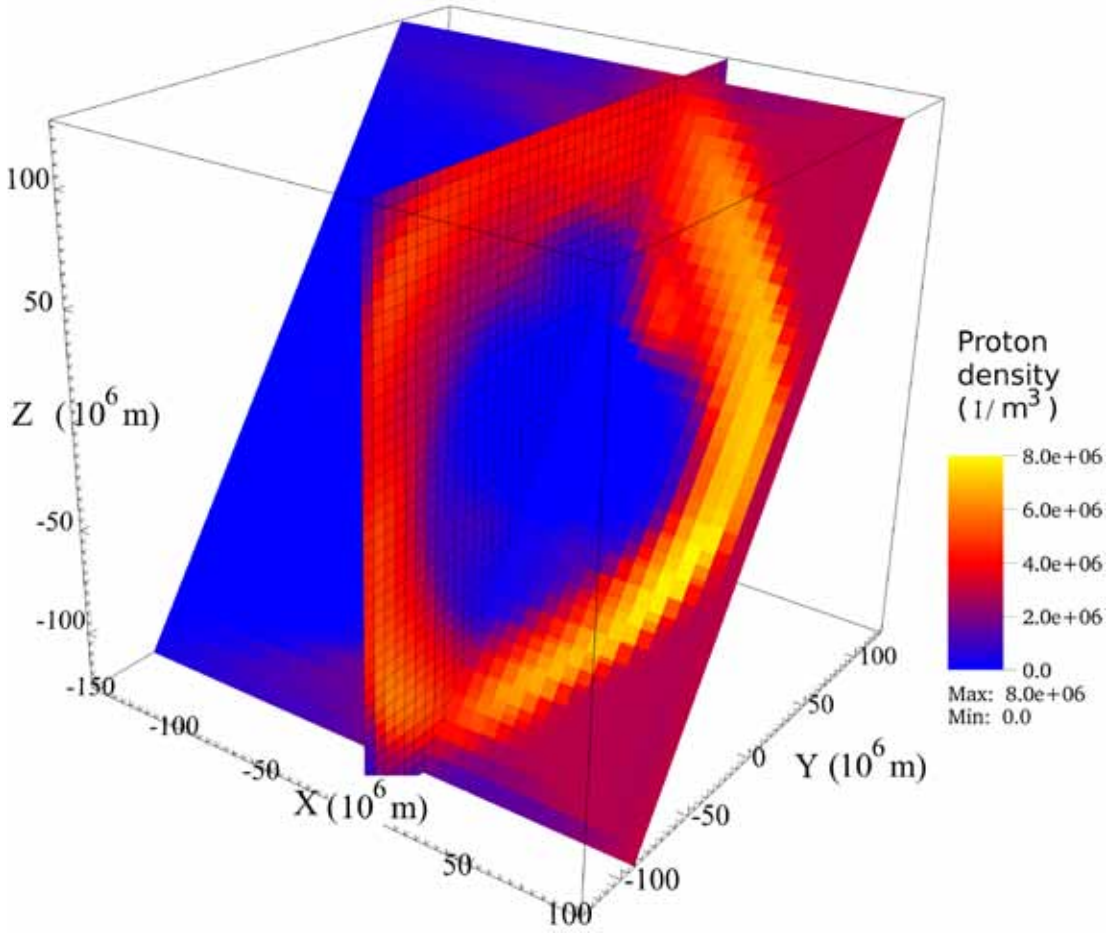
Space Research in Finland

Report to COSPAR 2012



COSPAR
Finnish National Committee

Tekes

Academy of Finland

Space Research in Finland

Report to COSPAR 2012

Editors

Tuija Pulkkinen
Sini Merikallio
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C O S P A R
Finnish National Committee

Tekes

Academy
of Finland

Helsinki 2012

Front cover:
Proton density in the near-Earth space as calculated by the six-dimensional hybrid Vlasov simulation Vlasiator. The Vlasov equation is propagated in the electric and magnetic fields calculated previously by the global magnetohydrodynamic simulation GUMICS-4. Solar wind protons given by a Maxwellian distribution are constantly inserted at the Sunward edge of the Vlasov simulation (at positive X direction). More on page 39.

Earth is at the origin and the inner part of the simulation starts at 7 Earth radii (about 45 000 km).

Back cover:
The Space Technology Group of the Aalto University develops nanosatellite technology through two current CubeSat missions: Aalto-1 will be the first Finnish satellite with launch scheduled for 2013/2014. More on page 22.

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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ISSN 0788-7434

Cover and page layout: Mercia Aadon Figol Oy
Printers: Tammer-Paino Oy
2012

Foreword

This is the bi-annual report of Finnish Space Research to the Committee on Space Research (COSPAR) prepared by the Finnish National Committee of COSPAR and Finnish Funding Agency for Technology and Innovation (Tekes). The report describes the overall structure of the Finnish space activities, introduces the research organizations participating in space activities at various fronts, and gives highlights of the scientific, applied, and technological developments during the 2010 - 2011 period.

The European Union 7th Framework Programme (FP7) opened for the first time a series of calls focused in particular to space activities in multiple fronts. Following a highly successful application round, Finnish space research received a significant boost when the projects started in the fields of space research, Earth observation, space weather applications, technology and research infrastructure development. All projects are carried out in wide international collaboration, which has further strengthened the already widespread networking throughout the world. A further demonstration of the high quality of the Finnish space research is the ongoing European Research Council (ERC) starting grant focusing on space plasma simulation development. In selected space activity areas, Finland is a key player in the European scale.

A new step in space technology for Finland is approaching in the near future, when the first Finnish satellite Aalto-1 gets ready for launch in 2013. Aalto-1 is a student satellite project utilizing the CubeSat technology. The project is carried out in national collaboration comprising universities, research institutes and local space industry. The platform will carry three technology demonstration instruments to space: a deorbiting device using the electric sail concept, a next-generation spectral imager for atmospheric remote sensing, and a small radiation monitor. A second CubeSat in the series will be built under the auspices of the EU programme QB50 consisting of 50 CubeSats focused on upper atmosphere and ionosphere monitoring.

This report is also available for download from:

http://www.cospar.fi/reports

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Figure 0.1, Launch of Atlas V rocket carrying Curiosity Mars Rover. The Rover has finnish pressure and humidity sensors on-board. © Pat Corkery/ULA, November 26, 2011.

1. Overview of Finnish Space Activities

1.1. Finnish Space Research Today

Finnish space activities span scientific research, space-based environmental monitoring, telecommunications, navigation, space technology and application development. The cornerstone of the Finnish space programme is membership in the European Space Agency (ESA), where Finnish scientists and industrial actors participate in practically all ongoing science and Earth observation missions as investigators, hardware suppliers and contractors.

University-level space education comprises MSc and PhD programmes in space research and technology offered at several universities including an international Erasmus Mundus Space Masters programme. The national Graduate School in Astronomy and Space Physics comprises all universities offering graduate education in the field and has been a major asset in fostering joint courses as well as national mobility and research collaboration.

As space research is highly dependent on costly infrastructure, the future directions for the scientific development are already well known: exoplanet search, formation and evolution of stars and galaxies, fundamental cosmological questions, solar system discovery, and space weather effects and predictions are all fields with upcoming major advances in observational facilities. Finnish scientists have activities in all these areas, either in instrument development, data taking, calibration and validation activities, data utilization, or numerical modeling and theory development. In Earth Observation, Finland is particularly strong in atmospheric sciences, both in space-based remote sensing of the atmosphere from the weather phenomena to ozone layer affected also by the particle precipitation from above. Both in space research and Earth observation activities, the Arctic Research Centre of the Finnish Meteorological Institute and the Sodankylä Geophysical Observatory co-located in Sodankylä offer a unique facility to perform complementary ground-based measurements in support of space-based observations. Especially the new Earth Observation satellites such as the ESA SMOS and NASA GPM have adopted Sodankylä as their test site for calibrating and validating the space-borne measurements.

Space-based methods are rapidly expanding to a variety of fields, which has also increased the number of players in the Finnish space activities: use of satellite techniques now covers fields important to the Finnish economy from forestry to mineral reservoir mapping and high-precision navigation applications. New user groups often act at the end of the development chain, making use of the acquired observations and turning the results to useful products. On the other hand, the increasing number of users also has clearly indicated the need for further

Figure 1.1, Aurora Borealis CC-BY-SA, Jason Ahms

development of the analysis methods and accuracy evaluations. The Finnish research groups have taken an active role in developing analysis methods and tools that require substantial and deep understanding of the instrument limitations, measurement techniques, and data capturing process.

A particular strength of the Finnish space community is the strong ties between the space-borne observations to the ground-based means of observing space and the environment: Finland hosts one of the European Incoherent Scatter Radar Facility (EISCAT) receiver in Sodankylä and one of the Super-Dual Auroral Network radars in Hankasalmi. Both radar systems monitor the ionospheric plasma motions related to auroral processes. In addition, Finland leads an international consortium (MIRACLE - magnetometers, ionospheric radars and all-sky cameras large experiment) focusing on monitoring of ionospheric auroral processes and their magnetic signatures on ground. Similarly astronomers making use of space-based assets equally use the Nordic Optical Telescope (NOT) and the European Southern Observatory (ESO) facilities. The Finnish Centre for Astronomy with ESO (FINCA) started operations in 2010 as a national research and coordination body for astronomers, and the Metsähovi Radio Observatory continues wide international collaborations especially through the VLBI measurement networks. As already mentioned, the large number of stations monitoring atmospheric processes is a significant asset independently as well as complementing space-based measurements.

1.2 Finnish Space Committee

The inter-ministerial Finnish Space Committee acts an overall coordinating body for the Finnish space activities. The Space Committee 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 Space Committee also produces regular 3-year strategic plans for Finnish space activities.

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 membership covers relevant ministries and main actors. The current Finnish Space Committee was nominated for the next three years in April 2010. The Committee meets 2 to 4 times per year, its Secretariat meets every month. Finnish Space Committee members are given in Table 1.2.

Contact details of the Finnish Space Committee:

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Table 1.2.

Members of the Finnish Space Committee (March 2012)

Peltonen Petri	Director General, Ministry of Employment and the Economy, Chairman
Plathan Pekka	Director-General, Ministry of Transport and Communications, Co-Chairman
Höijer Laura	Research Director, Ministry of the Environment
Jylhä-Pyykönen Annu	Director, Ministry of Education
Karanko Tuija	Secretary General, Association of Finnish Defence and Aerospace Industries (AFDA)
Vajavaara Raimo	Director for Unit for Land Survey and Geographic Information Policy, Ministry of Agriculture and Forestry
Laamanen Anu	Deputy Director General, Ministry for Foreign Affairs
Linko Susan	Director, Academy of Finland
Möttönen Matti	Deputy Chief, Rear admiral, The Finnish Boarder Guard
Taalas Petteri	Director General, Finnish Meteorological Institute
Tilli Kari	Director, Tekes - the Finnish Funding Agency for Technology and Innovation
Valtonen Veli-Pekka	Brigadier General, Finnish Defence Forces

Committee's Secretariat:

Kanto Kimmo	Tekes, Chair
Häme Tuomas	VTT
Klemola Olli	Finnish Defence Forces
Juuso Kummala	The Finnish Transport Agency
Kuusniemi Heidi	Finnish Geodeetic Institute
Laaksonen Sanna	Ministry of Defence
Miettinen Topi	Patria
Pulliainen Jouni	Finnish Meteorological institute
Sucksdorff Yrjö	Finnish Environment Institute
Strahlendorff Mikko	Ministry of Transport and Communications
Sulonen Kati	Academy of Finland
Stigell Pauli	Tekes, Secretary

1.3. Funding of Space Activities

The publicly funded space activities in Finland are financed mainly through Tekes (technology development, innovation, space technology development) and Academy of Finland (scientific research, ground-based research facilities). Other funding sources include several ministries largest being the Ministry of Employment and the Economy and the Ministry of Transport and Communications, universities and research institutes.

1.3.1. Tekes

Tekes, the Finnish Funding Agency for Technology and Innovation, is the main financing organization for applied and industrial research and development in Finland. Tekes operates under the Ministry of Employment and the Economy and receives its funding from the state budget. Tekes offers channels for cooperation with Finnish companies, universities and research institutes.

The primary objective of Tekes is to promote the development of industry and services by means of technology and innovations. This helps to renew industries, increase value added and productivity, improve the quality of working life as well as boost exports and generate employment and wellbeing.

Tekes coordinates and offers financial support for participation in international technology initiatives, including EU research programmes, EUREKA, research activities of OECD energy organization 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 growth in important business areas of today and the future. These programmes offer an effective form of cooperation for companies and the research sector. In 2012 Tekes had 24 national technology programmes. Especially, the Strategic Centers of Excellence (SHOK) offer joint research, development and innovation opportunities in the fields of energy and environment, mechanical engineering, forestry, built environment, health and wellbeing, and the ICT sector.

In 2011 Tekes total financing for national and international R&D-projects was 610 million euros. From this 19 million euros was provided for national and ESA space activities.

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Finnish Space Portal:

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Figure 1.1, Cryosat-2 was launched in 2012, © ESA

1.3.2. Academy of Finland

The Academy of Finland is an expert organization for research funding within the administrative sector of the Ministry of Education and Culture. The four research councils of the Academy of Finland are served by an Administrative Office and led by an independent board. The research councils comprise Biosciences and Environment, Culture and Society, Natural Sciences and Engineering, and Health.

The function of the Academy of Finland is to improve the excellence of Finnish basic research through competitive, long-term (typically 4 years) funding awarded based on peer-review evaluation and national science policy. The development initiatives focus on professional researcher careers and promotion of creative research environments. The research funding elements include research grants, personal career grants from post-doctoral to Academy research positions, centers of excellence, and targeted research programmes. Academy of Finland seeks to foster interdisciplinary and collaborative research efforts.

The research funding of the Academy of Finland to space research and astronomy has been quite stable, at the level of slightly above 3 million euros annually (2011: 3.2 M€), excluding membership fees to international organizations (ESO, NOT, EISCAT), which totaled about 2.8 M€ in 2011.

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1.3.2. MilliLab

MilliLab is a joint laboratory between VTT, Technical Research Centre of Finland and Aalto University. MilliLab is also an ESA External Laboratory on Millimetre Wave Technology since 1995.

The main purpose of MilliLab is to support European space industry to meet the demands of future ESA missions. These missions include several millimeter wave instruments. However, non-space companies and organizations also make use of the MilliLab expertise on millimeter wave technology.

MilliLab supplies services at millimeter wave frequencies in the fields of device modeling, device characterization, millimeter wave measurement and testing as well as in research and development. MilliLab is a member of European Network of Excellence on RF MEMS and RF Microsystems AMICOM.

1.3.3. RADEF

The Radiation effects (RADEF) facility is an official test site of the European Space Agency located in the Accelerator Laboratory at the University of Jyväskylä, Finland (JYFL). The facility includes beam lines dedicated to proton and heavy ion irradiation studies of semiconductor materials and devices. The heavy ion line consists of a vacuum chamber with component movement apparatus inside and ion diagnostic equipment for real-time analysis of beam quality and intensity. In the proton line irradiations are performed in air. There are also component movement equipment and beam diagnostic setups in the proton line. Both irradiation lines are located in the same cave.

The cyclotron used at JYFL is a versatile, sector-focused accelerator for producing beams from hydrogen to xenon. The accelerator is equipped with three external ion sources. There are two electron cyclotron resonance (ECR) ion sources designed for high-charge-state heavy ions, and a multicusp ion source for intense beams of protons.

Figure 1.2, Plancks 70 GHz receivers were developed by Millilab © ESA/AOES Medialab

1.4 International Collaboration

Finland has formal co-operation agreements with several space organizations listed below in Table 1.3 with the responsible Finnish body indicated.

Table 1.3: Finnish participation in international space organizations

COSPAR	Finnish National Committee of COSPAR
ESA	Tekes
ESO	Academy of Finland / Ministry of Education and Culture
EISCAT	Academy of Finland
EUMETSAT	Finnish Meteorological Institute
COSPAS/SARSAT	Finnish Border Guard / Ministry of the Interior

1.4.1. Finnish National Committee on Space Research

In October 1958, the International Council of Scientific Unions (ICSU) established the Committee on Space Research (COSPAR) 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 organization advancing the progress of scientific research carried out with space vehicles, rockets, and balloons in all fields of research. The international scientific community targets the COSPAR objectives through ICSU and its adhering National Academies and International Scientific Unions. Operating under the rules of ICSU, COSPAR is unbiased by political views and considers all questions solely from the scientific viewpoint.

The Finnish National Committee of COSPAR has taken part 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 bi-annual reports, the Committee has organized national FinCOSPAR Meetings roughly bi-annually since 1987, the latest one in September 2011.

The National Committee is an expert body nominated by the Council of Finnish Academies. The members of the National Committee represent the active community of space researchers in Finland.

The present National Committee members are given in Table 1.4.1.

Table 1.4.1. Finnish National Committee of COSPAR members:

Chair (from 2012)	Tuija Pulkkinen	Aalto University
Members	Martti Hallikainen	Aalto University
	Juhani Huovelin	University of Helsinki
	Hannu Koskinen	University of Helsinki (chairman until 2011)
	Jari Kotilainen	University of Turku, FINCA
	Kalevi Mursula	University of Oulu
	Minna Palmroth	Finnish Meteorological Institute
	Petri Pellikka	University of Helsinki
	Juri Poutanen	University of Oulu
	Markku Poutanen	Finnish Geodetic Institute
	Jouni Pulliainen	Finnish Meteorological Institute
	Erkki Tomppo	Finnish Forest Research Institute
	Merja Tornikoski	Metsähovi Radio Observatory
	Esko Valtaoja	University of Turku
	Martin Vermeer	Aalto University

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Figure 1.4. Finnish National Committee of COSPAR meeting December 19th 2011.
From left: Martti Hallikainen, Sini Merikallio, Erkki Tomppo, Hannu Koskinen, Juri Poutanen, Merja Tornikoski, Tuija Pulkkinen, Markku Poutanen ja Martin Vermeer

Figure 2.1, Auroras seen from Space, © NASA

2. Finnish National Strategy for Space Activities

The Space Committee defines the national space strategy for Finland. The strategic plan is updated at 3-year intervals. The present strategy document focuses on the period 2009-2011.

2.1. Vision

"Finland is at forefront in selected areas of space activities. Opportunities provided by technological development, remote sensing and navigation are utilized efficiently and widely in different sectors of the society."

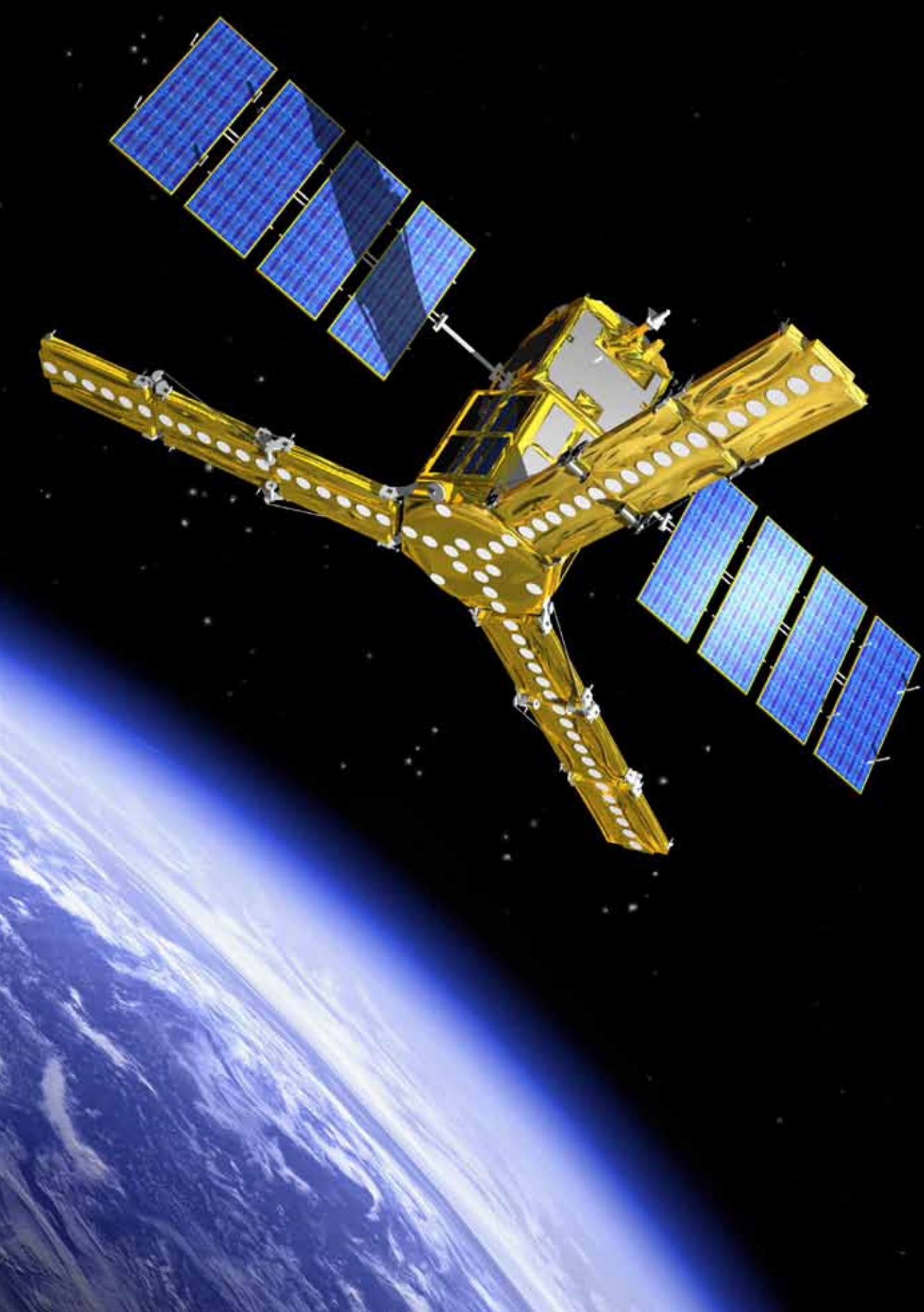
2.2. Strategic Elements

International and national collaboration continues to be at the heart of the Finnish space strategy: Finnish membership in the European Space Agency and targeted participation in the ESA programmes forms the backbone of the Finnish space activities. Tight collaboration between universities, research institutes and companies are fostered and developed in different sectors of the space segment from instrument building to scientific exploitation of the data, product and service development.

The national space strategy for 2009 - 2011 emphasizes business activities and the use of space technology across several industrial domains. The Finnish focus is on Earth observation (environment, natural resources, energy), navigation (satellite positioning), and space science (Earth's space environment, solar system, astronomy and astrophysics).

A strategic goal is to widen the use of space technology in non-space business sectors through technology transfer - both nationally and within ESA. This calls for advancing new methods and technologies to find synergies between key national technology areas and space technology development efforts. Companies and research institutes are encouraged to transfer their technologies and expertise from space projects to wider markets also in non-space domains.

The objective for the commercial space activities in Finland is to provide Finnish companies sustainable business in space, ground segment and applications through integrating them into delivery chains of the international principal contractors and equipment manufacturers. The main target is to gain access to markets outside the ESA's industrial return policy and nationally financed activities.



3. Space Programmess with Finnish Involvement

3.1. European Space Agency

Finland participates in the ESA space science, earth observation, telecommunications, navigation and technology R&D programs. Finland has not participated in launch vehicle or human space flight programs.

Space science

Table 3.1 summarizes those ESA space science missions where Finland has contributed either nationally funded scientific instruments or satellite platform equipment.

Earth Observation

Table 3.2 is a summary of those ESA earth observation programs and missions where Finland has contributed either satellite platform units or remote sensing instruments.

Telecommunications and Navigation

Table 3.3 is a summary of ESA telecommunication and navigation programs with Finnish contributions.

Technology programs

Finland participates in the development of technologies for ESA 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, SMOS satellite boards an interferometric radiometer measuring ocean salinity and soil moisture, © 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 mission	LFI microwave receivers onboard Planck; mirror polishing for Herschel, onboard software for both	Launched 2009
GAIA, ESA Galaxy mapping mission	Electronics and software	Launch 2013
LISA Pathfinder, ESA test mission for gravity wave observations	Solar array structures	Launch 2014
BepiColombo, ESA/ JAXA mission to Mercury	PI of SIXS , participation in MIXS (X-ray instruments), participation in SERENA particle instrument.	Launch 2015
Solar Orbiter	Power control electronics by Patria	Launch 2018

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/EU-METSAT 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 2013
SWARM, ESA Earth magnetic field measurement mission	Power distribution unit	Launch 2012
Sentinel 1 (ESA and EU)	SAR-radar	Launch 2013
Sentinel 3 (ESA and EU)	SAR-radar	Launch 2014

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 -
ARTES 20	Integrated Application Promotion – applications relating to. e.g. the Baltic Sea	2009 -

3.2 Technology Development

Finland does most of its space technology and space applications development in ESA's technology programmes and in European Commission's Framework Programmes. Below are shown programmes where Finland participates.

ESA GSP, TRP and CPT

TThese programmes are part of ESA's compulsory funding. General Studies Programme (GSP), Basic Technology Research Programme (TRP) and Core Technology Programme (CTP; part of the Science Programme) all focus on early development of technologies for ESA's satellite and spacecraft missions. The projects are often studies by prime contractors of spacecraft and smaller players like Finland have only few such projects. In TRP Finnish companies have recently developed e.g. radiometers and radio altimeters.

ESA GSTP

General Support Technology Programme (GSTP) is an á-la-carte technology programme that develops many technologies, even spin-outs from space technologies to everyday use on Earth. Thus the projects lead to technology readiness levels (TRL) that are near to market entry. The imaging spectrometer for Aalto-1 nanosatellite is developed by VTT as an ESA technology project.

ESA ARTES 1, 3, 4, 5 and 20 (IAP)

ARTES is the family of satellite telecommunications programmes in ESA. It has many sub-programmes that develops the satellite segment (ARTES 5) and the user segment (ARTES 3 and 4), e.g. terminals used on ground. ARTES 1 is for strategic studies. ARTES 20 aka Integrated Applications Promotion (IAP) – it develops applications that use satellite remote sensing, navigation and telecommunications plus various sensors on Earth for the benefit of e.g. healthcare, security of nuclear power stations, maritime use and wind energy applications. Finland runs the ambassador platform for Baltic Sea applications in IAP where first projects have started in year 2012. ARTES 5 has demonstrated its usefulness e.g. in the field of composite structures.

ESA EGEP

ESA's European GNSS Evolution Programme (EGEP) develops satellite navigation technologies. To large degree it studies the next generation of the flight segment of Galileo and EGNOS but it also develops science and applications of Global Satellite Navigation

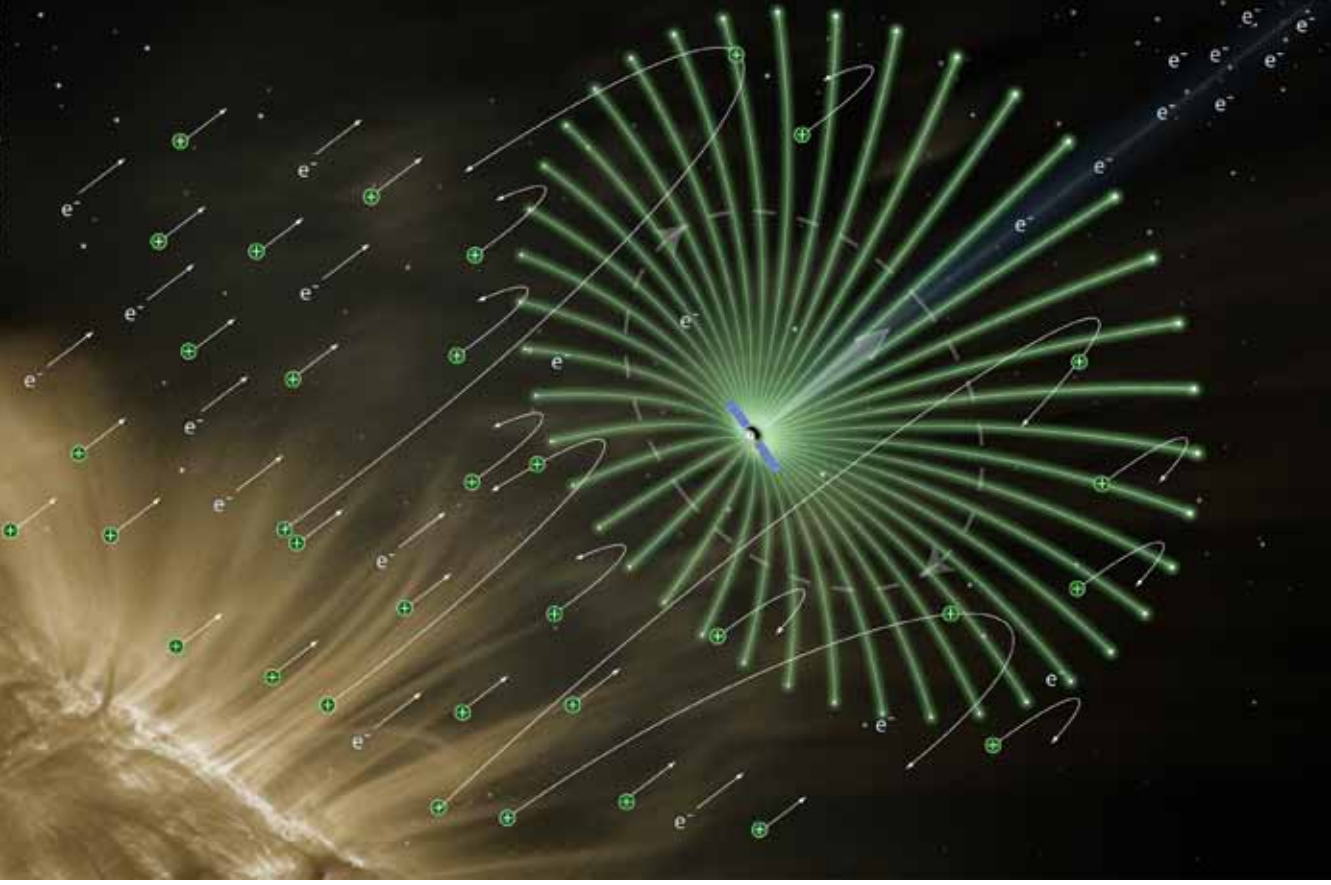


Figure 3.2. ESAIL EU FP7 project is developing the Electric Solar Wind Sail towards prototype phase (more on page 39, and on www.electric-sailing.fi). © Alexandre Szames

System on Earth. Oulu university has studied C-band signal satellite-to-indoor propagation, Finnish Geodetic Insitute has studied use of EGNOS in urban navigation and Finnish Meteorological Institute has studied ionospheric monitoring.

ESA EOEP and GSE

ESA's Earth Observation Programme's Envelope Progamme (EOEP) e.g. fosters commercial applications in it Value Added Element.

ESA's GMES Service Element programme (GSE) was a pre-runner for European Commission's GMES projects. Global Monitoring of Environment and Security (GMES) develops capabilities and solutions to global environmental and security issues. Finnish projects are related to air, water (seas, lakes, snow, ice), and forestry. Aalto university,. Finnish Environmental Institute and Finnish Meteorological Institute participate in e.g. Polarview project.

EU FP7

European Commission's Framework Programme 7 (FP7) has dedicated Special Programme for Space. It funds space science, satellite remote sensing and satellite technology development. Also FP7's Environment programme and European Research Council fund remote sensing and space research. Finland has won over 35 projects in the five call for proposals in space theme. Finland is participating in large GMES projects such as MACC (atmosphere), MyOcean and Geoland. VTT leads Recover project on sustainable forest management. Finnish Meteorological Institute leads a planetary exploration project and propulsion technology project in critical space technologies. University of Helsinki leads two space science projects.

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 magnetosphere 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 2011
Mars MetNet Precursor Mission	RUS, E	Novel landing station(s) to carried onboard Phobos Grunt	Launch 2014
BepiColombo MMO, JAXA part of the ESA/JAXA Mercury mission	Japan	Participation to MEFISTO-instrument	Launch 2015

3.3. Bilateral Collaborations

In addition to the ESA programs, bilateral collaborations continue to have a significant role in the Finnish space program. The most significant partners are the two neighboring countries Russia and Sweden, but significant collaborations have been carried out with the US and Canada, and more recently with the Asian space powers Japan and India. A list of the operative bilateral programs is given in Table 3.4.

Figure 3.3. BepiColombo will be launched towards Mercury in 2014. Finland is contributor in the MEFISTO instrument. ESA

Figure 4.1. Aalto-1 satellite by Pekka Laurila

4. Aalto University

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The space activities at the Aalto School of Electrical Engineering (Aalto-ELEC) focus on radio astronomy, space technology, Earth-oriented space research and remote sensing. The space activities at the Aalto School of Engineering (Aalto-ENG) focus on GPS techniques, photogrammetry and remote sensing.

The Aalto University Metsähovi Radio Observatory coordinates observations and science related to the ESA Planck mission. The recent observations include unprecedented spectra of extragalactic point sources at the Planck frequencies plus extended spectral energy distributions obtained via global multifrequency campaigns simultaneous with Planck. These are being used for variability models, including high-energy emission mechanisms, as well as studies of various source populations.

The Department of Radio Science and Engineering is the only institute in Finland providing space technology education in MSc and PhD levels. The Space Technology Group develops nanosatellite technology through two CubeSat missions currently under development: Aalto-1 will be the first Finnish satellite with launch scheduled for 2013/2014. The follow-on mission Aalto-2 is aimed to be part of the international QB50 project providing information on the upper atmosphere. Future plans include continuation of the nanosatellite program by a series of CubeSat missions in order to provide spaceflight opportunities for instruments and experiments as well as development and airborne testing of advanced microwave radiometer technologies and data interpretation methods.

Remote sensing research focuses on methods for space-borne monitoring of Earth surfaces and construction of microwave sensors. Methods are developed for environmental monitoring of northern areas and observations of forests, snow, sea ice, soil moisture, and ocean salinity as indicators of global change. Advanced radiometer and radar technology is developed for satellite, airborne and ground-based measurements. The Skyvan research aircraft is used for sensor testing and collection of data for application development. The group coordinates a national project to develop methods for retrieval of soil moisture, freezing, and ocean salinity from the European Space Agency's SMOS satellite and participated in European Space Agency's 6-week calibration/validation airborne radiometer campaign for the SMOS satellite.

Photogrammetry and remote sensing activities focus on dynamic phenomena of the physical environment through space borne, aerial, and terrestrial sensing systems, active

or passive electromagnetic imaging systems, especially on radiometric and geometric calibration of imaging systems, exact registration of multi-temporal data, applications of multisensory imaging to dynamic environmental modeling, and geographic visualization of local and global physical phenomena. Research is organized through a cooperative research institute between Aalto University and the Finnish Geodetic Institute, the Research Institute of Modeling and Measuring for the Built Environment. Current research projects consist of topics such as roadside modeling, flood monitoring, 4D spaces, precision forestry, mobile mapping, and integration of photogrammetry and laser scanning.

Aalto-1
First Finnish Nanosatellite

The Department of Radio Science and Engineering Space Technology Group coordinates the Aalto-1 project, whose goal is to develop, launch and operate a university satellite based on the CubeSat concept. The project is carried out in a consortium comprising Finnish universities, R&D institutes and space industry. The Aalto-1 project provides hands-on training to undergraduate and graduate students and close linkages to the international space technology and space research community. The main highlights are an open-source do-it-yourself approach, education-oriented development, a web-based design environment and a system engineering documentation of the entire design process. The project started in 2010, and launch is scheduled for 2013 or early 2014.

The multidisciplinary consortium brings innovative space technology and ambitious technological goals to the project through technology demonstrations of cutting edge

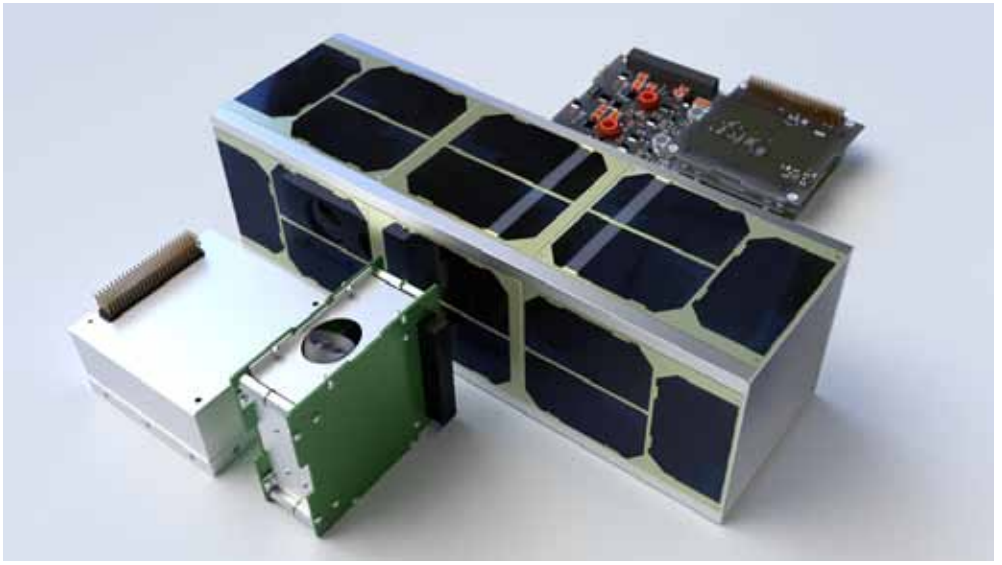


Figure 4.2, Computer generated image of Aalto-1 satellite and some of its subsystems. From left to right: spectrometer unit, attitude determination and control unit with star tracker, satellite body with attached solar panels and electrical power system and battery unit.

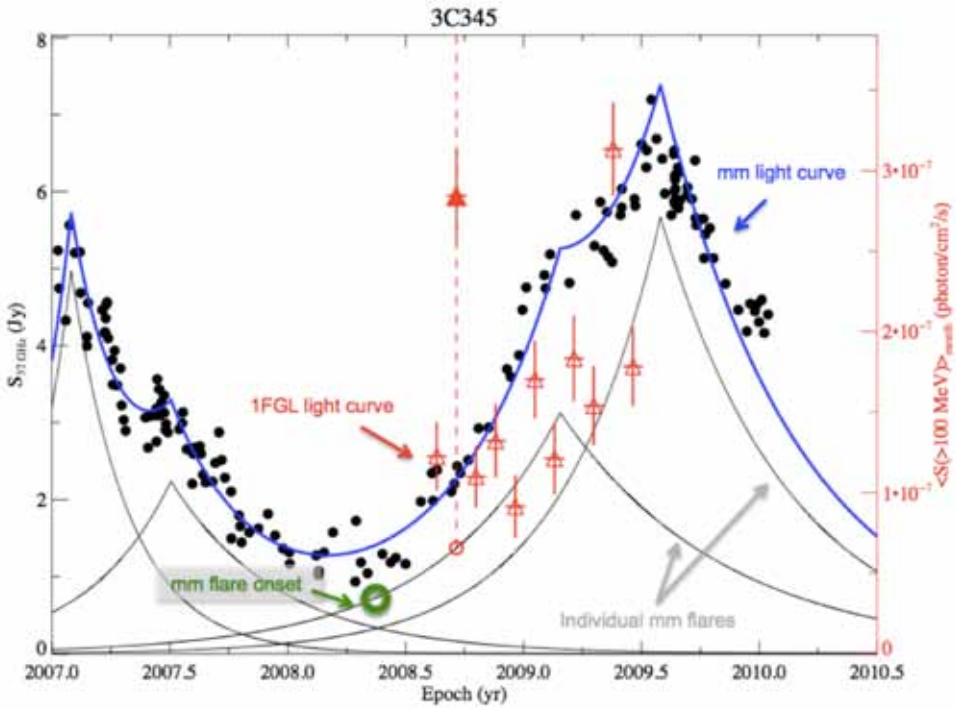


Figure 4.3, The recent flux history at 37 GHz (filled circles) and gamma-rays (triangles) of 3C345. The total flux density has been decomposed using individual exponential flares. The filled triangle represents the most significant peak in the gamma-ray flux density during the 1FGL (the First Fermi-LAT catalog) observing period. The dashed vertical line is drawn to highlight the relation between the peak in the gamma-ray curve and the ongoing millimetre-flare.

payloads. The payload includes an imaging spectrometer for Earth observation built by VTT Technical Research Centre of Finland, a radiation monitor (RADMON) built by University of Helsinki and University of Turku, and a novel de-orbiting plasma brake, built by the Finnish Meteorological Institute. All three payloads contain new technologies that have not yet been tested in space.

Blazar Observations: Comparing Fermi and Metsähovi observations

The gamma-ray photon flux variability of northern blazars in the NASA's Fermi gamma-ray satellite's LAT First Source Catalog were compared with the 37 GHz radio flux density curves from the Metsähovi quasar monitoring program. The results indicate a difference in the relationship between simultaneous millimeter flux density and gamma-ray photon flux for different types of blazars, while the flux relation between the two bands is positively correlated for quasars. Furthermore, the levels

Figure 4.4: Research aircraft of the Department of Radio Science and Engineering.

of gamma-ray emission in high states depend on the phase of the high frequency radio flare, with the brightest gamma-ray events coinciding with the initial stages of a mm-flare. The mean observed delay from the beginning of a mm-flare to the peak of the gamma-ray emission is about 70 days, which places the average location of the gamma-ray production at or downstream of the radio core.

Using VLBI for Satellite Tracking

Metsähovi radio telescope was used during 2010 and 2011 to Doppler track and determination of ESA's planetary spacecraft state vectors with VLBI technique. These can be used for a variety of scientic applications including acceleration of the satellites, atmosphere dynamics, internal structure and composition of planetary bodies, ultra-precise measurements of celestial mechanics of planetary systems, gravimetry and fundamental physics.

Measuring Soil Moisture from Space

The sole payload of European Space Agency's (ESA) Soil Moisture and Ocean Salinity (SMOS) mission is an L-band (1.4 GHz) interferometric radiometer measuring ocean salinity and soil moisture. The Department of Radio Science and Engineering Space Technology Group now focus on monitoring and optimization of the performance of the SMOS Reference Radiometers and on further development of data retrieval methods. Technological research concentrates on long-term tem-

poral and thermal stability of the radiometers originally designed at the department.

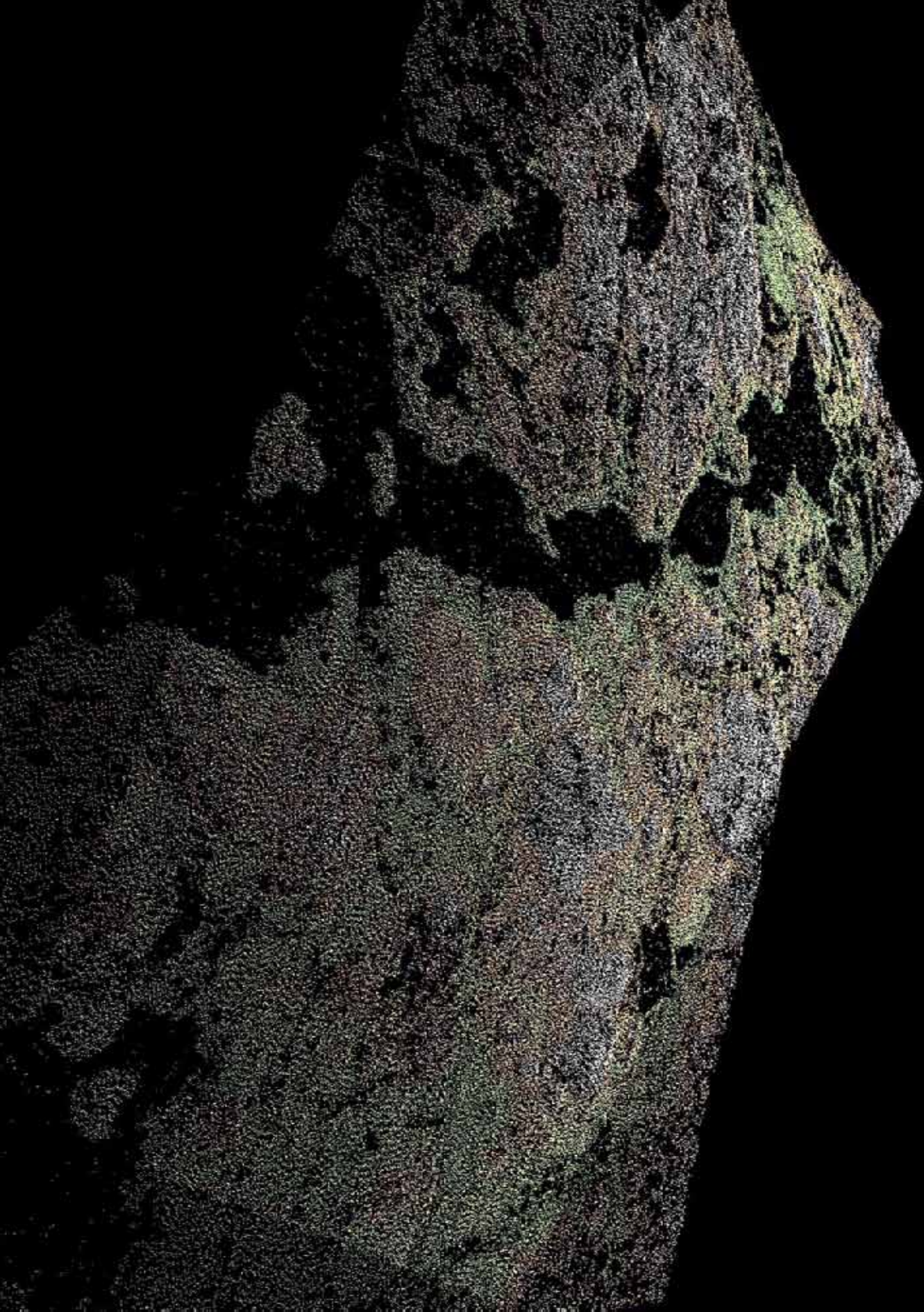
In order to develop methods for accounting for the influence of sea surface roughness to sea emissivity in the retrieval process of sea surface salinity, the Space Technology Group has organized two airborne experiments with ESA and the Spanish IEEC research institute using the research aircraft Skyvan equipped with an IEEC reflectometer and interferometric L-band radiometer HUT-2D. The results demonstrate the feasibility of the new technique for both altimetric and radiometric purposes.

Soil moisture retrieval algorithms have been developed especially for northern latitudes, as the capability of the present algorithm is limited in the boreal forest zone. SMOS observations have been compared with Finnish soil moisture models and data from ground stations provided by Finnish Meteorological Institute (FMI) and Finnish Environment Institute (SYKE). Airborne interferometric radiometer measurements in Sodankylä have been used to study L-band emission from forests and bogs in order to determine their effect to soil moisture retrieval. The effects of soil freezing and snowfall are also examined in co-operation with FMI.

GPS Measurements of Baltic Sea Level

The Geodesy Group of the Department of Surveying performed in May 2011 a GPS measurement including a number of permanent GPS stations and two mareograph GPS pillars in Southern Finland: Helsinki and Hanko. The objective was to acquire geodetic GPS data of the sea level at the Baltic Sea. A new baseline factorization technique was tested to obtain a precise link between the permanent station and mareograph pillar by using an intermediate point close to the pillar, but allowing longer occupation times. □

Figure 4.5: Measurement at the Hanko mareograph pillar, May 2011 GPS Campaign. © Panu Salo.



5. Finnish Geodetic Institute

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www.fgi.fi

The Finnish Geodetic Institute (FGI) carries out research and development for spatial data infrastructures. The institute provides a scientific basis for Finnish maps and geospatial information, carries out research and development on methods for the measurements, data acquisition, processing and exploiting of geospatial information, and co-operates with industry, universities and governmental organizations nationally and internationally.

Key research areas at the Finnish Geodetic Institute are

1. Reference systems: FGI maintains, develops and conducts research in national reference systems as well as their connection to international networks and geospatial metrology.
2. Mobile Mapping: Ubiquitous positioning, mobile mapping, context awareness, GNSS technologies, smart mobile geospatial solutions, cloud computing for mobile geomatics, and mobile GIS.
3. Spatial Data Infrastructures: Visualization and usability of spatial data, network-based processing services, ontology, data harmonization and standardization.
4. Changing Earth: Updating maps, change of land cover, growth of vegetation, change of land topography, changes of built environment, postglacial rebound, deformation studies, sea level variation, Earth orientation in space, gravity changes, and environmental aspects.

Figure 5.1, TSX point cloud

Figure 5.2, With the help of the double satellite formation, TerraSAR-X/TanDEM-X, it is possible to measure the entire land surface of the Earth with high accuracy. © DLR

Radar Satellite Imaging for 3D Forest Measurements

A new approach based on stereoscopic measurement of Synthetic Aperture Radar (SAR) images has been developed to extract forest canopy height related information. Stereoscopic measurement of SAR images, also known as radargrammetry, is a well-known technique, but now at the era of modern-day metric resolution SAR satellite images, the radargrammetric processing has undergone a renaissance. The German Earth observation satellite TerraSAR-X acquires SAR images with spatial resolution of about one meter on the ground. TerraSAR-X and its twin satellite, TanDEM-X, provide EO data globally for various environmental applications.

FGI has studied the feasibility of automatic extraction of 3D data from Stereo SAR images and has developed methods for accurately predicting forest-related information from this 3D data. The results show that radargrammetry can be used to obtain forest resources related information for wide areas. One of the key advantages of SAR imaging is change detection; the potential of the technique in frequent updating of forest resources will be studied.

Laser Scanning by Mini-UAV

A remotely piloted aircraft system (RPAS), shown in Figure 5.3., has been developed. The system comprises a remote control helicopter, an inertial navigation system, and a laser scanner; also cameras, near infrared cameras, spectrometers and thermal cameras can be used.

The aircraft is a hobby-grade Align T-Rex 700E helicopter modified to utilize up to 800 mm main blades to increase payload capacity to maximum takeoff weight of about 12 kg. Typical endurance with the laser scanning instrumentation is 8 minutes, which allows for the measurement of few hectares on a single flight. According to current regulations, the RPAS can be operated within line of sight at altitudes below 150 above ground. The RPAS can be used in many applications where the target area is relatively small and traditional aerial laser scanning (ALS) would be too expensive, e.g. in change detection, surface

modeling, forestry and fluvial studies. The accuracy of the laser scanning data is better than traditional ALS, and surface models can be created with accuracy better than 10 cm and tree heights can be estimated as accurately as 30 cm.

Navigation Satellites for Precision Measurements

The Finnish permanent GPS network FinnRef® consists of 13 stations with real-time data transfer over broadband internet connections. Four stations provide real time data stream to the European EUREF-IP service and their data are stored in international databases.

The Fennoscandian area is affected by the postglacial rebound causing intraplate deformations with respect to the stable part of the Eurasian tectonic plate. In a Nordic cooperation, a deformation model has been constructed that accurately takes into account also the horizontal component. The model greatly improves transformation accuracy compared to the global models. Maintenance of the national reference frames and their connection to the European network is a key issue in the use of the FinnRef® network.

Related to the high-precision GNSS networks and GNSS metrological quality, an extensive antenna test was performed to compare the absolute calibration of antennas to the actual conditions in field. The results are applied in design of precise deformation networks for local deformation studies. Work is continued at Olkiluoto and in Satakunta area to detect movements in the area. The work at Olkiluoto is done in co-operation with Posiva Oy as a part of the nuclear safety monitoring. Similar case study was made for Fennovoima to find possible crustal movements at the candidate sites of a new nuclear power plant.

In co-operation with the European Satellite Service Provider (ESSP), a Ranging and Integrity Monitoring Station (RIMS) of the European Geostationary Navigation Overlay Service (EGNOS) is operational in Virolahti, Finland. It will ensure the quality of the EGNOS service in Finland. FGI has developed methods to utilize navigation satellite signals for seamless smartphone navigation and intelligent transportation systems and applications. Properties of the emerging navigation satellite signals of GPS, Galileo and GLONASS are also studied. □

Figure 5.3, remotely piloted aircraft system (RPAS)

6. Finnish Forest Research Institute (METLA)

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www.metla.fi/ohjelma/vmi/vmi-moni-en.htm

The Finnish Forest Research Institute is a state research organization producing large-area forest resource information. The national forest inventory conducted by combining information from field measurements with satellite images and other numeric data sources is the first satellite image aided nation-wide inventory based on a statistical framework. In addition to thematic maps about forest resources, the method produces forest resource statistics for smaller areas, e.g. municipalities, than is possible using sparse field plot data only. New nation-wide products are produced bi-annually and are used as input in forest management planning by forestry authorities and for timber procurement planning by forest industries. Furthermore, the results are used in ecological studies, e.g., in analyzing the quality of the habitats of key-stone species, for assessing the habitat and landscape values for nature conservation planning.

The MS-NFI forest inventory method is continuously developed in order to decrease estimation errors at different spatial levels. Recently, optional methods have been developed for analytical error estimation for the k-NN method. Updates of NFI field plot data are now based on multi-temporal satellite images and a growth model. Low point density airborne laser scanner data has been used for developing methods for forest management inventories. The most recent achievements include feature selection, a semi-automated production line, and new estimation parameters. The methods have been successfully tested and employed also outside of Finland: variations of the model are in use in Sweden and in the US.

Figure 6.1, Finnish forest, photo by Sini Merikallio

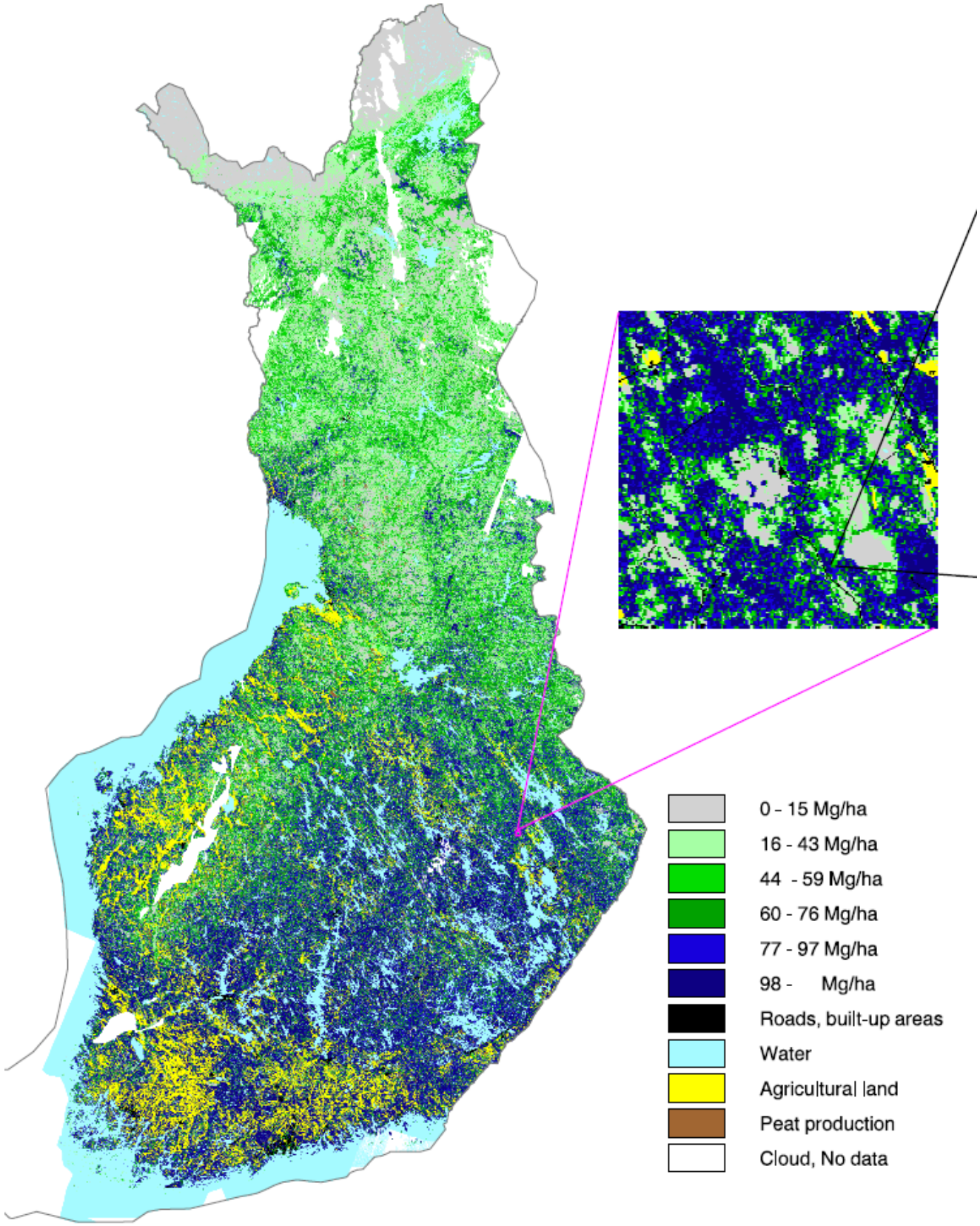

Figure 6.2, The total biomass of trees, above and below ground per hectare (Mg/ha), produced using multi-source national forest inventory of Finland. The estimates correspond year 2009. Some areas against East and West border in North Finland are indicated by the cloud colour (white), in addition to some areas inside the borders, due to lack of satellite images caused by clouds. © Finnish Forest Research Institute, MS-NFI 2009 National Land Survey of Finland MML/VIR/MYY/328/08

Photo: Erkki Oksanen, © Metla Photo Archive

Forest Resource Assessment in Africa, Asia and Latin America

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 tailored for Tanzania forest inventory late 2009 and early 2010. The input data comprises several country-wide GIS data layers and forest variable predictions based on remote sensing data. The estimation methods are under development. The team actively seeks to assist also other countries, such as Zambia and Vietnam, in establishing forest inventories.

European Approach from Multi-source National Forest Inventories

The MS-NFI team investigates methods for improving estimates of wood resources by integrating remote sensing and NFI field data. The overall aim is to develop practices for assessing tree biomass and other forest resources in support of periodic and rapid updates of estimates at NUTS3 and regional levels in Europe, as well as in selected countries outside Europe. The EU COST working group "Improving estimates of wood resources combining RS and NFI field data" led by the MS-NFI team will provide an overview of the extent to which NFIs use remote sensing data, tools, and methods (e.g., satellite and airborne imagery, optical area, lidar and radar data). The role of remote sensing in improving the efficiency of sampling designs and the precision of estimates will be considered. Methods to estimate forest attributes such as biomass and volume for small areas and methods to map their spatial distribution will be evaluated. □

7. Finnish Meteorological Institute (FMI)

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The Finnish Meteorological Institute is a governmental research institute responsible for the national weather service in Finland. It is the largest space research organization with about 50 staff working in space research and 50 staff on Earth observation. FMI is known for its scientific modeling capabilities including meteorological, climatic, and space plasma models and simulations. FMI has a competitive record of building space instruments for planetary, space research and Earth observation purposes, gathering and analyzing data, developing theoretical models for data interpretation, and publishing the results in leading peer-reviewed journals.

The northern location of Finland is optimal for operating ground-based instruments monitoring space phenomena related to aurora. FMI leads the international consortium maintaining the MIRACLE network of 30 magnetometers and several auroral cameras, and the FMI scientists are active users of the EISCAT and SuperDARN ionospheric radar systems.

In the Arctic Research Centre in Sodankylä, significant infrastructure upgrades have raised the site to become one of the foremost satellite calibration and validation (cal/val) areas in northern regions, with a particular capability to assist cal/val activities for cryosphere studies.

Figure 7.1, Mission lead Ari-Matti Harri showing MetNet Mars lander engineering model.

Using Ground Measurements to Calibrate Satellite Observations

The NoSREx campaign (Nordic Snow Radar Experiment) was initiated in 2009 in support of the ESA CoReH2O mission to provide a time-series of backscatter observations from snow-covered terrain in the boreal forest region. The campaign covers an entire winter period from snow free conditions to eventual snow melt-off to capture the seasonal evolution of the backscattering signal, and in particular, the effect of increasing snow volume. Active microwave observations from the ESA reference SnowScat-system were supported by comprehensive manual and automatic in situ measurements of snow cover, soil and atmospheric properties. The Sodankylä dataset has been of fundamental importance to CoReH2O: Results indicate that the baseline retrieval algorithm for the instrument is able to estimate the Snow Water Equivalent with satisfactory precision from the SnowScat measurements. An airborne campaign using the ESA SnowSAR instrument included 12 flights over the main test site in Sodankylä, over tundra regions, and sea ice. Several international research teams from NASA, Environment Canada and the Swiss Centre for Avalanche research (SLF) participated in the activities.

In support of the ESA SMOS (Soil Moisture and Ocean Salinity) mission, the Arctic Research Centre hosts one of the reference instruments, the ESA owned Elbara-II radiometer providing a stable and accurate ground reference for the instrument. Microwave signatures of soil freeze/thaw cycles and monitoring of these using SMOS have been studied at FMI, with the aim to improve accuracy of carbon balance estimates in northern areas.

Recreating Large-scale, Long-term Snow Cover and Albedo Records

The ESA-funded GlobSnow project has resulted in two new global records of snow parameters intended for climate research purposes. The datasets contain satellite-retrieved information on snow extent (SE) and snow water equivalent (SWE) extending 15 and 30 years respectively. The SWE record utilizes a data-assimilation based approach for the estimation of SWE that was shown to be superior to the approaches depending solely on satellite-based data. The GlobSnow SWE and SE data records have been released and are available through the GlobSnow web-pages.

Long-term time series are also created in the EUMETSAT Satellite Application Facilities. Surface albedo is a key parameter for climate modeling, as it has a direct link to the energy balance of the Earth. FMI has developed a unique global time series data set of surface albedo covering the years 1982-2009. The surface albedo time series is unique, for its length, homogeneity and topographic corrections, and covers also sea ice. An Arctic sea ice broadband surface albedo product developed at FMI is based only on microwave satellite data. The advantage in comparison to traditional optical methods is that the albedo can be estimated also under conditions of low sun elevation and cloud cover, thus enabling observations earlier in spring and later in the autumn than when using optical wavelengths. A daily snow cover product based on geostationary optical satellite data is based on a fully automated method. Recently, a corresponding polar satellite based version of the snow product has also been developed.

Satellite Observations Support Aviation

Volcanic eruptions release large amounts of ash and gases into the atmosphere. While the impact is most dramatic close to the volcano, large amounts of ash may enter the free troposphere and can thus be transported long distances. Because the volcanic ash clouds pose a hazard for the airplane engines, air traffic is re-routed to avoid volcanic ash plumes.

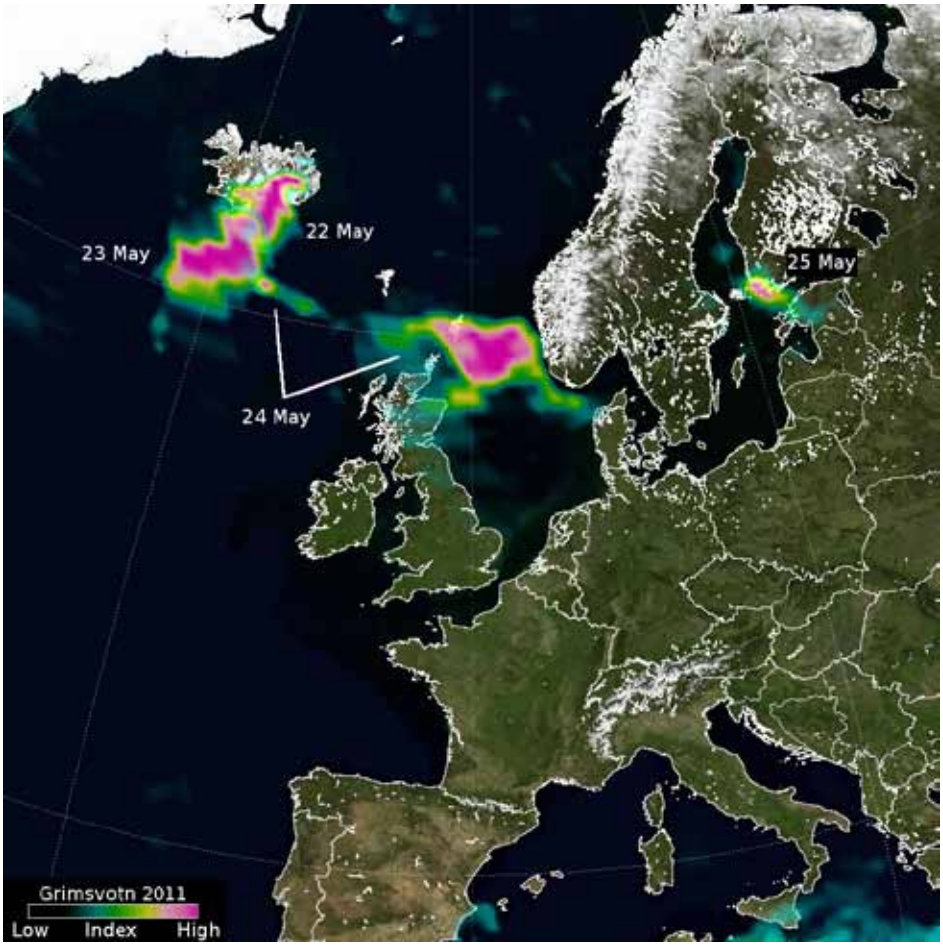


Figure 7.2, Ash (aerosol index) measurements by OMI during the Grimsvötn eruption in 2011 overlaid on top of MODIS visual image. The figure is a composite of measurements on 4 days with plume positions indicated by date. (The color coding is relative and different for each day). Image courtesy NASA.

The Icelandic Eyjafällajökull volcano erupted in April-May 2010 closing of most of the European airports for several days leading to financial losses of about 1.3 billion euros. In support of the aviation authorities, models based on data from the Ozone Monitoring Instrument (OMI) on-board the Aura satellite were used to forecast the dispersion of the ash. As real-time data are important in forecasting the ash cloud spreading, FMI upgraded the OMI Very Fast Delivery service with volcanic products such as the aerosol index and sulfur dioxide. The data products are now available within 15 min after the Sodankylä overpass.

Stratospheric Ozone Hole First Time in the Arctic

In early 2011, for the first time, dynamical and chemical conditions similar to the Antarctic occurred over the Arctic. This led to the enhancement in ozone-destroying forms of chlorine and to record high ozone loss reaching 80% at 18-20 km altitude. Observations at the FMI ozone sounding stations in Finland confirmed unprecedented Arctic ozone loss with largest differences to the climatological mean around the 18-20 km layer. International campaigns were run in Sodankylä to measure the

phenomenon. The results published in Nature and disseminated widely in the national and international press gained widespread public interest both in Finland and abroad.

The dynamical-chemical models predict that the ozone layer begins to recover in the time frame of 2050 - 2070. However, the ongoing climate change may change the positive development: Stratospheric and mesospheric temperatures decline due to increase in the long-wavelength cooling by the increased carbon dioxide. While the cooling slows down the chemical reactions destroying ozone, it favors formation of stratospheric clouds. An extensive international co-operation has been organized to monitor the long-term evolution of the ozone layer: The European Space Agency Climate Change Initiative aims to produce 10 Essential Climate Variables including ozone and aerosols, FMI produces the ozone data record from ESA's ENVISAT mission. The SPARC organization collects data from all limb-viewing instruments to create ozone and other constituent climatologies. The most recent activity is to revisit the 1998 ozone trend from vertical profiling instruments. FMI is preparing GOMOS-SAGE II time series that will generate a stable time series for 1984-2011 for ozone trend studies.

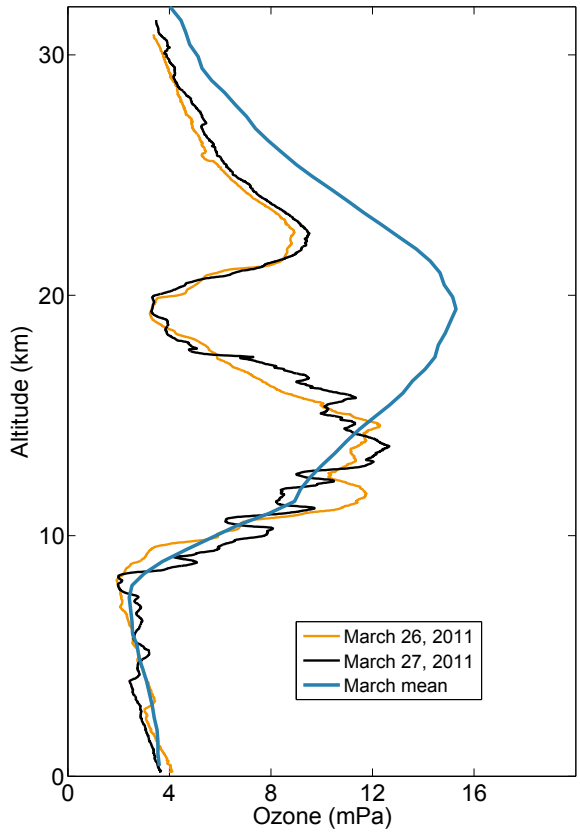


Figure 7.3, Ozonesonde profiles over Sodankylä in late March 2011. They show ozone depletion in the Arctic vortex at around 20 km. Lowest values of ozone partial pressure in the soundings were around 3 mPa.

Understanding Auroral Dynamics

Data from the IMAGE magnetometer network now covers almost two solar cycles providing opportunities for long-term climatological studies. Statistical analyses indicate that during solar activity minimum, the electrojet currents in midnight sector tend to be at higher latitudes and weaker than otherwise even under similar solar wind driving conditions. Substorms detected with an automated search engine appeared to be more frequent but weaker during solar minimum years; the results also revealed new interesting seasonal asymmetries. Investigations of time derivative values (dH/dt) reveal that rapid time variations occur predominantly in the westward electrojet and in the midnight and morning hours. These results bear also practical importance as they cause strong induced currents e.g. in natural gas pipelines.

While human eye quickly learns to trace auroras in all-sky camera (ASC) images, automating the routine has proved to be a difficult task. However, machine vision methods are needed to analyze the millions of images produced annually. A new auroral detection algorithm was developed based on a set of numeric image features computed from ASC data. The numeric features include simple intensity features, texture features, and brightness invariant features. Results are promising,

as the search engine managed to recognize auroras with tolerable error rates (6-8%) when compared to binning done by an experienced auroral scientist. The new method will enable more efficient storage of ASC data and facilitate finding relevant data for statistical studies.

A New Plasma Simulation Emerging From ERC Starting Grant

Vlasiator is a new hybrid-Vlasov code developed for global scale simulations in the QuESpace ERC-project. It is quickly maturing into a production level tool attracting interest in the space physics community at large. Both global test-particle simulations and local simulations are being developed, and novel beyond-MHD features especially in the shocked region at the front of the magnetosphere have been detected and are to be published in 2012.

The computational requirements for a global hybrid-Vlasov simulations are immense: The ions are described with a 6-dimensional distribution function in real and velocity space, and the entire magnetosphere region needs to be covered with sufficient resolution. Simulation development has required the use of latest numerical and computational techniques: The numerical kernels run both on normal processors and on graphics processing units (GPUs). Extreme scalability is obtained using two parallelization paradigms, message passing and threading. In collaboration with the PRACE research infrastructure experts, the code is already running on Europe's largest supercomputers on more than 10 000 cores efficiently and with almost linear scaling, indicating that a larger number of cores enables efficient large simulations.

E-sail: New Transport Mechanism in Space

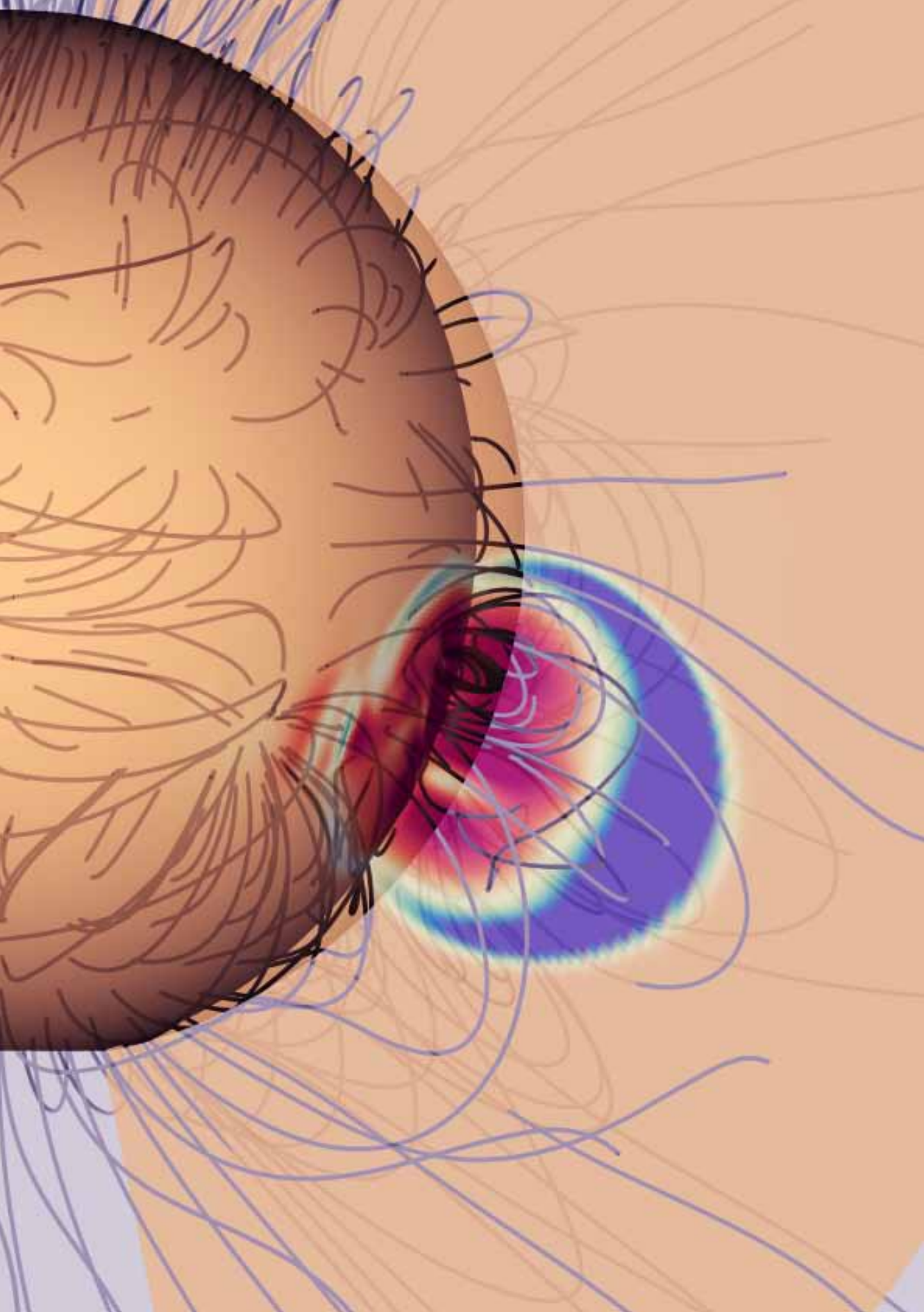
The electric sail (E-sail) is a Finnish invention that uses the solar wind momentum flux for producing spacecraft propulsion (Figure 3.2). The E-sail could in many cases revolutionize the transportation of payloads in the solar system outside the Earth's magnetosphere. Because the E-sail does not require propellant, the spacecraft mass budget is not proportional to the length of the journey. On the other hand, the E-sail thrust versus mass ratio is notably higher than other proposed non-propellant power systems such as photon sails.

Two CubeSat projects will carry the E-sail as test payload, the Estonian ESTCube-1 (launch early 2013) and the Finnish Aalto-1 (launch 2014). The laboratory prototypes (TRL 4-5) fo the key components of a full-scale interplanetary 1N class E-sail are being developed in an EU FP7-funded project.

Atmospheric Science at Mars

The Mars MetNet is a new type of atmospheric science vehicle to Mars, originally defined at FMI. MetNet is based on a unique type of semi-hard landing vehicle utilizing inflatable systems in the entry, descent and landing systems. This concept enables deployment of small payloads on the Martian surface with an excellent payload to system mass ratio: with the mass of one Spirit Mars rover, MetNet can deploy 10 to 15 landers on the Martian surface. The MetNet vehicle is built in collaboration between the FMI, Lavochkin Association, the Russian Space Research Institute (IKI) and Instituto Nacional de Técnica Aeroespacial (INTA).

The eventual scope of the MetNet Mission is to create a simultaneously operating network of 20 or more MetNet Landers on the Martian surface for exploration of in particular the atmospheric properties of Mars. The landers will carry a versatile atmospheric science payload of about 4 kg. In 2011, the team manufactured instrument qualification units for the MetNet Mars Precursor Mission aiming at sending the first lander to Mars in 2016-2018 to demonstrate the technical and scientific capabilities of the MetNet concept. □



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Space research of the University of Helsinki is conducted mostly at the Department of Physics, which is the largest Physics Department in Finland with the total annual work effort in space research of over 50 FTE. This work is conducted within the framework of the Kumpula Space Centre in collaboration with the Finnish Meteorological Institute and (from 2012) the Aalto University School of Electrical Engineering. The department is also active in the Finnish Centre for Astronomy with ESO (FINCA), with 4 FINCA staff members working in the premises. In addition, there are some remote sensing activities at the Department of Geosciences and Geography and space-related applied mathematics at the Department of Mathematics, totaling the space activities of the University of Helsinki at over 60 FTEs. In 2011 space research resulted in about 90 peer-reviewed articles.

The main fields of space research are studies of interstellar medium and star formation, stellar astrophysics, space-based cosmology, space physics, planetary system and planetary geophysics. Studies of the interstellar medium focus on the early stages of star formation process. Both ground-based (e.g., ESO's telescopes) and the satellite instruments (e.g., ESA's Herschel and Planck) are used. Stellar magnetic activity studies include both observational and numerical analyses. High-energy phenomena in the Solar corona and clusters of galaxies are studied using X-ray satellite data, including observations with X-ray detectors developed at the department. The Planck cosmology team is in the heart of analysis of the cosmic microwave background observations that will be released in early 2013. Solar-Terrestrial studies concentrate in particular on processes driving space weather in the near-Earth space. Planetary research focuses on asteroids, comets and small particles in regoliths and atmospheres. The department leads the largest Finnish space instrument project, the X-ray and particle detector instru-

Figure 8.1, Global 3D-MHD simulation of the first ten minutes following the onset of a CME in the corona. The model features a realistic magnetic field configuration using GONG magnetogram observations as input, and the eruption is driven by a non-equilibrium flux rope structure whose size and location matches that of the observed pre-eruption filament. The erupting structure initiates a dome-like shock that reaches all the way down to the coronal base, producing on-disk as well as off-limb wave signatures in close agreement with high-cadence SDO/AIA EUV imaging observations. The snapshot depicts the density compression relative to the pre-eruption state at the coronal base as well as in a meridional plane 2.5 minutes after onset, clearly highlighting the shock and post-shock compression regions (blue colors). Field lines of the magnetic field are also shown.

ment for ESA's Mercury mission BepiColombo. Studies of impact cratering processes combine space research and geophysical methods.

The department goal is to form a leading European astronomy and space research community and to provide the best doctoral training by 2015. In the international evaluation of the University of Helsinki conducted in 2011-2012 both strong international activities and the approach to combine space astronomy and space physics within a joint research unit were evaluated very positively.

Planck Unravels the Origins of the Universe

The Planck satellite began its fifth full-sky survey in August 2011. The coolant for the last cooling stage required for observations at the higher frequencies (100 GHz and above) ran out in January 2012 as planned, but observations at the three lowest frequencies (30, 44, and 70 GHz) will continue for most of 2012. The Planck group at the Department of Physics is responsible for producing the sky maps for the three lowest frequencies, as well as calibration, estimation of residual noise correlations on the maps, and producing large Monte Carlo simulations of the data. First astrophysical results were published in 2011, including observation of the cosmic infrared background and discovery of many galaxy clusters via the Sunyaev-Zeldovich effect (scattering of cosmic microwave photons to higher frequencies). The Early Release Compact Source Catalogue from Planck contains more than 15 000 astronomical objects: radio

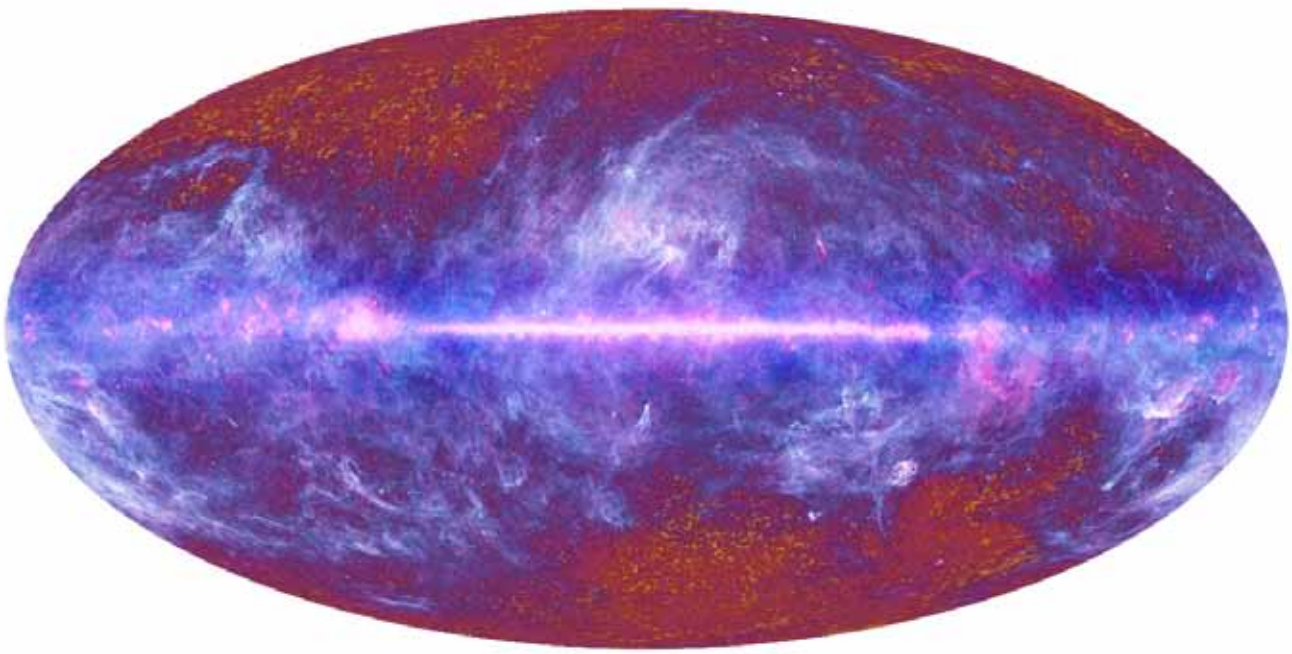


Figure 8.2, The first full-sky survey of Planck. For this image the lowest and highest frequencies of the 9 Planck channels have been given the most weight, so that it is dominated by the Milky Way. The microwave radiation from the Milky Way is mostly due to free electrons (lower frequencies) and dust (higher frequencies) in the interstellar matter. The cosmic microwave background lies behind it and is here visible in the high-latitude regions. Credit: ESA, HFI and LFI consortia.

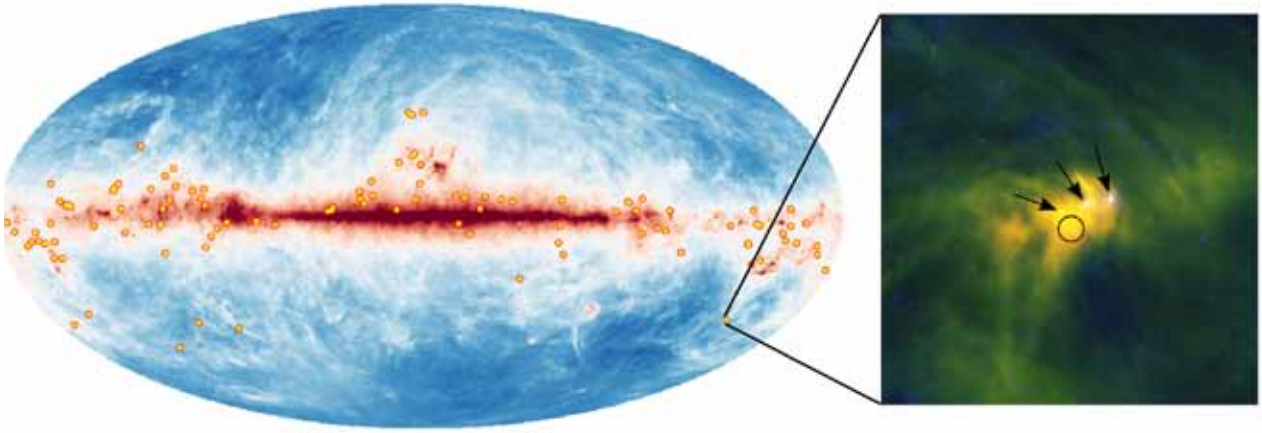


Figure 8.3, With its 3.5m main mirror, the Herschel satellite is the largest space telescope (© ESA).

Left: The project Galactic Cold Cores is carrying out Herschel studies of star forming regions within our Galaxy. The locations of the observed fields are shown on top of the allsky map produced by the IRAS satellite. The Galactic plane runs horizontally through the figure.

Right: Example of the Herschel maps. Planck identified this high latitude cloud as a source of cold dust emission. Herschel data and ancillary infrared data reveal three young stellar objects (arrows) and a pre-stellar core (circle).

galaxies, blazars, infrared-luminous galaxies, features in the galactic interstellar medium, cold molecular cloud cores, stars with dust shells, galaxy clusters and unidentified objects. First cosmological results are expected in early 2013.

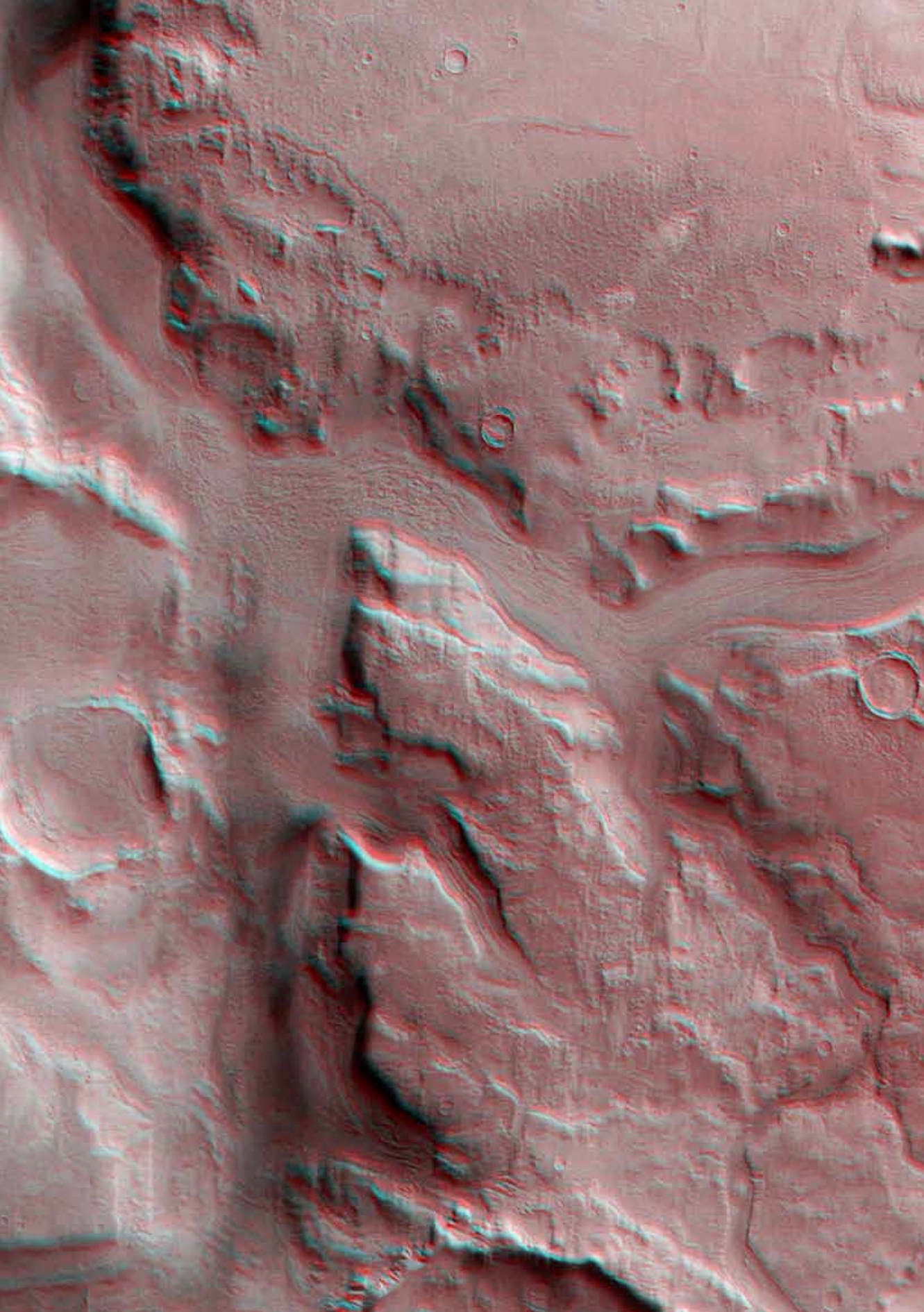
The Planck sub-millimeter maps were used for a global survey of future sites of the star formation within the Milky Way. Before their collapse into stars, the dense regions of the interstellar clouds are cold: The temperature of the dust particles can be less than 10K and their emission peaks at the wavelengths measured by the Planck HFI instrument. The Planck data were searched for potential pre-stellar cloud cores. These studies have continued with the Herschel key program Galactic Cold Cores in which more than one hundred separate fields have been mapped.

Lift-off of Solar Coronal Eruptions

A global 3D-MHD simulation of the first ten minutes following the onset of a coronal mass ejection features a realistic magnetic field configuration using GONG magnetogram observations as input, and the eruption is driven by a non-equilibrium flux rope structure whose size and location matches that of the observed pre-eruption filament. The erupting structure initiates a dome-like shock that reaches all the way down to the coronal base, producing on-disk as well as off-limb wave signatures in close agreement with high-cadence SDO/AIA EUV imaging observations.

FP7 Targets Space

In 2010, the University of Helsinki became involved in four new EU FP7 projects, acting as coordinator for two: E-SQUID, whose focus is on developing improved SQUID-based readout electronics for detector arrays covering a large range of the electromagnetic spectrum from far infrared to X-rays and SEPServer that aims at developing data services and analysis tools for Solar Energetic Particle events and related electromagnetic emissions.



9. University of Oulu, Department of Physics

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Space-related activities in the University of Oulu are concentrated at the Department of Physics and at the Sodankylä Geophysical Observatory. Research areas include astronomy, planetology, ionospheric and magnetospheric physics, cosmic rays as well as solar-terrestrial connections. Among about 50 researchers working in these units include 6 professors and almost 20 PhD students.

The Space Institute will become an umbrella organization uniting all space research activities at the University of Oulu. As a first step, a joint professorship in space physics has been established in 2012.

Atmospheric Imaging at Sodankylä

Sodankylä Geophysical Observatory, located about 120 km north of the Artic circle and 350 km from Oulu, conducts geophysical measurements of the ionosphere, atmosphere, magnetosphere, and solid Earth at 20 different locations in Finland, Sweden, Norway, and Svalbard. The data archive spanning almost 100 years allows studying the long-term evolution. The recent investment, the Kilpisjärvi Atmospheric Imaging Receiver Array completed in 2012, is a multi-purpose radio receiver used for atmospheric research and prototyping for the EISCAT_3D radar system.

Figure 9.1. Reull Vallis is an outflow channel that extends 1500 km across Promethei Terra in the direction of Hellas Basin. This Mars Express image was taken with a ground resolution of about 21 metres per pixel during Mars Express orbit 451. This anaglyph 3D-image shows an area located at about latitude 42° South and longitude 102° East. North is to the left.

Credits: ESA/DLR/FU Berlin (G. Neukum)

EISCAT Radar Studies the Polar Ionosphere

The ionospheric physics group at the Department of Physics focuses on the high latitude ionosphere and magnetosphere - ionosphere coupling especially using the EISCAT incoherent scatter radars and the Cluster satellites. The group is actively involved in the EISCAT_3D Preparatory Phase project, especially in planning the scientific use of the future radar system. New methods were developed to analyze E-region neutral winds and F-region electric fields from incoherent scatter radar measurements based on stochastic inversion, and for spectral analysis of unevenly sampled data with gaps. Research topics include small-scale structuring of auroral arcs, F-region troughs, open-closed field-line boundary identification. First simultaneous observations of bursty bulk flow return flows in the ionosphere and magnetosphere were recorded in accordance with the bubble model.

Space-Climate Relationship

The space climate group at the Department of Physics studies the long-term evolution of solar activity and its effects in the solar wind and interplanetary magnetic field, in the near-Earth space environment, the neutral atmosphere and climate. The group is one of the international originators of this new field, and participates in several EU FP7 projects. Among the recent important results are the accurate estimate of 2 degrees for the southward shift of the heliospheric current sheet and the recalibration of the entire 30-year, 15-satellite NOAA/POES energetic particle dataset. Long-term observations will in due course reveal why the Sun has been exceptionally active during the last century and exceptionally quiet during the last 5 years.

The Cosmic Ray Station in Oulu performs routine monitoring of the cosmic ray flux, and monitors atmospheric effects of cosmic rays. The group was heavily involved in the organization of the 22nd European Cosmic Ray Symposium in Turku in 2010.

Blazars and Galaxies

The astrophysics group at the Department of Physics is actively involved in research in accreting black holes, accreting millisecond pulsars, X-ray bursters, ultra-luminous X-ray sources, and gamma-ray bursts. The Fermi

Figure 9.2: The KAIRA 120-250 MHz array consists of 48 elements of 16 dipoles (left inset) each. Dipoles are broad-band bow-tie antennas (right inset).

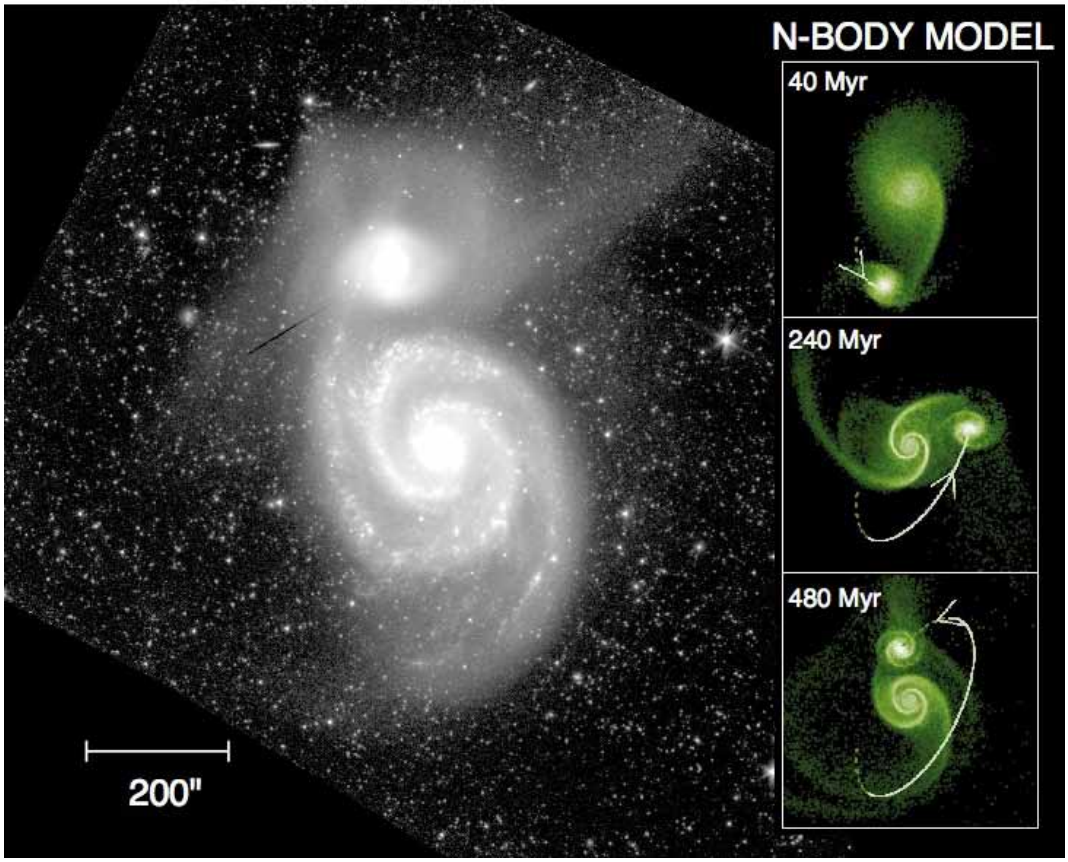
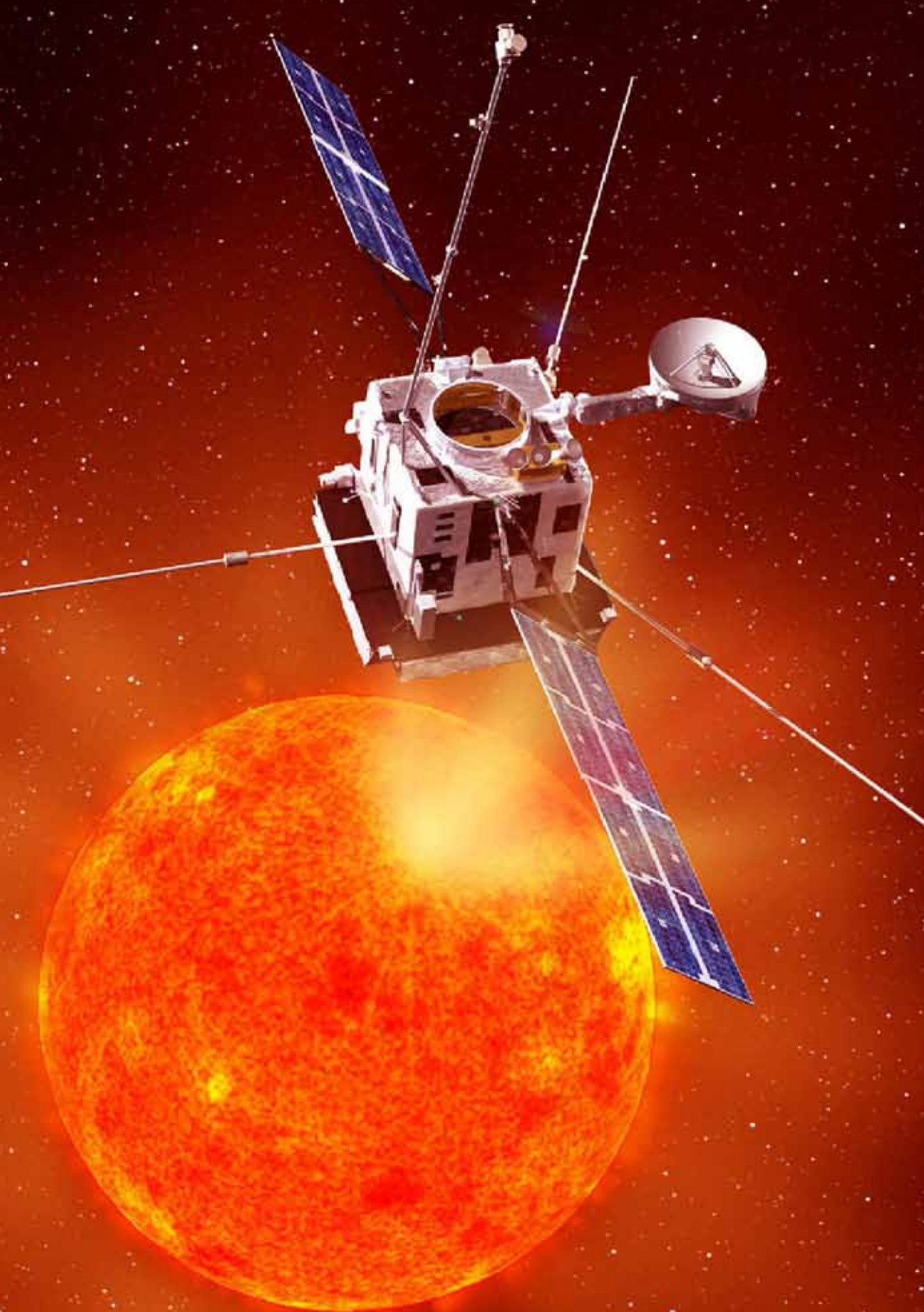


Figure 9.3: Spitzer observations of the M51 Whirlpool galaxy, together with a tidal interaction model made in Oulu (from Sheth et al. 2010, PASP 122, 1397).

satellite discovered GeV breaks in a number of bright blazars, which were proposed to be produced by photon-photon absorption by the Lyman continuum photons of hydrogen and helium from the quasar broad-line region. This result settled the issue of the location of the gamma-ray emitting region in blazars in favor of the black hole vicinity. The dynamics group is part of the S4G project (The Spitzer Survey of Stellar Structure in Galaxies) that was awarded 627 hours of Spitzer Exploration Science time for 2009-2011. Over 2000 nearby galaxies were observed in 3.6 and 4.5 microns, providing deep uniform maps of stellar mass distribution over a variety of galaxy types and environments.

Planetary Surface Imaging

The planetology group at the Department of Physics uses the cumulating planetary space data focusing on the surface properties and processes of Mars, Venus and Moon. The comparative planetological studies on the Martian and Hermean geology provide clues to the evolution of the Earth as well as other terrestrial bodies. Currently the group has studied the ice-cumulating periods in the history of Mars resulting in a series of papers that discussing the water-, climate- and environment-related history of the wider Hellas region on the southern hemisphere of Mars. □



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FINCA, Finnish Centre for Astronomy with ESO,
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Space research at the University of Turku is conducted both at the Space Research Laboratory (SRL) and at the Tuorla Observatory. Furthermore, the University of Turku hosts the Finnish National Centre for Astronomy with ESO (FINCA) located at the Tuorla Observatory premises.

The Space Research Laboratory carries out research in the fields of solar and heliospheric physics and cosmic ray physics. Experimental work at SRL is based on measuring high-energy (>1 MeV/nucleon) ions of solar, interplanetary and galactic origin by using space instrumentation, especially the PI-instrument ERNE onboard SOHO. Recently also ISS/AMS has started measurements, and an instrument for Solar Orbiter is under development. Simulations based on theoretical work are essential in the interpretation of experimental results, the principal goals are to investigate the validity of the impulsive-gradual paradigm of the solar energetic particle (SEP) events, capability of a CME-driven shock to produce major SEP events, connection between the electromagnetic and corpuscular imprints of the solar eruptions up to relativistic particle energies, and feasibility to predict the SEP production magnitude based on observations of the early phases of the eruption.

Tuorla Observatory is the only active optical observatory in Finland. With staff of about 35, Tuorla is the largest astronomical institute in Finland. The main areas of research are cosmology, active galaxies, dark matter, the Local Volume, supernovae, binary stars, solar system physics and numerical astronomy, solar research and astrobiology. A major initiative during the last decade has been to establish the new interdisciplinary research area of astrobiology with teaching offered from MSc to PhD levels. Tuorla Observatory participates in the MAGIC Collaboration hosting the most sensitive atmospheric imag-

Figure 10.1, SRL is part of an international collaboration selected to build an energetic particle experiment (EPD) for the Solar Orbiter mission. ©ESA

ing Cherenkov telescope and in the CTA (Cherenkov Telescope Array) project, which aims to build two next generation gamma observatories in the Northern and Southern hemisphere.

Finnish Centre for Astronomy with ESO (FINCA) 1) coordinates Finnish co-operation with the European Southern Observatory (ESO); 2) practices and promotes high quality research and technological development work, and 3) fosters and implements national collaboration in astronomy. FINCA started operations in 2010 funded by the Ministry of Education and Culture and by the participating universities (Turku, Aalto, Helsinki and Oulu).

The research at FINCA covers areas from cosmology, distant active galaxies, and galaxy formation and evolution, through studies of the structure of nearby galaxies, to binary stars, stellar magnetic activity, interstellar medium, star formation and exoplanets in the Milky Way. Instrumentation include ground-based and space telescopes, especially the four 8-m class Very Large Telescopes (VLT) and the three 2-4-m class telescopes of ESO in Chile, and the Nordic Optical Telescope (NOT) on La Palma, Spain.

Pioneering Supernova Research

ESO telescopes, Gemini-North, NOT, HST, and first Finnish-led Spitzer Space Telescope Program have been used to study the core-collapse supernovae, the end points of massive stars. Adaptive optics observations at near-infrared wavelengths were used for studies of heavily dust-obscured supernovae in the nuclear regions of nearby luminous infrared galaxies. At high redshifts, a large fraction of massive star formation took place in such galaxies; it is therefore crucial to gain better understanding on the hidden supernova activity in such galaxies of the local Universe. Tuorla Observatory participates in an ESO Large Programme aimed at a better understanding of SN variety and their nucleosynthesis yields. A large collaboration running the "Public ESO Spectroscopic Survey of Transient Objects" with NTT aims to classify 2000 SNe, with detailed follow-up observations obtained for about 150 SNe over the next 4 years.

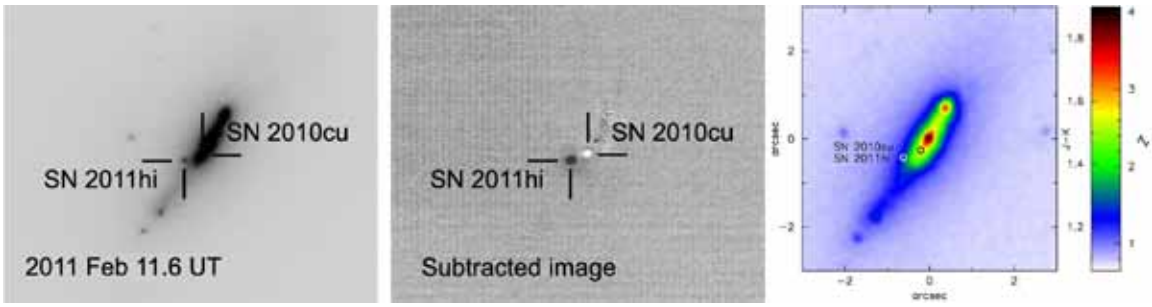

Figure 10.2, Two consecutive supernovae discovered within the nuclear regions of the luminous infrared galaxy IC 883 making use of adaptive optics with laser guide star at the 8.1-meter Gemini-N (left and middle panels). The SN locations are indicated in a J-K colour/extinction map (right panel) based on HST data. Credit: Kankare et al. 2012, ApJ, 744, L19.

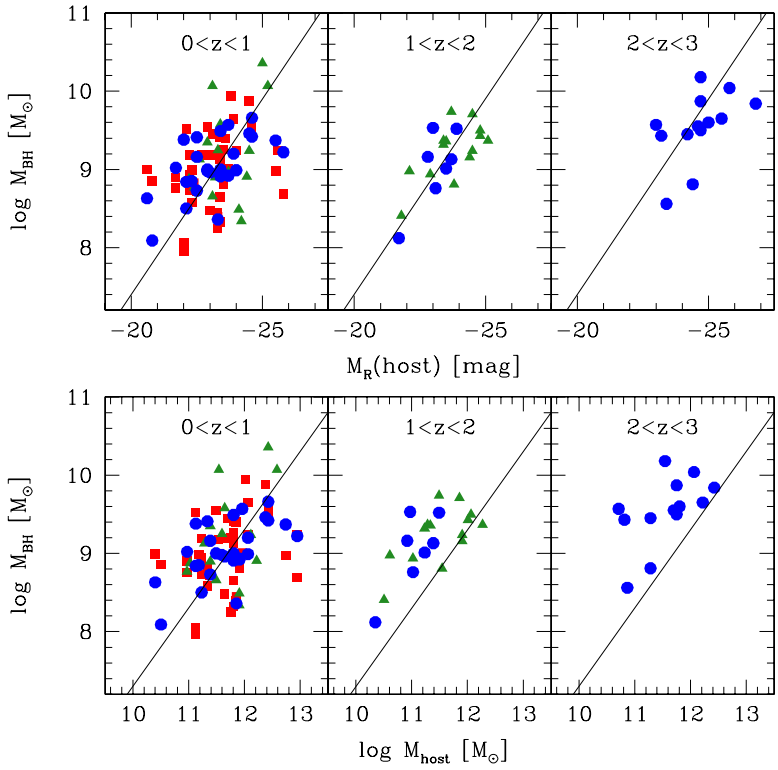

Figure 10.3, The M(BH)-L(host) and M(BH)-M(host) relations in three redshift bins. The solid line is the z=0 relation. A clear evolution is apparent in the M(BH)-M(host) relation

Cosmology With Planck

Tuorla cosmology group has an appointed task in the Planck satellite mission to search for WHIM (Warm Hot Intergalactic Medium) using Planck Sunyaev-Zeldovich (SZ) data. Combined observations with X-ray (XMM-Newton) and Planck SZ observations, together with the supercluster data based on Luminous Red Galaxies, suggested recently the presence of a massive triple system at z ~ 0.45. It likely forms the core of a larger-scale supercluster, the first to be discovered via the SZ effect. Theoretically, the SZ signal from such a supercluster is expected to arise from the sum of the signal from the individual clusters, plus a possible additional contribution from a filamentary inter-cluster gas, a possible WHIM component.

Co(?)-Evolution of Black Holes and Galaxies

The evolution of the black hole (BH) – host galaxy relation as a function of cosmic time was studied in a large sample of quasars from z = 3 to the present epoch (i.e. over 85% of the age of the Universe). The black hole masses of the quasars were derived from single-epoch spectra assuming virial equilibrium in the broad-line region, and host galaxy luminosities and inferred masses from imaging. The M(BH)-L(host) relation remains nearly unchanged. On the other hand, taking into account the ageing of the stellar population, the M(BH)/M(host) ratio Γ increases by a factor of ~7 from z = 0 to z = 3, regardless of the radio loudness and luminosity of the quasar. The most massive black holes, living their quasar phase at high redshift, become extremely rare

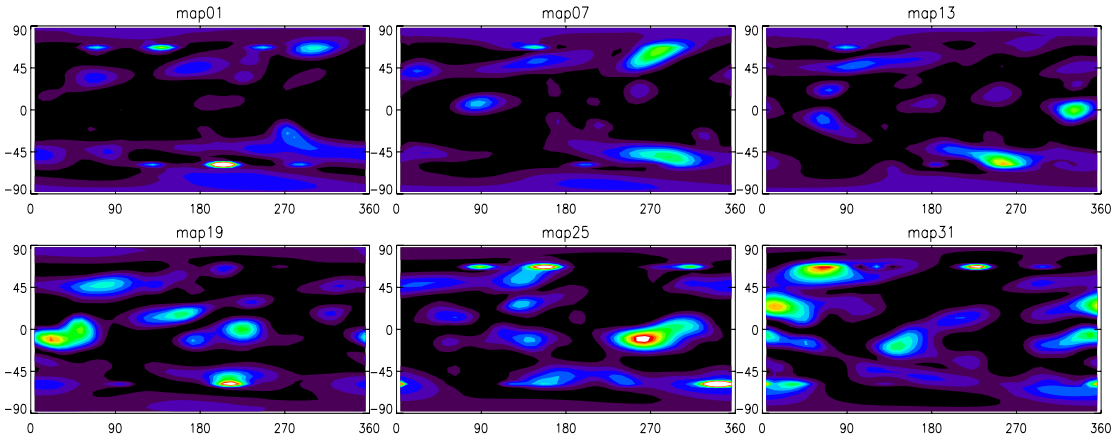

Figure 10.4, Examples of snapshots of dynamo simulations showing magnetic spots tracing stellar differential rotation.

objects in host galaxies of similar mass in the Local Universe.

Differential Rotation at Andromedae

Analysis of the unique, continuous, dataset of giant star zeta Andromedae from different observing sites reveals signs of weak differential rotation with strength of ~2% of the solar value, weaker than the theory predicts. As snapshots of dynamo models show that using only large-scale dynamo field the solution is dominated by its geometry, and the input rotation law is only recovered if additional small-scale fields are included. This raises the question whether the large starspots in active stars can even be expected to follow the surface differential rotation.

Observing Exoplanets

Multicolour polarimetric measurements (UBV bands) for the hot Jupiter -like exoplanet HD189733b clearly confirm the previously reported polarization in the B band. The polarization wavelength dependence indicates the dominance of Rayleigh scattering with a peak in the blue B and U bands of $10^{-4} - 10^{-5}$ and at least a factor of two lower signal in the V band. Effects of incomplete cancellation of stellar limb polarization due to starspots or tidal perturbations are negligible as compared to scattering polarization in the planetary atmosphere. Comparison of the observations with models suggests that the planetary atmosphere is optically thin in the visible and thick in the near UV. This result finally establishes polarimetry as a reliable means for direct studying exoplanetary atmospheres.

SOHO/ERNE

During its 15th year of operation, the Solar and Heliospheric Observatory (SOHO) saw the beginning of the long-waited 24th solar activity cycle. The first significant SEP event after December 2006 was observed by ERNE in August 2010. Use of archived ERNE data focused on particle acceleration in both solar corona and in interplanetary space. ERNE data are freely available both from the SRL internet site and from the SOHO archive.

Alpha Magnetic Spectrometer

After 16 years of design and building, the Alpha Magnetic Spectrometer (AMS) was carried to the International Space Station on STS-134 on May 16, 2011. AMS produces a data stream of 7 Gbits/s ,which by on-board processing is reduced to 2 Mbits/s average downlink telemetry. By the end of 2011 AMS had already collected about 10 billion cosmic-ray particles. Due to its enormous collecting power compared to any other space instrument, AMS will easily achieve unprecedented statistics of cosmic rays enabling precise measurements of many cosmic ray characteristics, and will search for antimatter and dark matter signatures with significantly better sensitivity than has ever before been possible.

Low Energy Telescope for the Solar Orbiter

SRL is part of an international collaboration selected to build an energetic particle experiment (EPD) for the Solar Orbiter mission. Mission Phase B2 started at the beginning of 2011, although the final confirmation of the mission did not take place until October 2011. During 2010 – 2011 SRL developed the instrument technology to TRL 5 by building a prototype, and reached readiness for the Instrument Preliminary Design Review by the end of 2011. LET development with the funding of the University of Turku and Tekes represents the most significant effort of the Space Research Laboratory during the past two years. □

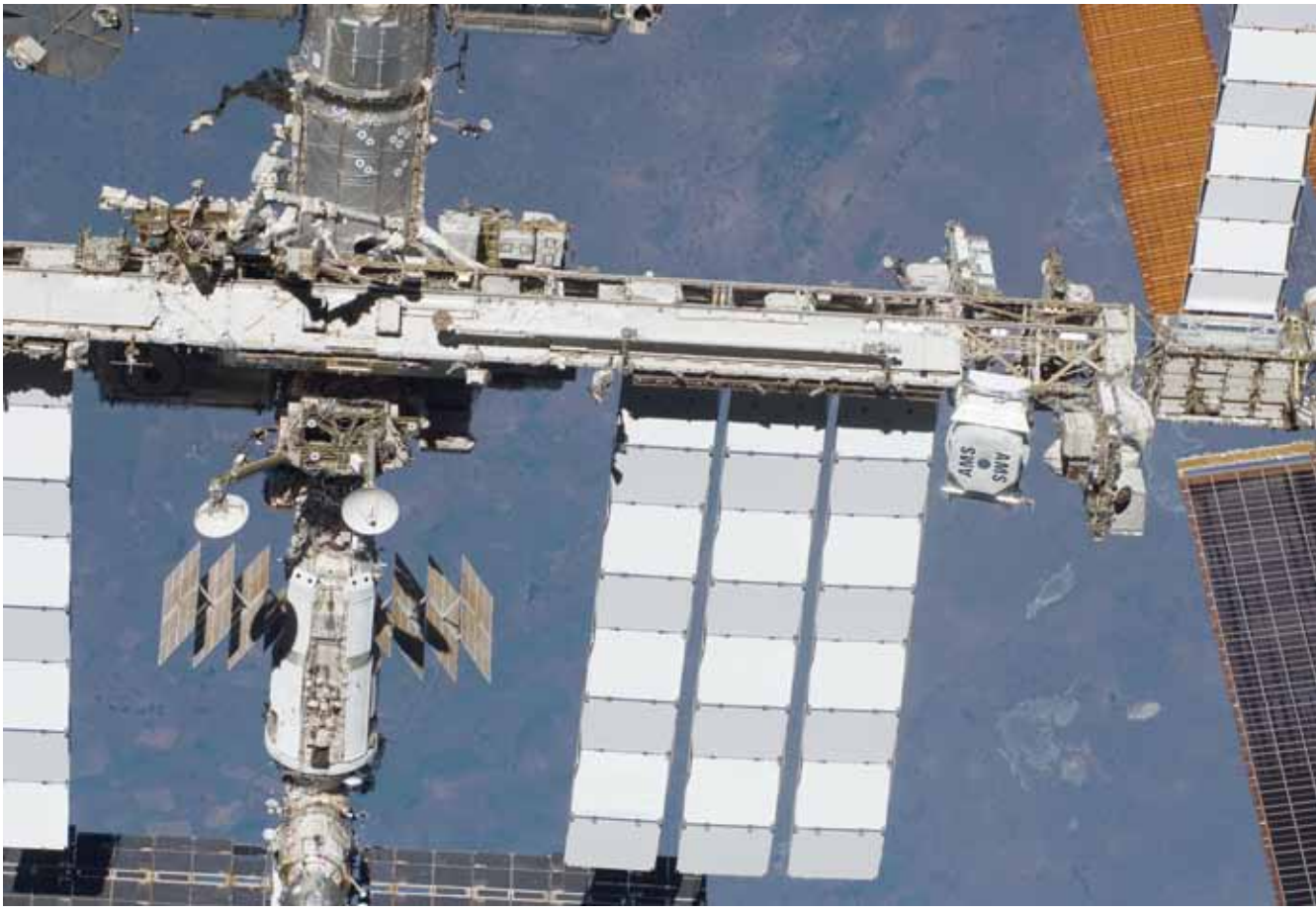

Figure 10.5, Alpha Magnetic Spectrometer installed on the International Space Station.
Photo Courtesy of NASA.

11. Millimetre Wave Laboratory of Finland (MilliLab)

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www.vtt.fi/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 Electrical Engineering. 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.

MilliLab, together with DA-Design Ltd., and Fraunhofer IAF, Freiburg, Germany, has been actively involved in development of low noise amplifiers (LNAs) for future MetOp Second Generation (MetOp-SG) instruments. Several LNAs have been realised for 50-200 GHz frequency range utilising GaAs MHEMT MMIC technology and preliminary reliability assessment for most promising designs will begin in 2012. MilliLab is working with ESA/ESTEC also in characterisation and evaluation of Schottky diodes which is a key technology for MetOp-SG instruments above 200 GHz. Moreover, novel internal calibration loads for millimetre-wave radiometers have been studied.

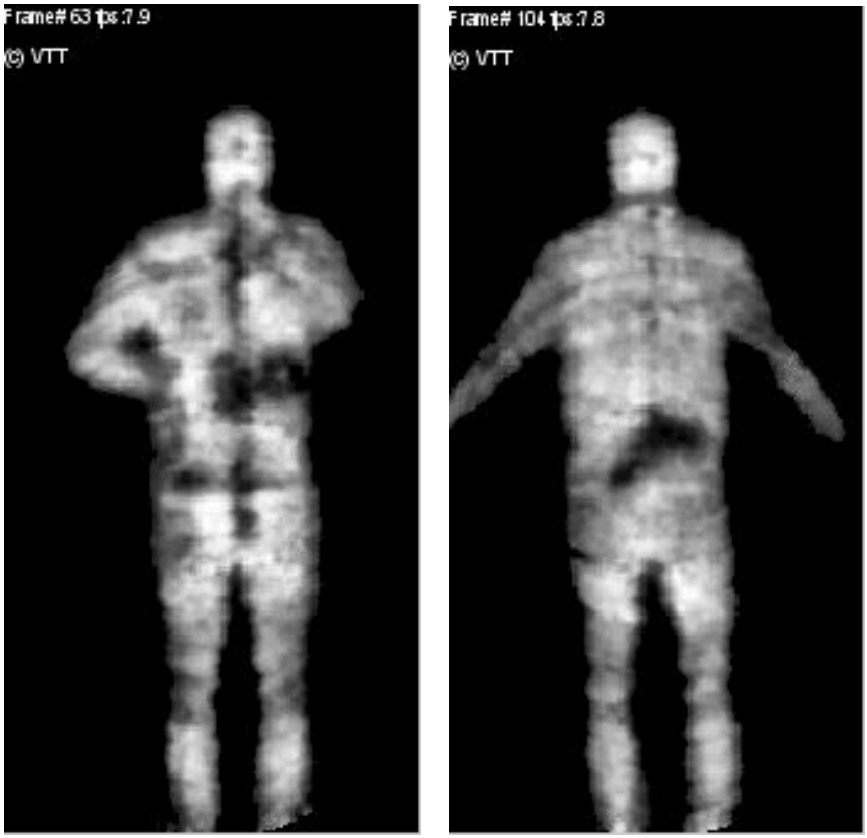

Figure 11.1: Two frames from a 10 fps, passive broadband THz video from the VTT/MilliLab system demonstrator. A CD ROM (front) and a handgun (back) are visible from underneath a ski jacket.

As a new activity in general technology development, MilliLab is currently building a passive terahertz imager demonstrator funded by ESA. This work started in 2010, and when completed, the terahertz camera will produce video rate data at three centre frequencies: 250, 450, and 720 GHz. The imager technology is based on bolometer detectors cooled to 4 K and arranged into three line arrays. The camera will have about 200 such detectors. In addition, conically scanning optics is used with the detectors to produce 2-D "colour" video. The technology has applications in safety and security as well as future space missions.

The 2009 launched ESA Planck mission has proceeded successfully. The six 70 GHz receivers developed and built by MilliLab and DA-Design Ltd. for the Planck Low Frequency instrument continue to produce excellent data. Planck has completed five full sky surveys, and the first cosmology results are expected early 2013. □

12. RADiation Effects Facility (RADEF)

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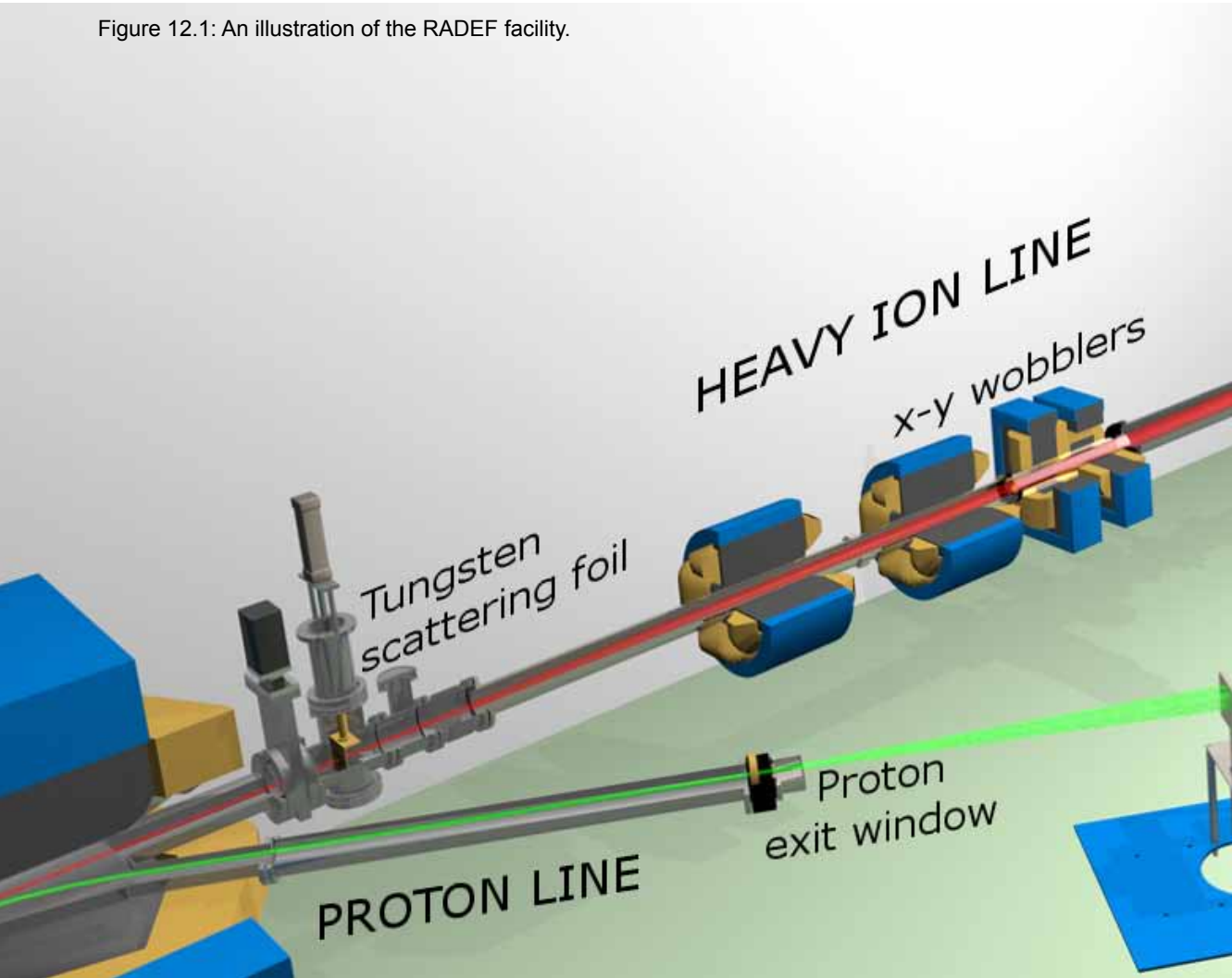
http://www.jyu.fi/fysiikka/en/research/accelerator/radef

The RADiation Effects Facility (RADEF) located at the Accelerator Laboratory of the University of Jyväskylä has been operated under the contract with the European Space Agency (ESA) since 2005 when accredited as one of the ESA's European Component Irradiation Facilities (ECIF).

RADEF consists of two separated beam lines, one for heavy ions and another for protons. An overview of the facility is illustrated in Fig. 12.1, where both beam lines are indicated.

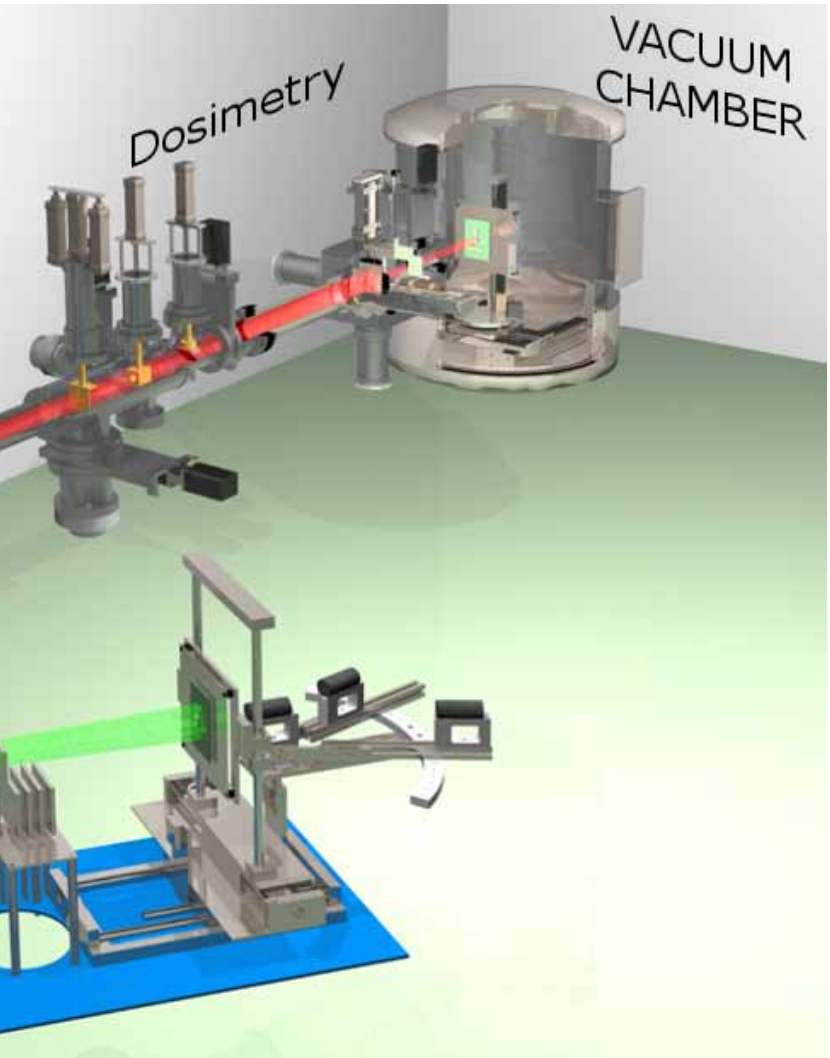
Figure 12.1: An illustration of the RADEF facility.



In the heavy-ion line the beam homogeneity is obtained by using a scattering foil upstream in the beam line and x–y wobblers. With this equipment beam homogeneity of better than the required ±10% can be achieved over an area of 4 x 4 cm2. The heavy-ion irradiations can be performed either in vacuum or in air. The proton beam is taken in air through a tungsten vacuum window

There are two different ion cocktails available in RADEF with energies of 3.6 MeV/u and 9.3 MeV/u. Recently the former is no longer routinely used, as the cocktail with higher energy (i.e. higher penetration) has been favored by the users performing Radiation Hardness Assurance (RHA) tests. Since its inauguration in 2005 RADEF has served 35 different users in more than 130 separate irradiation campaigns. During the last years an average of 28 campaigns a year has been performed.

RADEF became also part of EU FP7-Space-2010-1 program with a SkyFlash project. The aim is to develop stable and radiation-resistant flash memories for in-space applications. The consortium consists of two companies and six universities from Italy, Israel, Greece, Spain, Sweden and Finland



The customers are mainly from ESA and European space industry, but lately also researchers from NASA's Jet Propulsion Laboratory and Japan Aerospace Exploration Agency (JAXA) have been regular users. Thus, RADEF has become a leading heavy ion test facility with high penetration cocktail beams in Europe. Also, 12 peer reviewed articles have been published in the years 2010-11, including one with definitions of experimental LET values of heavy ions used in the ECIF facilities. □

Finnish National Committee of COSPAR

List of publications

H. Koskinen, S. Merikallio, P. Stigell (Editors):
Space Research in Finland, report to COSPAR 2010
106p., 2010. (PDF available at www.cospar.fi/reports)

H. Koskinen, S. Merikallio, P. Stigell (Editors):
Space Research in Finland, report to COSPAR 2008
90p., 2008. (PDF available at www.cospar.fi/reports)

H. Koskinen, S. Merikallio, P. Stigell (Editors):
Space Research in Finland, report to COSPAR 2006
75p., 2006. (PDF available at www.cospar.fi/reports)

H. Koskinen, P. Stigell, M. Takala (Editors):
Space Research in Finland, report to COSPAR 2004
80 p., 2004. (PDF available at www.cospar.fi/reports)

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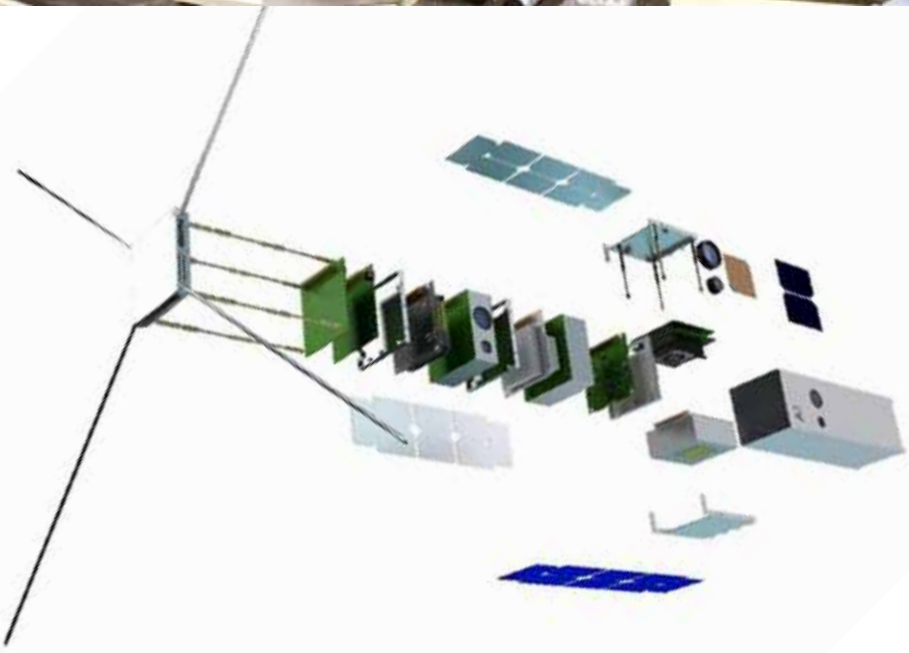

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ISSN 0788-7434

June 2012