



# Space Research in Finland

## Report to COSPAR 2014



*Finland 50 years in Cospar*

*Suomi 50 vuotta Cosparissa*

**COSPAR**  
Finnish National Committee

  
**Tekes**

  
ACADEMY  
OF FINLAND



COSPAR MOSCOW 2014

**COSMOS**

40<sup>th</sup> SCIENTIFIC ASSEMBLY  
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# Space Research in Finland

## Report to COSPAR 2014

Editors

Tuija Pulkkinen  
Sini Merikallio  
Pauli Stigell

**C O S P A R**  
Finnish National Committee



ACADEMY  
OF FINLAND

Helsinki 2014

**Front cover:**

Rosetta Lander Philae will land on the surface of a comet 67P/Churyumov–Gerasimenko. Several of Philae's instruments have Finnish involvement. picture by ESA.

**Back cover:**

Piece of Finnish space history: Pekka Riihelä, Finnish Meteorological Institute, is inspecting one of the first Aspera (Automatic Solar-system Particle Experiment with Rotating Analyser) instruments, Aspera-C destined for Mars-94 mission. Picture by Jouni Rynö.

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**Tekes, the Finnish Funding Agency for Technology and Innovation**

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

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

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

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# Foreword

This is the bi-annual report of Finnish Space Research to the Committee on Space Research (COSPAR) prepared by the Finnish National Committee of COSPAR and Finnish Funding Agency for Technology and Innovation (Tekes). The report describes the Finnish space activities, introduces the research organizations participating in space activities, and highlights a few of the scientific, applied, and technological developments during the 2012 - 2014 period.

In 2014, Finland celebrates its 50-year anniversary of membership in COSPAR. During 50 years, Finland has undergone major technological advancements including development of capabilities to build not only space-qualified instrumentation but also complete satellite systems. The final test will be seen next year, when Finland's first CubeSat Aalto-1 will be launched. We plan to continue these low-cost, student driven missions that serve as technology development platforms and learning experiences for graduate and undergraduate students in addition to bringing novel scientific results.

This report is available on the website of the Finnish national Committee of COSPAR:

**<http://www.cospar.fi/reports>**



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# 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 backbones of the Finnish space research are memberships in the European Space Agency (ESA) and the European Southern Observatory (ESO). In addition to opportunities offered by these organizations, Finnish space sector is widely networked with international space organizations, research institutes and universities as well as private industries and service providers. Increasingly, collaborative efforts under the auspices of the European Union and European organizations offer both research and industrial opportunities.

University-level space education comprises MSc and PhD programs in space research and technology offered at several universities including an international Erasmus Mundus Space Masters program. The doctoral education at universities of Helsinki, Oulu, Turku and Aalto University operates in a network that fosters student mobility and organization of joint summer schools and other educational activities.

The Finnish space committee operating under the ministry of Employment and the Economy coordinates the national space activities. The committee recently launched a national space strategy for 2013-2020, which outlines the key areas of interest: Earth observation (weather, climate, forest, environment, map-

ping), navigation (traffic, logistics, safety, mobile communications), science (space science, geosciences, environmental sciences), telecommunications (TV, telecommunications, devices), and instrument development (electronics, software, structures and sensors). The four areas of application all tie to the instrument development, which is a common element in all sectors of space activities.

The use of space-based methods increases the number of players in the Finnish space activities: Satellite techniques now encompass fields from forestry to mineral reservoir mapping and high-precision navigation applications. 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 in order to provide the new user groups a good understanding of the product they are using for further application development. In order to foster the backbone basic research, the Academy of Finland allocated two new Centers of Excellence in the fields of long-term solar variability and in laser scanning.

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)

radars 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. In recent years, also atmospheric researchers focusing at lower atmospheric processes have significantly increased their use of space-based assets.

## 1.2 Finnish Space Committee

The inter-ministerial Finnish Space Committee acts as 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 strategic plans for Finnish space activities; the latest was published in February 2013 covering years from 2013 to 2020.

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 in May 2013. The Committee meets 2 to 3 times per year, its Secretariat more frequently. Finnish Space Committee members are given in Table 1.1.

### Contact details of the Finnish Space Committee:

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E-mail: kimmo.kanto@tekes.fi

Table 1.1.

## **Members of the Finnish Space Committee (April 2014)**

|                     |   |
|---------------------|---|
| Petri Peltonen      | Director General, Ministry of Employment and the Economy, Chair   |
| Pekka Plathan       | Director-General, Ministry of Transport and Communications, ViceChair                                     |
| Timo Kantola        | Deputy Director General, Ministry for Foreign Affairs   |
| Tiina Peltola-Lampi | Director International Affairs, Ministry of the Interior  |
| Jukka Juusti        | Director General, Ministry of Defence   |
| Petteri Kauppinen   | Counsellor of Education, Ministry of Education and Culture  |
| Laura Höjer         | Research Director, Ministry of the Environment  |
| Raimo Vajavaara     | Director for Unit for Land Survey and Geographic Information Policy, Ministry of Agriculture and Forestry |
| Susan Linko         | Director, Academy of Finland  |
| Yrjö Viisanen       | Director, Finish Meteorological Institute   |
| Tilli Kari          | Director, Tekes   |
| Tuija Karanko       | Secretary General, Association of Finnish Defence and Aerospace Industries (AFDA)                         |
| Marjaana Aarnikka   | Commercial Counsellor, Ministry of Employment and the Economy   |

### **Committee expert member**

|                  |   |
|------------------|---|
| Pulkkinen, Tuija | Dean, Aalto University School of Electrical Engineering, Chair of the COSPAR national committee |
|------------------|---|

### **Committee's Secretariat:**

|                     |  |
|---------------------|--|
| Kanto Kimmo         | Tekes, Chair                             |
| Aarnikka Marjaana   | Ministry of Economy                      |
| Häme Tuomas         | VTT                                      |
| Järvelin Pertti     | Finnish Defence Forces                   |
| Kosonen Antti       | National Land Survey                     |
| Kuusniemi Heidi     | Finnish Geodetic Institute               |
| Lähti Harri         | Patria                                   |
| Pulkkinen Tuija     | Aalto university                         |
| Pulliainen Jouni    | Finnish Meteorological institute         |
| Laura Ruotsalainen  | Finnish Geodetic 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 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 tech-

nology 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 2013 Tekes had 24 national technology programmes. In 2013 Tekes total financing for national and international R&D-projects was 577 million euros. From this 19 million euros was provided for national and ESA space activities.

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Select interest area: Space

Finnish Space Portal:

<http://www.spaceinfo.fi>



### 1.3.2. Academy of Finland

The Academy of Finland provides funding for high-quality scientific research, acts as an expert in science policy and strengthens the position of science and research. The Academy is an agency within the administrative branch of the Finnish Ministry of Education, Science and Culture. The Academy's four research councils are served by an Administration Office and led by an independent board. The research councils are Biosciences and Environment, Culture and Society, Natural Sciences and Engineering, and Health.

The Academy works to contribute to the renewal, diversification and increasing internationalisation of Finnish research. The development initiatives focus on advancing professional researcher careers and promoting creative research environments. The Academy improves the excellence of Finnish basic research through competitive, long-term funding awarded based on peer-review evaluation and national science policy.

The Academy's research funding schemes include instruments such as Academy Projects, personal career grants from postdoctoral to professor-level positions, Centres of Excellence, targeted research programmes and research infrastructures.

The Academy's funding granted to space research and astronomy has been quite stable at around EUR 3 million annually. The 2013 level was higher (around EUR 4.5 million), because the Academy selected Professor Kalle Mursula's unit "Solar Long-Term Variability and Effects" for the 2014 – 2019 Centre of Excellence programme. Membership fees to international organisations (ESO, NOT and EISCAT) totalled some EUR 2.9 million in 2013.

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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.

## 1.4 International Collaboration

Finland has formal co-operation agreements with several space organizations listed below in Table 1.2 with the responsible Finnish body indicated.

Table 1.2: 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        |



In 2014, the COSPAR National committee was asked for recommendations for members in the European Academies Science Advisory Council. In accordance to the National Committee's suggestion, Ari-Matti Harri from the Finnish Meteorological Institute was chosen as a member of the EASAC.

Figure 1.2. Mission Lead Ari-Matti Harri (FMI) presents the prototype of the Mars MetNet Lander in FMI space laboratory. Photo: Antonin Halas, FMI

#### **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 aims to advance 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. The year 2014 marks our 50th anniversary of membership in COSPAR. In addition to bi-annual reports provided to the Council at the General Assemblies, the Committee organizes national FinCOSPAR Meetings roughly bi-annually, the latest one was held in August 2013 in Vantaa.

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

The present National Committee members are given in Table 1.4.1.

Figure 1.3. Finnish National Committee of COSPAR meeting January, 2014, at the Finnish Meteorological Institute. From left: Juhani Huovelin, Markku Poutanen, Merja Tornikoski, Martti Hallikainen, Juri Poutanen, Hannu Koskinen, Tuija Pulkkinen, Erkki Tomppo and Sini Merikallio

27.1.2014



Table 1.4.1. Finnish National Committee of COSPAR members:

|                |                    |                                   |
|----------------|--------------------|-----------------------------------|
| <b>Chair</b>   | Tuija Pulkkinen    | Aalto University                  |
| <b>Members</b> | Martti Hallikainen | Aalto University                  |
|                | Juhani Huovelin    | University of Helsinki            |
|                | Hannu Koskinen     | University of Helsinki            |
|                | 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, Vice Chair    |
|                | Markku Poutanen    | Finnish Geodetic Institute        |
|                | Jouni Pulliainen   | Finnish Meteorological Institute  |
|                | Erkki Tomppo       | Finnish Forest Research Institute |
|                | Merja Tornikoski   | Aalto University                  |
|                | Esko Valtaoja      | University of Turku               |
|                | Martin Vermeer     | Aalto University                  |

Figure 1.4. Finnish National Committee of COSPAR meeting February, 2013, at the Finnish Meteorological Institute. From left: Erkki Tomppo, Jari Kotilainen, Sini Merikallio, Esko Valtaoja, Martin Vermeer, Hannu Koskinen, Merja Tornikoski, Petri Pellikka, Markku Poutanen, Tuija Pulkkinen and Minna Palmroth.

**4.2.2013**



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## 2. Finnish National Strategy for Space Activities

The Space Committee defines the national space strategy for Finland. The present strategy document covers the period 2013-2020.

**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.”*



Figure 2.1, Auroras, VisitFinland.com

## 2.2. Strategic Elements

Finnish space activities fall in the areas of space research, Earth observation, navigation, telecommunication, and instrument development.

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 programs forms the backbone of the Finnish space activities. Opportunities offered by Finland's membership in the European Meteorological Satellite Organisation (EUMETSAT) and European Union whose space activities are rapidly increasing guide the strategic choices also in the national arena. 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.

Space science is in a research-intensive phase, as ESA missions such as Cluster, SOHO, MarsExpress, and Venus Express continue to bring results on the processes by which solar activity influences the space environment of the Earth, Mars and Venus, Planck has completed its full sky surveys, and the community is actively preparing for upcoming astrometric measurements from Gaia and cometary data from Rosetta. In Earth observation, a major milestone was reached when Envisat completed its decade of observations and the full and rich dataset now is exploited in conjunction with other still ongoing missions such as NASA's EOS program satellites.

The space strategy emphasizes opportunities for new businesses in the space sector. For example, navigation, communications and remote sensing service industry are all heavy users for space technology. Several small enterprises are already operative in the field of navigation, new opportunities are offered by the new navigation systems from Europe (Galileo), Russia (Glonass) and China (Compass). The use of Earth observation data utilization in commercial products is both increasing and transferring from research institutes to commercial activities. Strong research institutes in the field support the growth of the private sector.

Applications based on remote sensing, satellite communications and navigation aim for global business. However, they are equally important in securing the safety of the people (e.g., marine safety, forest fires, landslides, etc.) , operations of the society (seafaring in icy conditions, hydropower generation), or economical activity and environmental protection (mining activities, global change). Participation in European Galileo and Copernicus programmes and GEO (Group on Earth Observation) is a vital element to gain access to the vast body of observations needed for these services to be useful. Space assets are also important in guarding the safety and security of the society including monitoring of environmental changes as well as managing rescue missions or logistic services.

In order to reach these strategic aims, we have identified several key areas that Finland will focus on in the next year to come:

- Development of space-based applications for Arctic regions;
- Opening positioning data to foster growth of applications industry;
- Active participation in ESA and EU space research programmes to increase the impact of basic research;
- Increasing the volume of the space industry by specialization.



## 3. Space Programmes 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.

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

| <b>Programme</b>   | <b>Finnish participation</b>   | <b>Schedule</b>                    |
|--|--|------------------------------------|
| 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                      |
| Galileo IOV  | electronics for two navigation satellites  | Launched 2012                      |
| GAIA, ESA Galaxy mapping mission   | Electronics and software   | Launched 2013                      |
| LISA Pathfinder, ESA test mission for gravity wave observations              | Solar array structures   | Launch 2015                        |
| BepiColombo, ESA/JAXA mission to Mercury                                     | PI of SIXS , participation in MIXS (X-ray instruments), participation in SERENA particle instrument. | Launch 2017                        |
| Solar Orbiter  | Power control electronics  | Launch 2018                        |
| Euclid   | ESA dark energy mission data analysis (ground) system  | Launch 2020                        |

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

| <b>Programme</b>  | <b>Finnish participation</b>  | <b>Schedule</b>           |
|---|---|---------------------------|
| 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<br>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             |
| SWARM, ESA Earth magnetic field measurement mission                     | Power distribution unit   | Launched 2013             |
| Sentinel 1 (ESA and EU)   | SAR-radar   | Launched 2014             |
| Sentinel 3 (ESA and EU)   | solar array structures  | Launch 2015               |
| Sentinel 2 (ESA and EU)   | electronics   | Launch 2015               |
| ADM-Aeolus,<br>ESA Atmospheric Dynamics Mission                         | Instrument electronics  | Launch 2015               |

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 -   |
| ARTES 14  | NEOSAT geostationary orbit telecommunications satellite development programme    | 2012 -   |

### 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

These 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 à-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 telecommunication 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 started in year 2012. ARTES 5 has demonstrated its usefulness e.g. in the field of composite structures.



Figure 3.2. Mart Noorma and Urmas Kvell presenting an engineering model of the Estonians first satellite, Estcube-1, that was launched in 2013 with a Finnish payload that is going to perform the first space measurements of the electric solar wind sail effect. photo: Riina Varol, University of Tartu.

### **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 System on Earth. Oulu university has studied C-band signal satellite-to-indoor propagation, Finnish Geodetic Institute 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 Programme (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) had a dedicated Special Programme for Space. It funded 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 44 projects for proposals in space theme, leading 9 projects. Finland is participating in all large GMES projects such as MACC (atmosphere), MyOcean and Geoland that will become Copernicus core services during 2014-2020..

Its follow-on, Horizon 2020 programme started on 11 December 2013. First two space calls take place in year 2014.

## 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. DREAMS-H, a humidity device for ExoMars 2016, is assembled in the Finnish Meteorological Institute. Corresponding instrument is currently operating on Mars on board of the Mars Science Laboratory. photo: Markku Mäkelä, Finnish Meteorological Institute



Table 3.4. The main Finnish operative bilateral space programmes.

| <b>Programme</b>   | <b>Main Partners</b> | <b>Finnish participation</b>  | <b>Schedule</b>                          |
|--|----------------------|---|--|
| 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 atmospheric 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-instrument  | Launched 2008                            |
| Mars Science Laboratory                                    | USA, E               | Pressure and humidity instruments                                       | Launched 2011                            |
| Mars MetNet Precursor Mission                              | RUS, E               | Novel landing station(s) to carried onboard Phobos Grunt                | Launch 2015                              |
| BepiColombo MMO, JAXA part of the ESA/JAXA Mercury mission | Japan                | Participation to MEFISTO-instrument                                     | Launch 2015                              |



REMOVE BEFORE LAUNCH

## 4. Aalto University

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Space research at Aalto University spans the School of Electrical Engineering (Aalto-ELEC), School of Science (Aalto-SCI) and School of Engineering (Aalto-ENG). Activities at ELEC cover radio astronomy, plasma physics of planetary space environments (including the Earth), Earth observation by remote sensing methods and small satellite technologies. Aalto-ENG covers fields related to GPS techniques, photogrammetry and remote sensing. Aalto-SCI activities focus on numerical modelling of solar and stellar dynamo processes, and the development of related numerical methods and data analysis tools.

In the past two years, three new professors have been recruited and two new Academy of Finland -funded Centers of Excellence started operation. New recruitments are still ongoing to replace retirements in areas of remote sensing. Strong renewal of faculty has both strengthened earlier research areas and expanded activities to cover new fields. Aalto's MSc and PhD majors offer a full curriculum in space science and technology, and as such are unique in Finland.

Aalto space activities are well networked both nationally and internationally. Nationally the most important partners are on one hand the Kumpula Space Centre (KSC) comprising Aalto, the University of Helsinki and the Finnish Meteorological Institute, and on the other hand the Finnish Centre for Astronomy with ESO (FINCA) including the University of Turku (host institution), Aalto, and Universities of Helsinki and Oulu. Internationally, the European Space Agency ESA and the European Southern Observatory ESO offer key facilities and collaboration opportunities.

The Metsähovi Radio Observatory hosts a 14-m telescope for radio astronomical measurements. While recent activities have focused on coordinated observations and scientific utilization of ESA's Planck mission, the telescope operates continuously to provide long time series of quasar variability, participates in several networks making VLBI measurements, and makes dedicated geodetic VLBI measurements.

Space science has enhanced significantly as two new professors focus on planetary and terrestrial space environment research. Moreover, a new Center of Excellence on solar long-term variability and effects started under the lead of the University of Oulu with Aalto as a partner focusing on modeling the solar dynamo processes.

The nanosatellite technologies are developed in two CubeSat missions Aalto-1 and Aalto-2, of which the first is scheduled for launch in early 2015. While the first spinoff aiming for commercial services in the Arctic region is already active, the aim is to continue the student satellite program in a continuous manner to train multi-disciplinary engineers capable of designing, building, testing and operating spacecraft and its instrumentation. The satellite projects are conducted in wide national collaboration.

Remote sensing research focuses on methods and microwave sensors for space-borne monitoring of Earth surface, focusing especially in phenomena typical of the northern boreal forest and sea ice. The Skyvan research aircraft is used for high-accuracy measurements as well as sensor testing and satellite data validation.

The photogrammetry and remote sensing activities focus on dynamic phenomena of the environment through space borne, aerial, and terrestrial sensing systems. Methodology development includes electromagnetic imaging systems, especially their radiometric and geometric calibration. These multisensory imaging methods are applied to dynamic environmental modeling and geographic visualization of local and global physical phenomena. Research is organized in collaboration with the Finnish Geodetic Institute. Aalto is also part of the Academy of Finland Center of Excellence in Laser Scanning Research led by the Finnish Geodetic Institute.

### **Metsähovi part of record-breaking real-time data correlation experiment**

Pan-European 4Gbps EC FP7 NEXPreS e-VLBI demonstration on September 18, 2013: For the first time, scientific Very Long Baseline Interferometry (VLBI) data recorded at a data transfer rate of 4 Gbps by five participating European stations was successfully correlated in real-time. The WP8 FlexBuff team was lead by Metsähovi. The module can sustain multiple high-rate read and write streams of network data. It offers high-bandwidth, high-capacity networked storage on demand, to match future multi-Gbps bandwidth and petabyte-class capacity requirements of VLBI. Despite its name, it is fully applicable in any data acquisition where UDP data packets are being streamed over a high-speed Ethernet connection.

### **New results on microquasar jet generation**

A new X-ray/radio state has been identified for the microquasar Cygnus X-3: the hypersoft state. This state is softer in the X-ray spectra than previously classified states and exhibits very weak or nonexistent radio emission. The hypersoft state is found to be connected to the jet ejection episodes and to gamma-ray emission detected from Cygnus X-3. The fact that the sequence of events giving birth to a jet differs from other microquasars could be attributed to the strong stellar wind component and/or our line-of-sight almost coinciding with the jet axis. Principal Components Analysis showed that there are two main variability components in play during outbursts in Cygnus X-3. In addition, a double soft-seed population Comptonization scenario is proposed that might occur in other microquasars as well, where so far mostly single soft-seed photon Comptonization models have been used.

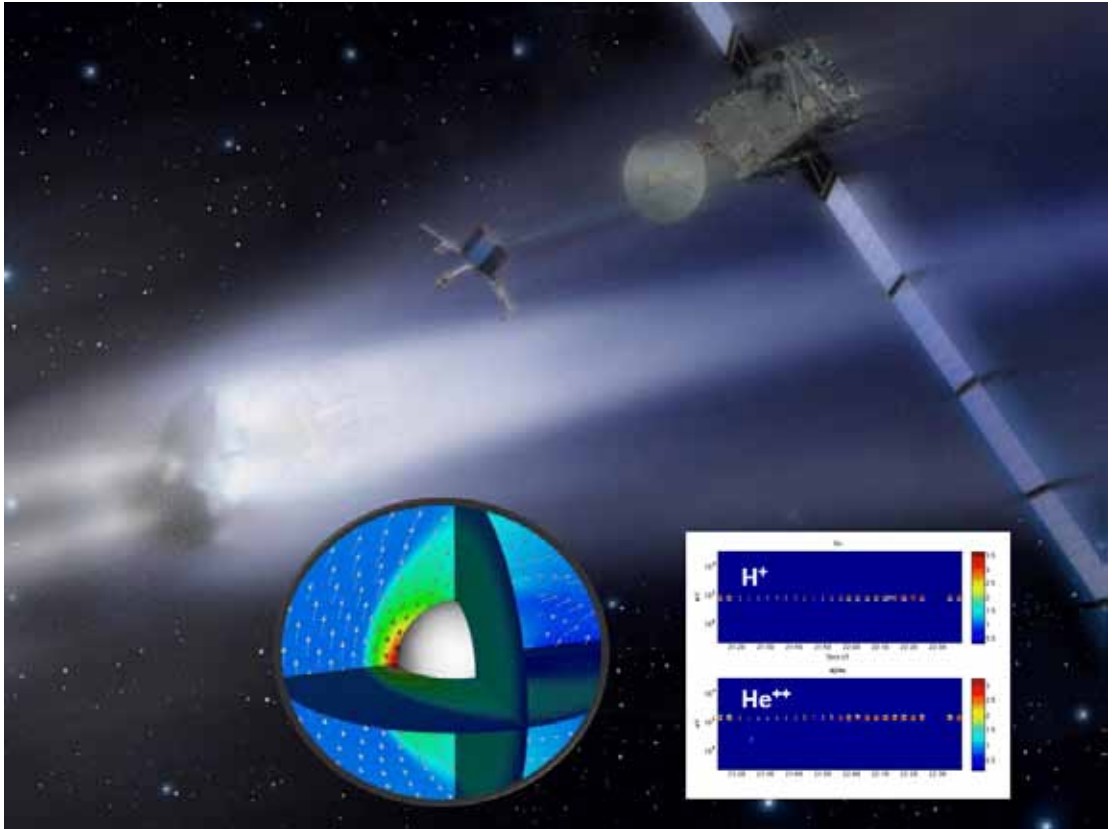


Figure 4.2, A new space weather model (circular insert) enables to study space weather effects at various places in the Solar System. The next target for the model is the same as that for ESA's Rosetta mission, namely comet 67 P/Churyumov-Gerasimenko (background figure: ESA; insert at the bottom right corner: Rosetta/ICA test data at April, 2014, courtesy Hans Nilsson/IRF).

### Getting ready for ROSETTA: development of a versatile modeling tool

A new global space weather simulation developed at Aalto allows following individual particles of solar origin, and thereby detailed studies of their properties and effects. The most energetic particles can cause malfunctions to technical devices and create health hazards for humans in space. The novelty of the model is in its capability to study the detailed space weather processes with a relative modest computational cost.

The model development is part of Aalto's contribution to ESA Rosetta cornerstone mission.

The next modelling and observational target is comet 67P/Churyumov-Gerasimenko, which will be characterised in-situ by Rosetta orbiter and lander in 2014 – 2015. The modelling work will be dedicated to interpret and study charged particle data from the Ion Composition Analyser (ICA) and dust particle observations made by the Cometary Secondary Ion Mass Analyser (COSIMA) onboard the Rosetta orbiter.

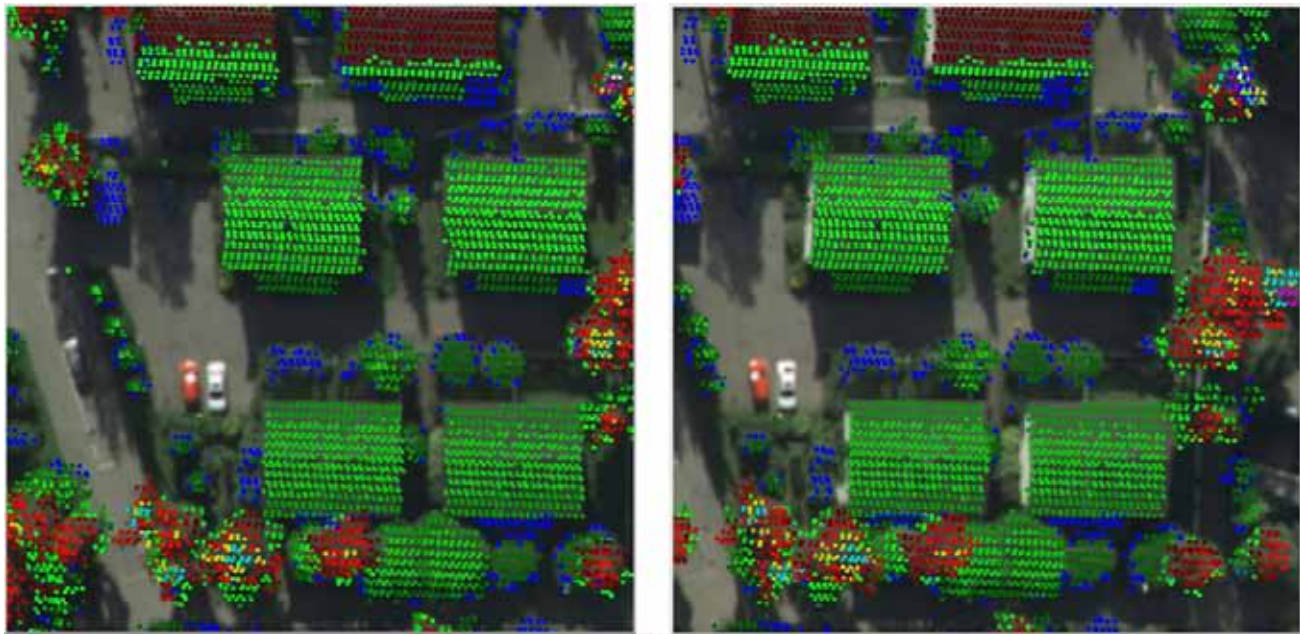


Figure 4.3. Geometric and radiometric sensor calibration is essential for exact integration of multiple geographic data sets. In photogrammetry, automatic algorithms are developed for exact three-dimensional registration of laser scanner point clouds and radiometric images. The tie-features in this crossed-eye stereo view comprise trees and building structures. pics: Petri Rönholm

### **Coordinated aircraft and satellite measurements for resolving surface properties**

Aalto University activities in ESA's Soil Moisture and Ocean Salinity (SMOS) mission have focused on theoretical properties of interferometric imaging and enhancements in the calibration algorithms, theoretical analysis of error propagation in SMOS calibration, and on the effects of radio frequency interference (RFI) on SMOS measurements.

Aalto University operates a highly modified Short SC.7 twin engine turbo-propeller research aircraft. In SMOS calibration and validation activities the main payload is HUT2D, a synthetic aperture 1.4 GHz radiometer designed and built at Aalto. In 2013 the Skyvan was used in two flight campaigns for development of emission models for boreal forests, calibration of

SMOS brightness temperature measurements and validation of the SMOS soil moisture retrieval algorithm. HUTRAD is a multi-frequency microwave radiometer system operating at 6.7 - 96 GHz frequencies and is used for detecting emissions from snow, ice, soil and vegetation. The Skyvan has been operated for aerosol research with the Finnish Meteorological Institute as well as in research of Global Satellite Navigation System and Reflectometry (GNSS-R) mostly concerning ocean salinity measurements. Currently the aircraft is undergoing further modifications for new GNSS-R measurements over the Gulf of Finland in 2014.

## Students to space: Aalto-1 and Aalto-2 cubesat projects

The Aalto-1 project is a university satellite mission carried out by a consortium of Finnish universities, RD institutions and space industry. The satellite project serves as an education platform for students, providing them with hands-on education and close linkages to international space technology and space research. The main highlights of the development process are an open-source do-it-yourself approach, education-oriented methods, a web-based design environment and a system engineering documentation of the entire design process.

The primary payload of the nanosatellite is an imaging spectrometer AaSI, built by VTT Technical Research Centre of Finland. As secondary payloads the satellite hosts a radia-

tion monitor (RADMON) provided by Universities of Helsinki and Turku and a novel deorbiting plasma brake experiment designed by the Finnish Meteorological Institute. The scientific goals encompass Earth observation and technology demonstration. All the payloads passed Critical Design Review at the end of 2013 and entered to manufacturing and integration phase with launch scheduled in early 2015.

The Aalto-2 satellite is being built for the international QB50 lower thermosphere multisatellite mission. Aalto-2 hosts the Multi Needle Langmuir Probe payload provided by QB50 consortium. Aalto designs and builds the satellite platform and ground segment for the mission. The project is currently in detailed design phase, after successful Critical Design Review in 2013.

Figure 4.4. Students working on Aalto-1 satellite.





## 5. Finnish Geodetic Institute

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The Finnish Geodetic Institute (FGI) carries out research and development for spatial data infrastructures.

The FGI :

- 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,
- co-operates with industry, universities and governmental organisations nationally and internationally.

The Finnish Geodetic Institute was established in 1918. It has five departments: 1) Geodesy and Geodynamics, 2) Geoinformatics and Cartography, 3) Remote Sensing and Photogrammetry, 4) Navigation and Positioning, and 5) Administration Services. The Finnish Geodetic Institute has personnel of 90 people.

The key research areas of FGI are

### 1. Reference systems

FGI maintains, develops and makes research in national reference systems, their connection to international networks and geospatial metrology.

### 2. Mobile Mapping

Areas of interest to FGI include ubiquitous positioning, mobile mapping, context awareness, GNSS technologies, smart mobile geospatial solutions, cloud computing for mobile geomatics and mobile GIS.

### 3. Spatial Data Infrastructures

Areas of interest to FGI include visualization and usability of spatial data, network-based processing services, ontology, data harmonization and standardization.

### 4. Changing Earth

Processes of interest to FGI includes updating of maps in all conditions, 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.

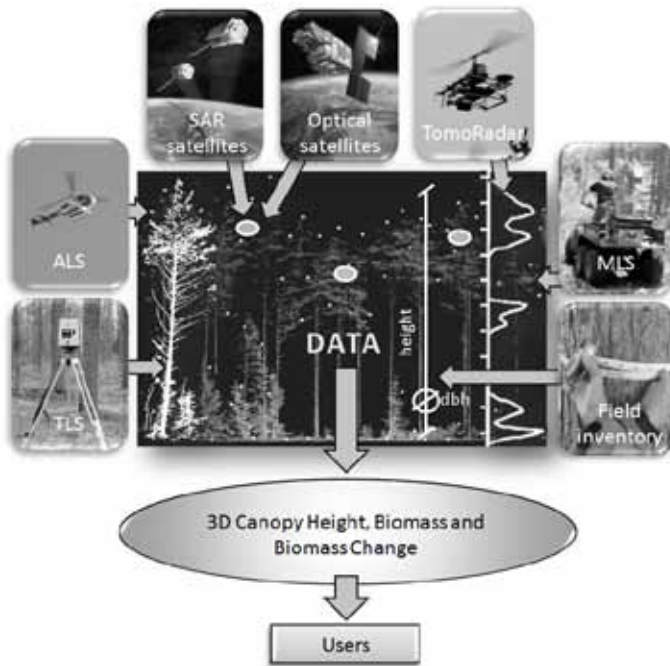


Figure 5.2. An example of current research from EC-funded Advanced\_SAR project. Radargrammetry, interferometry and images-based point clouds (from overlapping imaging and automatic stereophotogrammetry) are used to get 3D canopy information from space. Airborne Laser Scanning (ALS) is giving Digital Terrain Model (DTM), biomass, biomass change as well as canopy height (and height change) references for space-borne estimates. TomoRadar gives additional knowledge of microwave signal penetration into canopy used for modelling. Mobile Laser Scanning (background canopy profile is from MLS) is a totally new concept for cost-effective field inventory. Terrestrial Laser Scanning (TLS) gives 3D stem models. Conventional Field inventory is ground reference. Together, we can benchmark all 3D remote sensing techniques from forestry point of view.

## Renewal of Metsähovi Fundamental Geodetic Station

Metsähovi is the fundamental station for the national reference, height and gravity systems, and a part of global network of geodetic stations, being one of the northernmost station in the network. It is one of the few geodetic stations in the world having all major space geodetic observing techniques at the same site. It contributes several global services of the International Association of Geodesy (IAG). During years 2012-2013 the renewal of Metsähovi instrumentation was initiated. The goal is to upgrade all major instruments, including a new Satellite Laser Ranging (SLR) system, GNSS receivers, French DORIS beacon, a new radio telescope for geodetic VLBI observations, and several gravity instruments. The total budget is about 8 M€ and it is funded by the Ministry of Agriculture and Forestry. During first two years the absolute gravimeter and the superconducting gravimeter were updated. Also the DORIS station was renewed by CNES. A new SLR telescope was ordered, and preparations for the VLBI telescope were started. A new instrument, a reflector for the

German TerraSAR-X satellite was also installed in Metsähovi. The renewal work will be finished by 2017.

## Renewal of the permanent GNSS network and the positioning service

FinnRef is the basis for the national EUREF-FIN reference frame and connects it to the European and Global frames. It has been used for crustal deformation studies and for various positioning purposes. In 2012-2013 the FinnRef network was renewed with funding allocated by the Ministry of Agriculture and Forestry. 19 GNSS stations were built, most in the vicinity of old stations. The receivers track all visible GNSS satellites and transmit the data in real time to the processing center of the FGI where the data are analyzed and errors related to positioning are estimated. Reference station data, corrections and the positioning service are offered free of charge. Corrections are delivered via Internet and post-processing data through a www-service. The first stage of the positioning service, offering the 0.5 position-

ing accuracy, was launched in the beginning of 2014. There are a lot of anticipated users of the new free positioning service, ranging from traditional surveying and positioning to intelligent traffic and farming applications.

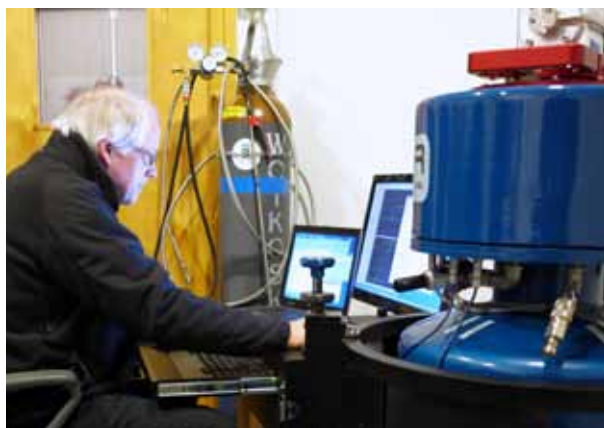
### Seeing all the Signals in the Sky by FGI's ground-breaking multi-GNSS receiver

In order to take advantage of the expanding availability of GNSS signals, researchers at the Finnish Geodetic Institute have been developing a first-of-its-kind, software-defined multi-GNSS receiver, known as the FGI GNSS Software Receiver or FGI-GSRx. In FGI-GSRx, measurements (i.e. pseudoranges) from different satellite constellations are combined, in order to achieve a more accurate multi-GNSS navigation solution. Not only does this approach lead to more accurate navigation solutions, it also provides greater reliability. In some cases it may not be possible to successfully acquire and track signals from the minimum number of satellites of a given constellation. This may be due to blockage of the signals from buildings, unintentional interference, or even signal jamming. When measurements from multiple constellations are combined in the manner described above, the chances of successfully acquiring and tracking at least four satellites in all circumstances are significantly improved.

### Center of Excellence in Laser Scanning

The Academy of Finland has selected the research consortium led by Professor Juha Hyypä as the Centre of Excellence in Laser Scanning Research for the period of 2014-2019. Laser scanning applications are essential for instance in forestry inventory and 3D modeling of built environment. In the future, the target is that laser scanning is omnipresent and affecting the life of every citizen. Currently laser scanning is utilized in i.e. driverless cars. Furthermore, the precise information provided by laser scanning applications is needed in forestry, where the new knowledge is used in optimizing the use of forest resources and planning of forest management. Both forest owners and companies in the field are expected to benefit from the advances in laser scanning. The Centre of Excellence in Laser Scanning Research will strongly contribute to this development and its task will be to provide next generation 3D- and 4D- (with time as a fourth dimension) knowledge on forest and built environment. The Centre of Excellence puts an effort to developing next generation 3D-maps. The consortium will cover the full complementary technology chain of Laser Scanning: hardware electronics, system integration, positioning technologies, information extraction and data processing, as well as applications and visualization, also in the 3D game engine of smartphones.

Figure 5.3. left: Petri Aarni and Hannu Koivula are inspecting the new FinnRef server of the FGI. The correction models for the free 0.5 m positioning service is computed in the FGI analysis center. right: Dr. Richard Warburton of GWR installs the new superconducting gravimeter in Metsähovi. It is currently the most sensitive gravimeter in the world to observe local and global changes in gravity, and thus an important addition to the observations of gravity satellites. photos: Markku Poutanen





## 6. Finnish Forest Research Institute (METLA)

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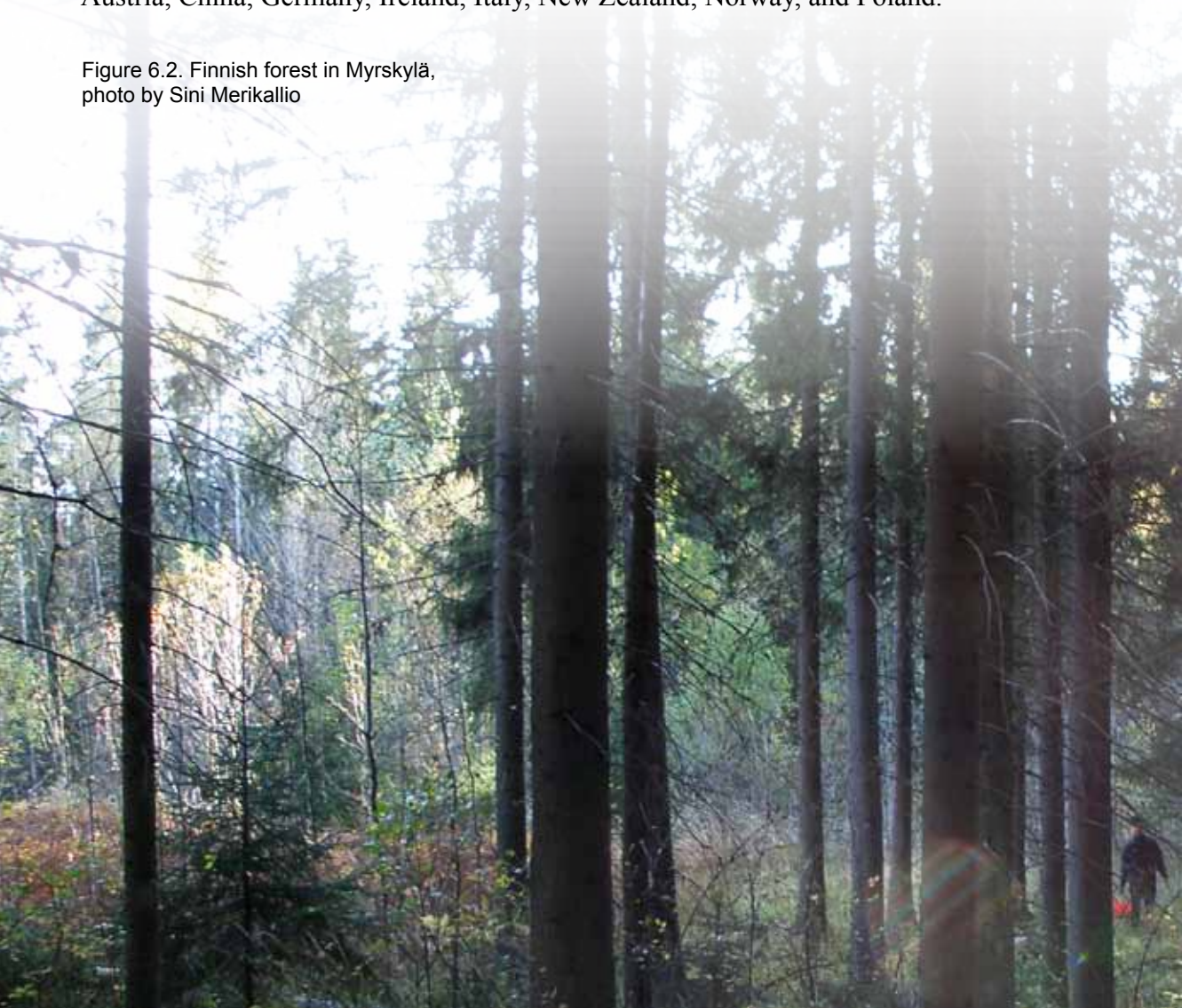
**[www.metla.fi/ohjelma/vmi/vmi-moni-en.htm](http://www.metla.fi/ohjelma/vmi/vmi-moni-en.htm)**

The Finnish Forest Research Institute, Metla, is an impartial state research organization founded in 1917. The National Forest Inventory (NFI) is one example of official duties of Metla. NFI has produced large-area forest resource information for about 90 years. Since late 1980's, the NFI has utilised the multi-source forest inventory method that combines information from field measurements with satellite images and other numeric data sources (multi-source national forest inventory, MS-NFI). It is the first satellite image aided nation-wide inventory based on statistical framework. An important feature of the method is that it produces forest resource statistics for smaller areas than what is possible using sparse field plot data only, like for municipalities, in addition to thematic maps about forest resources. The new nation-wide products are made currently every second year which frequency is high enough for the most purposes. MS-NFI products are employed as input information in forest management planning by forestry authorities and for timber procurement planning by forest industries. Furthermore, the results have been used in ecological studies, e.g., in analysing the quality of the habitats of key-stone species, for assessing the habitat and landscape values for nature conservation planning, and for other research purposes, and also in planning sampling designs both in Finland and outside Finland.

The MS-NFI method is under continuous development as a goal to decrease the estimation errors at different spatial levels. New features have been introduced regularly. Recently, optional methods have been presented for analytical error estimation for the k-NN method. Updating of NFI field plot data based on multi-temporal satellite images and growth model has been developed and used for making the up-dated estimates. The most recent developments include feature selection, a semi-automated production line, as well as new estimation parameters. The team has employed low point density airborne laser scanner data for developing methods for forest management inventories. Methods to use that data in MS-NFI, or optionally high point density data, are under development. The team works intensively for methods making it possible to merge the field measurements of the NFI and management inventories using low point density laser scanner data. It presumes both the development of sampling methods and estimation methods with laser data.

The MS-NFI team is firmly established in the field of forest remote sensing. The MS-NFI method has been successfully tested or employed also outside of Finland. Its variation is in use Sweden and USA. Examples of other countries with collaborative work are Austria, China, Germany, Ireland, Italy, New Zealand, Norway, and Poland.

Figure 6.2. Finnish forest in Myrskylä,  
photo by Sini Merikallio



## **Contributions on the forest resource assessment and monitoring in Africa, Asia and Latin America**

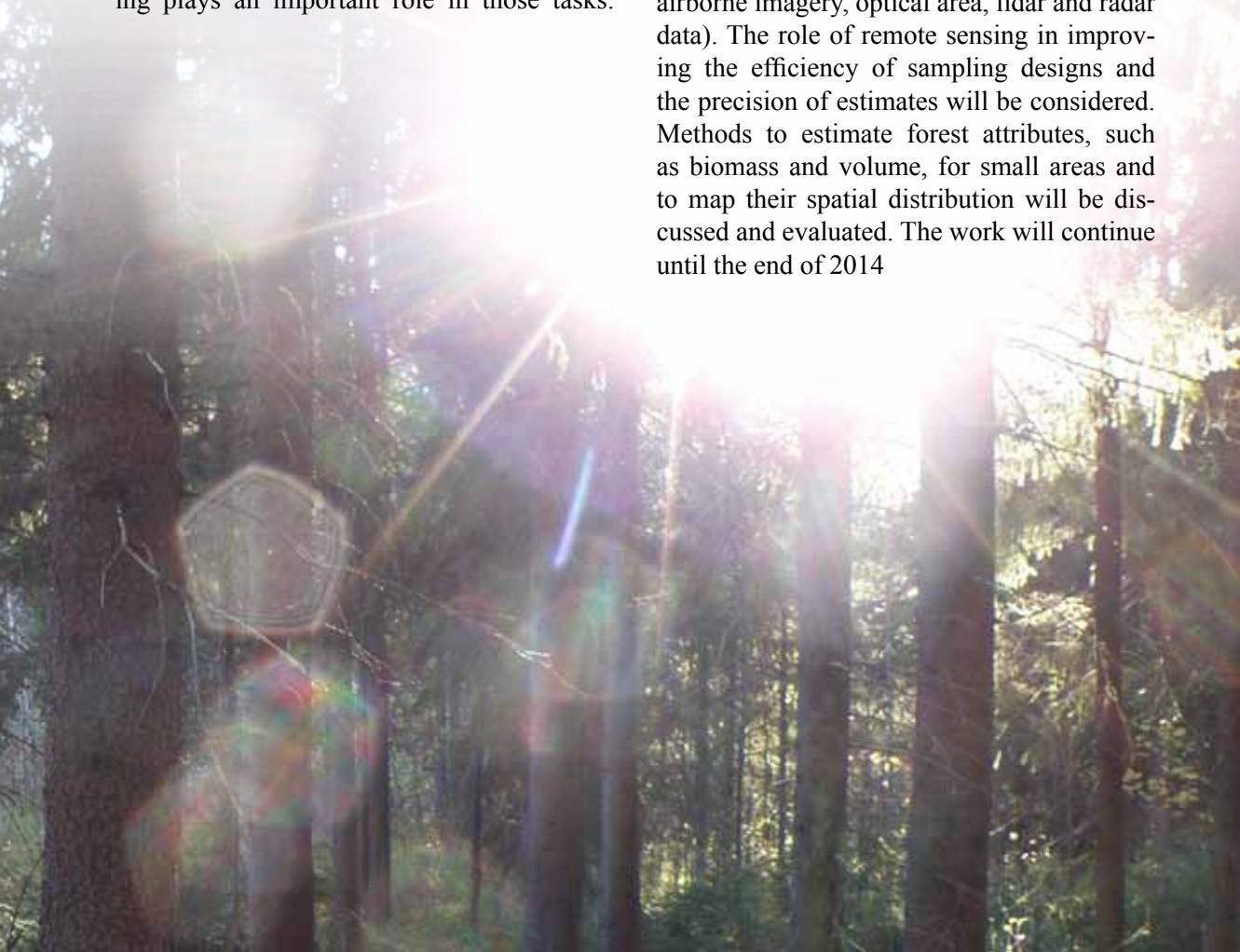
The MS-NFI team has worked with and assisted United Nations Forest Monitoring and Assessment Programme of Food and Agricultural Organization (FAO) for developing methods to create forest inventory sampling designs. A sampling design was tailored for Tanzania forest inventory late 2009 and early 2010. The input data are several country wide GIS data layers and forest variable predictions based on remote sensing data. The estimation methods are under development

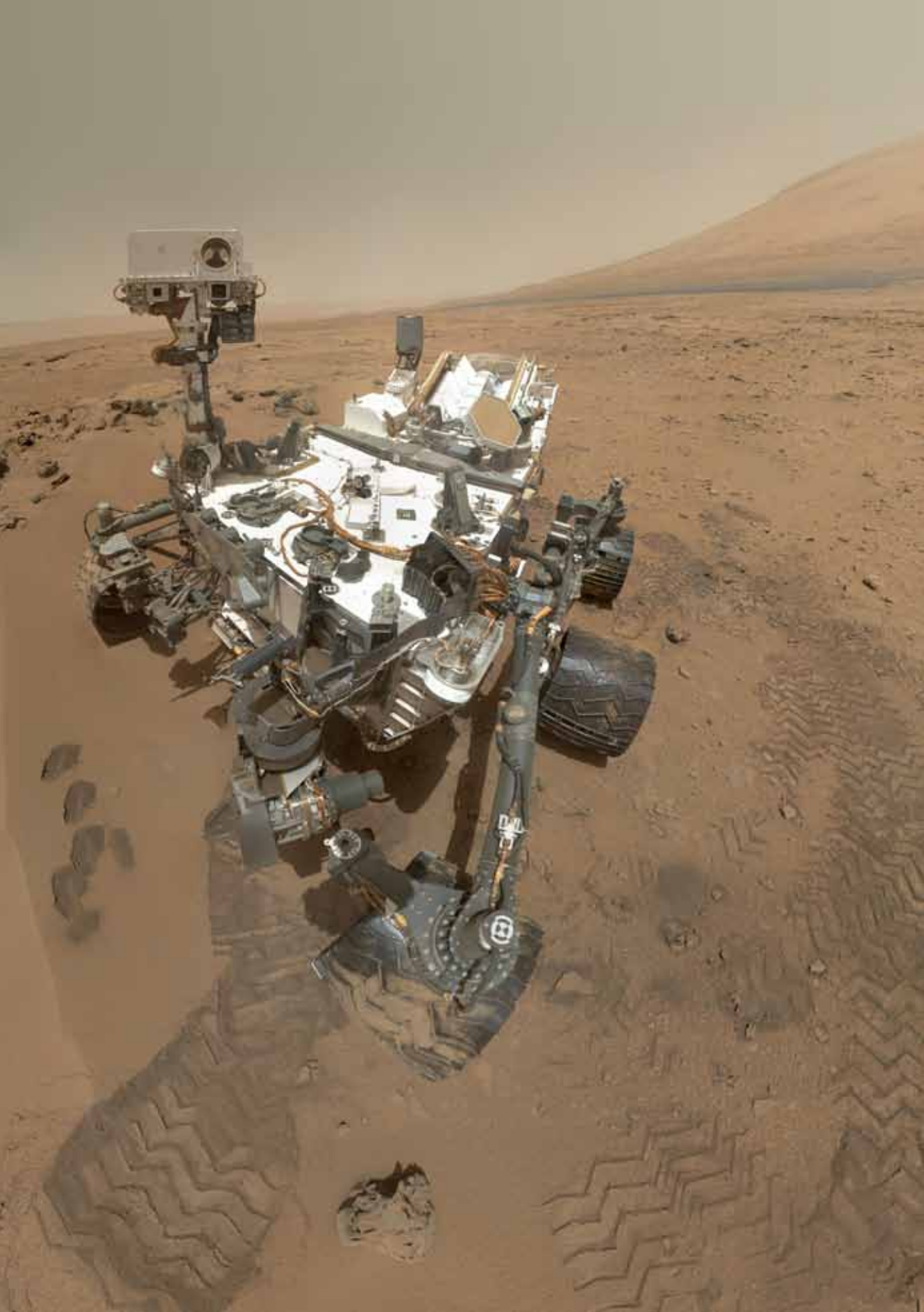
The members of the MS-NFI team have assisted, are currently assisting and will assist in the coming years also other countries in establishing forest inventories. Current examples are Zambia and Vietnam. Remote sensing plays an important role in those tasks.

## **Improving Data and Information on the Potential Supply of Wood Resources -A European Approach from Multisource National Forest Inventories**

The MS-NFI team leads the WG2 (remote sensing group) - Improving estimates of wood resources combining RS and NFI field data.

The Working Group investigates methods for improving estimates of wood resources by integrating remotely sensed and NFI field data. The overall aim is to develop scientifically sound practices for assessing tree biomass and other forest resources, inside and outside forests, in support of periodic and rapid updates of estimates at NUTS3 and regional levels in Europe, as well as in selected countries outside Europe. WG2 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 to map their spatial distribution will be discussed and evaluated. The work will continue until the end of 2014





## 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. On-board of the Mars Science Laboratory, currently roaming the surface of Mars, are two instruments assembled by FMI: REMS-H and REMS-P, which are measuring atmospheric humidity and pressure, respectively. These instruments are part of the Rover Environmental Monitoring Station (REMS). picture: NASA/JPL

## Ozone trends from SAGE II and GOMOS occultation measurements

We have studied data from two satellite occultation instruments in order to generate a high vertical resolution homogeneous ozone time series of 26 years. The Stratospheric Aerosol and Gas Experiment (SAGE) II solar occultation instrument from 1984 – 2005 and the Global Ozone Monitoring by Occultation of Stars instrument (GOMOS) from 2002 – 2012 measured ozone profiles in the stratosphere and mesosphere. Global coverage, good vertical resolution, and the self-calibrating measurement method make data from these instruments valuable for the detection of changes in vertical distribution of ozone over time. As both instruments share a common measurement period from 2002 – 2005, it is possible to inter-calibrate the data sets. We investigate how well these measurements agree with each other and combine all the data to produce a new stratospheric ozone profile data set. Above 55 km, SAGE II measurements show much less ozone than the GOMOS nighttime measurements as a consequence of the well-known diurnal variation of ozone in the mesosphere. Between 35 – 55 km, SAGE II sunrise and sunset measurements differ from each other. Sunrise measurements show 2% less ozone than GOMOS whereas sunset measurements show 4% more ozone than GOMOS. Differences can be explained qualitatively by the diurnal variation of ozone in the stratosphere recently observed by SMILES and modeled by chemical transport models. Between 25 – 35 km, SAGE II sunrise and sunset and GOMOS agree within 1%.

The observed ozone bias between collocated measurements of SAGE II sunrise/sunset and GOMOS night measurements is used to align the two data sets. The combined data set covers the time period 1984 – 2011, latitudes 60S – 60N, and the altitude range of 20 – 60 km. Profile data are given on a 1 km vertical grid, and with a resolution of one month in

time and ten degrees in latitude. The combined ozone data set is analyzed by fitting a time series model to the data. We assume a linear trend with an inflection point (so-called “hockey stick” form). The best estimate for the point of inflection was found to be the year 1997 for ozone between altitudes 35 and 45 km. At all latitudes and altitudes from 35 km to 50 km we find a clear change in ozone trend before and after the inflection time. From 38 km to 45 km a negative trend of 4 % per decade (statistically significant at 95% level) at the equator has changed to a small positive trend of 0 – 2% per decade. At mid-latitudes the negative trend of 4 – 10% per decade has changed to a small positive trend of 0 – 2% per decade. In the tropics between 30 and 35 km ozone has started to decrease after a small increase in the period of 1984 – 1997. At mid-latitudes near 20 km the ozone loss has still increased.

## FMI develops detection of soil freeze/thaw state from ESA’s Earth Explorer SMOS

The state of soil freezing in the Northern hemisphere affects in particular the transfer of atmospheric gases between the soil and the atmosphere as well as affects the total energy distribution of the Earth. In northern latitudes, the onset of soil freezing marks the point when the transpiration of gases is significantly reduced. Furthermore, the thermal state of the soil controls the mass and rate of water infiltration and, by extension, the partitioning between surface and sub-surface runoff. It is therefore essential to have accurate information on the thermal state of the soil for hydrological and climatological forecasts.

In recent studies funded by the European Space Agency, FMI has been developing novel tools for monitoring of soil freeze/thaw processes from space. Launch of ESA’s SMOS Earth Explorer mission in 2009 has for the first time provided access to continuous,

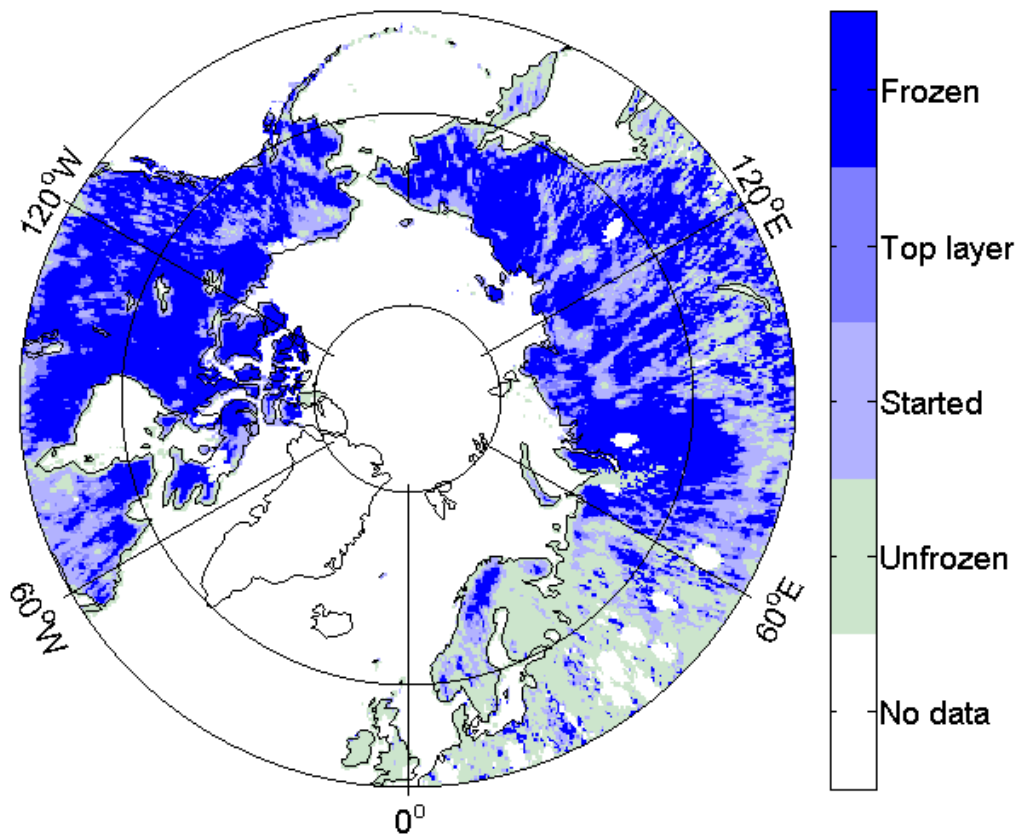


Figure 7.2. Example of hemispherical detection of the freeze/thaw state of soil for December 5th, 2012, using algorithm developed at FMI.

global observations of microwave radiation at the relatively low L-band frequency. Compared to higher frequencies, L-band radiometry offers relatively high emission depth as well as low sensitivity to surface vegetation. In addition, the contrast between the permittivity of water in solid and liquid states is higher at L-band than at shorter wavelengths. These make L-band observations a viable tool for monitoring of soil surface properties. Previous studies conducted at FMI and by other groups have investigated the relationship between soil freezing and L-band microwave signatures using experimental data, collected over several years and over various ecosystem types. Based on these studies, the inter-

actions between microwave radiance and the freeze/thaw state of soils have been explored in detail, allowing the development of basic retrieval algorithms for space-borne instruments. Advanced forward models predicting the influence of freezing on the microwave response of soils have also been developed as a part of these activities. Ongoing research at FMI aims at extending findings from these studies in order to develop operational freeze/thaw satellite products applicable over the whole Northern hemisphere.

A tentative algorithm developed at FMI applies SMOS observations at chosen incidence angles and multiple polarizations to detect the

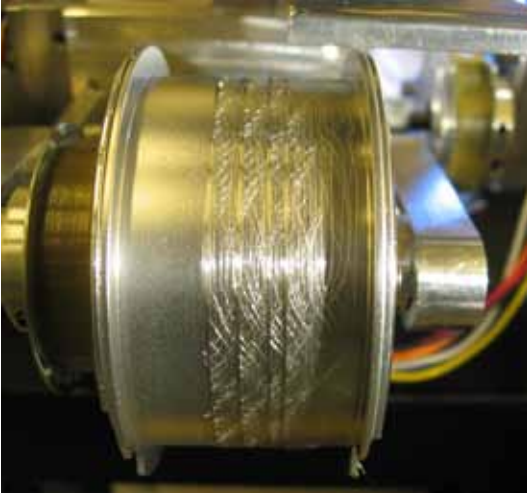


Figure 7.3. Piece of reeled E-sail tether

change in emission properties of soils related to soil freezing. In practice, coarse scale observations from SMOS allow the detection of the freeze/thaw state at a spatial resolution of tens of kilometers. An example of the freeze/thaw status over the Northern Hemisphere is shown below. Based on similar principles, operational monitoring of the freeze/thaw state will also be possible in the future at an improved spatial resolution with NASA's upcoming SMAP (Soil Moisture Active Passive) mission as well as the European Sentinel-1 SAR, launched in 2014.

### **Coulomb Drag Devices Revolutionizing Solar System Missions and Space Debris Cleaning**

The electric sail (E-sail) is a Finnish invention that uses natural solar wind momentum flux for producing spacecraft propulsion. The E-sail could in many respects revolutionize mankind's access to the solar system. A closely related but simpler single-tether Coulomb drag device (plasma brake) could be used for deorbiting small and medium-sized satellites with high efficiency to eliminate the growing problem of space debris.

The Estonian ESTCube-1 1 kg nanosatellite carries a 10 m E-sail and plasma brake tether experiment. ESTCube-1 was launched on May 7 2013 onboard the Vega launcher from French Guiana. The Finnish Aalto-1 will be launched later (end of 2014 or early 2015) with longer 100 m tether. Key components of a large scale 1 N level E-sail were successfully developed and tested in the FMI-coordinated ESAIL FP7 project which ended in November 2013.

### **FMI's first ERC Starting grant into grand finale**

Vlasiator is a new hybrid-Vlasov code, which has been developed for global scale simulations in the QuESpace ERC Starting grant project that ended in fall 2013. The computational demands for global hybrid-Vlasov simulations are extreme; ions are described with a 6-dimensional distribution function in real and velocity space and the entire solar wind-magnetosphere system has to be covered with sufficient resolution. This task was so massive that many thought it impossible. In the end of 2012, Vlasiator got a prestigious Partnership for Advanced Computing in Europe (PRACE) Tier-0 grant guaranteeing access to Europe's largest supercomputers. During 2013, the PRACE grant enabled the world's first global runs of the near-Earth space at resolutions close to ion kinetic scales. While the analysis of the results is still ongoing, the first results set our code Vlasiator as the world's new benchmark in global kinetic codes. Vlasiator results show rich plasma phenomena that are much more complicated than has been thought earlier. Many phenomena in the runs have only been observed by local spacecraft measurements before, but the mechanisms of explaining the phenomena have not been placed in a larger context

As the solar wind impinges on the magnetosphere, it forms a shock similarly as there is a shock wave in front of a boat moving in water (see Figure 7.4). Charged solar wind

particles are energized by the shock and reflected back into the solar wind generating the wave patterns in the foreshock region. The particles that are not reflected into the solar wind compose a region of hot plasma in front of the Earth's magnetosphere known as magnetosheath. The Vlasiator team investigated the plasma processes within the foreshock and magnetosheath, and found that Vlasiator is able to reproduce the key features of solar wind - magnetosphere interactions. Characteristics of the backstreaming ion populations and associated electromagnetic waves are in quantitative agreement with the properties of

ion velocity distribution functions and compressional magnetosonic waves typically observed in the Earth's ion foreshock region. The most striking difference with respect to other kinetic simulations is that the Vlasiator velocity distribution functions appear as noiseless and uniformly discretized functions similar to those seen in experimental data.

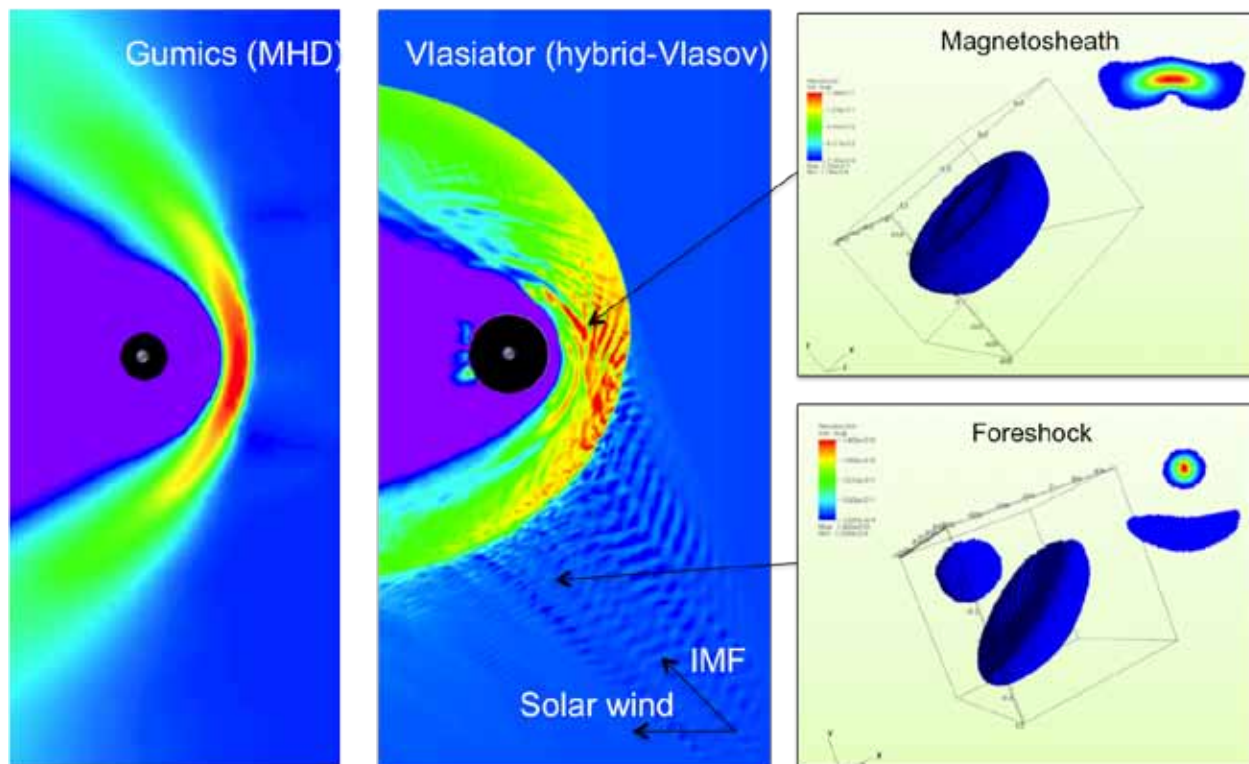


Figure 7.4. Global plasma density in an MHD simulation (left, representing the previous state-of-the-art in global simulations) and Vlasiator (center, the new benchmark in global kinetic simulations). Color-coding is plasma density, with blue sparse plasma and red dense shocked plasma. Solar wind flows from the right of the figure, and the Earth is the small blue dot within the black region. Earth's magnetic field deflects and shocks the solar wind flow similarly as a rock within a river. In this example, the interplanetary magnetic field (IMF) forms a 45° angle with respect to the solar wind flow. Vlasiator is able to capture the ion foreshock and the magnetosheath kinetic phenomena (the waves in lower right) in great precision due to the noise-free 3D distribution functions, which are shown for the magnetosheath (top-right), and ion foreshock (bottom-right). These kinetic features are absent in the MHD description because it represents plasma only with single-fluid Maxwellian distribution functions.



## 8. University of Helsinki, Department of Physics

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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 more than 300 FTE person years. The total annual resource allocation in space research at the Department exceeds 50 FTEs. This work is conducted within the framework of the Kumpula Space Centre in collaboration with the Finnish Meteorological Institute and (from 2012) the School of Electrical Engineering of Aalto University. We were also active members of the Finnish Centre for Astronomy with ESO (FINCA), having 4 of their staff members working in our 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, thus in total amount of space activities of the University of Helsinki is approximately 60 FTEs. In 2013 our space research resulted in about 110 peer-reviewed articles.

The main fields of our space research activities are, studies of interstellar medium and star formation, stellar astrophysics, extragalactic astronomy, cosmology, space physics, the Sun and solar activity, the planetary system, and planetary geophysics. In the studies of the interstellar medium our focus is in the early stages of the star formation process. Here we use observations from the ground (e.g., ESO's telescopes) and the satellites (e.g., ESA's Herschel and Planck), and apply numerical modelling to compare with the observations. In stellar astronomy our focus is in stellar magnetic activity where we conduct both observational and theoretical work. We also study high-energy phenomena in the Solar corona in and Clusters of Galaxies using X-ray satellite data, including observations using guest observer time for large space observatories like the XMM-Newton, Chandra and Suzaku, and with X-ray detectors developed in our own space projects, e.g. XSM/SMART-1 and XSM/Chandrayaan-1. In space-based cosmology our Planck team is in the core data analysis team of cosmic microwave background observations, which were released in 2013. In space physics, our emphasis is on Solar-Terrestrial relations,

Figure 8.1. Herschel has shown that cloud filaments form an important step in the star formation process. In this Herschel far-infrared image, a cold interstellar cloud is seen as a blue filamentary structure against the warmer background. The cloud is fragmenting and already contains a number of young stellar objects.

in particular, on processes driving the Space Weather phenomena in the near-Earth space. In planetary research our focus is on the orbital determination, shape and structure of asteroids and comets, and the surface regolith, atmospheres and the magnetosphere of solar system bodies. We are also leading the largest Finnish space instrument project, the Solar Intensity X-ray and particle Spectrometer (SIXS) for ESA's Mury mission BepiColombo.

In planetary geophysics we study impact cratering processes combining space research and geophysics methods. We have set as our goal to become a leading European astronomy and space research community and the best doctoral training unit by 2015.

We continued the development of the SIXS (Solar Intensity X-ray and particle Spectrometer) instrument and the common DPU and onboard software for SIXS and MIXS instruments for ESA's BepiColombo mission, and finalised the Flight Model of SIXS sensor unit in 2013. We also organised the 10th BepiColombo Science Working Team meeting which was held in 2 – 5 September 2013 at Saariselkä, Lapland.

### **Planck - eyes to the universe**

The Planck satellite operations were finished in October 2013 after over four years of observing the microwave sky.

The Planck group at the Department of Physics is responsible for producing the sky maps for the three lowest frequencies, as well as a number of related tasks, including calibration, estimation of residual noise correlations and other systematic effects on the maps, and

producing large Monte Carlo simulations (performed at CSC - IT Centre for Science in Finland) of the data. Cosmological results based on the first 15 months of Planck observations were released in March 2013. They include a high-resolution temperature map of the cosmic microwave background (CMB), its angular power spectrum, and updated values of cosmological parameters based on Planck data. The current 5-parameter "stand-



ard cosmological model”, LambdaCDM, is in remarkable agreement with this data. A number of features theoretically predicted by the standard cosmological model, but not observed previously, were detected by Planck for the first time: the (non-primordial) non-Gaussianity of the CMB due to the correlation between gravitational lensing of the CMB and its redshift variations (integrated Sachs-Wolfe effect) due to the gravitational effect of matter concentrations by which the CMB radiation has travelled, the correlation between this lensing if the CMB and the cosmic infrared background; and the effect of the motion of the solar system on higher multipoles (than the dipole) of the CMB sky.

## Solar-terrestrial physics

In Solar-terrestrial physics we have obtained new results on the structure of coronal mass ejection driven sheath regions and how they affect radiation belts.

Sheath regions ahead of fast coronal mass ejections (CME) are important drivers of strong disturbances in the geospace. The geoeffectiveness of sheath regions is suggested to stem from their turbulent characteristics, which are expected to enhance solar wind-magnetosphere coupling. We performed a detailed analysis of magnetic field and solar wind dynamic pressure fluctuations in the Ultra-Low-Frequency (ULF) range in sheath regions in the near-Earth solar wind and studied how sheaths affect the outer Van Allen radiation belt. We used a novel superposed epoch analysis where all sheath regions were compressed/stretched to our sample mean duration and the epoch time was fixed to the arrival of the shock. Unlike previous studies, we segregated the sheath from the CME ejecta when studying the radiation belt response.

Our studies revealed sheaths of a much higher ULF power both in the magnetic field and in dynamic pressure than their surroundings, and that the level and distribution of the power depends on the properties of the CME-driver. In addition, the magnetic field and dynamic pressure ULF power have the opposite profiles within the sheath. Our study showed that sheath regions cause strong and long-time depletions of the electron fluxes at the outer Van Allen radiation belt.

We concluded that sheaths are effective at depleting the electron fluxes because their high ULF power increases electron losses under magnetospheric compression conditions.

## Stellar magnetic activity

In stellar magnetic activity research we have for the first time reproduced solar-like dynamo action in a self-consistent 3D-MHD numerical model of turbulent convection.

Studies of Galactic interstellar clouds were continued with the Herschel and Planck satellites. The studies concentrate on the physical and chemical properties of star forming cloud cores. The project “Galactic Cold Cores”, a Herschel key programme coordinated by Helsinki, is nearing completion. The user-reduced data products were delivered to the public Herschel archive and the first statistical analysis of the full cloud sample was finalized. In parallel, we are working towards the publication of the final catalog of Planck-detected cold Galactic sources. The first papers describing Planck measurements of polarised dust emission in these objects are in preparation.

We continued in four EU FP7 projects of which we are coordinating two: E-SQUID, whose focus is on developing improved

Figure 8.2. ESA’s PA officer Emmanuel Rouvier gives his “blessing” to the SIXS Flight Model during the visual inspection of SIXS in the clean room at the instrument’s Pre-Shipment Review, which was held at Oxford Instruments Analytical Oy, Espoo on 10th September 2013. The other person facing the camera is Dr Seppo Korpela from University of Helsinki, who is responsible for the system engineering of SIXS. Photo: Courtesy of J. Huovelin.

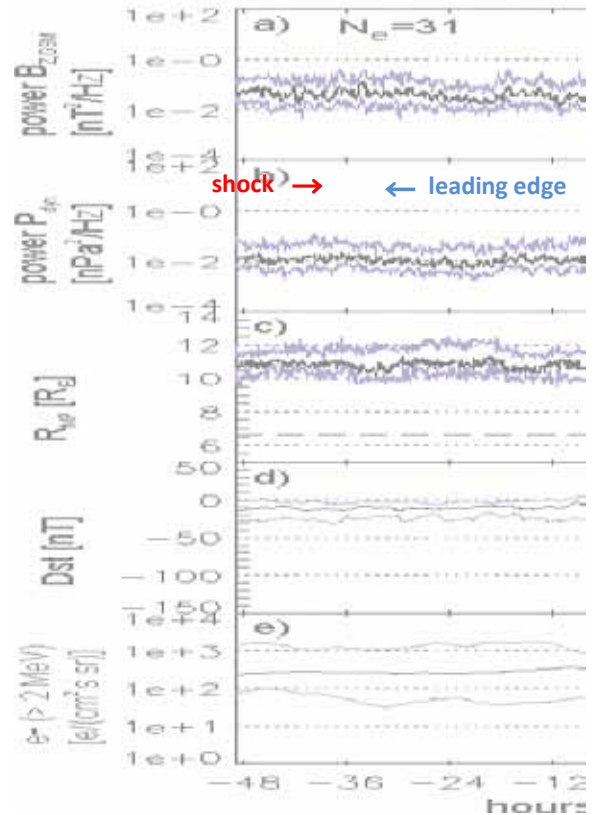
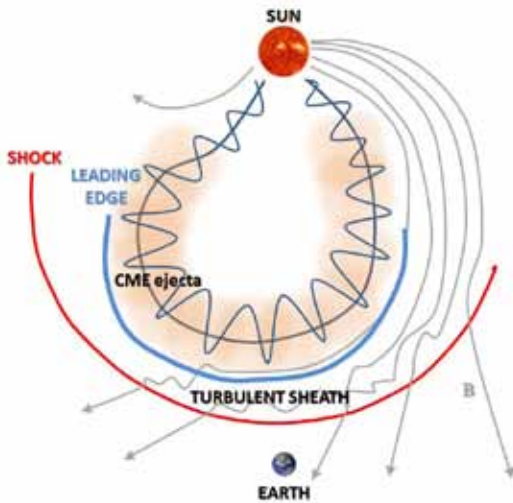


Figure 8.3. Left: Sketch of a CME ejecta, shock and sheath region. Right: Superposed epoch analysis of 31 CME-driven sheath regions. The panels show from top to bottom: ULF (3-10 minutes) fluctuation power a) in interplanetary magnetic field north-south component (in GSM) and b) in solar wind dynamic pressure measured by the ACE spacecraft, c) subsolar magnetopause position, d) Dst index, and e)  $e^- > 2$  MeV electron fluxes at the geostationary orbit measured by the GOES spacecraft.

SQUID-based readout electronics for detector arrays covering a large range of the electromagnetic spectrum from far infrared to X-rays (<http://fusion.gfl.helsinki.fi/esquid>), and SEPServer that aims at developing data services and analysis tools for Solar Energetic Particle events and related electromagnetic emissions.

## Planetary Science

In planetary-system research on small Solar System objects (such as asteroids and comets), studies on electromagnetic scattering (light scattering) by small particles and random media composed of such particles have culminated in the ERC Advanced Grant project for

Prof. Karri Muinonen entitled “Scattering and absorption of electromagnetic waves in particulate media” (SAEMPL). The primary goal of the SAEMPL project is theoretical, that is, the development of an unprecedented numerical method for multiple scattering by close-packed media of small particles. In the method, the ladder and maximally crossed cyclical diagrams of the multiple electromagnetic interactions are to be rigorously computed. For the validation of the method, the SAEMPL project includes a unique and substantial experimental part including the development of a nano-mechanical device for scattering measurements for single particles and media of such particles. The samples are to

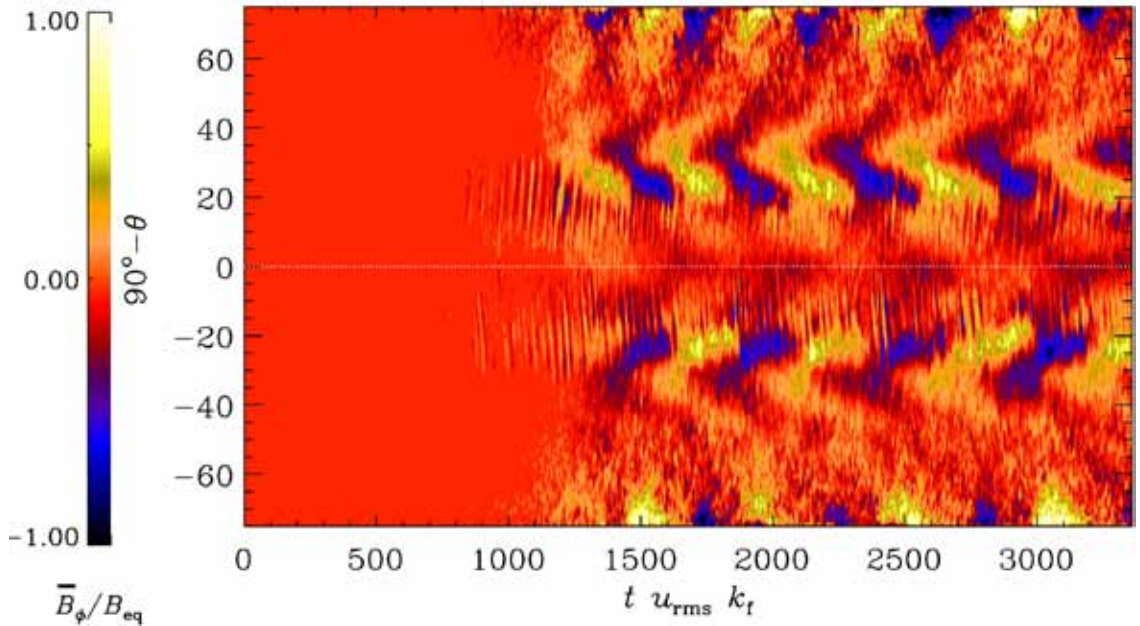


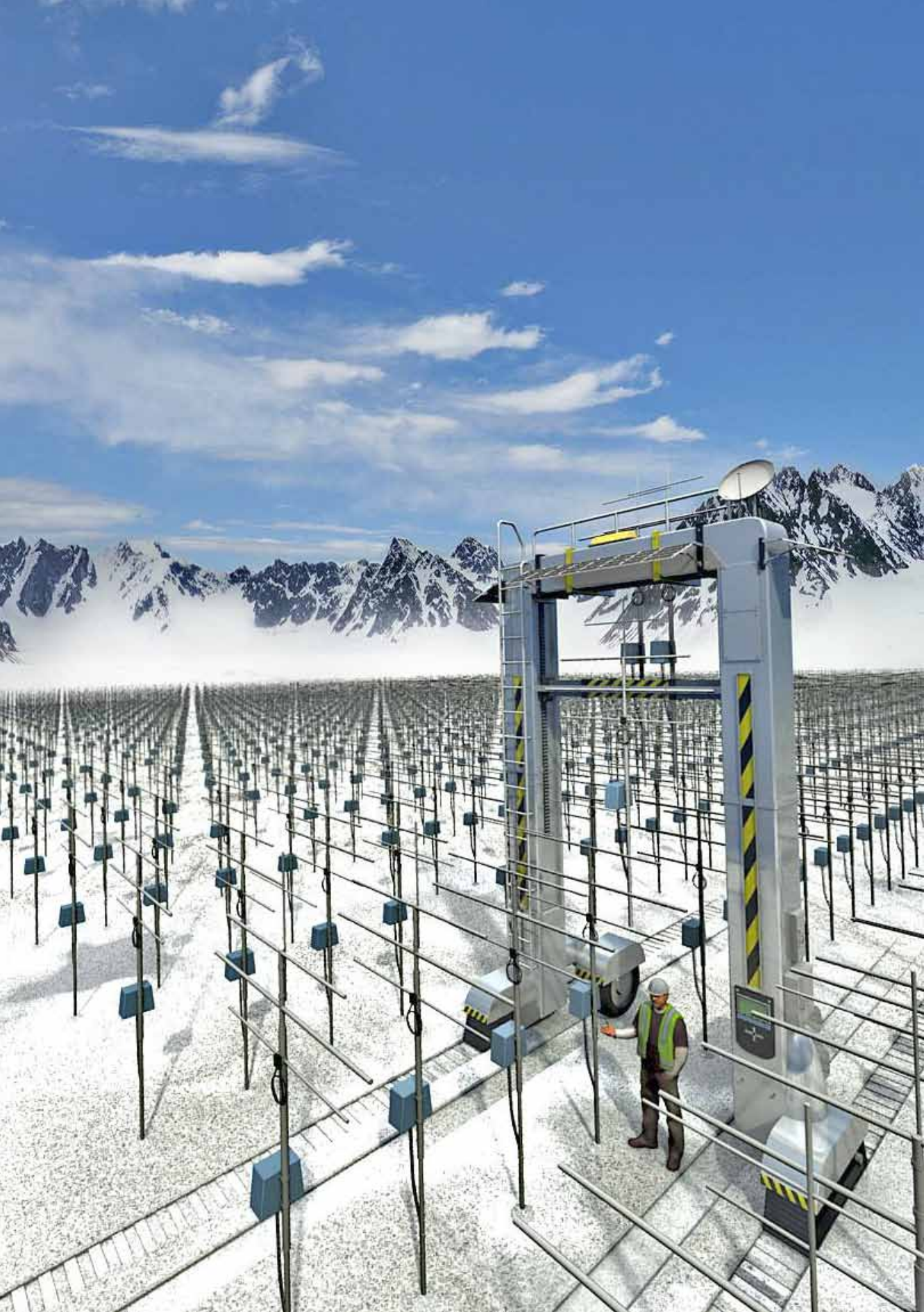
Figure 8.4. Longitudinally averaged azimuthal magnetic field near the surface of the star in a 3D-MHD simulation of dynamo action in turbulent convection in spherical coordinates. Strong magnetic fields propagate toward the equator at low latitudes and toward the poles at high latitudes with a magnetic cycle period of roughly 33 years.

be characterized by an Atomic Force Microscope.

Astronomical observations are carried out using modern ground-based telescopes (e.g., VLT of ESO and NOT) and satellite instruments. Our future spacecraft involvement includes ESA's astrometry mission Gaia (launched in December 20, 2013) and the Mercury mission BepiColombo. We also assess the risk of near-Earth asteroid collisions and participate in the upcoming Canadian NEOSat mission. In the StreakDet project funded by ESA, we develop automated pattern recognition methods and software for the analysis of space-debris streaks in both ground-based and space-based imaging data. As for the uncontrolled decay of the ESA GOCE satellite,

together with colleagues at the Finnish Geodetic Institute and Finnish Meteorological Institute, we have provided impact hazard advice for the government of Finland.

In February 15, 2013, a 20-m sized small asteroid exploded in the atmosphere over the Chelyabinsk region, resulting in a large number of meteorite pieces collected on the ground (in addition to causing harm for the human population). The reflectance spectra were measured by us for a number of these pieces with our new integrating-sphere spectrometer at the astrophysics laboratory across the Vis-SWIR part of the electromagnetic spectrum. Additional geophysical measurements were carried out at the geophysics laboratory. The unique combination of the measurements resulted in a novel interpretation of asteroid spectra and taxonomy. A press release was sent out at the DPS/AAS meeting (Division for Planetary Sciences, American Astronomical Society) in Denver, Colorado. For the extensive study of the Chelyabinsk meteor published in *Science* (November 7, 2013), we have contributed with an assessment on the origin and evolution of the Chelyabinsk meteoroid.



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Space-related activities in the University of Oulu take place in the Department of Physics and in Sodankylä Geophysical Observatory (SGO), which is located about 120 km north of the Arctic circle and 350 km from Oulu. SGO has research groups both in Sodankylä and in Oulu. The space research areas in the University of Oulu 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.

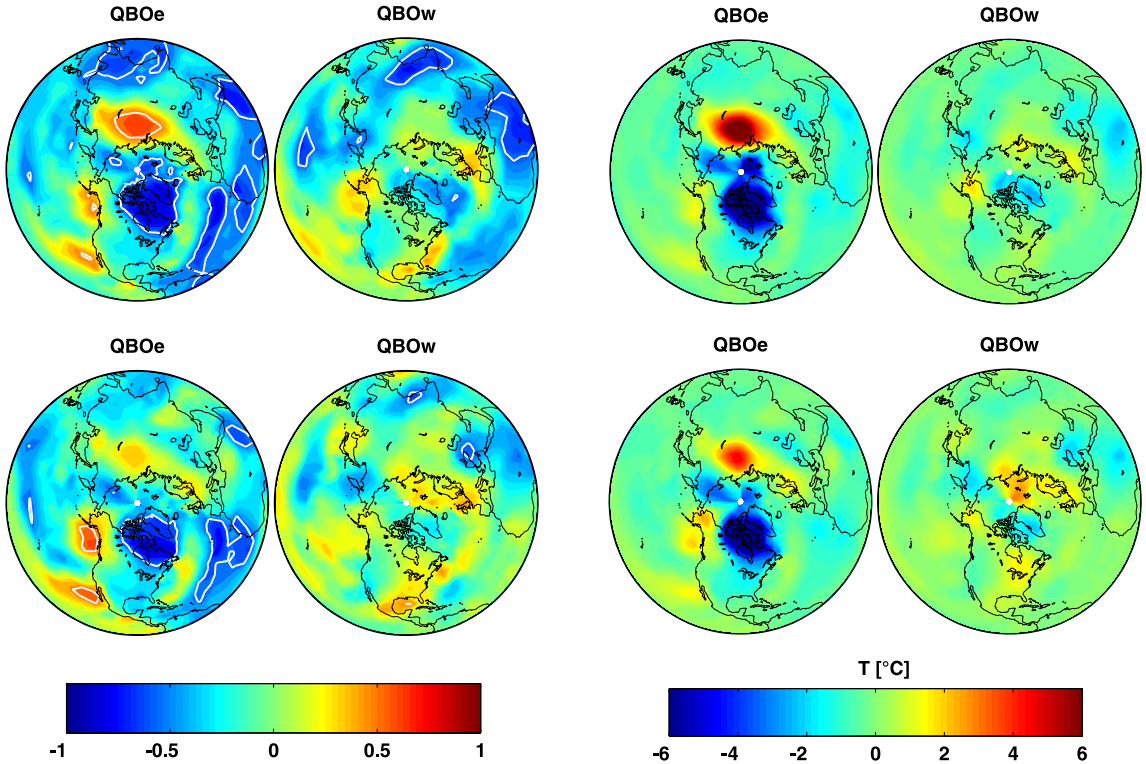


Figure 9.2. QBO-dependent relation between electron precipitation and wintertime surface temperature, JGR Atmospheres, VOL. 118, 6302–6310, doi:10.1002/jgrd.50518, 2013

## Geospace Environment Studies at Sodankylä

Sodankylä Geophysical Observatory conducts geophysical measurements of the ionosphere, atmosphere, magnetosphere, and the solid Earth at 20 different locations in Finland, Sweden, Norway, and Svalbard. The data archive spans over 100 years and allows to study the long-term evolution of the geospace environment. The new Radio Science Laboratory of SGO has a long history of developing innovative measurement methods, culminating in the recent construction of Finland’s largest radio telescope, the Kilpisjärvi Atmospheric Imaging Receiver Array (KAIRA). KAIRA is a multi-purpose radio receiver used for atmospheric research and prototyping for the future EISCAT\_3D incoherent scatter radar system.

## EISCAT Radar Studies of the Polar Ionosphere

The ionospheric physics group at the Department of Physics studies the high-latitude ionosphere, its coupling to the magnetosphere, and solar wind control of ionospheric phenomena by utilizing the EISCAT radar facilities as well as different ground-based and satellite measurements, like Cluster. The group is heavily involved in the EISCAT\_3D Preparatory Phase project and coordination of its Science case. Recent research topics include e.g. estimates of magnetospheric energy deposition rates in the ionosphere and the effect of E-region neutral winds on those processes.

## Space Climate: Solar Long-term Variability and Effects

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 has leading positions in the European TOSCA (Towards a more complete assessment of the impact of solar variability on the Earth's climate) network and in several EU FP7 projects, including eHEROES, STORM and SEPServer. The group was selected to lead the Centre of Excellence of the Academy of Finland in Research on Solar Long-term Variability and Effects (ReSoLVE) in 2014-2019. The group organized the Space Climate Symposium in Oulu in June 2013. Recent results include the causes and extent of the southward shift of the heliospheric current sheet, the properties of geomagnetic storms since 1932, the recalibration of the 35-year, 15-satellite NOAA/POES energetic particle dataset and the relation of energetic electron precipitation and winter time surface temperature at high latitudes. The Cosmic Ray Station in Oulu performs routine monitoring of the cosmic ray flux, and monitors atmospheric effects of cosmic rays.

## 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.

## 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 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 belongs to the core team of the S4G project (The Spitzer Survey of Stellar Structure in Galaxies) which is one of the Spitzer Exploration Science projects. Over 2300 nearby galaxies have been observed in 3.6 and 4.5 microns, providing deep uniform maps of stellar mass distribution over a variety of galaxy types and environments. Oulu group is leading the structural decomposition data analysis pipeline. In December 2013 the project received 188 additional hours for 2014-2015. The group also belongs to the DAGAL (Detailed Anatomy of GALaxies) Marie Curie EU ITN network, funding two PhD students in Oulu.



# 10. University of Turku, Department of Physics and Astronomy

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Space research at the University of Turku is conducted at the Tuorla Observatory and the Space Research Laboratory (SRL) both being parts of the Department of Physics and Astronomy. In addition, the University of Turku hosts the Finnish Centre for Astronomy with ESO (FINCA) located at the Tuorla Observatory premises. The number of staff members is about 40.

Tuorla Observatory together with FINCA constitute the largest astronomical institute in Finland. The main areas of research are high-energy astrophysics, active galaxies, supernovae, compact binary stars, stellar magnetic activity, cosmology, galaxy formation and evolution, solar system research and astrobiology. The researchers use multi-wavelength observational data from large ground-based and space telescopes, all the way from radio to gamma-rays. The staff members participate in the MAGIC Collaboration hosting the most sensitive atmospheric imaging 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. FINCA's ultimate goal is to improve the scientific and industrial benefit of Finland's membership in ESO, and Finland's international competitiveness in astronomical research as well as to promote high-quality ESO-related research. FINCA is funded by the Ministry of Education and Culture, and by the participating universities (Turku, Aalto, Helsinki and Oulu).

The research at SRL is focused on solar and heliospheric physics and on cosmic ray physics. Alpha magnetic spectrometer (AMS-02) on board of the international space station has a major role in the development of experimental research at SRL. Experimental research is supported by theoretical investigations and model development.

Figure 10.1. Using computer simulations, scientists from Hawaii Observatory, USA and Tuorla Observatory, Finland have figured out how wide binary stars—two stars that orbit each other at a distance up to a light-year—form. Reipurth B. and Mikkola S., 2012, *Nature*, 492, 221.

## Formation of Wide Binary Stars

The formation of very wide binary systems, such as the  $\alpha$  Centauri system with Proxima (also known as  $\alpha$  Centauri C) separated from  $\alpha$  Centauri (which itself is a close binary A/B) by 15 000 astronomical units, challenges current theories of star formation, because their separation can exceed the typical size of a collapsing cloud core. Various hypotheses have been proposed to overcome this problem, including the suggestion that ultrawide binaries result from the dissolution of a star cluster when a cluster star gravitationally captures another, distant, cluster star. Recent observations have shown that very wide binaries are frequently members of triple systems and that close binaries often have a distant third companion. Dr. Bo Reipurth (Institute for Astronomy, University of Hawaii at Manoa, USA) and Dr. Seppo Mikkola (Tuorla Observatory) run N-body simulations of the dynamical evolution of newborn triple systems still embedded in their nascent cloud cores that match observations of very wide systems. The result is that although the triple systems are born very compact and therefore initially are more protected against disruption by passing stars, they can develop extreme hierarchical architectures on timescales of millions of years as one component is dynamically scattered into a very distant orbit. The energy of ejection comes from shrinking the orbits of the other two stars, often making them look from a distance like a single star. Such loosely bound triple systems will therefore appear to be very wide binaries.

## Supernova Research

When stars greater than eight times the mass of our Sun exhaust their hydrogen fuel, the star collapses and explodes as a supernova. This may generate temperatures high enough to create much heavier elements by fusion, such as titanium, iron, cobalt and nickel. After the initial supernova flash has faded, the total luminosity of the remnant is provided by the

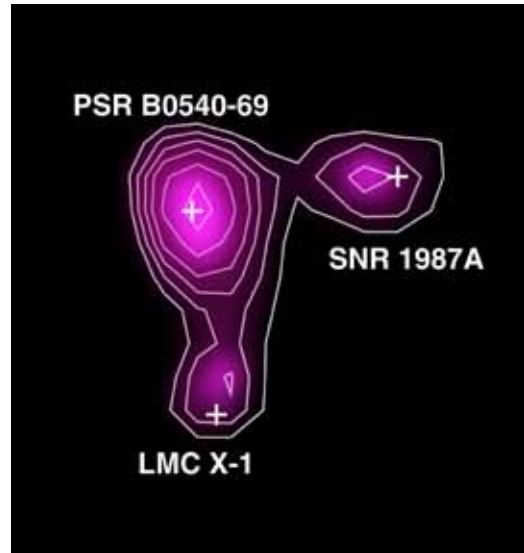


Figure 10.2. The first detection of  $^{44}\text{Ti}$  in supernova remnant 1987A. ESA's Integral space observatory made the detection in the energy range between 65 keV and 82 keV, which brackets two emission lines produced during the decay of  $^{44}\text{Ti}$ , at 67.9 keV and 78.4 keV. The detection required over 1000 hours of observation time with Integral. Also seen in the field of view are two other known hard X-ray emitting sources, the black hole binary known as LMC X-1 and the pulsar PSR B0540-69. From Grebenev S., Lutovinov A., Tsygankov S., Winkler C., 2012, *Nature*, 490, 373.

release of energy from the natural decay of radioactive elements produced in the explosion. Each element emits energy at some characteristic wavelengths as it decays, providing insight into the chemical composition of the supernova ejecta – the shells of material flung out by the exploding star. Supernova 1987A, located in one of the Milky Way's nearby satellite galaxies, the Large Magellanic Cloud, was close enough to be seen by the naked eye when its light first reached Earth in February 1987. During the peak of the explosion, fingerprints of elements from oxygen to calcium were detected, representing the outer layers of the ejecta. Soon after, signatures of the material synthesized in the inner layers could be seen in the radioactive decay of  $^{56}\text{Ni}$  to  $^{56}\text{Co}$ , and its subsequent decay to  $^{56}\text{Fe}$ . Now, the international group of researchers including Dr.

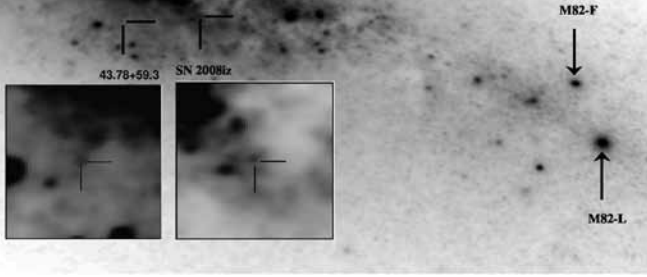


Figure 10.3. Gemini-N Altair/NIRI K-band  $50'' \times 33''$  image of the M 82 nuclear region. The sites of SN 2008iz and the 43.78+59.3 transient are shown in the  $3'' \times 3''$  subimages. From Mattila S. et al. 2013, MNRAS, 431, 2050.

S. Tsygankov (FINCA) using observations by ESA's Integral space observatory has detected for the first time high-energy X-rays from radioactive  $^{44}\text{Ti}$  in Supernova remnant 1987A, Figure 10.2. The total estimated mass of  $^{44}\text{Ti}$  that must have been produced just after the core collapse of SN1987A's progenitor star amounted to 0.03% of the mass of our own Sun. This amount is sufficient to have powered the remnant by radioactive decay over the last 20 years. A high amount of  $^{44}\text{Ti}$  is near the upper boundary of theoretical predictions and is likely produced in exceptional cases, favouring supernovae with an asymmetric geometry, and perhaps at the expense of the synthesis of heavier elements. This discovery represents a new constraint on the physics of supernova explosions.

In a study led by Dr. S. Mattila (FINCA), the radio supernova 2008iz and a radio transient (43.78+59.3) within the nuclear regions of the prototypical starburst galaxy M 82 were studied. Using an adaptive optics system on the 8-meter Gemini-North Telescope together with archival data from the Hubble Space Telescope high resolution images were obtained that allowed to recover near-infrared counterparts of both objects (see Figure 10.3). SN 2008iz was found to be a normal core-collapse, but the nature of the 43.78+59.3 tran-

sient remains still elusive, with an extremely bright microquasar from a high-mass X-ray binary being considered as the most plausible candidate.

## Alpha Magnetic Spectrometer

The principal goal of AMS-02 is to search for antimatter, investigate the origin of dark matter, and measure the properties of galactic cosmic rays with unprecedented accuracy. The first results of AMS-02 were published in 2013. The measured ratio of the number of cosmic ray positrons to the total number of positrons and electrons was reported in the energy range 0.5 – 350 GeV, see Figure 10.4. The amount of about 400 000 cosmic positrons collected by AMS-02 increased by a hundred-fold the total sample of positrons collected before and extended the energy range. The results confirmed the positron excess and its strong increase with energy measured earlier by other instruments. The source of the excess may be annihilation of dark matter particles or be a result of the inhomogeneity of the distribution of supernova remnants. More statistics at energies above 350 GeV are needed, however, in order to definitely resolve the origin of the excess.

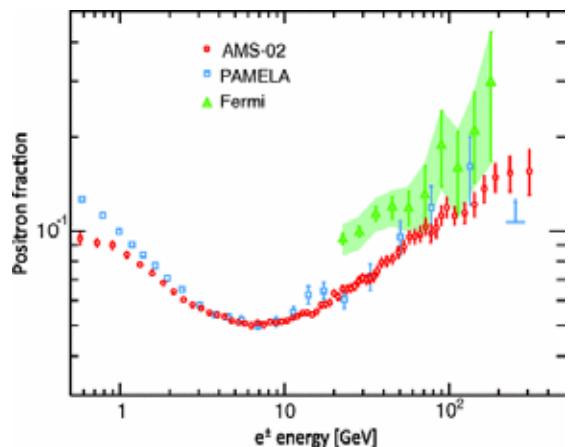
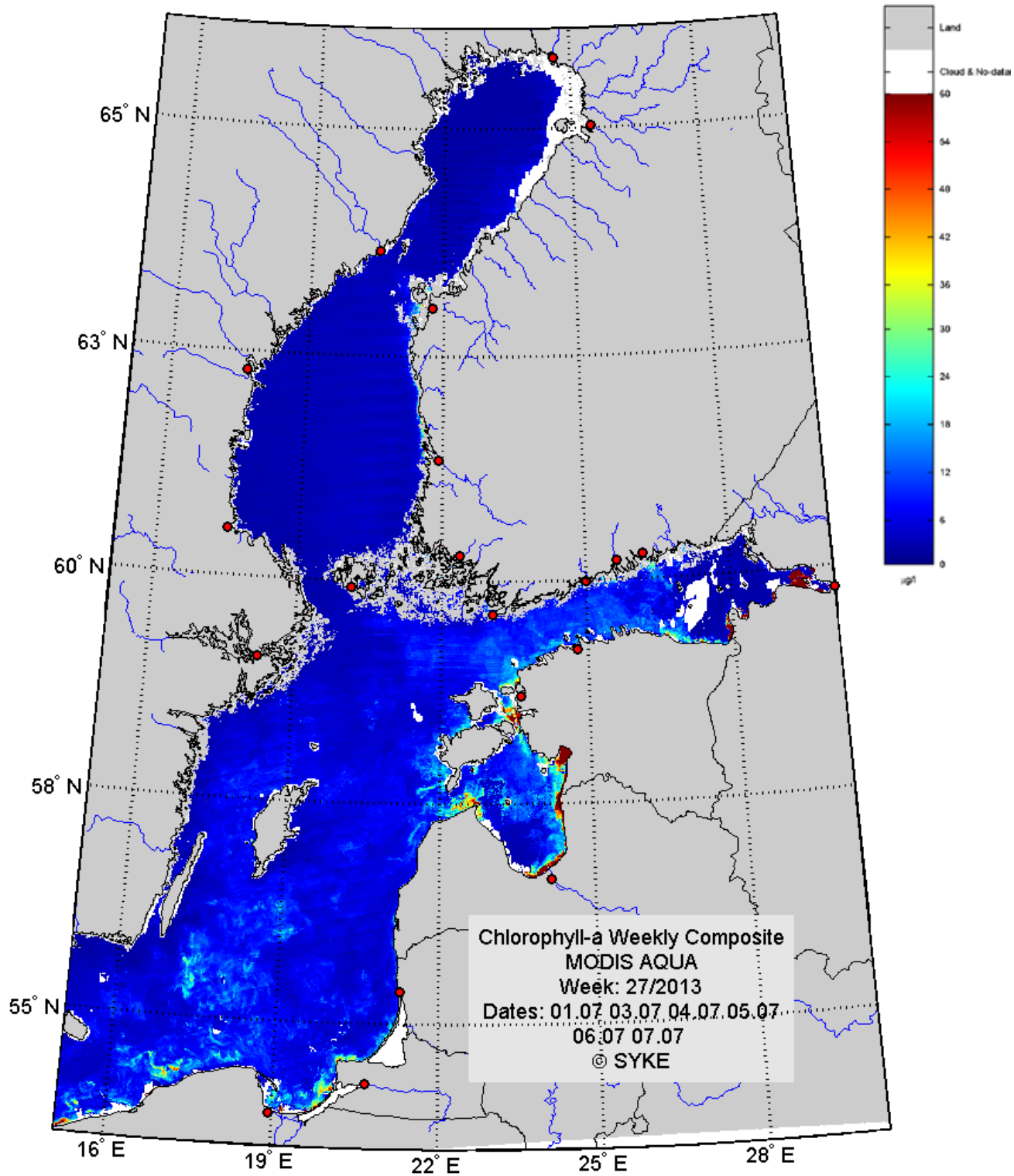


Figure 10.4. The positron fraction compared with the most recent measurements from PAMELA and Fermi-LAT. From Aguilar M. et al. (AMS Collaboration), 2013, Phys. Rev. Lett. 110, 141102.



# 11. Finnish Environment Institute (SYKE)

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Finnish Environment Institute SYKE is both a research institute, and a centre for environmental expertise under the Ministry of Environment. SYKE is responsible for carrying out environmental research, monitoring and assessment, publishing and disseminating the results, and maintaining the appropriate information systems. As a national centre of environmental information SYKE provides expert services and takes care of diverse statutory tasks. There is a strong emphasis at SYKE on providing support to the decision-making process, including scientific and technical advice and through the development of methods to combat harmful environmental changes.

The Data and Information Centre of SYKE compiles and manages data systems, provides technical support and training on information technology, harmonises and develops SYKE's international reporting, and deals with other centralised aspects of data management. In addition, the centre is responsible for the development of the Finnish Environmental Administration's geographic information systems (GIS) and Earth Observation (EO) information systems. The EO research and development concentrates on operational monitoring of snow cover, water quality, land use / cover and phenology. The research includes validation of EO products with in-situ observations. Additionally, theoretical and experimental research on the optical characteristics of water, snow and land cover is performed in cooperation with national and international partners.

The customers of SYKE are researchers in environmental administration, governmental and municipal authorities, general public and private industry. Data are also delivered to the international research community in collaborative projects and upon requests. Most of the operative production of EO services at SYKE is part of the European network of service providers in GMES (Global Monitoring of Environment and Security) programme funded by EU and ESA.

Figure 11.1. Chlorophyll-a composite map of the Baltic Sea on week 27 (1.7.-7.7.), 2013.

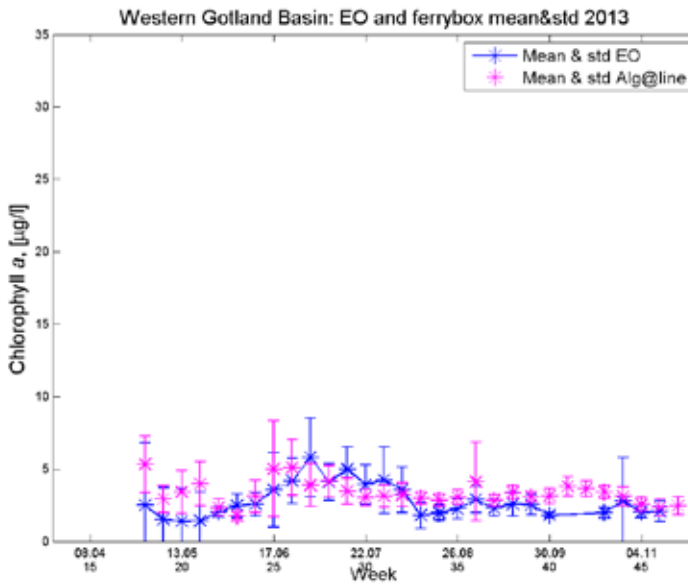


Figure 11.2. Example of spatially aggregated time series from the Western Gotland Basin during summer 2013.

### Water quality EO products from the Baltic Sea used in WFD monitoring

In the field of water quality monitoring, SYKE has continued the operational production of EO data for the Baltic Sea. The parameters include chlorophyll a concentration, algal blooms, and turbidity. Due to the ENVISAT failure, SYKE switched to using MODIS data for these products in 2012. In addition, sea surface temperature images were produced from NOAA-AVHRR data. The water quality monitoring has been part of MarCoast I & II GMES service chains during 2006-2013.

In 2013 the chlorophyll a data were used as input for the reporting required by the Water Framework Directive (WFD) in the framework of national project EOMORE. EOMORE concentrated on comparing monitoring methods for determining chlorophyll-a as an indicator for eutrophication. EO methods can greatly complement the monitoring required by WFD & MSD in areas (outer parts) and seasons (spring) where monitoring with traditional methods is difficult and expensive.

WFD & MSD needs are primarily in assessing the state of the water body with temporal and spatial variability. According to the results, 67% of WFD coastal water bodies of Finland can be monitored with an instrument of 300 m ground resolution, such as forthcoming Sentinel3a OLCI. All open water bodies can be covered with EO instruments.

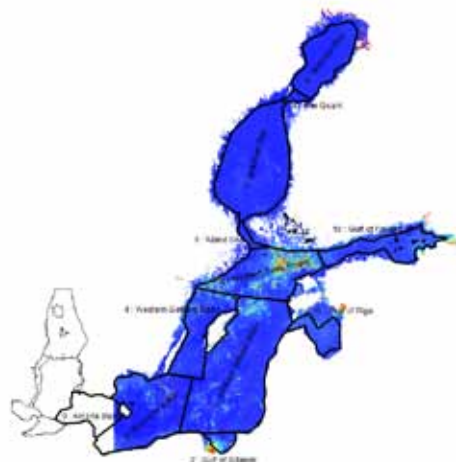


Figure 5.1. HELCOM open sea monitoring areas.

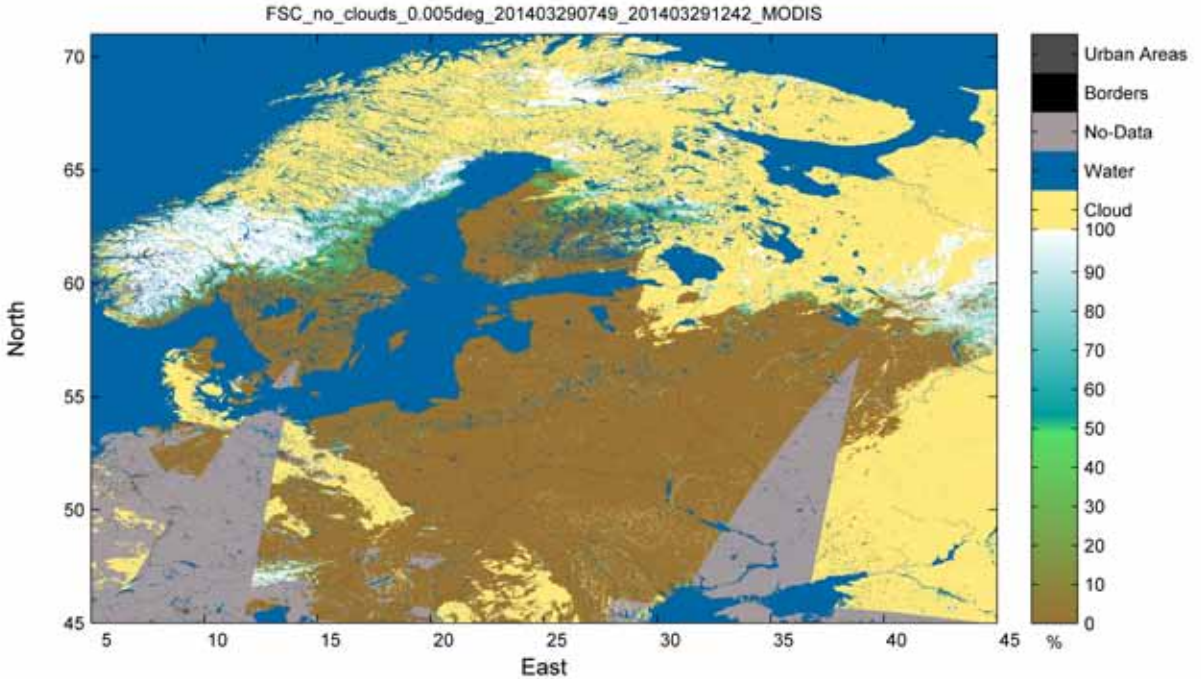


Figure 11.3. Fractional Snow cover on March 29, 2014, as provided by SYKE in Copernicus project Cryoland. The result is based on MODIS data.

### Snow remote sensing of SYKE is an elementary part of two international snow mapping key initiatives

Regarding snow, SYKE has both national and international activities on remote sensing. In the national scale, the provision on daily maps on Fractional snow cover (FSC) continues with the following improvements implemented during 2013:

1. Enhanced cloud screening method,
2. Fully automated production lines, in cooperation with the Finnish Meteorological Institute,
3. Provision of statistical uncertainty for FSC estimates. The FSC are also further processed to drainage basin scale, which is the format needed by SYKE's Hydrological modelling and forecasting system which ingests the data to improve the national hydrological forecasts.

International activities are mainly related to the EU Copernicus service Cryoland and ESA DUE GlobSnow, where the Fractional Snow Cover algorithm developed and maintained by SYKE plays a key role. Cryoland provides several services on snow. SYKE is responsible (together with FMI) for the daily provision of the Baltic Sea snow maps from MODIS acquisitions. In addition, the fractional snow mapping method developed at SYKE is applied in provision of the Pan-European snow map operated by Enveo IT GmbH in Austria. GlobSnow has produced two versions of Climate Data Record on Snow Extent for the Northern Hemisphere. SYKE has a strong contribution to the provision of this dataset. The fractional snow cover algorithm, cloud screening method and several auxiliary data fields needed in the production are based on SYKE's scientific and technical work on this project.

## 12. Millimetre Wave Laboratory of Finland (MilliLab)

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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.

MilliLab supplies services at millimetre wave frequencies in the field of device modeling, device characterisation, measurements, testing, research, and development. The parent organisations of MilliLab, VTT and Aalto University School of Electrical Engineering 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.

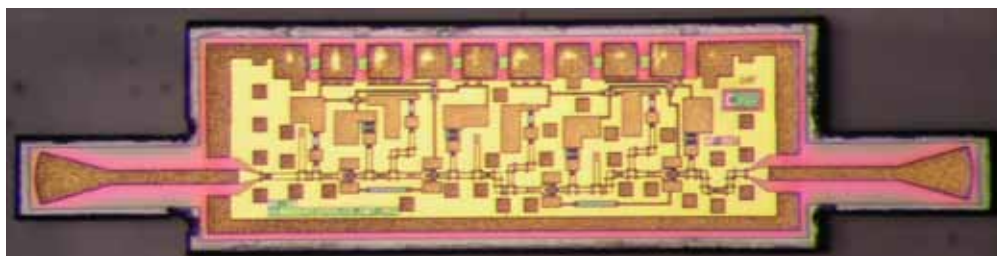


Figure 12.1. Low noise amplifier with integrated waveguide to MMIC transitions for 325 GHz. Core chip size 1250  $\mu\text{m}$  x 500  $\mu\text{m}$ , transition size 400  $\mu\text{m}$  x 180  $\mu\text{m}$ .

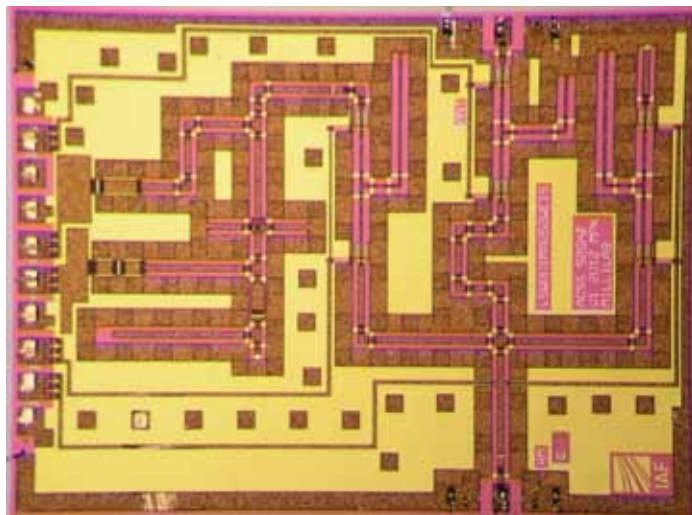


Figure 12.2. Unique active internal calibration sub-system MMIC for 50-54 GHz radiometer. Active calibration circuit includes a switch, an ambient temperature load, and a below ambient temperature active cold load all integrated on a same chip. Switch includes also a through path between an antenna and a radiometer. Chip size 1.5 mm x 2.0 mm.

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 50-330 GHz frequency range utilising GaAs MHEMT MMIC technology and preliminary reliability assessment for most promising designs is currently on-going. MilliLab is working with ESA/ESTEC also in reliability assessment of Schottky diodes for MetOp-SG instruments above 200 GHz. Additionally, novel internal calibration loads for millimetre-wave radiometers have been realised for 30-100 GHz range.

As a new activity in general technology development, MilliLab has completed building a passive terahertz imager demonstrator for ESA in 2013. The built terahertz camera produces 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 has 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 imager is in the process of being commercialised by a Finnish company Asqella Oy.

The 2009 launched ESA Planck mission has completed its sky surveys. The six 70 GHz receivers developed and built by MilliLab and DA-Design Ltd. for the Planck Low Frequency instrument produced excellent data throughout the mission reliably. The instruments were switched off in October 2013. 2013 saw also the first major data release containing cosmology results, and another one is due in 2014.

# 13. RADIATION Effects Facility (RADEF)

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The University of Jyväskylä with its seven faculties is one of the largest universities in Finland. The Department of Physics (JYFL) belongs to the Faculty of Mathematics and Science and the Accelerator laboratory (JYFL-ACCLAB) is part of JYFL. Laboratory's research covers experimental subatomic and material physics and their applications.

JYFL-ACCLAB has operated very successfully as a Centre of Excellence (CoE) of the Academy of Finland since 2000 and belongs its Roadmap 2020 programme. It is one of only two Physics and Technology national-level research infrastructures listed by the Ministry of Education and Culture (OKM) and has also been designated by the OKM as a centre of expertise in radiation- and ion-beam research, education and applications. It operates in close collaboration with the Helsinki Institute of Physics (HIP) and has operated as one of the Large Research Access Infrastructures in the FP4 - FP7 programmes of the EU since 1996. It is also an accredited radiation test facility of ESA.

The increased demands for radiation testing in Europe attracted ESA to the JYFL-Accelerator Laboratory in 2004, when an ESTEC/Contract No. 18197/04/NL/CP: "Utilization of the High Energy Heavy Ion Test Facility for Component Radiation Studies" between ESA and JYFL was signed. After the upgrade RADEF was qualified to one of ESA's External European Component Irradiation Facilities (ECIF).

RADEF includes heavy-ion and proton beam lines in the same test cave. The heavy-ion line consists of vacuum chamber and equipment for beam quality and intensity analysis. A special beam cocktail and user interface for monitoring flux and fluence has been developed. RADEF's specialty is the high penetration ion cocktail with the maximum energy of 1.22 GeV for xenon. The beam homogeneity is obtained by using a scattering foil upstream in the beam line together with x-y wobblers. With this equipment beam homogeneity of better than the required  $\pm 10\%$  can be achieved

over an area of  $4 \times 4 \text{ cm}^2$ . 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. An overview of the facility is illustrated in Fig. 1, where both beam lines are indicated.

The customers are mainly from European space industry, but also e.g. Jet Propulsion Laboratory of NASA and Sandia National Laboratories from USA as well as Japan Aerospace Exploration Agency (JAXA) are regular users. In total, 82 test campaigns for 30 companies or institutes and for five universities were performed in RADEF during the years 2012-2013. Thus, RADEF has become favored by the users performing Radiation Hardness Assurance (RHA) tests and today it is a leading heavy ion test facility with high penetration cocktail beams in Europe. Also, 11 peer reviewed articles have been published since 2012, including one with definitions of

# Heavy-ion line

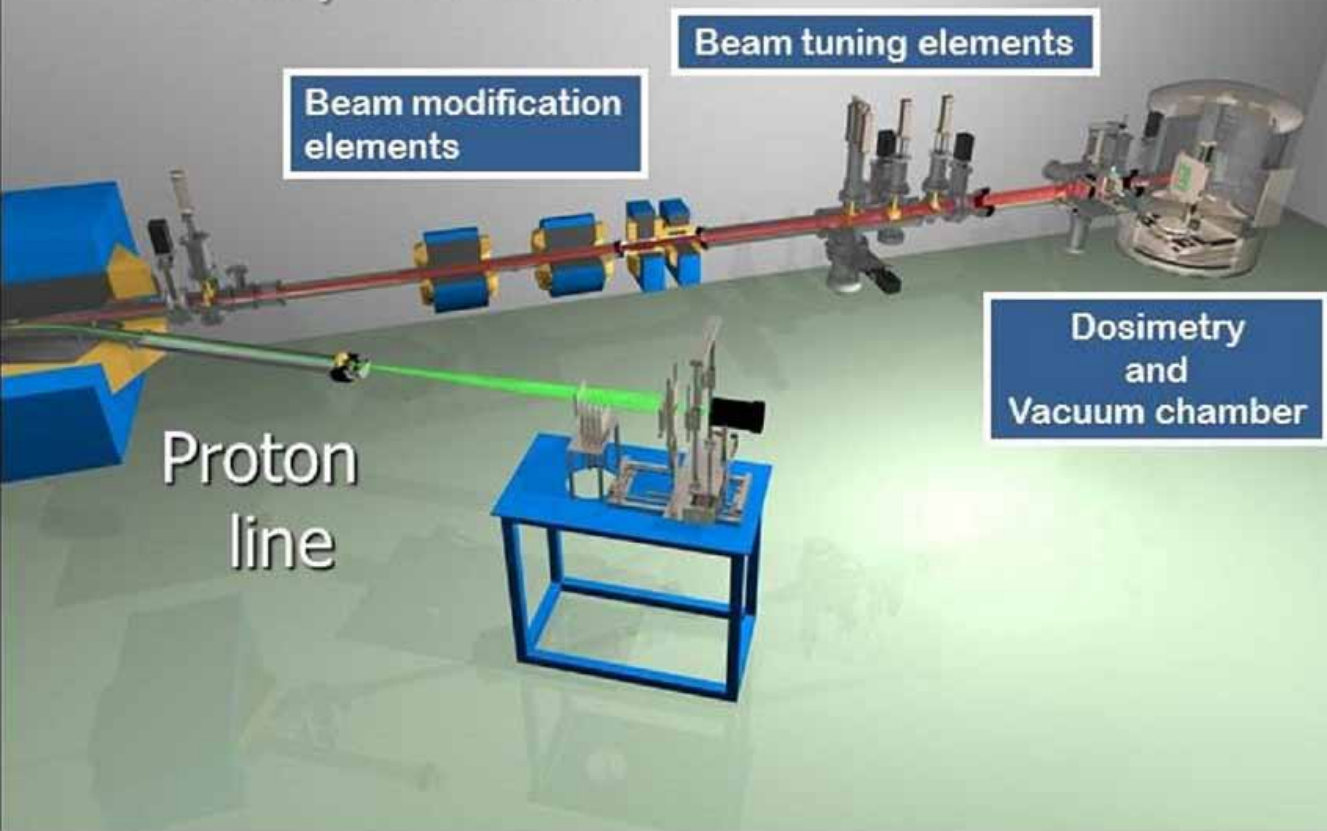


Figure 13.1. An illustration of the RADEF facility.

experimental LET values of heavy ions used in the ECIF facilities.

In 2012 ESA had a technical assessment study on “Effects of the ion species and energy on the oxide damage and SEGR failure”. Results, which created a semi-empirical model for SEGR prediction, have recently been published in a series of Transaction on Nuclear Science of IEEE. The objective of the study was to determine the worst-case conditions for Single Event Gate Rupture (SEGR) testing and to include the results in the next Single Event Effects (SEE) test guidelines of ESA.

An EU-FP7 Project, SkyFlash, was also performed at RADEF during the years 2012-2013. It aimed to develop a RadHard by design (RHBD) methodology for non-volatile flash memories. The methodology focused on environments affected by radiation due to charged particles. Other partners were from Cyprus, Israel, Italy, Spain and Sweden (<http://www.skyflash.eu/>). Three heavy ion tests were

performed at RADEF during the project. In addition to SkyFlash, RADEF recently joined to act as partner to perform irradiation tests in five international proposals submitted to EU’s Horizon 2020 program of Competitiveness of the European Space Sector (COMPET).

Recently ESA also decided to support the development of a new 15 MeV/nucleon ion cocktail, which will be carried out together with the construction of 18 GHz ion source project funded by Academy of Finland. This enables us to compete in energy with Texas A&M University, which is the owner of world’s leading irradiation test facility. ESA’s support includes also the development of high energy electron beams produced by the LINAC accelerator, which was installed in RADEF in 2013. The purpose will be to test electronic components exposed to electron-rich environments, such as for the JUICE mission and the MEO orbit programmes of ESA.

# Appendix - Pictures from FinCospar 2013

<http://www.cospar.fi/fincospar2013>

Figure A1, Keynote speaker Joy Crisp (NASA/JPL) was interviewed by YLE to appear in Finnish prime-time television programme. photo: David Crisp, NASA JPL



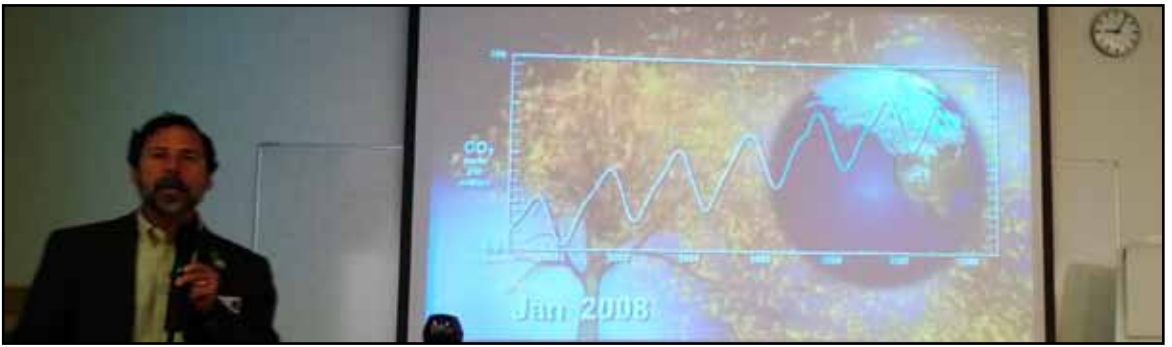


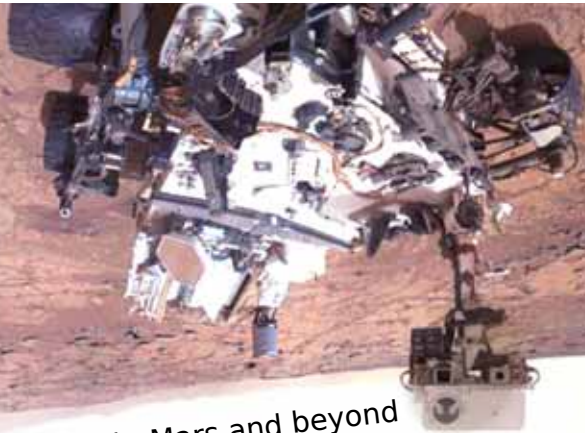
Figure A2. Keynote speaker David Crisp (NASA/JPL) brought the congress audience up-to-date on the OCO-2 satellites current status and the measurements it will be doing in the future. photo: Sini Merikallio

Figure A3. Coffee breaks were filled with uplifting discussions. photo: David Crisp, NASA JPL



Figure A4: Group photo by Erkki Oksanen, Metla

August 29 - 30, 2013, Vantaa, Finland



Earth, Mars and beyond

**METLA**



ILMATIETEEN LAITOS  
METEOROLOGISKA INSTITUTET  
FINNISH METEOROLOGICAL INSTITUTE

## FinCospar 2013

The XIV meeting of Finnish space researchers 29-30.8.2013 at The Finnish Forest Research Institute. The meeting will bring together around 60 space researchers from all the Finnish institutes engaged in space research, astronomy and remote sensing as well as our colleagues from several foreign universities.

### Invited speakers:

Thursday 9:00

**Joy Crisp**

**NASA Jet Propulsion Laboratory**

The Curiosity Rover Mission

Thursday 15:30

**Marko Pekkola**

**Tähdet ja Avaruus, URSA**

Scientists Navigating Media Space

Friday 9:00

**David Crisp**

**NASA Jet Propulsion Laboratory**

The OCO-2 Mission

- the Next Step in Space-Based  
CO2 Measurements

Friday 15:00

**Jaan Praks**

**Aalto University**

Modern spaceborne radar in  
forest applications

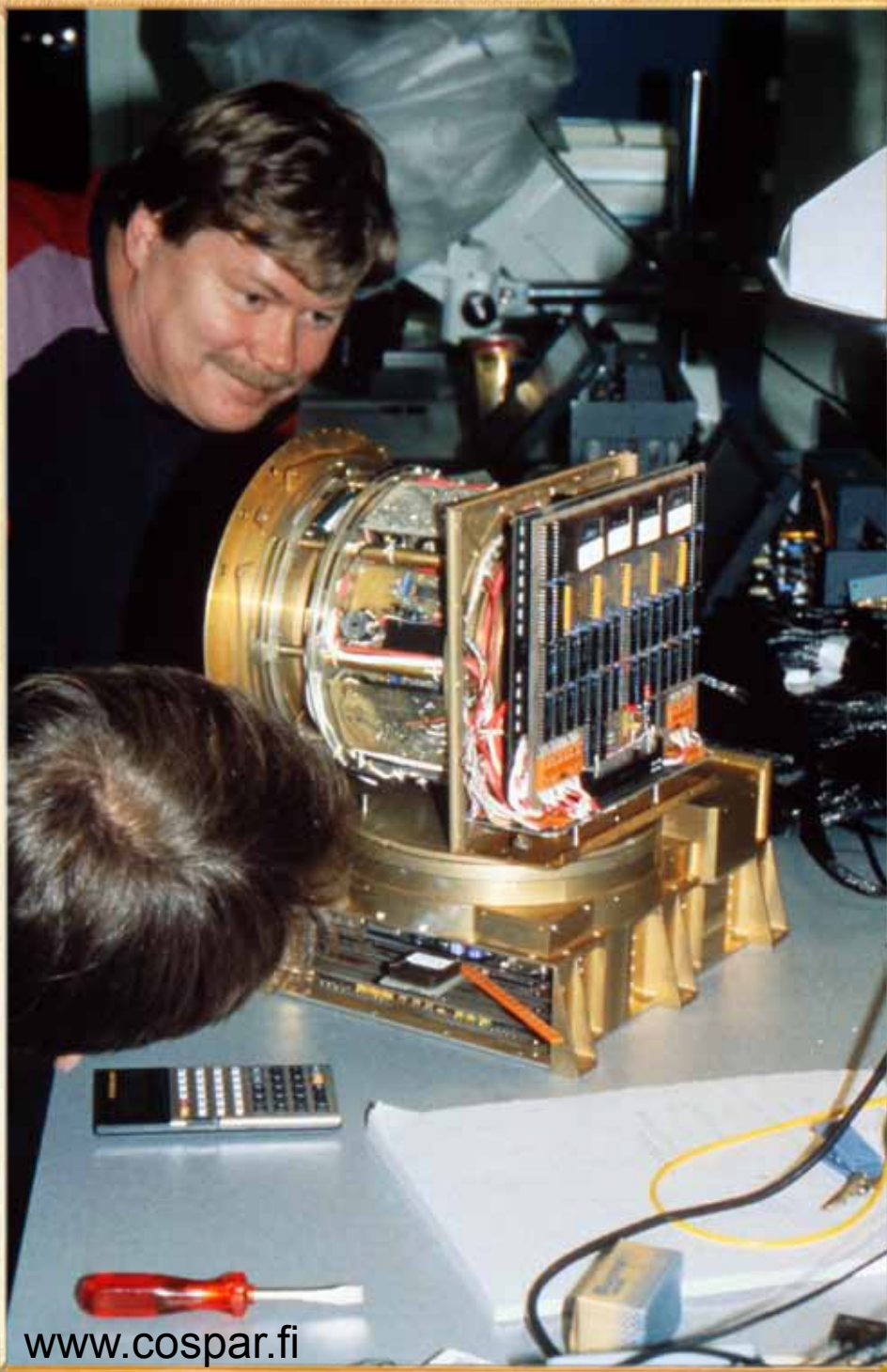
*Suomi Cosparissa jo 50 vuotta!*  
*Finland member in Cospas for 50 years and counting!*



# Finnish National Committee of COSPAR

## List of publications

- T. Pulkkinen, S. Merikallio, P. Stigell (Editors):  
Space Research in Finland, report to COSPAR 2012  
66p., 2012. (PDF available at [www.cospar.fi/reports](http://www.cospar.fi/reports))
- H. Koskinen, S. Merikallio, P. Stigell (Editors):  
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- H. Koskinen, S. Merikallio, P. Stigell (Editors):  
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4 p., 1969.



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