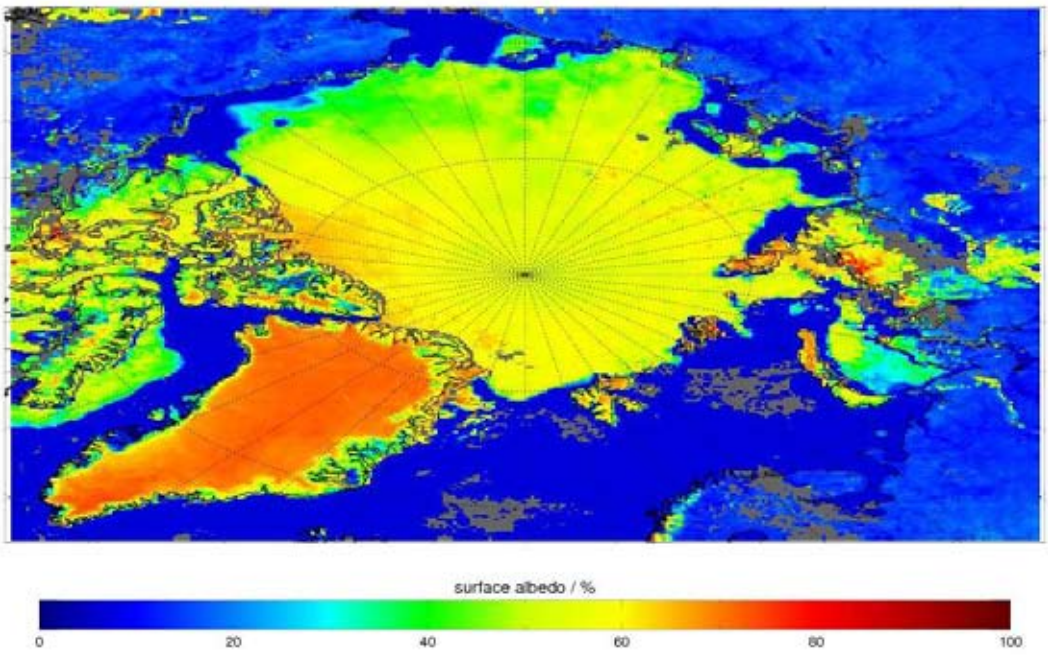


Figure 5.11. The weekly mean Arctic surface albedo product SAL of June 15 – June 22, 2009 processed in Climate-SAF project financially supported by EUMETSAT. The grey pixels correspond to areas, which were cloud covered in all available images of the week.

and high-altitude winds in polar regions from a Molnyia-type orbit. Additionally, FMI participates to NASA's spaceborne weather radar mission (GPM) as developer of snow precipitation algorithm. FMI will also provide CAL/VAL sites (Helsinki Testbed and Sodankylä Pallas) for the mission devoted, especially, for winter precipitation.

One of the focus areas is development of techniques to apply space-borne Earth Observation data for the monitoring of cryospheric processes. This includes the use of satellite data products to improve and validated climate models and climate trend analyses. The related research work also aims to the development of operational data assimilation and fusion techniques for NWP and hydrological forecasting.

FMI has initiated together with its partners development of operational global wide snow monitoring system that will employ satellite data, models and in situ observations. This will be developed in framework of several international projects: HydroSAF, Polarview, Snow-Clim, GlobSnow, FloodFore. The goal is to develop operational snow maps and asses the trend of snow cover in Northern hemisphere and Eurasia and its role as a climate change indicator.

Polarview is part of the ESAs GMES Service Element programme. Polarview aims to provide operational information from sea ice, lake and river ice and snow. FMI's responsibility is to provide high-resolution ice thickness maps and ice forecasts over the Baltic Sea, and snow water equivalence information from northern Eurasia, Service users groups are including Baltic maritime administrations, icebreakers, shipping, reindeer herders, climate monitoring, hydrology and weather forecast.

The FloodFore project aims at creating a multi-source information system for hydrological forecasting and runoff modeling systems, to be used in flood forecasting and e.g. hydropower production. The project, funded

by Tekes and several national companies, is coordinated by the Finnish Environment Agency (SYKE), with VTT and FMI acting as partners in the project consortium.

FMI has finalized a novel method to estimate daily total rainfall at high resolution, through the combination of weather radar and generic weather station information. Also, a novel method to estimate peak season snow water equivalent (SWE), the largest single factor affecting spring flooding levels, has been implemented. The method applies satellite radiometer observations and available in situ readings of snow depth in an assimilation scheme. In the first phase, a demonstration system using state-of-the art methods for rainfall detection, retrieval peak season snow properties has been established in northern Finland. The products of these methods are inserted into the watershed runoff model created by SYKE, which is used at a national level to predict river runoff and flooding. The new products have already been demonstrated to improve the estimates given by the watershed model.

The ESA Data User Element (DUE) funded GlobSnow project aims at creating a global database of snow parameters for climate research purposes. The main objective is to create a long term dataset on two essential snow parameters. The project will provide information concerning the areal extent of snow on a global scale and SWE for the Northern Hemisphere. Both products will include the end product derived from the satellite data along with accuracy information for each snow parameter.

The main objective of the SnowCarbo project is to implement and demonstrate a new innovative approach for the net carbon balance mapping in Europe and northern Eurasian region. This approach is based on a combination of different information sources describing snow evolution, phenomenology, land cover, CO2 fluxes and concentrations. The implemented method combines local in situ observations and global Earth observation satellite data together with land cover class information in a new way.

KaraX aims to develop several operational sea ice and snow products for the Barents, Pechora and Kara Seas: (1) sea ice type classification charts, (2) level ice thickness charts, and (3) snow depth over sea ice charts. These multisource products are based on the application of thermodynamic snow/ice model and on the optimized use of several satellite data sets: C-band SAR images, scatterometer data, radiometer data and spectrometer data.

The Sodankylä-Pallas satellite CAL-VAL site is currently the main super site in the boreal forest/sub-arctic zone of the Earth for investigating the performance of current and planned polar orbiting remote sensing satellites. Especially, the activities are related to cryospheric processes and surface-atmosphere interaction. The on-going projects are related to various missions of ESA, NASA and JAXA. Short descriptions on selected currently ongoing projects are given below.

In 2008 long lived plans for acquiring a Fourier transform spectrometer (FTS) to monitor greenhouse gas total atmospheric columns at Sodankylä became a reality. The main pur-

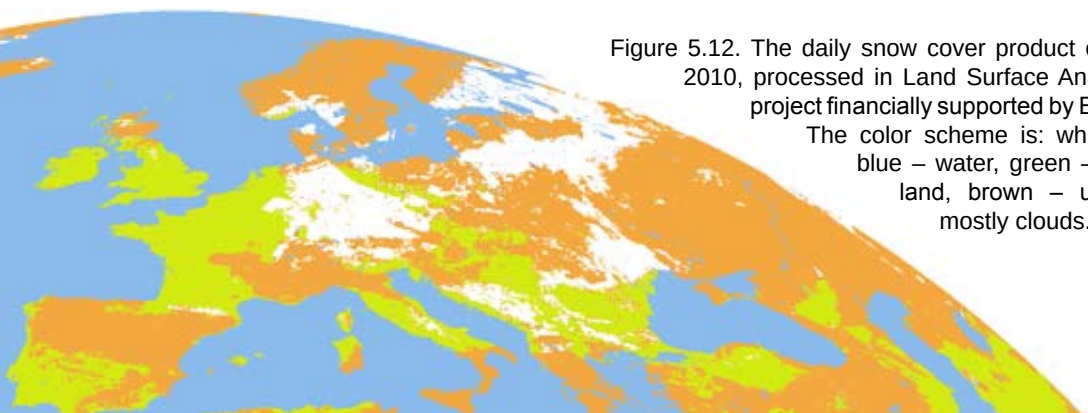


Figure 5.12. The daily snow cover product of March 7, 2010, processed in Land Surface Analysis -SAF project financially supported by EUMETSAT. The color scheme is: white – snow, blue – water, green – snow free land, brown – unclassified, mostly clouds.

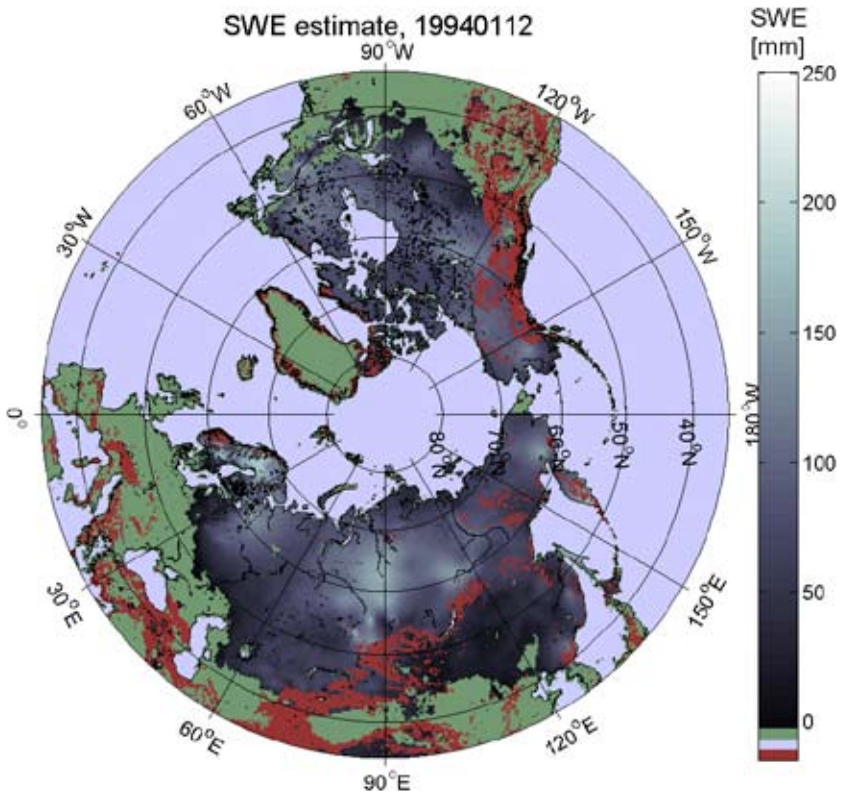


Figure 5.13. Prototype of the GlobSnow Snow Water Equivalent (SWE) product for 12 January 1994. GlobSnow-project will provide 30-year long time-series of the SWE at the northern hemisphere for the climate research community. The product is based on the assimilation of space-borne microwave radiometer observations (SMMR, SSM/I and AMSR-E) with global synoptic weather station observations on snow depth. The approach is based on the radiative transfer modeling of satellite observations as a function of SWE. Mountains are masked by red, snow free and non-classified regions by green.

pose is to complement tower and surface in situ GHG network and provide reference material for satellite missions. The first space-borne instrument dedicated to greenhouse gas measurements is TANSO-FTS onboard GOSAT satellite. Sodankylä FTS team has actively participated in GOSAT data validation activities and this work will continue.

SMOS cal/val operations included two measurement flights by Aalto University with their HUT2D instrument in Sodankylä. FMI personnel performed ground measurements of soil moisture and temperature or snow depth and collected soil and vegetation samples.

SnowRadiance is a joint ESA project between Brockmann Consult, FMI, and Universities of Bremen and Berlin, funded by ESA. The project aims at better forward modeling of snow to enhance interpretation of satellite measurements. The most noticeable event of the project was a two-day measurement campaign of snow reflectance and reference snow pit data on Lake Orajärvi, Sodankylä, in March 2009.

FMI and DA-Design have a joint TEKES-funded project to develop a new atmospheric profiling radiometer. DA-Design is responsible for the mechanics and electronics while FMI's task is algorithm development for atmospheric temperature and water vapour

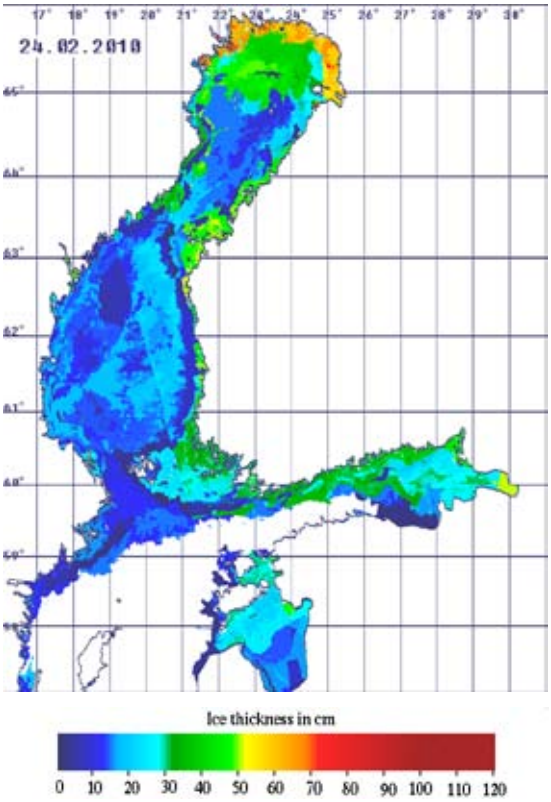


Figure 5.14. An example of automatic provided High-Resolution Ice Thickness map in February 24, 2010. The map is a combination of RADARSAT-2 and Envisat scenes, and it is updated every time new SAR data is available (see http://polarview.fimr.fi).

profiles. In spring 2009 FMI had an intensive testing campaign for the radiometer with the conclusion that it is still not working properly, and that algorithm development is impossible without good enough data.

FMI operates a data reception and processing facility in Sodankylä. Currently, the Sodankylä station receives and processes data form EOS Terra, Aqua and Aura satellites for several national and international end-use applications (monitoring of UV radiation, sea ice, snow cover and polar winds). These activities were boosted in 2009 by the governmental stimulus funding obtained from the Ministry of Transport and Communications. Through this funding work for constructing a new satellite data receiving system was started. This investment will substantially enlarge the satellite data receiving facilities of FMI for operational real-time environmental monitoring applications from the beginning of 2011. This includes the capacity of receive and process high-spatial resolution satellite images.

The processing and archiving facilities were also substantially developed in 2009. This includes the installation of ESA MMFI ground segment feasible for the processing and archiving of data from all ESA missions. The work to establish an European cryospheric data centre at Sodankylä was also started through ESA GlobSnow and EC Life and SnowCarbo-projects. The data archives under construction will include the 30-year-long satellite data-based global snow information for climate research (Fundamental Climate Data Record).

Figure 5.15: Reference instruments for ESA CoReH2O SAR, ESA SMOS and NASA/Jaxa AMSR-E at Sodankylä.

University of Helsinki Department of Geosciences and Geography

GeoInformatics Research Group (GIRG) within the newly established Department of Geosciences and Geography consists of 15 staff members, while remote sensing is the major topic of roughly 7 persons. The group has produced in 2008–2010 three PhD theses in remote sensing, while another two are coming in 2010. The main fields of research in remote sensing are land cover and land use change studies in East Africa, glacier change studies in the Alps and vegetation studies in Northern America and Europe.

In the centre of the research has been the applied use of remote sensing and geographic information systems in environmental monitoring and modelling studies. Research conducted within the TAITA and TAITATOO projects funded by the Academy of Finland has focused on understanding the interactions between land use change, climate variations, biological diversity and natural resources conservation in the Taita Hills, Kenya. Mapping this complex landscape through optical remote sensing techniques utilized both

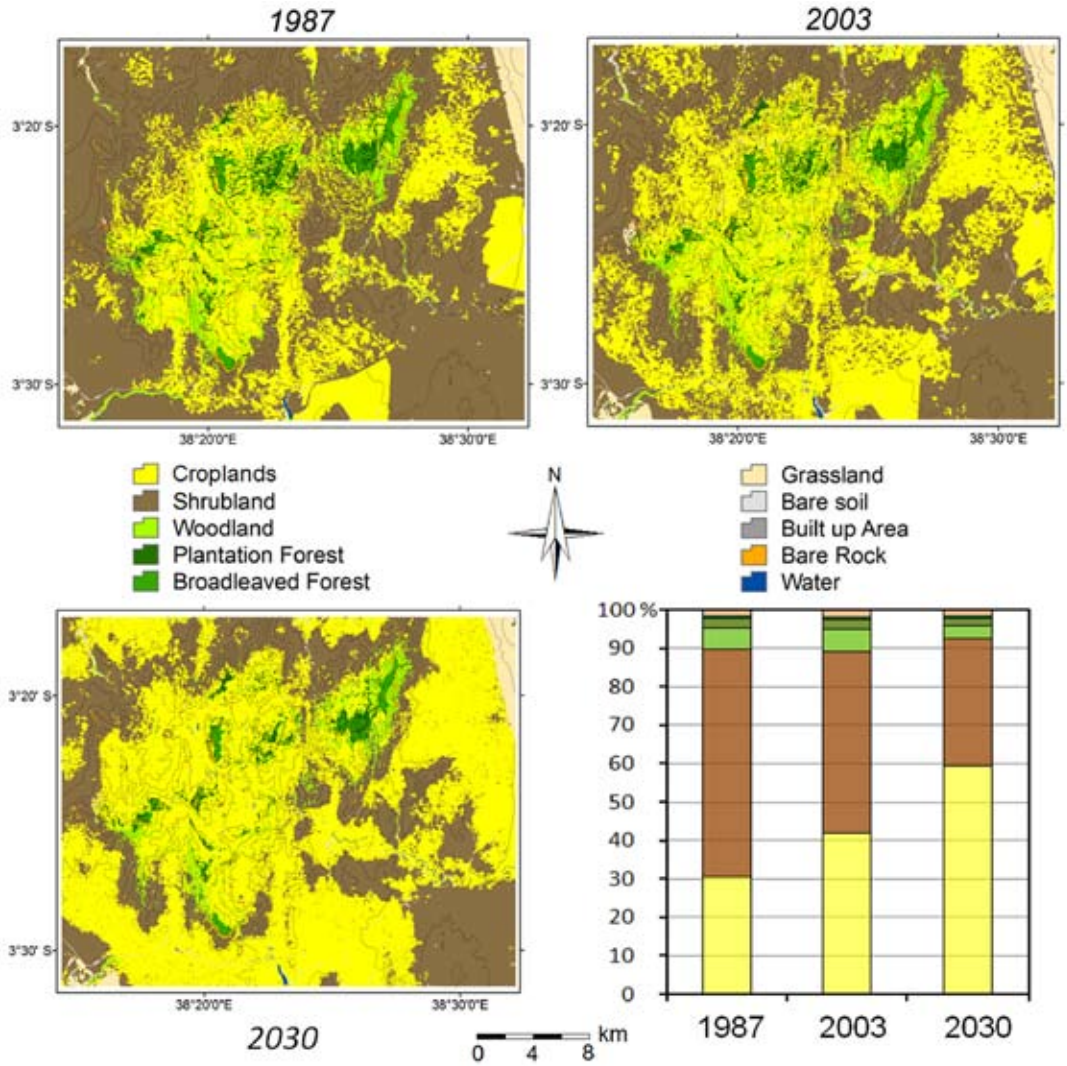


Figure 5.15. The expansion of croplands in Taita Hills, Kenya from 1987 to 2003 and scenario for 2030

multi-temporal SPOT satellite imagery and detailed 0.5 m resolution digital mosaics created using EnsoMOSAIC. The remote sensing research specifically focused on the methodological development of pre-processing, data calibration and validation, classification and change detection techniques to enhance the accuracy of land cover mapping in this rough study area 3 degrees south of equator. Further research within the project considered soil erosion modelling, forest fragmentation and connectivity studies between fragmented forest patches, and the development of participatory rural appraisal methods. The potential impacts of agricultural expansion and climate change for soil and water conservation in the Taita Hills was assessed by integrating remote sensing and geospatial data with spatially-explicit simulation models in order to evaluate plausible scenarios up to the year 2030. The results allowed a clear identification of priority regions for land use allocation policies and water resources management in the Taita Hills.

The research programme in the Taita Hills will continue in the future. The University of Helsinki purchased a research station in Wundanyi, Taita Hills and research funding is will be provided for four years by Ministry for Foreign Affairs of Finland for climate change impact studies on ecosystem services. The research area will also expand to Kilimanjaro area in Tanzania and Jimma area in Kenya.

Hyperspectral remote sensing and imaging spectroscopy research at the department focuses on applications with vegetation and snow and water surfaces. The principal data is provided by AISA Eagle and Hawk sensors acquiring data from visible - near infrared and middle infrared wavelength areas, respectively. A flight campaign was carried in synergy with SNORTEX campaign in cooperation with SYKE and FMI in Lapland in March 2010 for snow characteristic and forest leaf area index studies.

Thematically, remote sensing of vegetation and especially forest characteristics using

Fiugre 5.16. Unrectified AISA flight line over Tähtelä, Sodankylä, Finland representing winter landscape on 18.3.2010, 11:51. Wavelength bands from AISA DUAL used for this figure were at 640,551 and 462 nm. Swath width is 300 m and spatial resolution is 0.8 m.

multispectral satellite imagery and hyperspectral and multispectral airborne remote sensing data is in the research focus of GIRG. The main aim is to develop leaf-area-index (LAI) assessment methods using remote sensing data and to enhance ground truth methods by developing correction and software packages for hemispherical photography. Forest LAI studies have been practiced in Finland, Estonia, Canada and Kenya. Another aim has been to use LAI as a variable in ecological studies, such as forest succession, ornithological studies and biogeographical studies, especially in east African mountains. In large-scale land cover and vegetation studies the research topics have been forest and bush fires in Namibia and Brazil.

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.

Basic research of sea ice dynamics has been performed for interpretation of remote sensing imagery for ice mechanics processes. Geometry of fracture systems has been classified for ice mechanics, and fracture mechanics models have been employed for quantitative analyses and modelling investigations. ERS-2 and Radarsat imagery were used in this work. Also in efforts to validate ice models, MODIS and AMSR-E imagery was used for reference data of ice compactness in application for calculations of drift and dispersion of oil spill from Runner-4 ship accident in the Gulf of Finland. 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. Also investigation for estimating ice thickness based on the surface temperature is ongoing.

Glacier and ice sheet remote sensing has involved the Dronning Maud Land, Antarctica, and Svalbard. The work is done mainly 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 Svalbard for the calibration of methods. The latter case was part of the IPY Kinnvika programme.

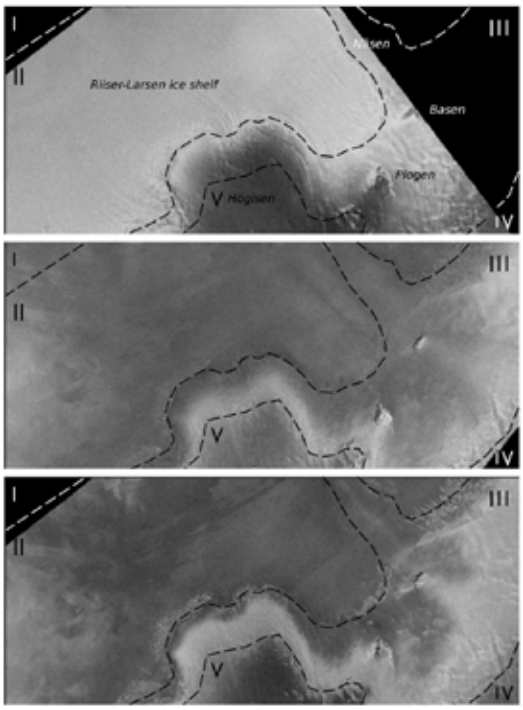


Figure 5.17: Envisat ASAR wide swath images from Dronning Maud Land, Antarctica near the Finnish research station Aboa on nunatak Basen. The darkening color in the images is due to increasing amount of free water in the snow pack during the Austral summer. Dates of the images are Sep 29th 2003 (top) representing the winter conditions, Jan 4th 2004 (center) and Jan 12th 2004 (bottom) representing the Austral summer conditions. Similar images were taken during season 2009-2010.

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. In 2009 a Nordic Network on Aquatic Remote Sensing was started up, with Department of Physics representing Finland.

Figure 5.18. A series of optical sensors are deployed for a vertival profile of light level.

University of Joensuu
Faculty of Forest Sciences

"New Technologies to Optimize the Wood Information Basis for Forest Industries – Developing an Integrated Resource Information System 2008–2010 (WW-IRIS)" is a Wood-Wisdom-Net Research Programme project coordinated by the Norwegian University of Life Sciences. Altogether five countries and more than ten partners are involved in the project. The major objectives of the research are (1) to develop and optimize laser scanner methods for assessment of wood qualities and quantities at high spatial resolution and validate these methods across countries, and (2) to further improve the flow of information regarding wood resources along the forest/wood-products chain by adapting forest information and planning systems to utilize improved information from laser scanner aided inventories. The Finnish part of the project is funded by Tekes, Ministry of Agriculture and Forestry and SamNordisk Skogsforskning. The target is Eucalyptus plantation forests in South America including ALS based inventory, forest information systems and forest planning. So far data collection by laser data acquisition, about 6700 hectares, and field measurements, about 200 field plots, have been carried out. Airborne Laser Scanning (ALS) data have been used as to predict stand attribute information for compatible growth and yield model used operationally in plantation. As a result standing volume is calculated in a wall-to-wall manner for the whole test area using hexagons with a size of 300 m² and this information is used in forest planning calculation.

In the project "Mapping rare forest characteristics using remote sensing material and field data 2007–2010" funded by the Academy of Finland and lead by the University of Helsinki the role of the University of Joensuu has been to study different sample-based dead wood inventory methods and investigate the possibilities for utilizing ALS data in the inventory. Main findings of the study are that

Figure 5.19. Laser scanning of Eucalyptus plantation in August 2008.

Finland. In Joensuu the use of ALS data collected under leaf-off conditions for species group level forest inventory purposes was examined. The results indicate that airborne laser scanner data collected under leaf-off conditions is suitable for forest inventory purposes in Finland.

The project "The use of airborne laser scanning and aerial photographs in the inventory of timber sortiments by tree species 2008–2010" funded by TEKES /European Regional Development Fund continues the work to develop a forest inventory method that produces tree species specific stand characteristics information by combining ALS and digital aerial photographs. Specific aims of this project are to estimate species specific diameter distributions, to optimise field sampling intensity, to assess bionergy and to combine ALS data and logging machine data. Accurate biomass estimates can be obtained for the stand tree stock as whole by using ALS data but the accuracy is worse when timber sortiments or removed tree stock is considered.

Mapping, Tekes 2009–2010" is joint project with VTT (main contractor), Arbonaut, Storaenso, Metsähallitus and Finnmap. The major research effort has been made to improve stand level estimates using segmentation approach and data fusion techniques. Comparison of high resolution satellite data will be main task of project.

The project "Applying forest planning and environmental informatics to develope bioenergy economics" of The University of Eastern Finland (2007–2010) has multidisciplinary research topics and contains remote sensing component. ALS based bioenergy mapping data and optimal bucking algorithms were integrated. Biomass component specific results were analyzed to demonstrate uncertainties in stand level decision making. It is not very easy to identify bioenergy stands and uncertainties are still quite high.

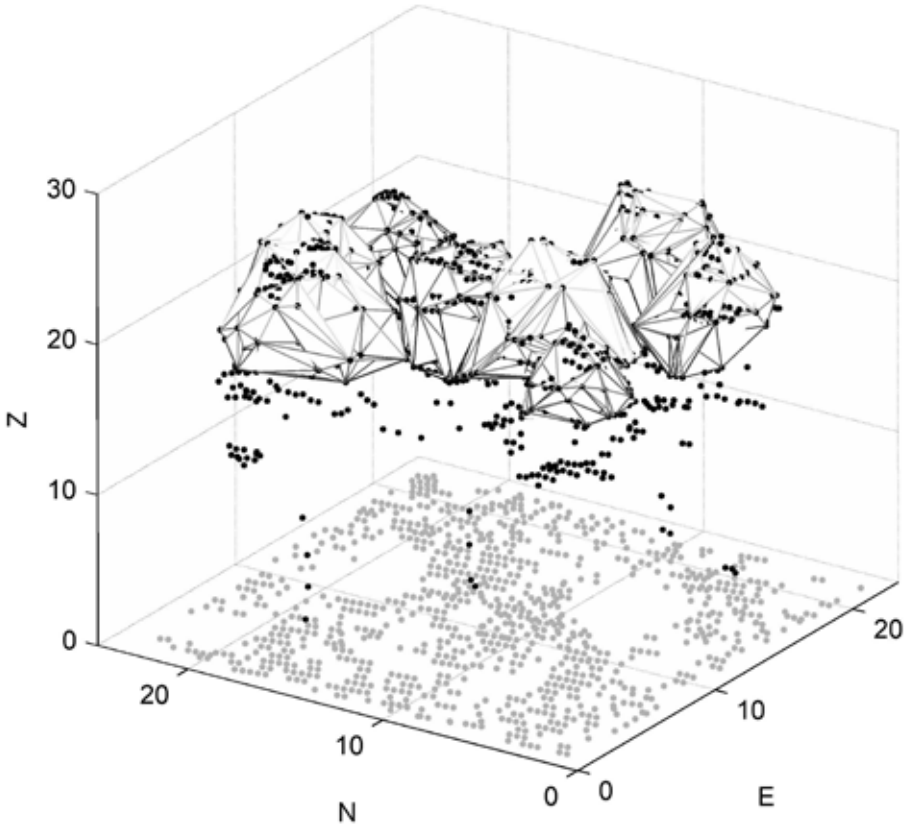


Figure 5.20. Tree crowns generated from 3-D laser data using the alpha shape technique

VTT Technical Research Centre of Finland

VTT is the biggest contract research organisation in Northern Europe. It 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' competitiveness and competence. In the field of remote sensing the annual volume of the research work in the years 2008–2009 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). The VTT Remote Sensing team is a forerunner in the utilisation techniques of Earth observation data, helping their customers to improve their competitiveness by timely and research-based information on the environment. VTT is involved in the research network that comprises key actors in Earth observation in Europe, North America and Japan. International cooperation is mostly connected to ESA and EU projects and to the exchange of personnel. VTT carries out projects for international customers in collaboration with domestic companies. As an example of activities in the field remote sens-

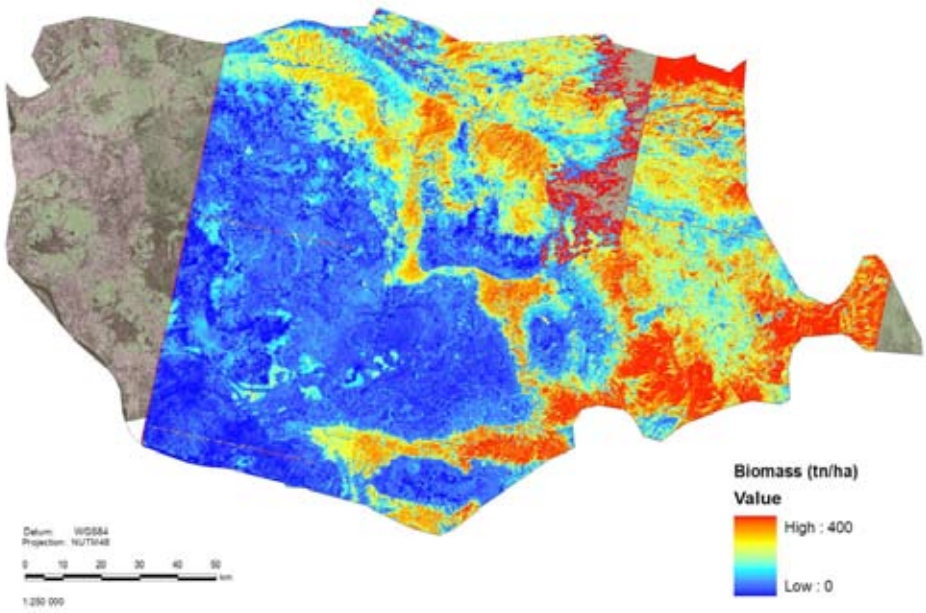


Figure 5.21. Biomass map of Savannakhet province in Lao PDR from AVNIR image data. Field plot locations are shown in the lower part of the map. The dark red in the upper right part is due to the cloud shadows.

ing at VTT, an overview of few projects carried out 2008–2009 is presented.

In LaoSilva project methods for satellite image based forest resources inventory for tropical region were developed and tested. The new method combined a sample of very high resolution satellite (VHR) data with wall-to-wall satellite data with lower spatial resolution. QuickBird and Kompsat-2 optical date were the VHR data and AVNIR and ALOS PalSAR data the wall-to-wall data. Ground sample plot data were available from a restricted area for the estimation of biomass. The study site was in Lao PDR. The sampling design for the VHR data was developed for the whole country and the empirical image interpretation was done on one province of Lao of 2.1 million hectares.

Simulations showed that the same accuracy could be achieved in forest area estimation with 6.25% non-stratified sampling as with 1% stratified sampling. Visual interpretation of sample plots on VHR images was effective to evaluate land cover classes reliably. Also degraded forest was possible to separate from intact forest. Good agreement with the lower resolution satellite map classes was achieved. The visual interpreters should be trained well in future operative work.

Growing stock volume estimation had to be done using medium resolution satellite data only due non availability of VHR data but the results were better than what were expected. The coefficient of determination (R2) value for the biomass estimation was 0.6. We conclude that the procedure that was developed in this pilot study can be applied operatively.

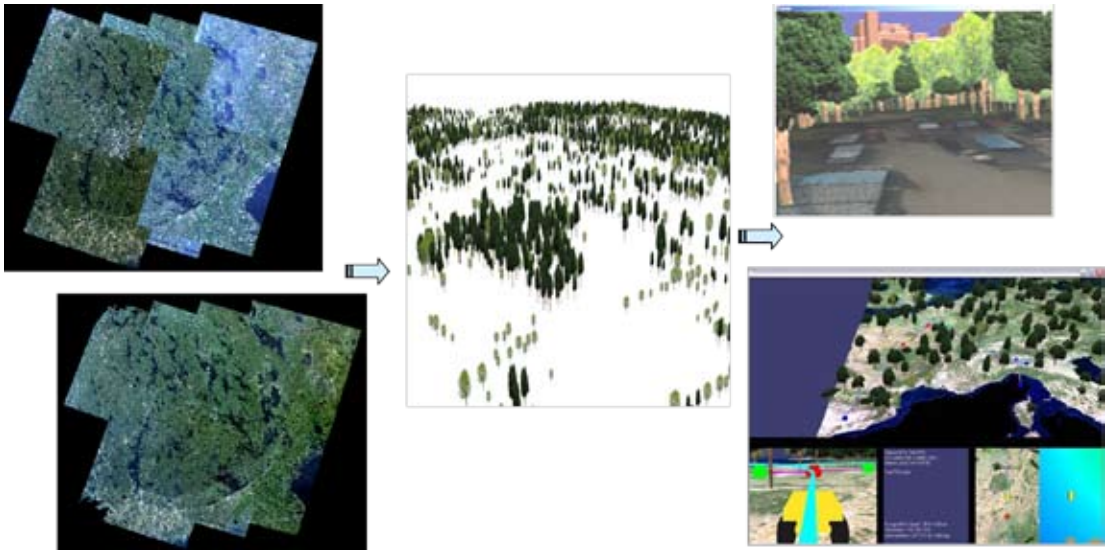


Figure 5.22 Tree layer from satellite images to TALOS virtual prototype.

Also research should be continued to further improve the method.

The study was done under the SUFORD (Sustainable Forestry for Rural Development) project that is Managed by Indufor Oy and funded by the Ministry for Foreign Affairs of Finland and Lao government. It supported preparation for the REDD (Reduction of Emissions from Deforestation and forest Degradation) process. The European Space Agency provided most of the satellite data under a Category 1 agreement.

EU FP7 project geoland2 (2008–2012) is carried out in the context of GMES, a joint initiative of European Commission and ESA, which aims to build up a European capacity for Global Monitoring of Environment and Security. Within eight sub-projects, the 56 geoland2 partners develop products and services, utilizing available Earth Observation resources in combination with in-situ measurements, and integrating them with existing models into pre-operational geo-information services. These so called core services are supposed to be used later on for making downstream services and support the implementation of European directives and their national implementation, as well as European and International policies. VTT is involved in the forest part of the project. The team's end product is a high resolution Forest Layer with Forest Area maximum outline information, as well as geometrically consistent and synergistic pixel-based Forest Type, Forest Crown Cover Density and historic Forest Area Change information (e.g. 1990–2009) at high thematic accuracy.

TALOS project (Transportable Autonomous Patrol for Land bOrder Surveillance) is an International research project for years 2008–2012 co-funded by the EU 7th Framework Programme in Security priority. The project is aimed at designing, implementing and field-testing a prototype of a land border surveillance system based on unmanned ground and aerial vehicles. TALOS project consortium is formed of research teams from industry, research and academia from Belgium, Estonia, Finland, France, Greece, Israel, Poland, Romania, Spain and Turkey, see: **http://www.talos-border.eu**

VTT core responsibility is to build the virtual prototype of the TALOS system. The virtual

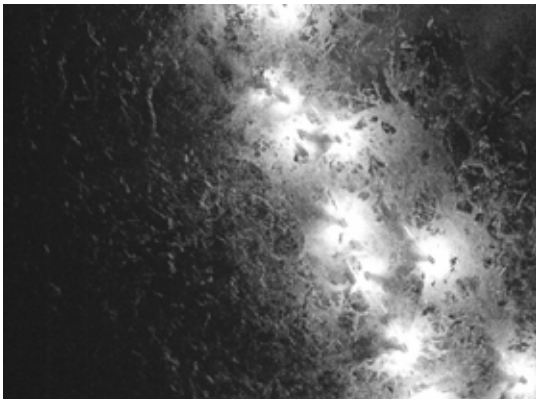


Figure 5.23. Mosaic of ship radar images. This image shows that real-time high resolution information of the ice cover can be obtained over a larger area by making a mosaic of ship radar images from moving vessels.

prototype is used to enable distributed development of the system, testing in early development phase, and pre-operation training. The virtual prototype includes the 3D environment model with command centre, sensor towers and sensors, the UGV dynamic model, the UAV model, the radio coverage model, and the tools for realistic dynamic rendering of the operation environment. Satellite imagery is utilised to update the vegetation and tree layer of the environment model. The calibration of the satellite image radiance into absolute reflectance value is based on the actual aerosol optical depth estimated from the satellite images, so that the amount of needed ground reference can be decreased. This is advantageous especially in large area applications, like the land border surveillance system. Other potential applications of the virtual prototype and the TALOS system are the survey of large dangerous areas, and the planning and management of rescue operations in natural disasters.

In the ShipSensorNet (2007–2009) project the aim was to study to what extent near real-time coastal radar data, ship radar data and ship performance measurements collected from multiple ships going in ice could be used to derive useful information about the ice field properties and to estimate how different ships would perform in different sea areas. A prototype system was set up to collect ship radar

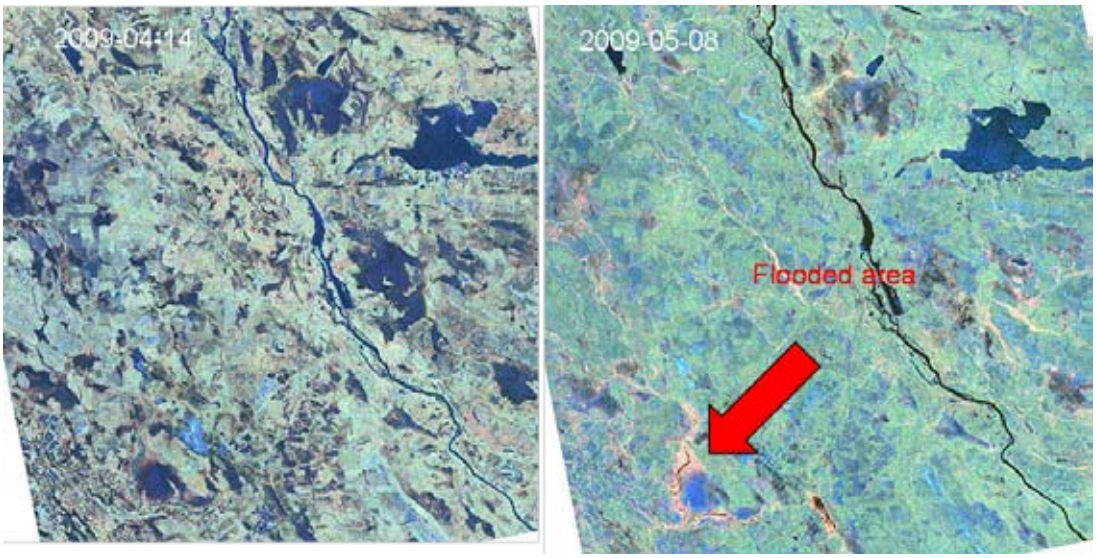


Figure 5.24. Radarsat-2 polarimetric images of Sodankylä. The colours of the Pauli decomposition (red = HH-VV, green = HV, blue = HH+VV) emphasize volume scattering in green band, surface scattering in blue band, and double bounce scattering in red band. In flooded areas where horizontal water surface forms a mirror under vertical trees the dominance of double bounce scattering gives these areas a reddish tone. RADARSAT-2 Data and Product © MacDonald, Dettwiler and Associates Ltd.

data and ship performance measurements. Using the prototype system, ice field drift was calculated from ship radar image sequences. The image mosaics that were made from a moving icebreaker showed the potential of this technique as a complement to satellite image data thus going one step further towards the vision of a distributed ice navigation system that would automatically collect information from multiple sources, fuse the data, and provide the users with observations, predictions, and route suggestions. The partners in the TEKES supported project, coordinated by VTT, were the Finnish Institute of Marine Research (now part of FMI), Aalto University, Image Soft Oy, Rettig Group Ltd Bore and BP Shipping.

FloodFore project is a joint project (2008–2011) between SYKE, FMI, and VTT. The objective is to develop information systems and techniques for flood forecasting by applying (a) satellite observations, (b) weather radars and (c) in situ measurements from automatic stations. Polarimetric data from the Radarsat-2 satellite can be used to map flooded areas around river channels during the snow-melting season.

5.3. Space Technology

Finnish Meteorological Institute

The space research at FMI has adopted a strategy to cover the full chain of research starting from the original scientific questions leading to instrument definition and development. This involves measurements and data analysis, scientific data interpretation utilizing theoretical modelling and simulation efforts. To this end the key asset is the knowledge and utilization of space technology.

FMI has own expertise on key disciplines of space technology, e.g., sensor technology, microcontrollers and software development as well as on instrument manufacturing tasks. In addition, we use various Finnish industrial subcontractors at regular basis to complement the space instrument development work. FMI's expertise in space technology dates back to the year 1985, when we started with the instruments for the Russian Phobos mission and joined its multinational science team. Currently FMI provides systems, instrument and sensors to space projects as well as also participates initiating new space missions.

The configuration of the flight software of the mass-spectrometer COSIMA on board the ESA/Rosetta comet mission, originally developed at FMI, was prepared in autumn 2009 for the July 2010 fly-by of the asteroid Lutetia and the comet operations in 2014. The Rosetta plasma instruments ICA and LAP with FMI-built control electronics participated successfully in the 2009 Earth fly-by observations. The control software for the Finnish PI-instrument SESAME/PP on board of the Rosetta Lander Philae was upgraded and tested during 2009 for on-comet operations and is performing as expected.

FMI delivered the flight units REMS-P and REMS-H (pressure and humidity measurement instruments) to the Mars Science Laboratory (MSL) Mission led by NASA. The MSL mission is slated for launch in 2011.

FMI participates in a number of technology activities for the ESA Mercury mission Bepi-Colomobo. For the X-ray instrument MIXS/SIXS and the plasma instrument SERENA FMI is providing a total of 7 ground support equipments for instrument development, integration and flight operation. The first devices were delivered in autumn 2009.

MetNet is a new type of atmospheric science mission to Mars (MetNet), initiated and defined by FMI. MetNet is based on a unique type of semi-hard landing vehicle utilizing inflatable parts in the entry, descent and landing systems. The mission is being put together by the consortium including the FMI, Lavochkin

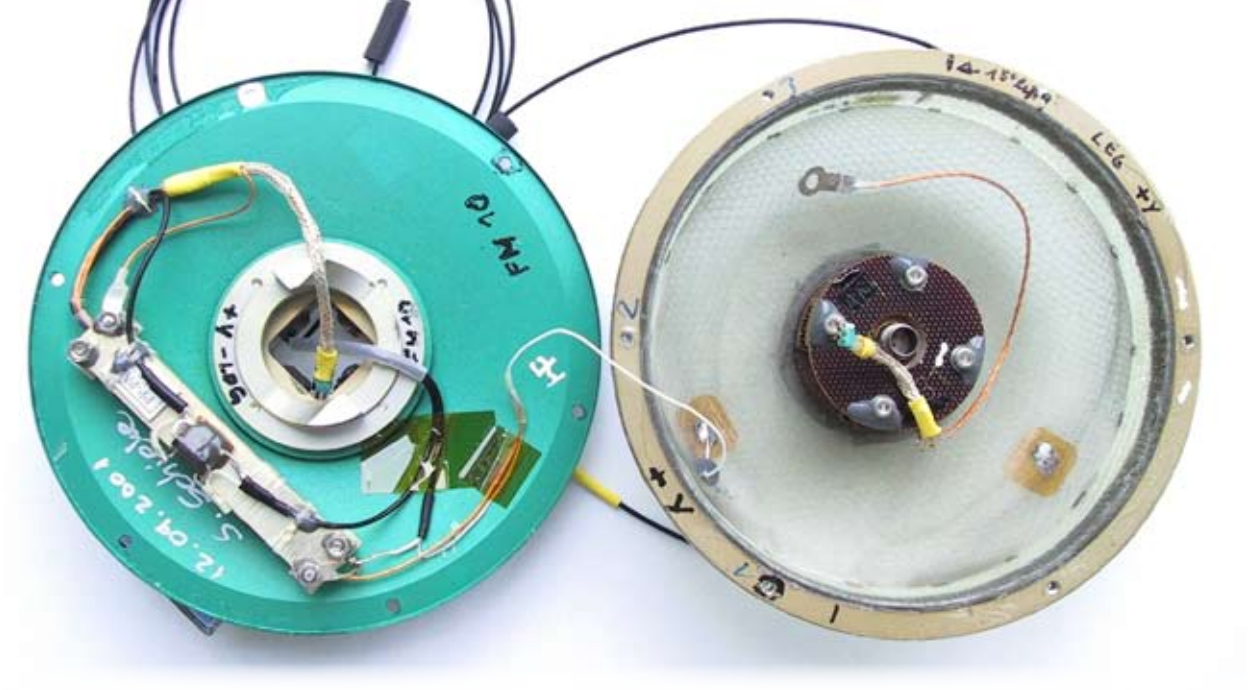


Figure 5.25. The prototype unit of the PP instrument.

Association (LA), the Russian Space Research Institute (IKI) and Instituto Nacional de Técnica Aeroespacial (INTA). The scope of the MetNet Mission is to create an observational network to Mars by deploying tens of MetNet Landers (MNL) on the Martian surface. The surface network at Mars is currently the main missing component in the field of Martian investigations, and the MetNet mission is to fill in this gap. The MNL will carry a versatile science payload focused on the atmospheric science of Mars. In 2009 the MetNet team was manufacturing the instrument engineering units for the MetNet Mars Precursor Mission (MMPM) aiming at sending the first MetNet lander to Mars in 2011 onboard Russian Phobos Grunt spacecraft to demonstrate the technical and scientific capabilities of the MetNet concept.

The electric solar wind sail (or electric sail) is a novel device that can utilise the solar wind momentum flux for spacecraft propulsion. The electric sail deploys a set of long, thin and conducting tethers which are kept in a high positive potential by an onboard, continuously operating electron gun (see picture on the cover). 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 electric sail is a significant technical spinoff of basic research and simulation work of solar wind interacting with solar system bodies. According to numerical calculations, the efficiency of the electric sail is quite revolutionary in comparison to existing methods: about 100 times more efficient than an ion engine, for example, in a 10-year long asteroid touring or asteroid resource utilisation mission. The first Estonian satellite ESTCube-1 (a 1 kg CubeSat) with planned launch in 2012 will carry a 10-m tether to orbit to measure the electric sail effect for the first time. There is a Europe-wide consortium pursuing the electric sail technology which is led by the inventor

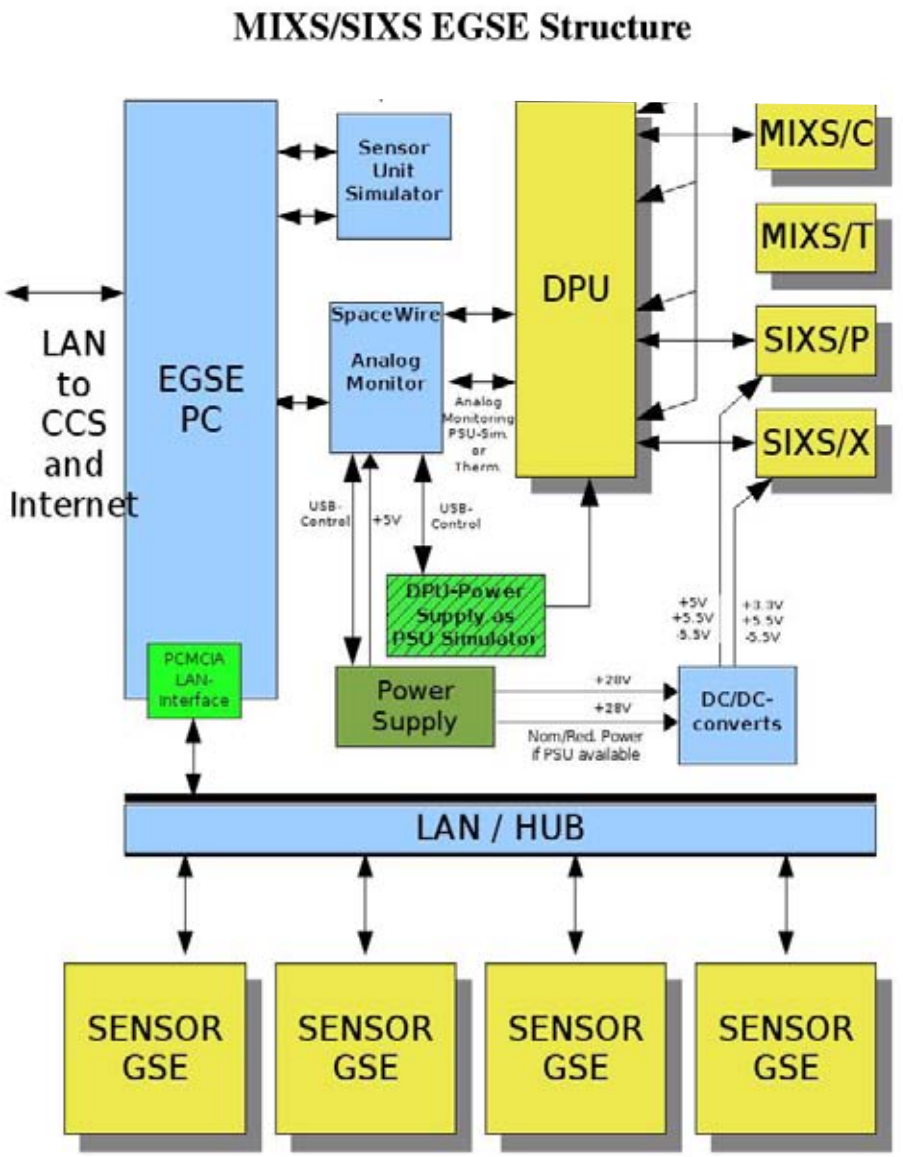


Figure 5.26. The structure of the EGSE developed for the MIXS/SIXS instrument.

at FMI and funded by the EU 7th Framework Programme.

FMI is managing the integrated and distributed information system for planetary research IDIS, which is under development as part of the EU-FP7 funded European Europlanet-Research Infrastructure. In its final stage it will provide a planetary virtual observatory for access to space based and laboratory observations, model data and tools, spectral data bases and additional information about test- and simulation facilities in Europe, related to planetary research. For details see **http://www.idis.europlanet-ri.eu/**

FMI is also developing a radiation hardened central data processing unit for the Particle Environment Package (PEP) proposal intended for the ESA Jupiter Ganymede Orbiter mission JGO. The main challenge is the harsh radiation environment around Jupiter.

Aalto University School of Sciencce and Technology (TKK) Department of Radio Science and Engineering

The SMOS satellite (Soil Moisture and Ocean Salinity) of the European Space Agency was launched successfully in orbit in November 2, 2009. The Space Technology Group of the Department of Radio Science and Engineering (RAD/STG) has participated in the development of the Satellite payload over a decade by studying the measurement concept, testing satellite prototypes, designing payload instruments, and participating in airborne validation campaigns. RAD/STG also participates in the commissioning of the payload and in calibration and validation activities related to the SMOS mission by carrying out measurements with an airborne remote sensing radiometer developed by the group.

Figure 5.27. The SMOS satellite of ESA.

The HUT-2D radiometer is accommodated underneath the TKK research aircraft fuselage and operates at the same frequency as the MIRAS radiometer on SMOS. The soil moisture retrieval research in Department of Radio Science and Engineering focuses on emission models in the conditions of the boreal forest zone and effects of snow and frost to the soil emission. The instrument features the same new technology for climatological studies as SMOS does. With the instrument, the group participated in an extensive measurement campaign at soil moisture test sites in Europe during spring 2008. Together with other state-of-the-art remote sensing equipments provided by European scientific institutes, HUT-2D was installed in Department's research aircraft Skyvan. The 6-week campaign, consisting of multiple measurement flights in northern and southern Germany and in southern Spain, was conducted in the frame of ESA's SMOS calibration and validation activities.

The data acquired during the campaign was delivered to the scientific community in late 2008, and a number of institutes (e.g. University of Cambridge, Ludwig-Maximilians University,Munich) are working with the data to support soil moisture algorithm development.

A new direction of studies with HUT-2D is Radio Frequency Interference (RFI) measurements. RFI on the ground may severely harm radiometric remote sensing missions. HUT-2D has been used to detect possible RFI sources on the protected 1.4 GHz band, which is utilized by the SMOS mission. Good ground resolution of the HUT-2D enables pinpointing and recognizing RFI sources with great accuracy. Possible RFI sources have been detected over urban and industrial areas.

TKK has been widely involved in snow monitoring activities employing satellite based synthetic aperture radar (SAR) data in cooperation with key national and international snow research teams. Between the years 2007–2009 the snow remote sensing team at TKK developed an operationally feasible methodology for estimation of SAR-based snow-covered areas (SCA) for the boreal forest zone. The team characterized the accuracy of TKK-developed estimation procedure for the boreal forest zone and created a methodology for producing uncertainty information related to satellite-based SCA estimation. The TKK snow remote sensing team further demonstrated the automation of the SCA estimation method, including the development of

a semi-automatic system that can be utilized in operational hydrological monitoring. The satellite radar-based SCA monitoring system has been incorporated into operational use by the Finnish Environment Institute (SYKE). The work was carried out in different national and international projects in close co-operation with the Finnish Environment Institute (SYKE) and the Finnish Meteorological Institute (FMI).

The ESA funded project "Development of MERIS lake water algorithms" (MERIS LAKES, 2007 – 2008) was successfully concluded in July 2008 with the public release of two new MERIS data processors. The processors were the first designed specifically for lake water. The validation of the processors showed that even though the results still contain errors they can provide valuable information about lake water quality. The project was coordinated by the RAD Department and included partners from Finland, Germany, Spain and Norway.

The MERIS LAKES processors were tested during the TEKES funded Catchlake 2 project (2008 – 2009), which was concluded in December 2009. The final results of the project include a time series of turbidity and chlorophyll a derived from Envisat-MERIS data for the Lake Säkylän Pyhäjärvi during summer 2009. The tested processor was able to estimate turbidity values that corresponded well with in situ measurements. The chlorophyll method requires further development. The project was coordinated by the Finnish Environment Institute (SYKE).

In the ongoing TEKES funded project Lake Water Quality Service (2009 – 2010), the objective of the TKK is to develop an inexpensive in situ measurement device for water quality estimation. The device will be based on consumer digital camera technology. The use of inexpensive sensor units will allow also the general public to participate in environmental monitoring. In 2009 the first prototypes of the measurement device were tested and the basic measurement principles were

Figure 5.28. Skyvan and its flight route of during the SMOS calibration campaign.

confirmed. The project is coordinated by the University of Helsinki.

Polarimetric weather radars are next generation instruments in weather monitoring and forecast. A Tekes-funded project on multidisciplinary use of polarimetric radar, initiated a collaborative research between FMI, University of Helsinki and Aalto University of utilizing volume integral equation methods in the modelling of melting hydrometeors. At TKK the research during 2008–2009 focussed on modelling spheroids with increasing water volume fraction. This study was aimed to clarify the changes in the propagation attenuation with the increasing water volume fraction in the particles and the effect of water's differential accumulation on weather radar's different polarization components at 5.6 GHz. In 2009 this research is expanded to concentrate also higher frequency region, from 13 to 94

Figure 5.29. HUT-2D remotes sensing radiometer developed by RAD/STG. The instrument is pointed upwards for Galactic measurements. Nominally, the instrument is attached at the bottom of the fuselage of the research aircraft Skyvan. Right: Brightness temperature images composed using measurements of HUT-2D instrument from several overpasses of a test area near Munich during the SMOS validation campaign in 2008.

GHz under NASA-project Global Precipitation Monitoring.

Because of the shrinking of sea ice extent in the Arctic Sea the marine transportation as well as the amount of off-shore operations are expected to increase significantly. This creates a growing demand of operational high-resolution sea ice and snow products for these users. In co-operation FMI and the Aalto University are involved in creating for this area a multi-source product, where a thermodynamic snow/ice model is combined with several satellite data sets: C-band SAR images, scatterometer data, radiometer data and spectrometer data. At TKK some of the pre-processing of the satellite data is performed and a time series of backscattering coefficients for the selected test area is collected. The dependence of the backscattering coefficient in Envisat ASAR radar images on incidence angle has been examined for two ice types, deformed ice and level ice, including regression analysis for the test area in the Kara Sea. The outcome follows the results obtained earlier in a similar study for low-salinity sea ice in the Baltic Sea.

RAD/STG has developed a simulator for the ESA's Airborne SAR/Interferometric Radar Altimeter System (ASIRAS) altimeter echoes from snow-covered first-year sea ice. The simulated echoes are used to investigate how measurements are affected by the snow and ice characteristics. Our simulations show that when the snow cover is dry, the echo from the upper ice surface typically dominates. The simulated echoes prove to be very sensitive to the presence of liquid water in snow and the small-scale roughness of the ice surface. The accurate estimation of the ice freeboard is likely possible only under dry snow conditions and when the snow load is known. The ASIRAS simulator concept can also be used for the CryoSat altimeter.

In MEGAPOLI (Megacities: Emissions, urban, regional and Global Atmospheric POLlution and climate effects, and Integrated tools for assessment and mitigation) project, leaded by Finnish FMI, RAD/STG has created a city morphology database based on satellite images for modellers studying the anthropogenic impact on air quality and on climate. In order to work with required accuracy, the models require databases of emissions and surface characteristics as initial and boundary conditions. Among others high resolution urban data are needed. In this project, a morphology database was designed and created for cen-

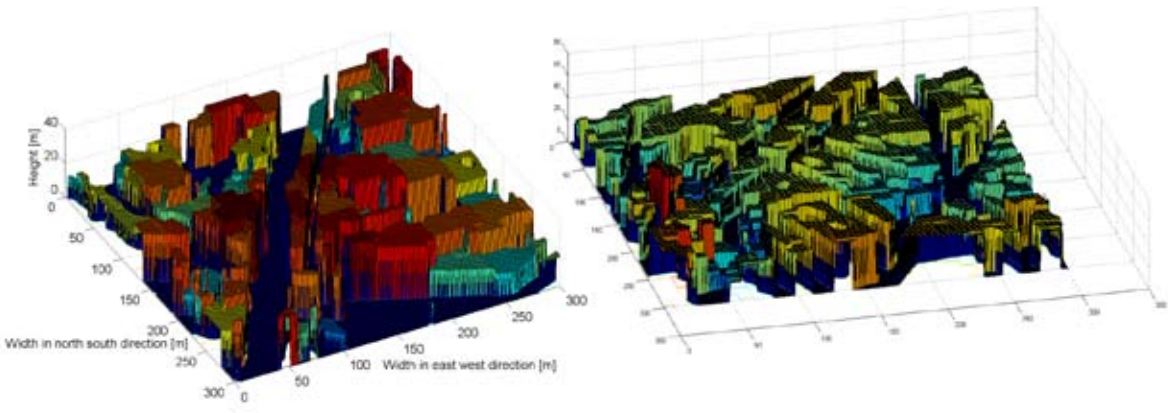


Figure 5.30. Two figures of block height layer of urban morphology database created in MEGAPOLI project. Roads and street canyons are extracted from optical images and block height is derived from space-borne ENVISAT radar images by using interferometry.

tral Paris, France, which is the location of the main experimental campaign of the project. The model consists of various thematic layers and among others comprises a block height for urban area. Layers are created by using classification of optical satellite images and modern interferometric techniques and space-borne radar images.

RAD/STG has studied the latest synthetic aperture radar (SAR) techniques utilizing polarimetric and interferometric measurements. In the project "Imaging of objects under forest canopy with polarimetric SAR-tomography" the possibilities of modern SAR Polarimetric Interferometry and multibaseline Polarimetric Coherence Tomography (PCT) were evaluated to see the objects hidden under forest canopy. These techniques allow to measure forest height and study scattering inside the forest and in some cases "see" the objects underneath the foliage by approximating vertical structure function of the canopy with Fourier-Legendre polynomial series. The multi-baseline interferometric SAR material of the project was collected in cooperation with the German DLR by E-SAR (L- and X-band) instrument in 2003 in Finland. Objects under the canopy were mainly corner reflectors of various sizes. Project results show, that in certain cases, the objects under forest canopy are visible for SAR and can be seen on tomograms. The method is very sensitive to de-correlation of various sources, occurring often on SAR images.

Millimetre Wave Laboratory of Finland (MilliLab)

Millimetre Wave Laboratory of Finland – MilliLab, established in 1995, is a joint laboratory between VTT, Technical Research Centre of Finland and Aalto University School of Science and Technology. MilliLab is also a European Space Agency Centre of Competence called ESA External Laboratory on Millimetre Wave Technology. 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. Recently, ESA and MilliLab have signed a contract extending the Center of Competence status for the five-year period 2010–2015.

MilliLab supplies services at millimetre wave frequencies in the field of device modelling, device characterisation, measurements, testing, research, and development. The parent organisations of MilliLab, VTT and Aalto University have a substantial amount of experience and expertise in the field of microwave and millimetre wave technology. The total research personnel with experience in millimetre waves is over 25.

A low noise receiver for the ESA Planck-mission and an antenna test method for future mm-wave space telescopes were in recent years the main development projects in MilliLab, related to space applications. MilliLab is working with ESA/ESTEC also in characterisation and evaluation of Schottky diodes which are, e.g., intended for use in future European space mission instruments.

In the Planck Low Frequency Instrument (LFI) MilliLab's responsibility together with DA-Design Ltd. was 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 (LNA) which were realised by utilising the InP MMIC technology. The use of integrated circuits is important due to the large number of receivers in the LFI. Altogether 6 identical back- and front-end receiver chains were made in Finland. 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. In 2008, the spacecraft went through tests at cryogenic temperatures in Belgium, after which Planck was transferred via ESTEC to the launch site. The launch took place on May 14, 2009, in Kourou together with the Herschel spacecraft. Currently, Planck is operating in L2 and has completed the first full sky survey.

Figure 5.31. Corner reflectors pointed towards the airborne SAR measurement.

Figure 5.32. Planck waiting integration with Ariane 5. Source: ESA.

University of Jyväskylä Radiation Effects Facility RADEF

The RADiation Effects Facility, RADEF, is located at the Accelerator Laboratory of the University of Jyväskylä. The facility includes two beam lines dedicated to radiation effect studies of semiconductor materials and devices exposed by heavy ions and protons. This allows one to perform both the single-event-effect and total-ionising-dose tests. The heavy ion line consists of a component movement apparatus and ion diagnostic equipment for real-time analysis of beam quality and dosimetry. The irradiations can be made either in vacuum or in air, depending on the penetration requirements of the ions. In the proton line irradiations are performed in air and the line includes a dosimeter setup and the movement apparatus similar to that in the heavy ion line. Both irradiation lines are located in the same cave close to each other providing the possibility to perform both tests with similar set-up during the same test campaign. For more details and contacts, see: **https://www.jyu.fi/accelerator/radef**

RADEF became ESA's European Component Irradiation Facility (ECIF) in 2005 and since that has served and collaborated with more than 30 world's biggest space organisations, universities and European satellite companies. These include e.g. ESA, NASA/JPL, JAXA, CNES, SANDIA, Thales Alenia Space, EADS Astrium, RUAG, ALTER Tchnology Group etc. It is annually visited by about 50 space researchers and test engineers and has become one of the most known and used radiation test sites in the world. This collaboration has also created 15 peer reviewed articles and several conference proceedings in the international publications in the years 2008 and 2009. Table 1 lists the users, who have performed campaign at RADEF during the years 2008 – 2009.

One of RADEF's highlights in 2008 was to organise RADECS'08 (Radiation Effects on Components and Systems) workshop with 232 participants from 29 countries. Meeting included 93 technical presentations and 13 companies exhibited their products. RADECS was for the first time in The Nordic countries dur-

ing the community's 20 years history. According to the feedback and comments received, the workshop was highly appreciated not only for its high quality technical content, but also notified by the Convention Bureau of the City of Jyväskylä, which awarded RADECS 2008 as the best organized international conference in the city during the year 2008

Another highlight was when our long range research project was completed in 2009. This was a continuation to a series of our published works for ESA to develop semi-empirical linear energy transfer descriptions of heavy ions. The experimental work was carried out in Jyväskylä and the international collaborators in this project were ESA/ESTEC in The Netherlands, Paul Scherrer Institute from Switzerland and Université Catholique de Louvain from Belgium. The aim is that the values will be used in the ECIF facilities. The compilation of the work was introduced to the community in RADECS 2009 conference in Brugge, Belgium, and the results will be published in IEEE's Transactions of Nuclear Science June volume, 2010. The "ECIF cocktail calculator" is available for the users at:
https://www.jyu.fi/accelerator/radef/ECIFCalc

Table 5.1. The companies, institutes or space organizations, which have used RADEF during the years 2008 - 09.

Company/Organization	City	Country
ATMEL	Nantes	France
Astrium SAS	Paris	France
CEA, Comité Européen des Assurances	Bruyere-le-Chatel	France
EASII IC SAS	Grenoble	France
Democritus University of Thrace	Xanthi	Greece
EADS Space Transportation Co	Bremen	Germany
ESA, European Space Agency	Noordwijk	The Netherlands
HIREX Engineering Ltd. (ALTER)	Toulouse	France
IDA,Institut für Datentechnik und Kommunikationsnetze	Braunschweig	Germany
INTA, Instituto Nacional de Tecnica Aeroespacial	Madrid	Spain
JAXA, Japan Aerospace Exploration Agency	Sengen	Japan
Kayser Threde		Germany
NASA/JPL	Pasadena, CA	USA
RUAG Sweden	Gothenburg	Sweden
Saab Ericsson Space Co.	Gothenburg	Sweden
Sandia National Laboratories	Albuquerque, NM	USA
ST Microelectronics	Crolles	France
Thales Alenia Space	Toulouse	France
TRAD	Labege	France
University of Braunschweig	Braunschweig	Germany

VTT Technical Reseseach Centre of Finland

The remote sensing activities at VTT were described in Section 5.2 above. VTT also has a long history in space instrument projects starting from the mid of 1980s. Substantial contributions to instruments and missions include: ERNE and SWAN instruments on SOHO, CAPS and MIMI instruments on Cassini, GOMOS instrument on Envisat, OMI instrument on EOS-Aura, TWINS instruments for NASA. VTT has continually performed various ESA technology development projects.

In 2008 – 2009 VTT Optical Instruments Centre has participated in the TRP and GSTP programs of ESA. Under a GSTP contract a prototype for a programmable line imaging correlation spectrometer was developed. The imaging spectral signature instrument (ISSI) concept aims at the identification of pixels with a predefined spectral signature in an image using optical processing. The idea is to disperse the spectrum, modulate it in the spectral domain with a programmable spatial light modulator and recombine the spatially dispersed spectrum back to the spatial domain. The result is then obtained in real time with fewer processing resources and potentially with a better signal to noise ratio. ISSI has been tested in laboratory conditions and in an air campaign.

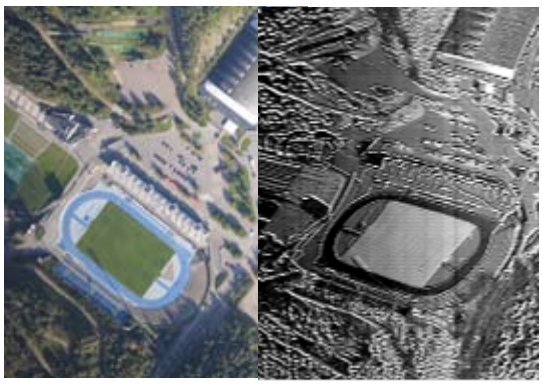


Figure 5.33. An instrument demonstator for a compact NIR correlation spectrometer implemented with a commercially available PMDG component.

Figure 5.34. Example of a raw ISSI correlation image, where the signature of grass is used. On the left is a context image from a frame camera.

Under a TRP contract the performance of programmable micro diffraction gratings (PMDGs) was investigated. An instrument demonstrator for a near infrared (NIR) spectrometer based on a linear variable bandwidth filter and a single detector was designed, manufactured and characterised. The performance of the demonstrator is comparable to existing LVBF/linear array spectrometers.

VTT has developed a new miniaturized staring hyperspectral imager with a weight of 350 g making the system compatible with lightweight nanosatellites and UAS platforms. The instrument is able to record 2D spatial images at the selected wavelength bands simultaneously. The operational wavelength range of the imager can be tuned in the range 400 – 1100 nm and spectral resolution is in the range 5 – 10 nm @ FWHM. The field of view of the system is 20 x 30 degrees and ground pixel size at 100 m flying altitude is around 7.5 cm. The system contains batteries, image acquisition control system and memory for the image data. It can operate autonomously recording hyperspectral data cubes continuously or controlled by the autopilot system of the UAS. The new hyperspectral imager prototype was first tried in co-operation with the Flemish Institute for Technological Research (VITO) on their UAS helicopter. The instrument was configured for the spectral range

Figure 5.35 VTT Staring FPI Hyperspectral Imager integrated on VITO six-rotor rotorcraft.

500 – 900 nm selected for the vegetation and natural water monitoring applications.

VTT develops in the TRP program the ESA SAR receiver circuit, which is intended for X, C or L-band SAR (synthetic aperture radar) receiver. It is a direct conversion receiver circuit consisting of three parallel signal channels, one for each band. Every channel consists of an input buffer amplifier, a down-conversion mixer, a baseband filter and an analogue-digital (AD) converter. The circuit has single-sided inputs for RF and local oscillator (LO) signals and 8-bit parallel LVDS-compliant output for digital data. The interfaces parallel I/Q Data out, as well as the Test out/in, are multiplexed between the channels (bands) according to the band selection. The circuit uses an external 440 MHz low jitter reference clock. There is also a clock output for synchronizing several parallel circuits.

Optical solutions for high bit rate digital interconnections in satellite payloads are currently under development at ESA. This covers all possible applications from box-to-box, board-to-board and eventually ASIC-to-ASIC. VTT actively participates in this research by developing photonic component and module technologies within several projects. Compared to copper-based solutions, optical communication offers higher data rates, distance-independent performance, high connector density and low mass cabling.

A fibre-optic transceiver designed for the SpaceFibre data link provides a point-to-point data rate of 2 × 10 Gbit/s (transmit and receive). It employs 850 nm vertical cavity surface emitting lasers, radiation-resistant multimode fibres and GaAs PIN photodetectors. Transceiver uses a single 3.3 V power supply and has a power consumption of 230 mW. Module is hermetically sealed and it has dimensions of 17 × 17 × 5 mm^3 and its mass excluding the fibre pigtails is 4 grams. □

Aurora Borealis

Finnish National Committee of COSPAR

List of publications

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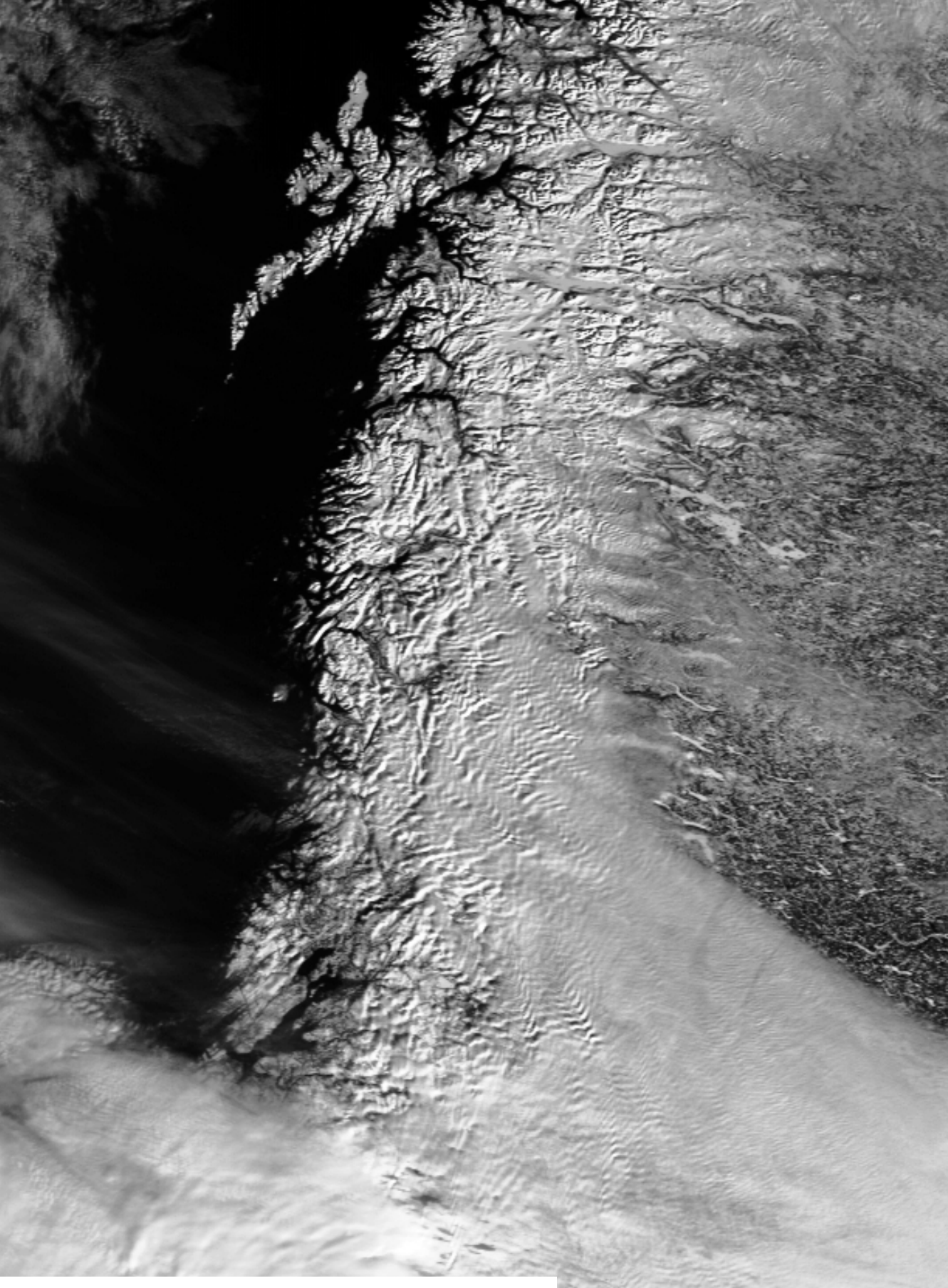
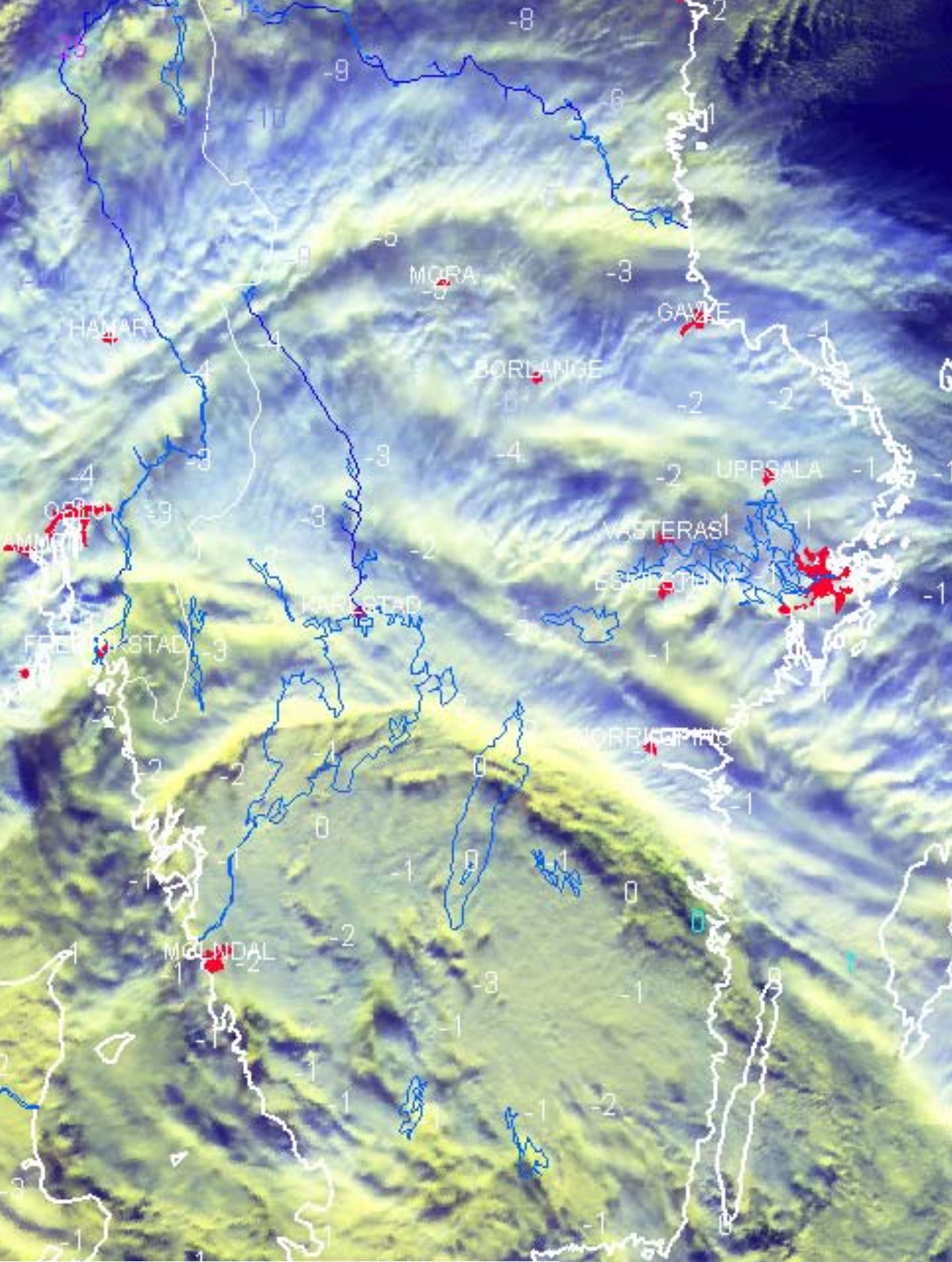
Aurora Borealis above finnish forest
Photo:Jouni Jussila



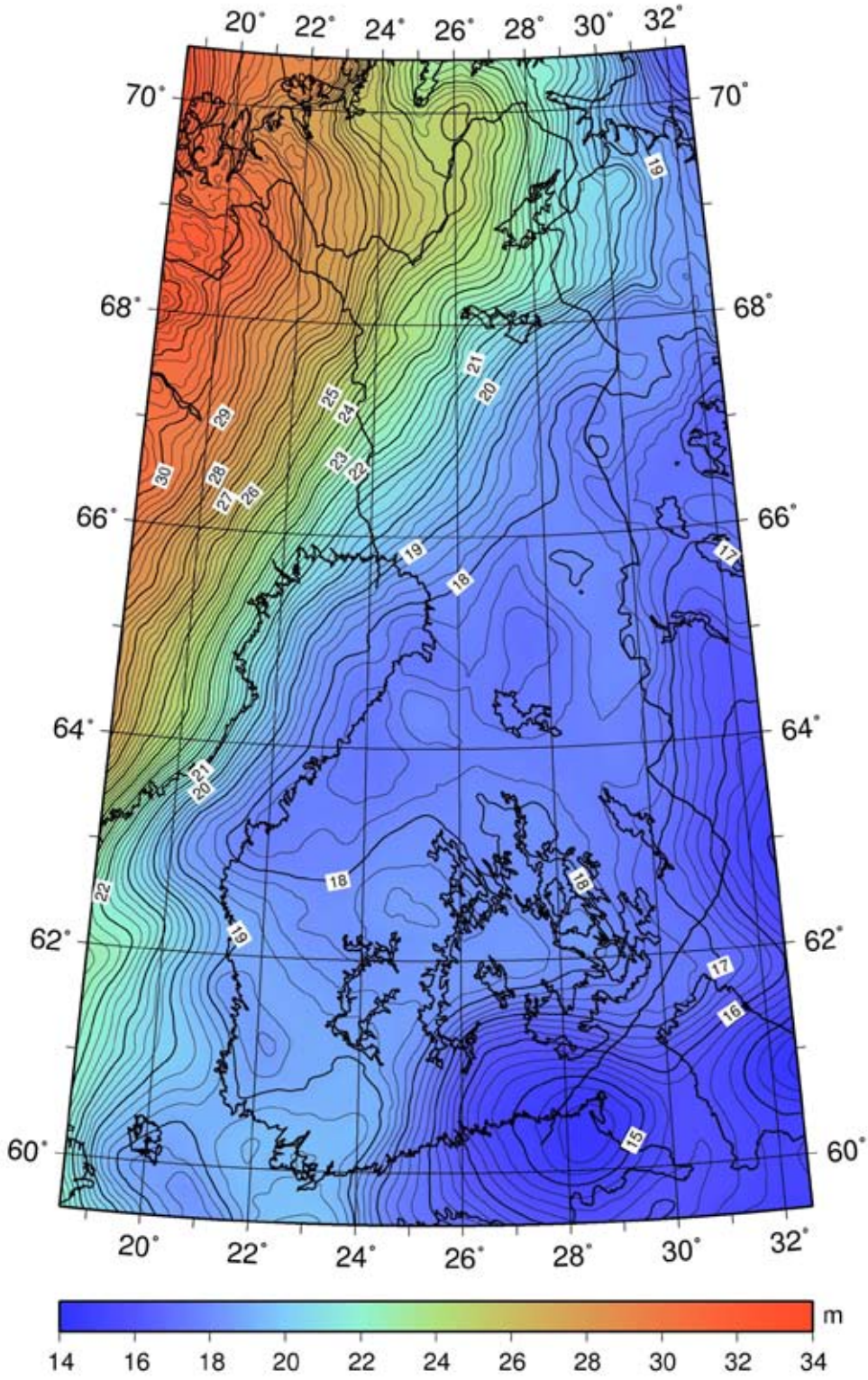
Ice-covered bay of Bothnia as seen by Metop-A, AVHRR Channel 1.



High ice concentration in the Gulfs of Finland and Riga, as well as between the Finnish mainland and Aland taken on Feb 3th, 2010. (source: NOAA), copyright: EUMETSAT.


HELSINKI
TALLINN
RIGA
KAUNAS
VILNIUS

Ice-covered bay of Bothnia as seen by Meteosat-8, Channel 12.



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