Space Research in Finland

Report to COSPAR on activities 2014-2016
Editors: Tuija Pulkkinen, Markku Alho

June 20, 2016
ISSN 2341-6351

Finnish National Committee of COSPAR
Helsinki
Finland
www.cospar.fi

Foreword

This document is the bi-annual report of Finnish Space Research to the Committee on Space Research (COSPAR) prepared by the Finnish National Committee of COSPAR. 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 2014 - 2016 period.

During the first century of independent Finland (since 1917), the country has undergone major technological advancements especially in the ICT area, but also including capabilities to build space-qualified instrumentation and complete satellite systems. At the time of writing, in summer of 2016, we are eagerly waiting for the launch of Finland's first CubeSat, named Aalto-1. To celebrate the first centennial of the nation in 2017, we plan a second launch of Suomi100 (Finland 100) CubeSat. These low-cost, student driven missions are valuable technology development platforms and offer learning experiences for 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

Table of contents

FOREWORD **1**

TABLE OF CONTENTS **3**

OVERVIEW OF FINNISH SPACE ACTIVITIES **4**
- Finnish National Strategy for Space Activities 4
- Finnish Space Committee 5
- Tekes 6
- Academy of Finland 6
- National Committee of COSPAR 7

SPACE PROGRAMMES WITH FINNISH INVOLVEMENT **8**
- Memberships in International Space Organizations 8
- European Space Agency (ESA) 9
  - *Science Programme* *9*
  - *Earth Observation Envelope Programme* *10*
  - *Telecommunication Programmes* *11*
  - *Technology Programmes* *12*
- European Southern Observatory (ESO) 13
- European Incoherent Scatter Radar (EISCAT) 14
- European Meteorological Satellite Organization (EUMETSAT) 15
- International Satellite System for Search and Rescue (COSPAS-SARSAT) 15
- European Union 15
- Bilateral collaborations 16

FINNISH SPACE RESEARCH **18**
- Aalto University 19
- Finnish Environment Institute (SYKE) 22
- Finnish Meteorological Institute (FMI) 23
- National Land Survey of Finland (NLS) 27
- Natural Resources Institute Finland (LUKE) 31
- University of Helsinki 32
- University of Oulu 39
- University of Turku 40
- Millimetre Wave Laboratory of Finland (MilliLab) 44
- Radiation Effects Facility (RADEF) 46

Overview of Finnish Space Activities

Finnish National Strategy for Space Activities

Mission statement:

> *"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."*

Finnish activities comprise space research, Earth observation, navigation, telecommunication, and instrument development, with membership in the European Space Agency as the backbone of the program. Opportunities offered by the European Meteorological Satellite Organization (EUMETSAT) and rapidly increasing European Union space activities 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, Venus Express, and Rosetta continue to bring results on the processes by which solar activity influences the space environment of the Earth, Mars, Venus, and comet Churyumov-Gerasimenko, and Planck has completed its full sky surveys. In Earth observation, the rich dataset from Envisat 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 of space technology, and several small enterprises are already operative in those fields. The use of Earth observation data utilization in commercial products is both increasing and transferring from research institutes to commercial activities; 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), 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.

The key focus areas in the time frame 2016-2020 include:

> *Develop of space-based applications for Arctic regions;*
> *Open positioning data to foster growth of applications industry;*
> *Participate actively in ESA and EU research programmes to increase the research impact;*
> *Increase the volume of the space industry by specialization.*

Finnish Space Committee

The inter-ministerial Finnish Space Committee under the Ministry of Employment and the Economy acts as the coordinating body for the Finnish space activities. 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 for a period of three years. The membership covers relevant ministries and main actors. 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 current Finnish Space Committee was nominated in March 2016. The Committee meets 2 to 3 times per year, its Secretariat more frequently. Finnish Space Committee members are:

Petri Peltonen, Permanent State Under-Secretary, Ministry of Employment and the Economy, Chair
Päivi Antikainen, Director, Ministry of Transport and Communications, Vice-Chair
Deputy Director-General Timo Kantola, Ministry for Foreign Affairs
Director of International Affairs Tiina Peltola-Lampi, Ministry of the Interior
Director-General Raimo Jyväsjärvi, Ministry of Defence
Counsellor of Education Petteri Kauppinen, Ministry of Education and Culture
Senior Officer Petri Liljaniemi, Ministry of the Environment
Research Director Yrjö Viisanen, Finnish Meteorological Institute
Research Director Tiina Sarjakoski, National Land Survey of Finland
Director Susan Linko, Academy of Finland
Director Ilona Lundström, Finnish Funding Agency for Technology and Innovation Tekes
General Manager of RUAG Space Finland Harri Lähti,
representative of the Association of Finnish Defence and Aerospace Industries

Contact details of the Finnish Space Committee:

Mr. Kimmo Kanto
Mr. Pauli Stigell
Secretary general - Finnish Space Committee
Tekes, P.O. Box 69
FIN-00101 Helsinki, Finland
Tel: +358- 50 5577 856
E-mail: pauli.stigell@tekes.fi

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 objective of Tekes is to develop Finnish industries and services by means of technology and innovation funding. The target is to renew industries, increase value added and productivity, and boost exports and thereby generate wellbeing and improve employment.

Tekes coordinates and offers financial support for participation in international technology initiatives, including European Union's Horizon 2020, COST and EUREKA, the research activities of International Energy Agency, European Space Agency and Nordic cooperation. Tekes fosters new technologies, product development and growth of various business areas. Tekes programmes offer cooperation for companies and the research sector. In 2016, Tekes total financing for national and international R&D&I-projects was 378 million euros. From this total sum, 16,2 million euros were allocated to European Space Agency programmes.

Contact details: Mr. Kimmo Kanto
Tekes, PO Box 69
FI-00101 Helsinki, Finland
+358 1060 55852
kimmo.kanto@tekes.fi
www.tekes.fi

Academy of Finland

The Academy of Finland provides funding for high-quality scientific research and acts as an expert in science policy. The Academy is an agency within the Ministry of Education, Science and Culture. The Academy works to contribute to the renewal, diversification and internationalization of Finnish research through 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, research infrastructures and strategic research funding. The Academy's funding granted to space research and astronomy has been stable at around 3 million euros annually. In addition to that, Professor Kalevi Mursula's *Solar Long-Term Variability and Effects* is in the 2014–2019 Centre of Excellence programme. Membership fees to international organizations (ESO, NOT and EISCAT) total some 3 million euros annually.

Contact details: Dr Kati Sulonen
Academy of Finland, PO Box 131
FI-00531 Helsinki, Finland
+358 295 335 110
kati.sulonen@aka.fi
www.aka.fi

National Committee of COSPAR

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. In addition to bi-annual reports provided to the Council at the General Assemblies, the Committee organizes national FinCOSPAR Meetings in years between the international general assemblies. The latest national meeting was held in August 2015 in Sodankylä in Northern Finland.

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 members of the committee are:

Tuija Pulkkinen, Aalto University, Chair
Marku Alho, Aalto University, Secretary
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
Martin Vermeer Aalto University

Space Programmes with Finnish Involvement

Memberships in International Space Organizations

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.

Finland has formal collaboration agreements with several international space organizations

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

European Space Agency (ESA)

Science Programme

Launch Programme and Finnish participation

1995 SOHO, ESA Solar and Heliospheric Observatory
SWAN and ERNE instruments
1997 Huygens, ESA descent module to Titan in the NASA/ESA Cassini/Huygens mission
HASI instrument; ESA funded radar altimeter
1999 XMM-Newton, ESA X-ray mission
Telescope structure and satellite electronics
2000 Cluster / Cluster-2, ESA 4-spacecraft magnetospheric mission
EFW instruments; satellite power system electronics units
2002 Integral, ESA gamma-ray mission
JEM-X instrument
2002 SMART-1, ESA Moon mission
XSM and SPEDE instruments
2003 Mars Express, ESA Mars mission
ASPERA-3 instrument, participation in Beagle-2-lander; satellite power electronics
2004 Rosetta ESA cometary mission
COSIMA, PP, MIP instruments and lander CDMS; satellite structure and power electronics
2005 Venus Express, ESA Venus mission
ASPERA-4 instrument participation; power distribution units for spacecraft
2009 Herschel/Planck, ESA infrared and cosmic mission
LFI microwave receivers onboard Planck; mirror polishing for Herschel, onboard software for both
2012 Galileo IOV
Electronics for two navigation satellites
2013 GAIA, SA Galaxy mapping mission
Electronics and software
2015 LISA Pathfinder, ESA test mission for gravity wave observations
Solar array structures
2018 BepiColombo, ESA/JAXA mission to Mercury
PI of SIXS, participation in MIXS (X-ray instruments), participation in SERENA particle instrument.
2018 Solar Orbiter, ESA solar mission
Power control electronics
2020 Euclid, ESA dark energy mission data analysis
(Ground) systems

Earth Observation Envelope Programme

Launch Programme and Finnish participation

1986 EOPP
Earth Observation technology programme
1998 EOEP
Earth Observation Envelope Programme developing scientific Earth observation satellites
2001 Earth Watch, GMES
Global Monitoring of Environment and Security (ESA-EU collaboration) Sentinels 1-5 missions
2001 Earth Watch, Infoterra/TerraSAR
Synthetic Aperture Radar mission development programme
2002 ENVISAT-1, ESA environment mission
Software and hardware for GOMOS observation instrument
2002 Meteosat Second Generation (MSG-1)
Software for the satellite platform, hardware for the SEVIRI observation instrument
2006, METOP-A, -B and -C
2010, ESA/EUMETSAT polar orbit weather satellite series
2015 GOME-2 instrument electronics and satellite bus S/W development
2009 GOCE, ESA Gravity Field and Steady-State Ocean Circulation Mission
Onboard software
2009 SMOS , ESA Soil Moisture and Ocean Salinity
Radiometer modules, aircraft campaigns for reference measurements
2010 Cryosat-2, ESA Radar altimetry mission
Secondary structures
2013 SWARM, ESA Earth magnetic field measurement mission
Power distribution unit
2015 Sentinel 2 (ESA and EU)
Electronics
2015 ADM-Aeolus, ESA Atmospheric Dynamics Mission
Instrument electronics
2016 Sentinel 1 (ESA and EU)
SAR-radar
2016 Sentinel 3 (ESA and EU)
Solar array structures

Telecommunication Programmes

Schedule Programme and Finnish participation

1993 ARTES 1
System analysis and market surveys
1994 ARTES 5
Telecommunication systems and equipment technology programme
1998 ARTES 9
Galileo satellite navigation system development
2002 ARTES 8
Large platform development, telecommunications satellite programme (AlphaBus)
2006 ARTES 11
Small geostationary orbit telecommunications satellite development programme
2009 ARTES 20
Integrated Application Promotion, applications related to e.g. the Baltic Sea
2012 ARTES 14
NEOSAT geostationary orbit telecommunications satellite development programme

Technology Programmes

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.

ESA GSP, TRP and CPT 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 space missions. The projects are often studies by spacecraft prime contractors, leaving smaller players only few such projects. In TRP Finnish companies have recently developed e.g. radiometers and radio altimeters.

ESA General Support Technology Programme (GSTP) is an a-la-carte technology programme that develops many technologies, even spin-outs from space technologies for everyday use. Projects aim at technology readiness levels (TRL) 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) is the family of satellite telecommunications programmes. Its many sub-programmes develop 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) 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 2012. ARTES 5 has demonstrated its usefulness e.g. in the field of composite structures.

ESA's European GNSS Evolution Programme (EGEP) develops satellite navigation technologies. To large degree it focuses on next generation flight segment of Galileo and EGNOS but also targets science and applications of Global Satellite Navigation System. University of Oulu 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's Earth Observation Programme 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) programme 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. the Polarview project.

European Southern Observatory (ESO)

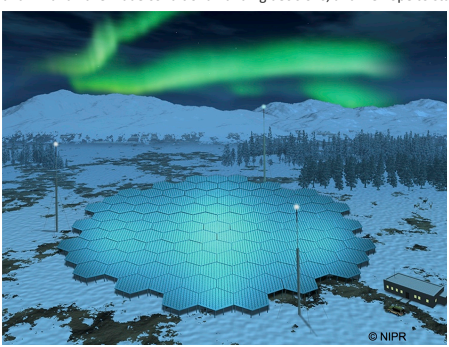
The European Southern Observatory (ESO) is the pre-eminent intergovernmental science and technology organization in astronomy. ESO operates three unique world-class observing sites in the Atacama Desert region of Chile, La Silla, Paranal and Chajnantor. La Silla is equipped with several optical telescopes with mirror diameters of up to 3.6 meters. The Paranal site with the Very Large Telescope array (VLT), the flagship facility of European astronomy, is an array of four telescopes each with a main mirror of 8.2 meters in diameter. The Atacama Large Millimeter/submillimeter Array (ALMA) comprises an array of 66 12-meter and 7-meter diameter antennas. The next step beyond the VLT is to build the European Extremely Large optical/infrared Telescope (E-ELT) with a 39-meter primary mirror and planned start of operations in 2024.

The Finnish Centre for Astronomy with ESO (FINCA) carries out and co-ordinates Finnish high quality research in fields of astronomy with European Southern Observatory (ESO) and promotes technological development work related to ESO. FINCA participates in research training and promotes co-operation of Finnish universities in astronomy. FINCA members are Aalto University, University of Helsinki, University of Oulu, and University of Turku. FINCA researchers actively apply for observing time at ESO instrumentation, and receive it roughly in proportion of the Finnish participation in the program.

European Incoherent Scatter Radar (EISCAT)

Finland is a member in the European Incoherent Scatter Scientific Association (EISCAT), which has been established to conduct research in the terrestrial atmosphere and ionosphere by using the incoherent scatter radar technique. Other associates are Norway, Sweden, UK, Japan and China, and affiliates are Russia, France, South Korea and Ukraine. The radar facilities are located in Tromsø, Kiruna, Sodankylä and on Svalbard. During 2014-2016 Finnish scientists made several measurement campaigns in international collaboration e.g. for the following purposes: optical auroral tomography, energy transfer from the magnetosphere to the ionosphere, D-region heating and cooling, atmospheric gravity waves, interplanetary planetary scintillation (IPS) by the solar wind, pulsating aurora, development of quadriphase-coded incoherent scatter experiments, validation for beacon satellite tomography (LEO/TomoScand), and coordination with ESA's SWARM satellite measurements for investigating ionospheric electrodynamics. All the measurement campaigns have utilized the extensive space physics related ground-based measurement networks in Finland.

Finnish EISCAT community has actively taken part in planning and designing the next-generation incoherent scatter radar, EISCAT_3D, which will be realized by using phased array techniques. The radar will have a transmitter/receiver in Norway (Skibotn), and two receiver sites in Finland (Karesuvanto) and Sweden (Kiruna). The key concepts of the facility are volumetric vector measurements, great flexibility, altitude coverage from the upper troposphere to the base of the magnetosphere, and continuous measurements. Norway, Sweden and Finland have made conditional funding decisions, and we hope to start constructing the radars in 2017.



European Meteorological Satellite Organization (EUMETSAT)

EUMETSAT is a global operational satellite agency with the purpose to gather accurate and reliable satellite data on weather, climate and the environment and to deliver them to members, international partners, and to users around the world. Finland became a member of the organization in 1986.

International Satellite System for Search and Rescue (COSPAS-SARSAT)

The International COSPAS-SARSAT Programme is a satellite-based search and rescue distress alert detection and information distribution system, best known for detecting and locating emergency beacons activated by aircraft, ships and backcountry hikers in distress. Finland became a member of the programme in 2010.

European Union

European Commission Framework Programme, Environment programme and European Research Council fund remote sensing and space research.

Finland has received three ERC grants focused on space research and astronomy.

Finland participates in all large GMES projects such as MACC (atmosphere), MyOcean and Geoland that will become Copernicus core services during 2014-2020.

The FP7 had a dedicated Special Programme for Space funding space science, satellite remote sensing and satellite technology development. Finland won 44 projects for proposals in space theme, leading 9 projects.

The Horizon 2020 programme started on 11 December 2013. FINNISH SUCCESS IN H2020 CALLS

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

Launch Programme and Finnish participation

1988 Phobos, Soviet mission to Mars and Phobos, USSR, SE, D
Electronics for ASPERA instrument and test system for LIMA-D instrument
1992 Freja, Swedish magnetosphere mission, SE
Plasma and wave instruments
1995 Astrid-1, Swedish microsatellite, SE
Instrument electronics
1995, Interball Soviet/Russian magnetosphere mission, USSR/RUS, SE
1996 Electronics for Promics-3 instrument
1996 Polar, NASA magnetosphere mission, USA
Mechanisms for EFI instrument
1996 Mars-96 Russian Mars mission, RUS
(failed) Central electronics units, sensors and software for two landers
1997 Cassini NASA Saturn mission, USA
Hardware for IBS, CAPS and LEMS instruments
1998 Space Shuttle USA
AMS instrument
1999 Stardust, NASA heliospheric mission, USA
CIDA instrument
1999 Mars Polar Lander, NASA Mars mission, USA
(failed) Pressure instrument
2000 Odin, Swedish-led atmospheric and astronomy mission, SE, F, CAN
119 GHz receiver and antenna measurements
2004 EOS-Aura, NASA EO mission, USA
OMI instrument
2008 Phoenix NASA Mars lander USA, CAN
Pressure instrument
2007, TWINS, NASA magnetosphere mission, USA
2008 Scanning mechanisms for TWINS instruments
2007, TerraSAR-X and Tamdem-X, German EO mission, Germany
2010 Leaf amplifiers for the SAR-radars

2008 Chandrayaan-1 Indian Moon mission, India, UK
XSM-instrument
2011 Mars Science Laboratory USA, E
Pressure and humidity instruments
2016 Mars MetNet Precursor Mission, RUS, E
Novel landing station(s) onboard Phobos Grunt
2018 BepiColombo MMO, JAXA part of the ESA/JAXA Mercury mission, Japan
Participation in MEFISTO-instrument

Finnish Space Research

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.

In order to foster the backbone basic research, the Academy of Finland has 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. In addition, Finland leads an international consortium (MIRACLE - magnetometers, ionospheric radars and all-sky cameras large experiment) focusing on monitoring of ionospheric 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) acts as a national research and coordination body for astronomers, and the Metsähovi Radio Observatory is part of wide international VLBI measurement networks.

Aalto University

Aalto University
PO Box 13000, FI-00076 Aalto, Finland www.aalto.fi/en

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 and Earth space environments, Earth observation by remote sensing methods, and small satellite technologies. Aalto-ENG covers GPS techniques, photogrammetry and remote sensing. Aalto-SCI activities focus on solar and stellar dynamo processes and development of related numerical methods and tools.

In the past two years, three new professors have been recruited and two new Academy of Finland -funded Centers of Excellence started operation. Renewal of faculty has strengthened earlier research areas and expanded activities to cover new fields; further recruitments are expected to compensate retirements. Aalto MSc and PhD majors offer a full curriculum in space science and technology, and as such are unique in Finland.

Aalto space activities are nationally and internationally networked. Nationally key partners are the Kumpula Space Centre (KSC) comprising Aalto, the University of Helsinki and the Finnish Meteorological Institute, and the Finnish Centre for Astronomy with ESO (FINCA) together with Universities of Turku, Helsinki and Oulu. Internationally, the ESA and ESO offer key facilities and collaboration opportunities.

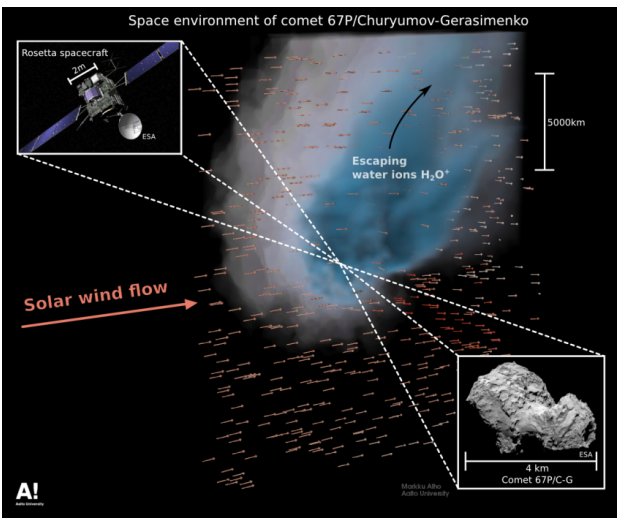
The Metsähovi Radio Observatory hosts several radio telescopes dedicated to radio astronomical measurements. The largest telescope (14 meters), previously used for coordinated observations with ESA's Planck mission, focuses on long time series of active galaxy variability and solar activity. It is also used in several networks to make high-resolution VLBI observations and dedicated geodetic VLBI measurements, as well as for high-precision tracking of spacecraft. Smaller telescopes are dedicated to solar monitoring.

Space science has enhanced significantly as two new professors focus on planetary and terrestrial space environment. Furthermore, a new Center of Excellence on solar long-term variability and effects started with Aalto as a partner. The nanosatellite technologies are developed in two CubeSat missions Aalto-1 and Aalto-2, of which the first is scheduled for launch in mid-2016. While the first spinoff aiming for commercial services in the Arctic region is already active, the aim is to continue the student satellite program to continuously 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, especially phenomena typical of the northern boreal forest and sea ice. The photogrammetry and remote sensing activities cover 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. Aalto is also part of the Academy of Finland Center of Excellence in Laser Scanning Research.

Escaping water ions from the comet 67P/CG observed by Rosetta spacecraft

ESA's Rosetta mission has provided unique observations about the comet 67P/Churyumov-Gerasimenko. Aalto team has developed a comprehensive 3D numerical space plasma model, which enables studies of cometary space plasma environment and its response to varying solar wind conditions. Especially, the team evaluated the atmospheric loss rate of the 67P/CG and its dependence on the distance from the Sun. The team has also used the same model to study space weather at Mercury, Venus, Earth, the Moon, Mars and asteroids.



Numerical simulation and figure by Aalto University.
See: https://www.youtube.com/watch?v=LsdmH3RB_kA

Metsähovi Compact Array under construction

Metsähovi began the construction of the first radio-astronomical interferometer, the Metsähovi Compact Array, consisting of four 6-metre radio telescopes. The first telescope, MCA-1, was erected in late 2015, and will see its “first light” in 2016.

Finnish Environment Institute (SYKE)

Finnish Environment Institute
PO Box 140, FI-00251 Helsinki, Finland www.syke.fi/en-US

Finnish Environment Institute SYKE is both a research institute, and a center 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 center 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, harmonizes and develops SYKE international reporting, and deals with other centralized aspects of data management. In addition, the center is responsible for the development of the Finnish Environmental Administration 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, land 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.

Finnish Meteorological Institute (FMI)

Finnish Meteorological Institute
PO Box 501, FI-00101 Helsinki, Finland www.fmi.fi

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.

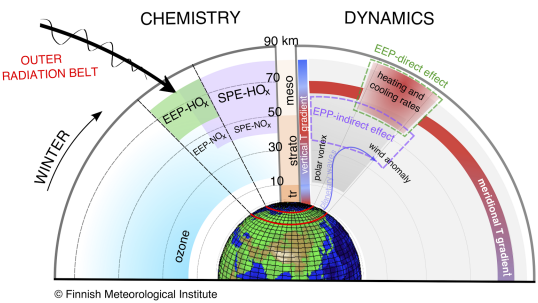
In the Arctic Research Centre in Sodankylä, significant infrastructure upgrades have raised the site to become one of the foremost satellite calibration and validation (cal/val) areas in northern regions, with a particular capability to assist cal/val activities for cryosphere studies.

Advancement in understanding effects of solar electron precipitation on atmosphere and regional climate

Led by scientists from the Finnish Meteorological Institute, a study based on satellite observations has shown that upper middle atmospheric ozone is varying significantly, by more than 30%, over the 11-year solar activity cycle. The ozone variation occurs in the wintertime polar region, is caused by electron precipitation from space, and is driven by solar activity. The wider implications of such ozone changes come from a proposed connection to ground-level polar weather systems and wintertime climate in Europe.

High solar activity means more electron precipitation and less polar ozone. Ozone changes affect the middle atmospheric dynamics (e.g. the polar vortex). Over wintertime, these perturbations can propagate from higher altitudes towards the ground level and make mild and moist winters in Northern Europe more likely. And when solar activity is low, colder and drier winters can be expected. So far, correlation between electron precipitation and ground-level temperature anomalies indicates this, but the full details of the atmospheric connection mechanisms are not understood yet.

On-going, leading research at FMI now aims to better understand the connection mechanisms between solar-driven electron precipitation and regional climate. Important part of the work is the development and utilization of an entire atmosphere chemistry-climate model, to represent adequately the temporal and spatial variability of electron forcing and the connection between middle atmosphere ozone changes and ground-level climate. The work on this topic at FMI is, and has been, possible due to long-term funding from the Academy of Finland. Essential have been the satellite observations of middle atmospheric composition from instruments such as GOMOS (Global Ozone Monitoring by Occultation of Stars), development of which has been supported in Finland by Tekes for many years.



A schematic view of the connection between electron precipitation (EEP) from the outer radiation belt, atmospheric chemistry (HOx = odd hydrogen, NOx = odd nitrogen, ozone), and atmospheric dynamics (heating/cooling, temperature gradients, winds, wave propagation, polar vortex). SPE = solar proton event. EPP-indirect effect refers to the stratospheric ozone changes caused by descent of precipitation-produced NOx from higher altitudes.

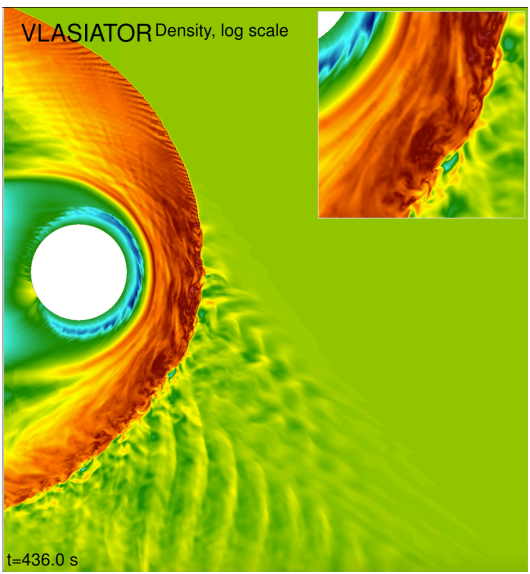
Reference: Andersson, et al., Nature Commun., 5:5197, http://dx.doi.org/10.1038/ncomms6197, 2014.

A major grant towards 6D hybrid-Vlasov simulations of the Earth's magnetosphere

A much competed-for ERC consolidator grant of 2 M€ was awarded to Minna Palmroth to develop the flagship model Vlasiator and make the first global magnetospheric simulations using the hybrid-Vlasov method in full three spatial and three velocity dimensions possible within the next five years. The project Plasma REconnection, Shocks and Turbulence In Solar System Interactions: Modelling and Observations (PRESTISSIMO) will tackle questions at the forefront of space physics and further the understanding of solar-terrestrial physics. This grant will significantly strengthen the position of FMI as an internationally recognized player in the field of global-scale space plasma simulations and follows the ERC starting grant awarded in 2007 to Minna Palmroth. Palmroth is the first space researcher in Finland ever to receive both a Starting- and Consolidator Grant. Key national and international collaborators of the Prestissimo team include Prof. Rami Vainio (U. Turku), Dr. Heli Hietala (UCLA, USA), Dr. Jonathan Eastwood (Imperial College London, UK), Dr. David Sibeck (NASA/GSFC, USA) and Dr. Markus Battarbee (U. Central Lancashire, UK).

The high quality of the model especially in the representation of the ion velocity distribution function is a major step forward in magnetospheric physics and has already allowed to solve long-standing open questions such as the oblique propagation of foreshock ULF waves, which has been observed by spacecraft and known for years, but not properly explained theoretically. Planned evolutions on the physics side are among others the inclusion of more ion species such as helium and oxygen into the model and the possibility to use test electrons to trace their behavior in the magnetosphere. This will not only allow to address key topics in space plasma physics like magnetic reconnection, collisionless shocks, ion and electron acceleration, but also shed light into magnetosheath, magnetopause, inner magnetosphere and magnetotail processes as well as their coupling between each other, to the solar wind and to the ionosphere. The gained insights will profit the space physics and space weather communities at large.

The concurrent development of the code and available supercomputing facilities for research will enable the team at FMI to reach the set scientific goals. Although Vlasiator has recently been shown to scale very well up to more than 98,000 processors on one of Europe's largest supercomputers, the Cray XC40 "Hazel Hen" at the Highest-power supercomputing center (HLRS) in Stuttgart, Germany, this is still not enough to extend the currently two spatial dimensions to the full three-dimensional magnetosphere. Indeed, state-of-the computing techniques will need to complement significant algorithmic improvements such as physics-based optimization of the load balancing and the time stepping as well as adaptive mesh refinement in position and velocity space. Close collaboration and common computational research and development projects with experts at CSC and major companies such as Cray and Intel will also be instrumental in making full six-dimensional magnetosphere simulations reality.



A frame extracted from the Vlasiator simulation illustrating solar wind interaction with the magnetosphere. Earth is at the center of the white area excluded from the simulation.

National Land Survey of Finland (NLS)

Finnish Geospatial Research Institute
PO Box 15, FI-02431 Masala, Finland www.fgi.fi

The Finnish Geodetic institute (FGI) was merged into the National Land Survey of Finland 1.1.2015, with the new name Finnish Geospatial Research Institute (FGI). The Finnish Geospatial Research Institute (FGI) is a research and expert institute that carries out research and development for spatial data infrastructures. The FGI provides a scientific basis for Finnish maps, geospatial information and positioning and carries out research and development on methods for the measurements, data acquisition, processing and exploiting of geospatial information.

The strategic research areas of the Finnish Geodetic Institute are reference systems, mobile geomatics, spatial data infrastructures, and changing Earth.

Renewal of Metsähovi Geodetic Fundamental Station

Metsähovi is the fundamental station for the reference, height and gravity systems in Finland and a part of global network of geodetic core stations within the Global Geodetic Observing System (GGOS). It is one of the few stations in the world having all major space geodetic observing techniques at the same site: Satellite Laser Ranging (SLR) system, GNSS receivers, French DORIS beacon, geodetic Very Long Baseline Interferometry (VLBI) system, in addition to several gravity instruments. Being one of the northernmost stations, it contributes to several global services of the International Association of Geodesy (IAG). In 2012, the renewal of the Metsähovi station was initiated with special funding from the Ministry of Agriculture and Forestry. During 2014-2015, the station upgrade focused on building a new SLR system. Metsähovi SLR has been used for high-accuracy satellite positions since 1978. Due to the increasing demands for e.g. GNSS satellite tracking and following the recommendation by the Satellite Laser Ranging Service (ILRS), a modern kHz-capable SLR system is being built. The new system includes a fast 0.5m bistatic telescope with a 2kHz laser as the light source housed in a modern observatory building with an automated dome. Final system integrations take place in 2016 with first light expected by 2017. In 2014 preparations were also started for a new geodetic VLBI system at Metsähovi to be in compliance with the VLBI Global Observing System (VGOS) concept and become a part of the international VGOS network. Late 2015 NLS initiated the procurement process for purchasing a 12-14 m radio telescope, and the Metsähovi VGOS system is planned to be fully operational by 2019.

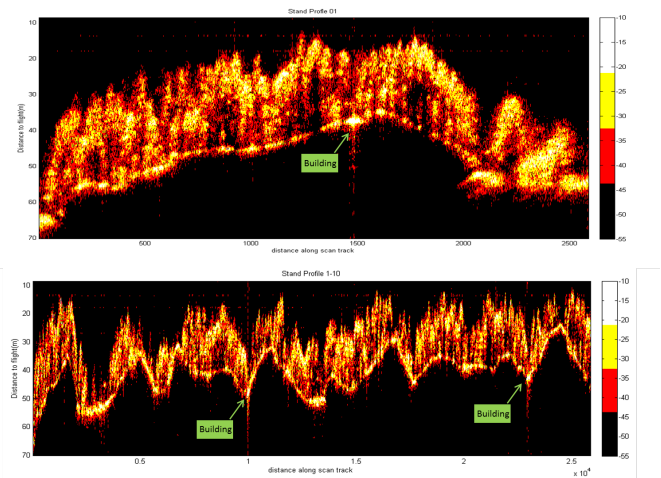
FGI performs various research related to the abovementioned space geodetic techniques. The performance capabilities of the upcoming SLR system for space-debris ranging have been simulated. New GNSS receivers at Metsähovi allow tracking of all navigation satellite systems. Research on GNSS antenna calibration and metrologically traceable distance measurement was carried out using a novel GNSS antenna test field at Metsähovi. The aim is to develop automated local tie measurements between the major instruments at Metsähovi with a traceable scale down to 1 mm accuracy.

Remote Sensing and Laser Scanning

FGI coordinates FP7 project Advanced_SAR. The S&T objectives of the project are: 1) to develop advanced Earth Observation methods by combining 3D data derived from various Remote Sensing systems in an novel way and 2) to show their improved performances in forest biomass estimation and biomass change detection with respect to present GMES services. The methodology is based on object-based, multi-date analysis of Sentinel-1 (C-band), TerraSAR/TanDEM-X (X-band), ALOS-2 PALSAR-2 (L-band) SAR data utilizing radargrammetry and InSAR. This project will increase our understanding of the 3D forest responses through comparing results to other modern 3D methods: optical satellite stereo-photogrammetry, simulated space-borne LiDAR, and Airborne Laser Scanning (ALS). We will demonstrate that high-quality estimation and change detection can be done at different scales (thus improving estimation accuracy at national level). We develop methods to derive the best possible cost-efficiency out of the given SAR data with an aim to significantly advance current GMES services. The methodological quality will be verified by comparing the relationship between SAR canopy height estimates with those of two probing systems: TomoRadar (profiling radar) and ALS. ALS gives more information of canopy gaps whereas TomoRadar will give information of canopy penetration at radar frequencies. A physical model is created between the SAR response and the ground truth. Deep physical understanding of where the radar signals originate in the vertical dimension is created for SAR scenes using ALS and TomoRadar data as a high-quality reference. Moreover, Mobile and Terrestrial Laser Scanning methods for field inventory are tested in real-life scenario. Two super test sites 1) boreal test site Evo (Finland) and 2) hemi-boreal test site Remningstorp (Sweden) are used to verify and demonstrate SAR-based 3D methods. For demonstration purposes, we create SAR-based biomass and change maps covering a large region of Sweden for Swedish National Forest Inventory. Tomoradar is FGI-developed SAR tomography simulator based on forest canopy profiles, as shown in the figure.

Finnish Geospatial Research Institute (FGI), University of Oulu (UO), Aalto University (Aalto) and University of Turku (UTU) and foreign universities (from Japan, Europe, USA, Canada) collaborate in FGI-lead Academy STN project COMBAT dealing with a) Intelligent Digitized Cities, b) Improving Digitalization of 3D Forests, and c) Novel Corridor (e.g. roads, power lines, waterways, railways) Technologies. Technology partners have leading knowledge in 3D & laser scanning, automation and robotics, and image processing/computing having references/knowledge from such as Centre of Excellence in Laser Scanning Research (2014-2019) and Centre of Excellence in Generic Intelligent Machines (2009-2014), and several of the best cited science papers in computing in Finland. The project conduct can be followed from @pointcloudfi and www.pointcloud.fi.

FGI leads the Centre of Excellence in Laser Scanning Research, www.laserscanning.fi. More than 30 PhDs from FGI, University of Oulu, University of Helsinki and Aalto University aim to create new knowledge, science, openings and breakthroughs in the emerging field of Laser Scanning by integrating the full complementary technology chain of laser scanning inside the Center of Excellence: hardware electronics, system integration, positioning technologies, information extraction/data processing, applications and visualization, even in the 3D game engine of smartphones. Research is directed with a process based on three research directions and continuous brainstorming of new ideas and openings, utilizing the full knowledge chain.



FM-CW radar for simulating future space-borne missions. The system is also benchmarked against other lidar and radar systems in FGI permanent test fields.

Natural Resources Institute Finland (LUKE)

The Natural Resources Institute Finland
Viikinkaari 4, FI-00790 Helsinki, Finland www.luke.fi/en

Researchers and specialists working at Luke provide new solutions towards the sustainable development of the Finnish bioeconomy and the promotion of new biobased businesses. Together with its partners, Luke will build a society based on bioeconomy. The National Forest Inventory (NFI) is one example of official duties of Luke. NFI has produced large-area forest resource information for about 90 years. Since late 1980's, the NFI has utilized a 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 analyzing 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.

University of Helsinki

University of Helsinki
POBox 64, FI-00101 Helsinki, Finland www.physics.helsinki.fi/

Space research at the University of Helsinki is mostly the responsibility of the Department of Physics. We also have some remote sensing activities at the Department of Geosciences and Geography. The multidisciplinary environment includes materials researchers involved in planetary geophysics, and the particle physics and astrophysics community include a continuum from particle cosmology, observational cosmology, astrophysics and space environments of the Earth and planets. Space activities comprise 50 FTE, of which 40 FTE in astronomy and space physics. We produce annually about 100 peer-reviewed articles. Year 2014 was productive with about 120 publications owing to the peak of publications from the ESA Planck mission.

Two most important national organizational frameworks are the Finnish Centre for Astronomy with ESO (FINCA) and the Kumpula Space Centre in collaboration with the Finnish Meteorological Institute and the School of Electrical Engineering of Aalto University. In planetary research we have active co-operation with the Finnish Geospatial Institute (FGI) of the National Land Survey of Finland.

While strategic focus is in ESA and ESO activities, research utilizes observations from a variety of international observatories and spacecraft through collaboration and utilizing open databases. Particularly in training of new generation of space researchers, smaller-scale facilities are very useful, one important tool being the Nordic Optical Telescope. We have also contributed to Aalto University's student satellite Aalto-1's radiation monitor in collaboration with University of Turku and plasma brake in collaboration with FMI.

The our research activities include interstellar medium and star formation, extragalactic astrophysics, cosmology, stellar astrophysics solar activity and its consequences on planetary environments, terrestrial planets and small solar system bodies, as well as planetary geophysics.

In 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 modeling to compare with the observations. We also study high-energy phenomena in Clusters of Galaxies an in the Sun using guest observer time for large space observatories like the XMM-Newton, Chandra and Suzaku. Our research in cosmology forms a seamless continuum from theoretical particle cosmology to space-based utilization of Planck observations where our team has contributed to the core of data analysis of cosmic microwave background observations. In space physics, our emphasis is on Solar-Terrestrial relations, in particular, on solar 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 magnetospheres of solar system bodies.

Our major contributions to future space missions are the Solar Intensity X-ray and particle Spectrometer (SIXS) onboard ESA's Mercury mission BepiColombo to be launched in 2018 and the participation in the Science Ground Segment of ESA's dark energy mission Euclid, to be launched in 2020.

International conference "Asteroids, Comets, Meteors 2014"

We organized the international conference "Asteroids, Comets, Meteors 2014" in Helsinki in 2014 with some 500 participants from over 40 countries. According to the participant feedback, a new scientific and organizational standard was set for the ACM conferences regularly held since 1983. The meeting focused on Solar System bodies, which are key to understanding the formation and evolution of the Solar System, carrying signals from pre-solar times. Understanding the evolution of the Solar System helps unveil the evolution of extra-solar planetary systems. Societally, small bodies will be important future resources of minerals. The near-Earth population of small bodies continues to pose an impact hazard, whether it be small pieces of falling meteorites or larger asteroids or cometary nuclei capable of causing global environmental effects.

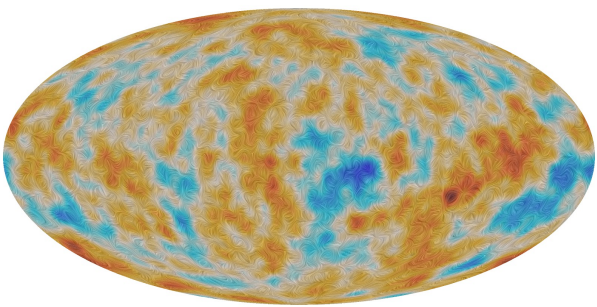
Group photo of ACM 2014 participants

Meteor tracking

Meteor trajectory and orbit research done jointly with FGI resulted in the successful recovery of meteorites from a fireball observed over Kola Peninsula on April 19, 2014, by a joint Finnish-Russian expedition within an area between the city of Murmansk and the Finnish border. The meteorites bear the name of the nearby Annama river and are classified as H5 ordinary chondrites.

Exploiting the Planck observations: Cosmic microwave background

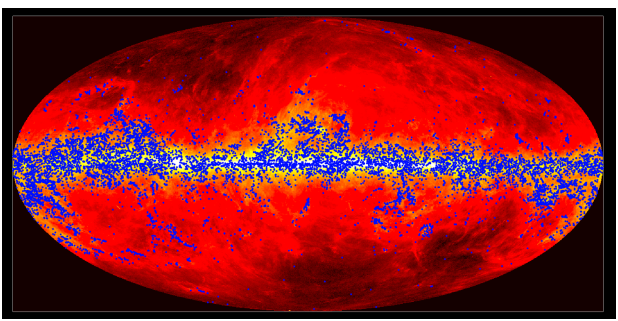
2014 – 2015 has been a rich harvest time of our decade-long effort put in the extensive data analysis software and map-making tools of the Cosmic Microwave Background from Planck observations. Here we present two recent results where our team has had a key role



The large-scale cosmic microwave background anisotropy and polarization as measured by Planck. The map has been smoothed to show structiures larger than 5 degrees on the sky. The colour scale represents temperature differences in the CMB, while the texture indicates the direction of the polarised light. The patterns seen in the texture are characteristic of 'E-mode' polarisation, which is the dominant type for the CMB. Credit: ESA and the Planck Collaboration.

Exploiting the Planck observations: Interstellar matter

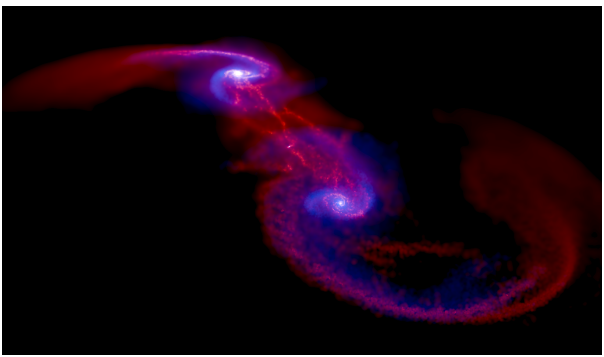
In research on physical and chemical composition of interstellar matter and the formation of new stars in the Milky Way the emphasis was on the interpretation of data from the recent Planck and Herschel satellite missions.



The Planck Catalogue of Galactic Cold Clumps (PGCC) was made public in January 2015 (Planck Collaboration, Planck 2015 results XXVIII). The catalogue contains details of over 13000 Galactic clouds that were identified from Planck survey data based on their cold temperature, which is only some 14K above absolute zero. The distribution of these very cold Galactic clouds (in blue) overlaid on the Planck satellite allsky map at 857GHz.

Theoretical research on extragalactic dynamics

In theoretical extragalactic research we study the formation and evolution of galaxies using both numerical simulations performed on high-performance computing facilities and analytical calculations. During 2014-2015 the main focus of the research group has been on the supermassive black holes, which reside at the centers of galaxies. We have studied their formation at high redshifts, the accurate modeling of their dynamics at lower redshifts and analytically the expected accretion disc impacts in binary black hole systems.



Output from a numerical simulation of a merger between two gas-rich disk galaxies right after the two galaxies have passed their first pericenter. The smoothed gas density is shown in red and the smoothed stellar component is shown in blue. In the simulation we see the formation of tidal dwarf features as clump-like stellar concentrations both in the overlap region between the galaxies and in their respective tidal arms. (Lahén, Johansson et al., 2016 in prep)

Extreme space weather

In the field of space physics high-lights of 2014-2015 were the analysis of extreme storms, in particular the super-solar storm of July 2012 (published in Nature Communications), establishment of a new framework for studying dramatic variations in the Van Allen radiation belts, and the launch of our own heliospheric shock database (ipshocks.fi).

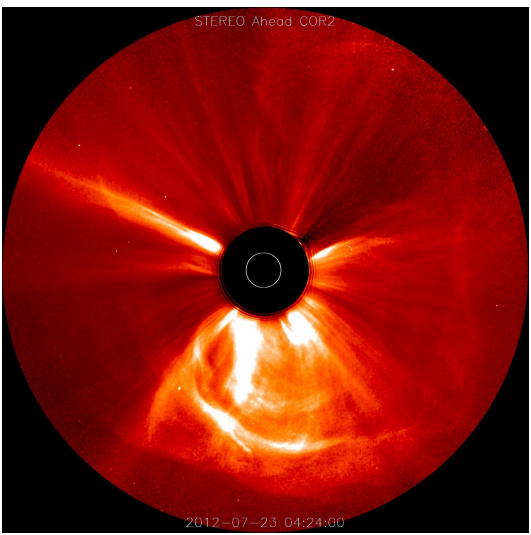


Figure (stereo_120723.jpeg): Merging of two powerful CMEs on July 23rd, 2012 seen by the twin STEREO spacecraft. These CMEs led to some of the strongest magnetic fields ever recorded near the orbit of the Earth.

University of Oulu

University of Oulu
PO Box 8000, FI-90014 University of Oulu, Finland www.oulu.fi/english

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

Geospace Environment Studies at Sodankylä

The Sodankylä Geophysical Observatory (SGO), located about 120 km north of the Artic circle and 350 km from Oulu, conducts geophysical measurements of the ionosphere, atmosphere, magnetosphere, and solid Earth at 20 different locations in Finland, Sweden, Norway, and Svalbard. The data archive spanning more than 100 years allows studying the long-term evolution of the geospace environment. The 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. SGO has been granted 2,5 million euro of infrastructure funds from the Academy of Finland for the construction of the EISCAT_3D site in Karesuvanto, Finland. These funds are part of a 12,8 million euro allocation of funds by the Academy for the construction of the large international EISCAT_3D distributed incoherent scatter radar.

University of Turku

University of Turku
FI-20014 University of Turku, Finland www.physics.utu.fi

Tuorla Observatory and FINCA
Väisäläntie 20, 21500 Piikkiö, Finland www.astro.utu.fi www.finca.utu.fi

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 constitutes the largest astronomical institute in Finland. The main areas of research are high-energy astrophysics, active galaxies, supernovae, compact binary stars, cosmology, galaxy formation and evolution, and solar system research. 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. Alpha magnetic spectrometer (AMS-02) on-board the International Space Station and Energetic and Relativistic Nuclei and Electron experiment (ERNE) on-board Solar and Heliospheric Observatory (SOHO) are the present SRL experiments delivering data. SRL participates also in future ESA missions: Solar Intensity X-ray and particle Spectrometer (SIXS) on-board ESA's BepiColombo mission will be launched in 2018 and Turbulence Heating ObserveR (THOR), pending on final selection by ESA, in 2026. Experimental research is supported by numerical model development on energetic particle transport and acceleration in turbulent plasmas and shocks.

Light black hole challenges supernova explosion models

Compact objects such as black holes and neutron stars are the end point of massive star evolution. Most of them are thought to have been formed in supernova explosions due to the collapse of the massive stellar core. It is expected that the masses of the resultant compact remnants correlate with the masses of their progenitor stars, which have a smooth distribution in the range from the heaviest to the lightest stars. Surprisingly, the observed distribution of compact object masses seems to have a gap in the range between 2 to 5 solar masses. This gap, whose existence in the current sample of the mass measurements was fairly well established, has become a significant challenge to our understanding of compact object formation. However, the existence of the gap has been brought into question by the detailed spectroscopic observations of SWIFT J1753.5-0127 which exhibits properties typical for the black hole X-ray binary (Neustroev V. et al. 2014, MNRAS, 445, 2424). It was shown that it hosts one of the smallest stellar-mass black hole found to date, with the mass below 4 solar masses. The presence or absence of the mass gap is a critical clue in understanding the formation of neutron stars and black holes and the engine behind supernova explosions. The result of the paper supports the possibility of existence of compact objects in the mass gap. This conclusion greatly limits the formation scenarios. For instance, in the rapid supernova explosion mechanisms, it is not possible to produce the compact objects with masses 3–5 solar masses, even accounting for the binary evolution effects. The black hole in SWIFT J1753.5-0127 can either be produced in the delayed explosion or be the result of the accretion-induced collapse of a neutron star.

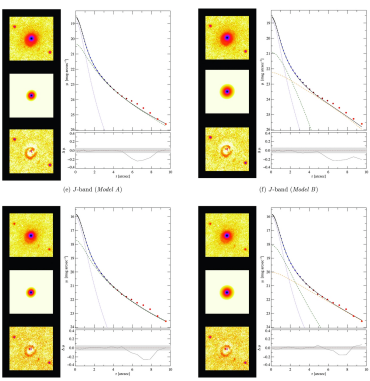
X-ray pulsars as ultra-luminous X-ray sources

Some of accreting strongly magnetized neutron stars, aka X-ray pulsars, show strong absorption-like lines in their X-ray spectra associated with the cyclotron harmonics, which can be used to directly measure the magnetic field strength in these stars (typically B=1012–1013 G). In spite of the fact that these objects have been studied for more than 40 years, new advances are still possible thanks to the more sensitive X-ray telescopes having flexible schedule and/or to the telescopes with the large field of view (such as RXTE and INTEGRAL). It was only recently realized that the energy of these lines varies with the source luminosity, being positively correlated at low luminosities and anti-correlated at high luminosities. The understanding of the physics behind this strange behavior was missing. Theory explaining the observed behavior was developed in a set of papers by Mushtukov A.A. et al. at Tuorla observatory. Radiation pressure from the X-rays produced by the infalling material is playing an important role affecting the structure of the accretion column and the velocity of the gas. At extremely high accretion rates, it was shown that the pulsar luminosity can greatly exceed the classical Eddington limit because of the geometry and because of the reduction of the scattering cross-section in strong B-field. This theory provided support to the interpretation of the recently discovered pulsating ultraluminous X-ray source in the galaxy M82 as an accreting magnetar with B=1014 G.

Artist impression of the complicated physics involved in the production of X-rays from accreting magnetized neutron stars. From the PhD thesis of Mushtukov A.A. (2015, Univ. of Turku). For a more scientific approach, see Mushtukov A.A. et al. 2015, MNRAS, 447, 1847; 2015, MNRAS, 454, 2539; 2015, MNRAS, 454, 2714.

Gamma-ray loud active galaxies

Narrow-line Seyfert 1s (NLSy1) are commonly hosted by spiral galaxies with ongoing star formation. The recent detection of high-energy gamma-rays from an increasing number of NLSy1s casts doubts on the paradigm of relativistic jets being only produced in giant elliptical galaxies. Leon-Tavares and Kotilainen (studied the nearest gamma-ray emitting radio-loud narrow-line Seyfert 1 galaxy 1H 0323+342. Near-infrared and optical images were used to reveal the structure of the host galaxy. Based on 2D multi-wavelength surface brightness modeling, the best model for the host galaxy is a spheroid (Sersic profile n~2.8), with suggestion of a disk component (n ~ 1.2). A spiral-arm-like structure in the images is revealed by 2D Fourier analysis to correspond to an asymmetric ring, likely associated with a recent violent dynamical interaction triggering nuclear activity. Similar imaging data of all known gamma-ray emitting NLSy1s is studied to determine their host galaxy morphologies, with implications to relativistic jet production and galaxy evolution.



2D surface-brightness profile decomposition of 1H 0323+342 at J- and Ks-band for bulge model (left) and bulge + disk model (right). Top left: the observed image at each band. Middle left: the host galaxy model. Bottom left: the residual image. Top right: radial profile of 1H 0323+342: observations (circles), model (solid line), PSF (violet), bulge (green) and disk (orange). Bottom right: residuals. From Leon-Tavares et al. 2014, ApJ, 795, 58.

Millimetre Wave Laboratory of Finland (MilliLab)

MillliLab
FIN-02044 VTT, Finland www.millilab.fi

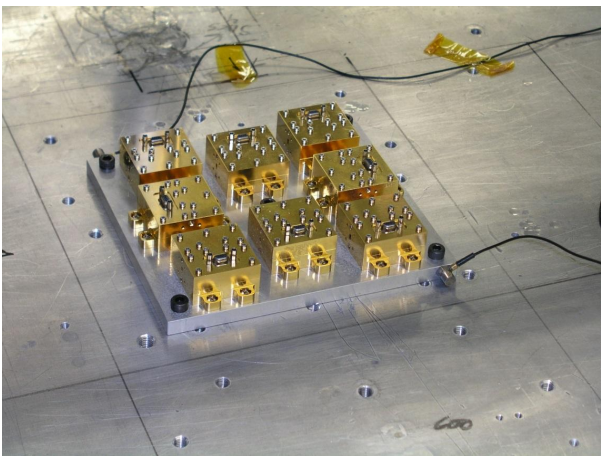
Millimetre Wave Laboratory of Finland – MilliLab, established in 1995, is a joint laboratory between VTT, Technical Research Centre of Finland and Aalto University School of Electrical Engineering. MilliLab is also a European Space Agency Centre of Competence called ESA External Laboratory on Millimetre 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 millimeter wave instruments for astronomical and remote sensing applications.

MilliLab supplies services at millimeter wave frequencies in the field of device modeling, device characterization, measurements, testing, research, and development. The parent organizations of MilliLab, VTT and Aalto University have a substantial amount of experience and expertise in the field of microwave and millimeter wave technology. The total research personnel with experience in millimeter waves is over 40.

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. Preliminary reliability assessment for most promising LNA designs continued in 2014-2015 and is now in its final stage. MilliLab participated also in reliability assessment of Schottky diodes for MetOp-SG instruments above 200 GHz.

In 2014 ESA awarded the main contract of building the MetOp-SG instruments to Airbus. In return, Airbus launched an invitation to tender to sub-contractors to participate in building the instruments in fall 2014. The main three instruments together contain a large number of micro to millimeter wave channels from 23 to 664 GHz. MilliLab participated in the bidding and is currently involved in several channels from 50 GHz upwards in a supporting role. MilliLab's work in MetOp-SG concentrates on activities related to RF performance and reliability testing of the critical LNA and diode components.

As a new activity in general technology development, MilliLab built a passive terahertz imager demonstrator for ESA in 2013. The built terahertz camera produced video rate data at three center frequencies: 250, 450, and 720 GHz. The imager technology was based on bolometer detectors cooled to 4 K. The technology was spinned off to a Finnish company, Asqella Oy, which commercialized the camera in 2014-15 and is now offering it to customers. The technology has applications in safety and security as well as future space missions. Currently the technology development has concentrated more on the first two utilizing other European technology programs outside ESA.



LNA modules under mechanical tests during preliminary reliability assessment for MetOp-SG radiometers.

Radiation Effects Facility (RADEF)

Radiation Effects Facility
PO Box 35, FI-40014 University of Jyväskylä, Finland www.jyu.fi/fysiikka/en/research/accelerator/radef

The University of Jyväskylä with its seven faculties is one of the largest universities in Finland. The Department of Physics (JYFL) is part of the Faculty of Mathematics and Science and the Accelerator laboratory (JYFL-ACCLAB) is part of JYFL. The 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 is part of 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 and has also been designated by the ministry as a center 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. 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. 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.