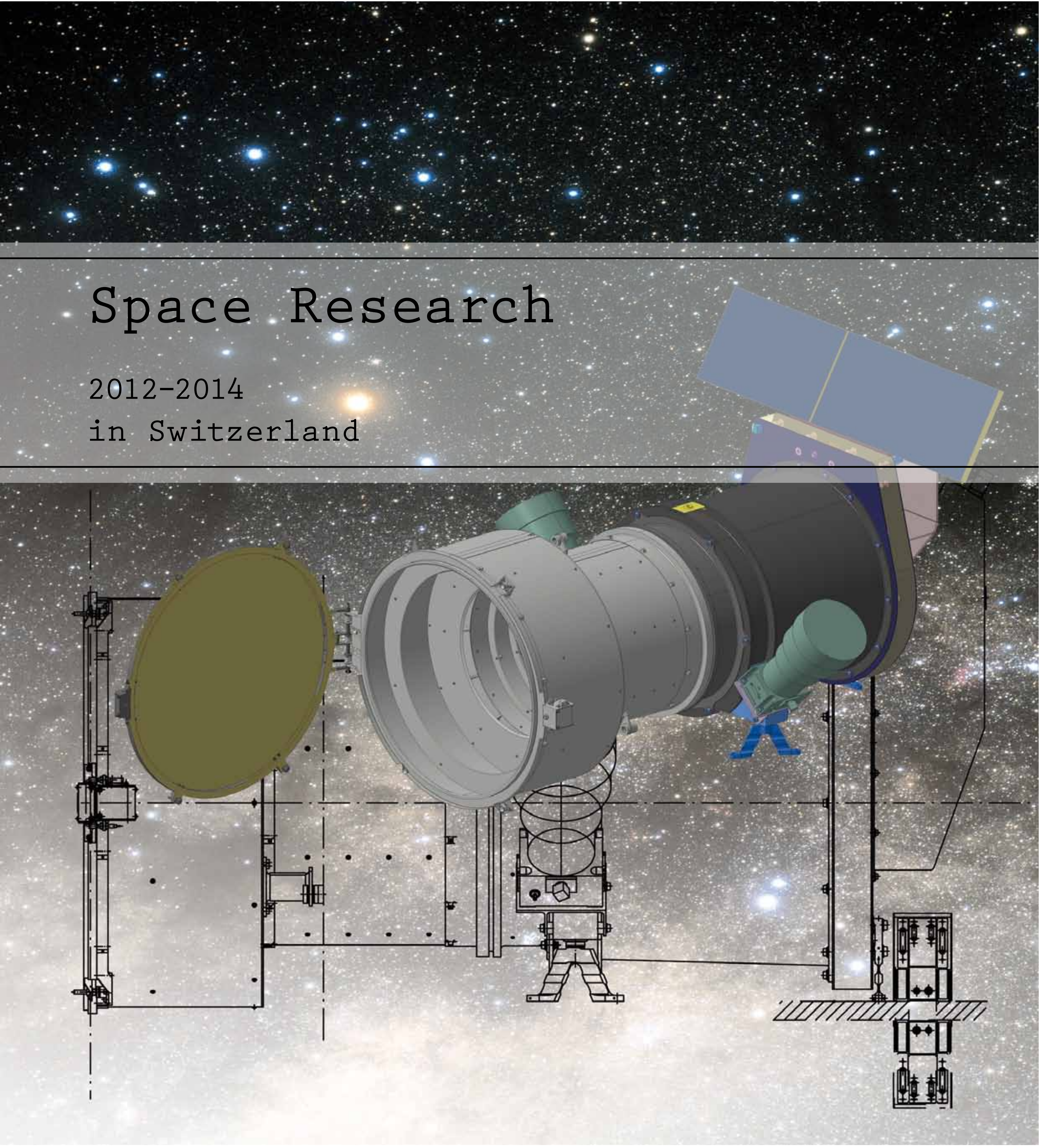
Space Research

2012–2014
in Switzerland



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Swiss Academy of Sciences
Akademie der Naturwissenschaften
Accademia di scienze naturali
Académie des sciences naturelles

Space Research 2012–2014 in Switzerland

Report to the 40th COSPAR meeting, Moscow, Russia, August 2014

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Layout: Stephanie Ebert

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(working group of the Swiss Academy of Sciences)

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Contents

1 Foreword

The Committee on Space Research (COSPAR) was established in 1958 by the International Council for Science to promote scientific research in space on an international level. COSPAR is an interdisciplinary scientific organization focused on the exchange of information on progress of all kinds of research related to space. Its main activity is the organization of biennial Scientific Assemblies. The Swiss National Committee on Space Research (CSR) is a working group of the Swiss Academy of Sciences. In coordination with the schedule of COSPAR assemblies the CSR biennially compiles an overview of space-related national activities.

The majority of Swiss space research activities are related to projects of the European Space Agency (ESA) and therefore, ESA's science program is of central importance to the Swiss science community. In the report period, an important decision of ESA's current Cosmic Vision 2015–2025 long-term science program was the selection of the first large mission JUpiter ICy moons Explorer (JUICE), which has a launch date in the early 2020s. There were four candidates for ESA's Cosmic Vision third medium class science mission. The final M3 selection recently chose the observatory PLAnetary Transits and Oscillations of stars (PLATO). All selected Cosmic Vision missions have prominent Swiss groups who are participating, as testified by their respective contributions to the current Swiss COSPAR report.

The selection of ESA's science program first small mission was the most important event in Swiss space science as the mission CHaracterizing ExOPlanet Satellite (CHEOPS) was selected. CHEOPS is a Swiss led project and is the first "real" Swiss satellite, i.e. a project in which the goal is research and not just the design and manufacture of the satellite, as was the case for the two CubeSats that Switzerland has successfully launched. The science goal of CHEOPS is to determine the radii of exoplanets with ultra-high precision photometry measurements of exoplanetary transits and as such it will strengthen a science area in which Switzerland has traditionally been strong in. The combination of CHEOPS, which will characterize planets starting in 2018, and PLATO to be launched in 2024 is particularly favorable, as it will give a strong long-term perspective to the Swiss exoplanet science community. The fact that CHEOPS is the current Swiss flagship mission is emphasized by a design image on the cover page of this report.

Despite the fact that large missions draw most attention, which is arguably justified for technology challenging missions to Jupiter or an approach close to the Sun, there is a remarkable development of small, cheap, and fast missions using a minimum of documentation and without the use of expensive space-grade components. It seems that this is the alternative to the ever-increasing costs of the big projects. All the effort is justified if there is only one chance of flying to e.g. Mercury in the next several decades. However, the mission satellites must attain a well-defined goal in low Earth orbit without all the margins and administrative safety measures. This capability is being offered more and more, especially by small companies. A good example is e.g. the Norwegian NORSAT-1 mission, which is a platform for the Swiss Compact Lightweight Absolute Radiometer experiment that is included in this report, NORSAT-1 will enable two science experiments the opportunity of reaching low Earth orbit for a tenth of the usual space agency costs. If the first attempt fails, it is still far cheaper to try again. This technology trend towards affordable small missions is probably more important for the future of space science than the high profile flagship missions. Another example in this respect is the idea by the Swiss Space Center to realize the Clean-mE project to actively remove space debris in Earth orbit. I am convinced that in the not so distant future there will be many more ideas for small missions to address dedicated science questions.

Werner Schmutz
President of CSR

Weblinks

COSPAR:
http://http://cosparhq.cnes.fr

Swiss Committee on Space Research:
www.spaceresearch.scnatweb.ch

Swiss Commission for Remote Sensing:
www.geo.uzh.ch/microsite/skf

Swiss Academy of Sciences:
www.scnat.ch

2 Institutes and Observatories

2.1 International Space Science Institute (ISSI)

Directors

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Anny Cazenave
Rudolf von Steiger
John Zarnecki
Johannes Geiss (Honorary Director)

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7 Administrative

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Fields of Research

The programme of ISSI covers a widespread spectrum of disciplines from the physics of the solar system and planetary sciences to astrophysics and cosmology, and from Earth sciences to astrobiology.

Introduction

The International Space Science Institute (ISSI) is an Institute of Advanced Studies at which scientists from all over the world are invited to work together to analyze, compare and interpret their data. Space scientists, theorists, modelers, ground-based observers and laboratory researchers meet at ISSI to formulate interdisciplinary interpretations of experimental data and observations. Therefore, the scientists are encouraged to pool their data and results. The conclusions of these activities – published in several journals or books – are expected to help identifying the scientific requirements of future space science projects. ISSI's study projects on specific scientific themes are selected in consultation with the Science Committee members and other advisers.

ISSI's operation mode is fivefold: International Teams, multi- and interdisciplinary Workshops, Working Groups, Visiting Scientists and Forums are the working tools of ISSI.

The Young Scientists scheme is designed to bring PhD students and young post docs in contact with the science community at work. These young scientists are invited by ISSI to complement the membership of Workshop, Working Groups, International Teams and Forums. More than 530 young scientists have participated in the ISSI activities since its implementation in 2007.

The European Space Agency (ESA), the Swiss Confederation, the Swiss National Science Foundation (SNF) provide the financial resources for the ISSI's operation. The University of Bern contributes through a grant to the Director and in-kind facilities. Since 2010 the Russian Academy of Sciences is supporting ISSI with an annual financial contribution.

Realizations in 2012 and 2013

In total, 140 International Team meetings, 8 Workshops, 6 Forums and three Working Group meetings took place in the years 2012 and 2013. ISSI welcomes by now about 900 visitors annually.

ISSI also offers a unique environment for facilitating and fostering interdisciplinary Earth Science research. Consequently ESA's Earth Observation Programme Directorate went into a contractual relationship with ISSI in 2008 for facilitating synergistic analysis of projects of the International Polar Year, International Living Planet Teams, Workshops and Forum. In 2010 ESA decided to continue and expand the existing service contract with ISSI until 2013.

All scientific activities result in some form of publication, e.g. in ISSI's hardcover book series Space Sciences Series of ISSI (SSSI), ISSI Scientific Report Series (SR), both published by Springer (reprinted from Space Science Reviews), or individual papers in peer-reviewed international scientific journals. As of the end of 2013, 45 volumes of SSSI, and 13 volumes of SR have been published. Information about the complete collection can be found on ISSI's website http://www.issibern.ch, in the section "Publications".

Publications

In 2012 and 2013, following new volumes appeared:

SSSI Volume 43: *Cosmic Rays in the Heliosphere*
B. Heber, J. Kota and R. von Steiger (eds.), ISSI-Workshop held in April 2010, published in September 2013. Reprinted from Space Science Reviews Volume 176, 1–4, 2013. ISBN 978-1-4614-9199-6.

SSSI Volume 44: *Quantifying the Martian Geochemical Reservoirs*
M. Toplis, J. Bell III, E. Chassefière, C. Sotin, T. Spohn, M. Blanc (eds.), ISSI- and Europlanet Workshop held in April 2011, published in June 2013. Reprinted from Space Science Reviews Volume 174, 1–4, 2013. ISBN 978-1-4614-7773-0.

SSSI Volume 45: *Particle Acceleration in Cosmic Plasmas*
A. Balogh, A. Bykov, R.P. Lin, J. Raymond, M. Scholer (eds.), ISSI-Workshop held in May 2011, published in January 2013. Reprinted from Space Science Reviews Volume 173, 2012. ISBN 978-1-4614-6454-9.

SR Volume 13: *Cross-Calibration of Far UV Spectra of Solar System Objects and the Heliosphere*
E. Quémerais, M. Snow, R.-M. Bonnet (eds.), Results of an ISSI-Working Group, published in April 2013. ISBN 978-1-4614-6383-2.

There are a number of upcoming publications, which result from ISSI activities from 2012 to 2013:

Volume 46: *The Earth's Hydrological Cycle*
L. Bengtsson et al. (eds.), ISSI-Workshop held in February 2012, to be published in 2014.

Volume 47: *Microphysics of Cosmic Plasmas*
A. Balogh, A. Bykov, P. Cargill, R. Dendy, T. Dudok de Wit, J. Raymond (eds.), ISSI-Workshop held in April 2012, to be published in 2014.

Volume 48: *Helioseismology and Dynamics of the Solar Interior*
L. Culhane et al. (eds.), ISSI-Workshop held in September 2012, to be published in 2014.

Volume 49: *The Physics of Accretion on to Black Holes*
M. Falanga et al. (eds.), ISSI-Workshop held in October 2012, to be published in 2014.

Results and published papers of international Teams in scientific journals or books can be found in ISSI's Annual Reports 17 (2011–2012) and 18 (2012–2013), which are available online (http://www.issibern.ch/publications/ar.html).

Outlook

32 new International Teams – approved in 2013 by the Science Committee – start their activities in the nineteenth business year (2013/14). Furthermore, four Workshops will take place in the nineteenth business year:

- The Strongest Magnetic Fields in the Universe
- The Disk in Relation to the Formation of Planets and their Protoatmospheres (joint Workshop with ISSI Beijing)
- Remote Sensing and Water Resources
- Solar Magnetic Fields

In 2013 ISSI established jointly with the National Space Science Centre of the Chinese Academy of Sciences (NSSC/CAS) a new branch called ISSI-BJ (International Space Science Institute – Beijing). ISSI-BJ shares the same Science Committee with ISSI and operates its research activities using the same ISSI study tools. In 2014 ISSI will release together with ISSI-BJ its first joint Call for Proposals for International Teams in Space and Earth Sciences.

2.2 Integral Science Data Centre (ISDC)

Director

Prof. Thierry J.-L. Courvoisier

Staff

About 20 scientists and software engineers plus administrative/support staff

In Cooperation with

European Space Agency
German Aerospace Center
Polish Academy of Sciences
Istituto nazionale di astrofisica (Italy)
APC (France)
CNRS (France)
DTU Space (Denmark)
Centro de Astrobiología (Spain)

Method

Data from the INTEGRAL gamma-ray space observatory are processed, archived, and distributed to scientists worldwide together with the software to analyze them. Quick-look and automated analyses ensure the data quality and the discovery of relevant astronomical events.

Contact Information

INTEGRAL Science Data Centre
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Fax: +41 22 379 21 33

http://www.isdc.unige.ch/integral
e-mail: isdc@unige.ch

Purpose of Research

The INTEGRAL Science Data Centre (ISDC) has been established in 1996 as a consortium of 11 European institutes plus NASA. It has a central role in the ground-segment activities for the ESA's INTernational Gamma Ray Laboratory (INTEGRAL). INTEGRAL operates a hard-X-ray imager with wide field of view, a gamma-ray spectrometer, radiation, X-ray, and optical monitors, which have significantly advanced our knowledge of high-energy astrophysical phenomena. INTEGRAL's ground segment activities are divided into Mission Operation Center, Science Operation Center (both operated by European Space Agency), and the ISDC, which is a PI partner of the mission and provides essential services for the astronomical community to exploit the mission data.

ISDC processes the telemetry stream from the spacecraft to elaborate a set of widely usable products and it performs a quick-look analysis to assess the data quality and discover transient astronomical events. These products are distributed to guest observers and archived at ISDC, which is the only source of publicly accessible and distributed INTEGRAL data. ISDC has also the task to integrate and distribute the Software for the Offline Analysis of INTEGRAL data together with the relative handbooks and give support to the users. Only owing to the ISDC contribution, INTEGRAL data can be used by the astronomical community.

The presence of the ISDC has guaranteed to the Swiss scientists a central role in the exploitation of the INTEGRAL scientific results: to date, there are about 350 participation from ISDC's members in the 2000 published papers based on INTEGRAL data in the field of high-energy astrophysics, cosmology, and fundamental physics.

Status

INTEGRAL was launched in October 2002 and its data have generated about 90 PhD theses (plus 20 ongoing), more than 2000 publications (800 in referred journals, increasing steadily), and several astronomical telegrams per month. Moreover, every second day, a gamma-ray burst is detected by INTEGRAL. ESA conducted reviews in 2010 and 2012, and concluded that fuel consumption, solar panel and battery aging, and orbital evolution allow to prolong the mission for many more years. In 2014, an operational review will ascertain the reliability of INTEGRAL for the next extension (2015–2016), for which the budget has already been approved by the ESA SPC. Further extensions will be discussed based on scientific relevance of the mission and budget constrains.

ISDC is an essential pillar of the mission and is currently funded by the Swiss Space Office, the University of Geneva, and ESA, with contributions from Germany and Poland. It counts on the contribution of about 20 software engineers and scientists, who work in synergy with other space mission, within the department of astronomy at the University of Geneva.

The importance of the quick-look analysis to find transient events is witnessed by the high number of citations of several telegrams. Remarkably, INTEGRAL managed to capture the first pulsar swinging from accretion and rotation powered emission, which has been searched since the first evolutionary theories appeared in 1982 (Papitto et al., 2013). The quick-look analysis of INTEGRAL data has also lead to the discovery of a rare tidal disruption event of a super-Jupiter object around a supermassive black-hole residing in the centre of a galaxy at 47 millions light year from us (Nikołajuk & Walter, 2013). A search for gamma-ray bursts is routinely performed by an automatic system which sends automatic alerts to robotic telescopes within seconds since the discovery.

The follow-up studies performed at ISDC are mainly in the field of high-energy astrophysics, which was and remains its core science. Although a significant fraction of the research topics is linked to areas in which INTEGRAL makes a significant contribution, a variety of other observation facilities, like XMM-Newton, RXTE, Chandra, Planck, and Fermi, have been exploited so far. The science topics span from the nearby X-ray binaries up to the cosmological scales, with the study of active galactic nuclei and clusters of galaxies.

High-energy astrophysics extends naturally to particle physics in the field of astroparticle with the investigation of the Universe's dark constituents and the origin of cosmic rays in the astrophysical particle accelerators. ISDC is thus involved in current ground-based gamma-ray experiments and in the development of the future Cherenkov Telescope Array.

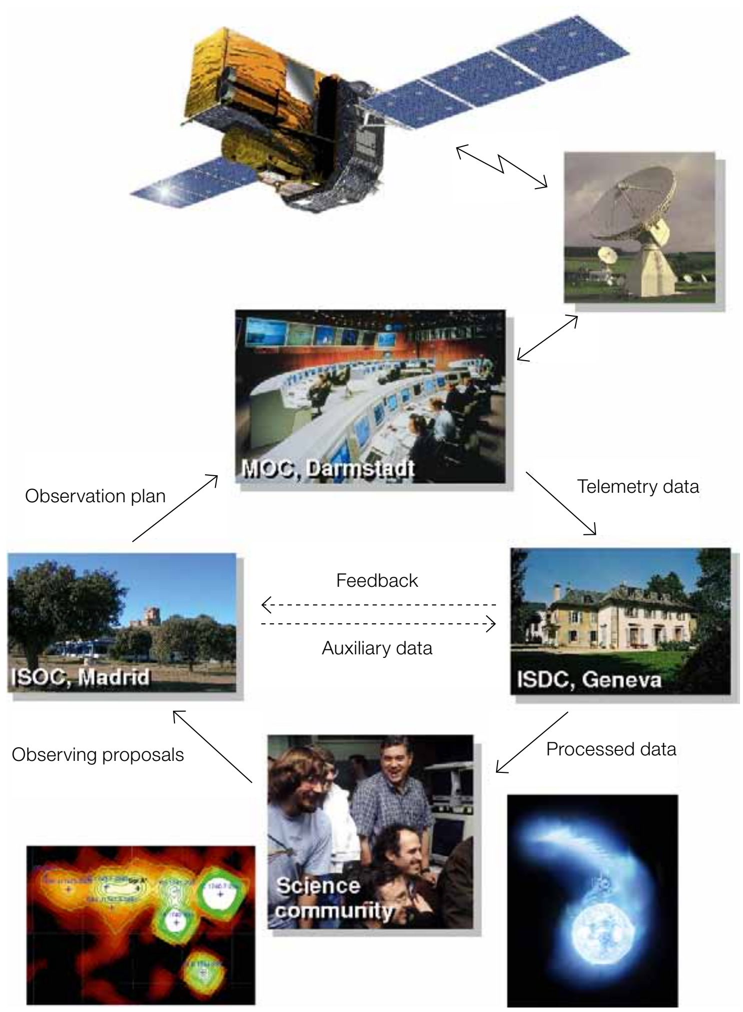
Publications

1. Courvoisier, T. J.-L.; Walter, R. et al. The INTEGRAL Science Data Centre (ISDC) Astronomy and Astrophysics, v.411, p.L53–L57 (2003)

2. Nikołajuk, M.; Walter, R. Tidal disruption of a super-Jupiter by a massive black hole Astronomy & Astrophysics, Volume 552, id.A75 (2013) see the ESA press release http://sci.esa.int/integral/51600-black-hole-wakes-up-and-has-a-light-snack/?%20

3. Papitto, A.; Ferrigno, C.; Bozzo E. et al. Swings between rotation and accretion power in a binary millisecond pulsar, Nature, Volume 501, Issue 7468, pp. 517–520 (2013), see also the ESA press release http://sci.esa.int/integral/52866-volatile-pulsar-reveals-millisecond-missing-link/

Schematic view of the INTEGRAL ground segment activities.



2.3 Center for Orbit Determination in Europe (CODE)

Abbreviations

GNSS	Global Navigation Satellite Systems
IGS	International GNSS Service
ITRF	International Terrestrial Reference Frame
CODE	Center for Orbit Determination in Europe

Institute

Astronomical Institute of the University of Bern (AIUB)

In Cooperation with

Bundesamt für Landestopographie (swisstopo), Wabern, Switzerland

Bundesamt für Kartographie und Geodäsie (BKG), Frankfurt a. M., Germany

Institut für Astronomische und Physikalische Geodäsie (IAPG), Technische Universität München, Germany

Director

Adrian Jäggi

Co-Investigator

Rolf Dach (AIUB)
Elmar Brockmann (swisstopo)
Daniela Thaller (BKG)
Urs Hugentobler (IAPG)

Method

Measurement

Developments

GNSS Data Analysis and Software Development.

Purpose of Research

Using measurements from Global Navigation Satellite Systems (GNSS) is (among many other applications) well established for the realization of the global reference frame, the investigation of the system Earth, or the precise geolocation of Low Earth Orbiting (LEO) satellites in space. To support the scientific use and the development of GNSS data analysis the International GNSS Service (IGS) has been founded by the International Association of Geodesy (IAG) in 1994.

CODE is one of the leading global analysis centers of the IGS. It is a joint venture of the Astronomical Institute of the University of Bern (AIUB), Bern, Switzerland, the Bundesamt für Landestopographie (swisstopo), Wabern, Switzerland, the Bundesamt für Kartographie und Geodäsie (BKG), Frankfurt a. M., Germany, and the Institute of Astronomical and Physical Geodesy (IAPG) of the Technische Universität München, Munich, Germany. Since the early pilot phase of the IGS (21 June 1992) CODE is continuously running. The operational processing is located at AIUB.

Nowadays data of about 250 globally distributed IGS tracking stations are processed every day in a rigorous combined multi-GNSS (currently the American Global Positioning System (GPS) and the Russian counterpart GLONASS) processing for all IGS product lines (with different latencies). CODE has started with the inclusion of GLONASS in its regular processing scheme already in May 2003. During five years it was the only one following this approach. Meanwhile other IGS analysis centers started to follow this strategy as well.

Status

The main products are precise GPS and GLONASS orbits, satellite and receiver clock corrections, station coordinates, Earth orientation parameters, troposphere zenith path delays, and maps of the total ionospheric electron content. The coordinates of the global IGS tracking network are computed on a daily basis for studying vertical and horizontal site displacements and plate motions, and to provide information for the realization of the International Terrestrial Reference Frame (ITRF). The daily positions of the Earth's rotation axis with respect to the Earth's crust as well as the exact length-of-day is determined for each day and provided to the International Earth Rotation and Reference Systems Service (IERS).

Apart from regularly generated products CODE significantly contributes to the development and improvement of modeling standards. Members of the CODE group contribute or chair different IGS working groups, e.g., the working group on Bias and Calibration. With the ongoing modernization programs of the established GNSS and the upcoming GNSS, e.g., the European Galileo, such work is highly relevant because of the increasing manifold of signals that need to be consistently processed in a fully combined multi-GNSS analysis scheme. Other contributions from CODE are the derivation of calibration values for the GNSS satellite antenna phase center model, GLONASS ambiguity resolution, and the refinement of the CODE orbit model.

Publications

A list of recent publications is available at http://www.bernese.unibe.ch/publist/

2.4 International Space Situational Awareness (SSA)

Purpose of Research

The central aim of Space Situational Awareness is to acquire information about natural and artificial objects in Earth orbits. The growing number of so-called space debris – artificial non-functional objects – results in an increasing threat to operational satellites and manned spaceflight. Research in this domain aims at a better understanding of the near Earth environment through extending the catalogs of "known" space objects toward smaller sizes, by acquiring statistical orbit information on small-size objects in support of statistical environment models, and by characterizing objects to assess their nature and to identify the sources of space debris. The research is providing the scientific rationale to devise efficient space debris mitigation and remediation measures enabling sustainable outer space activities.

Status

This is an ongoing international collaboration between the Astronomical Institute of the University of Bern (AIUB), the Keldish Institute of Applied Mathematics (KIAM), Moscow, and ESA. Optical surveys performed by AIUB using its ZIMLAT and ZimSMART telescopes in Zimmerwald and the ESA telescope in Tenerife on behalf of ESA, as well as the surveys performed by KIAM using the ISON telescopes provide the data to maintain orbit catalogs of high-altitude space debris. These catalogs enable follow-up observations to further investigate the physical properties of the debris and to eventually discriminate sources of small-size debris. Results from this research are used as key input data for the European ESA meteoroid and space debris reference model MASTER. The AIUB telescopes constitute primary optical sensors in the ESA Space Situational Awareness preparatory program.

Publications

1. Fujimoto K., D. Scheeres, J. Herzog, T. Schildknecht, Association of Optical Tracklets From a Geosynchronous Belt Survey via the Direct Bayesian Admissible Region Approach, Adv. Space Res., Volume 53, Issue 8, pp 1184–1194, 2014

2. Schildknecht, T., A. Hinze, A. Vananti, T. Flohrer, An Optical Survey for Space Debris on Highly Eccentric MEO Orbits, 29th International Symposium on Space Technology and Science, 2–9 June 2013, Nagoya-Aichi, Japan, 2013

3. Milani, A., G. Tommei, D. Farnocchia, A. Rossi, T. Schildknecht, and R. Jehn, Orbit determination of space objects based on sparse optical data, Mon. Not. R. Astron. Soc., Volume 417, Issue 3, pp. 2094–2103, 2011, doi: 10.1111/j.1365-2966.2011.19392.x

Abbreviations

SSA	Space Situational Awareness
ISON	International Scientific Optical Observation Network
KIAM	Keldish Institute of Applied Mathematics

Institute

Astronomical Institute of the University of Bern (AIUB)

In Cooperation with

Keldish Institute of Applied Mathematics (KIAM), Moscow

International Scientific Optical Observation Network (ISON)

Principal Investigator

Thomas Schildknecht

Co-Investigator

Vladimir Agapov (KIAM)

Method

Measurement, Compilation

Observatories

Zimmerwald (Switzerland)
ESA Tenerife
ISON telescopes

Graphical representation of the space debris population of objects larger than one centimeter as seen from 3 Earth radii (ILR TUB).

2.5 Swiss Space Center (SSC)

Mission

The Swiss Space Center (SSC) provides a service supporting institutions, academia and industry to access space missions and related applications, and promote interaction between these stakeholders.

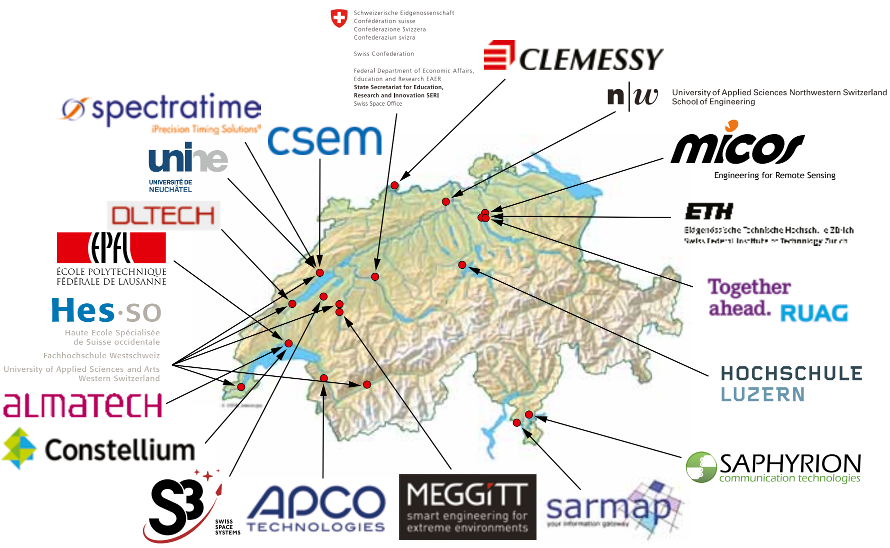
Roles

- To network Swiss research institutions and industries on national and international levels in order to establish focused areas of excellence internationally recognized for both space R&D and applications;
- To facilitate access to and implementation of space projects for Swiss research institutions and industries;
- To provide education and training;
- To promote public awareness of space.

Members

During the year 2013, the Swiss Space Center welcomed seven new Swiss industries within its members: Almatech, Clemessy, DLTECH, Meggitt, Sarmap, Spectratime and Swiss Space Systems (S3).

Therefore, the Swiss Space Center currently counts 20 members from each region of Switzerland and representing all types of companies (large size, medium and start-up), academies (Swiss Federal Institutes, Universities, Universities of applied sciences) and institutions (Swiss Space Office, CSEM).



Members of the Swiss Space Center.

Director

Prof. Volker Gass

Staff

16 Scientific & Technical
4 Administrative

Board of Directors

Daniel Neuenschwander
Prof. Philippe Gilet
Prof. Roland Siegwart

Steering Committee

Prof. Markus Rothacher
Prof. Zeno Stössel
Nathalie Pichard
Urs Frei
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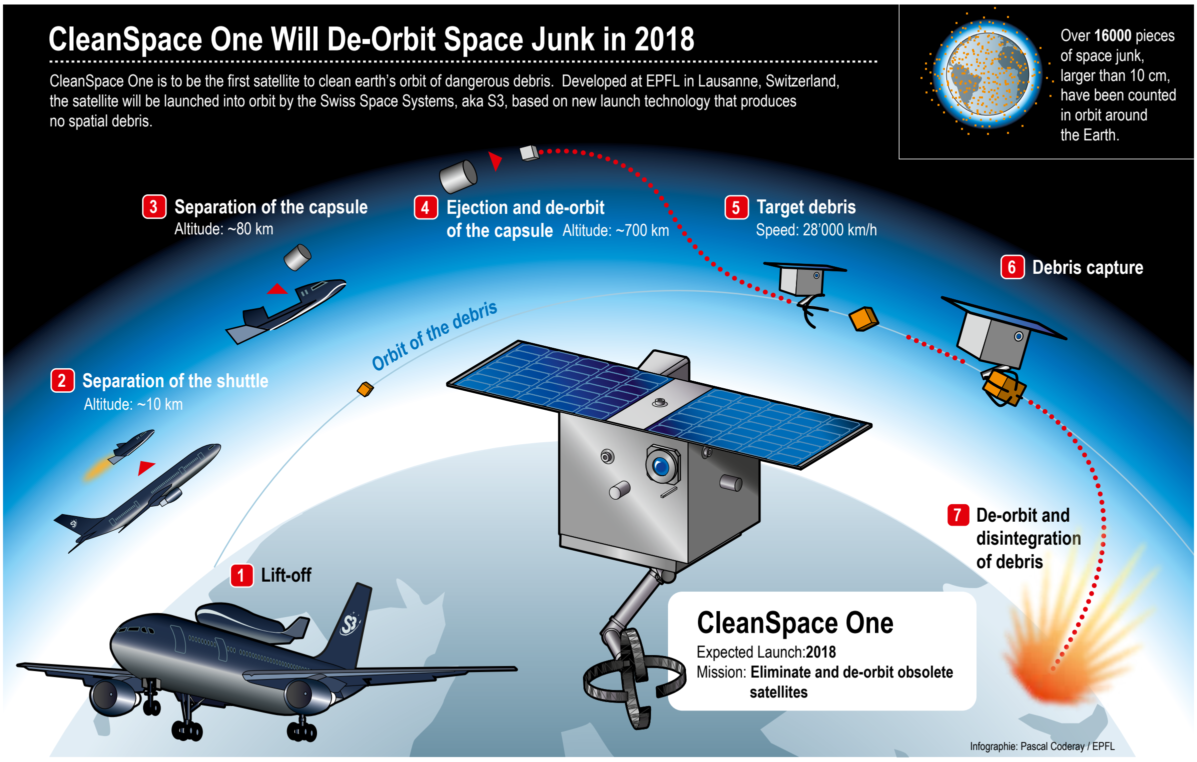


CleanSpace One will de-orbit space junk: After ejection from the launch vehicle, propulsion maneuvers will be performed to reach SwissCube's orbit. These maneuvers will rely on ground radar observations of the debris and the onboard GPS on CleanSpace One. Approach maneuvers will performed to further reduce the distance to a few meters. These maneuvers will rely on optical, radar or lidar technologies.

Activities 2013

The events heralded in 2012 came with a rapid pace in the beginning of 2013. The growth of membership, the clarification of our mission and tasks spelled out clearly for the first time in the terms of Reference document, the election of the first Steering Committee and the appointment of its first chairman served to strengthen or purpose and direction.

The reputation of the Swiss Space Center is steadily growing among the national and international actors. This allowed us to participate in important conferences such as the RAST in Istanbul and the IAF/IAC in Beijing as invited speakers or as session chair persons and gave us the opportunity to inform the international space community about activities in Switzerland.

The first summer school with Beihang University as well as the now established summer school with Baumann University of Moscow were a great success and will be enhanced and repeated in the future.

The Swiss Space Center has equally been busy at a national level. Projects such as CubETH and the ESA GSTP study provide positive synergies between large and small industrial members as well as universities of applied sciences and the two federal institutes of technology. Continuing education has found strong interest with the prototype of a week-long systems engineering course that will be opened to all members from 2014 onwards.

The new initiative “call for ideas” launched in 2013 showed a strong resonance in the country with more than 30 proposals submitted, a third of which could be funded. We are confident that more than one of these studies will result in a project under the up-coming “Mesures de Positionnement” or other international funding measures.

It is thanks to the support and trust of our members and partners, as well our thoroughly dedicated staff that we are able to accomplish the activities presented in this executive summary and we are looking forward to the challenges that lie ahead of us.

2.6 Satellite Laser Ranging (SLR) at the Zimmerwald Geodynamics Observatory

Purpose of Research

The Zimmerwald Geodynamics Observatory is a station of the global tracking network of the International Laser Ranging Service (ILRS). SLR observations to satellites equipped with laser retro-reflectors are acquired with the monostatic 1-m multi-purpose Zimmerwald Laser and Astrometry Telescope (ZIMLAT). Target scheduling, acquisition and tracking, and signal optimization may be performed fully autonomous whenever weather conditions permit. The collected data are delivered in near real-time to the global ILRS data centers, official products are generated by the ILRS analysis centers using data to the geodetic satellites LAGEOS and Etalon. SLR significantly contributes to the realization of the International Terrestrial Reference Frame (ITRF), especially with respect to the determination of the origin and scale of the ITRF.

Status

The design of the 100 Hz Nd:YAG laser system used at the Zimmerwald Geodynamics Observatory enables a high flexibility in the selection of the actual firing rate and epochs, which also allows for synchronous operation in one-way laser ranging experiments to spaceborne optical transponders such as the Lunar Reconnaissance Orbiter (LRO). The highly autonomous management of the SLR operations by the in-house developed control software is mainly responsible that the Zimmerwald Geodynamics Observatory has evolved in the last decades to one of the most productive SLR stations worldwide. This achievement is remarkable when considering the facts that weather conditions in Switzerland only allow operations at about two third of the time, and that observation time is shared during nights between SLR operations and the search for space debris with CCD cameras attached to the multi-purpose telescope.

Publications

1. Ploner, M., P. Lauber, M. Prohaska, P. Schlatter, J. Utzinger, T. Schildknecht, A. Jäggi, The new CMOS Tracking Camera used at the Zimmerwald Observatory, Proceedings of the 18th International Workshop on Laser Ranging, Fujiyoshida, Japan, 11–15 November 2013

2. Jäggi, A., M. Ploner, J. Utzinger, M. Prohaska, E. Pop, W. Gurtner, "ILRS Station Reports: Zimmerwald, Switzerland", 2009–2010 ILRS Report, p 12–81/82, 2011

Abbreviations

SLR	Satellite Laser Ranging
ILRS	International Laser Ranging Service
ZIMLAT	Zimmerwald Laser and Astrometry Telescope

Institute

Astronomical Institute of the University of Bern (AIUB)

In Cooperation with

Bundesamt für Landestopographie (swisstopo), Wabern, Switzerland

Principal Investigator

Thomas Schildknecht

Co-Investigator

Martin Ploner
Pierre Lauber
Adrian Jäggi

Method

Measurement

Laser beam transmitted from the 1-meter Zimmerwald Laser and Astrometry Telescope (ZIMLAT) to measure high accuracy distances of artificial satellites.

3 Swiss Space Missions

3.1 CHEOPS

Institute

Center for Space and Habitability &
Physikalisches Institut
University of Bern

In Cooperation with

Institut für Weltraumforschung Graz
Centre Spatial de Liege
ETH Zürich
Swiss Space Center
Observatoire Geneve
Lab. d'astrophysique de Marseille
DLR Inst. for planetary research
DLR Inst. for optical sensor systems
Konkoly Observatory
INAF Osserv. Astrofisico di Catania
INAF Osserv. Astronomica di Padova
Centro de Astrofisica da Universidade do Porto
Deimos Engenharia
Onsala Space Observatory
Stockholm University
University of Warwick

Principal Investigator

Willy Benz

Co-Investigator

Ch. Broeg	T. Barczy
W. Baumjohann	M. Deleuil
D. Ehrenreich	A. Fortier
M. Gillon	A. Gutierrez
A. Heras	L. Kiss
A. L.-d-Etangs	R. Liseau
G. Olofsson	G. Piotto
D. Pollacco	D. Queloz
R. Ragazzoni	E. Renotte
N. Santos	T. Spohn
M. Steller	N. Thomas
S. Udry	

and the CHEOPS Team

Purpose of Research

The CHaracterising ExOPlanet Satellite (CHEOPS) was selected on 19 October 2012 as the first small mission (S-mission) in the ESA Science Programme. CHEOPS will be the first mission dedicated to search for transits of exoplanets by means of ultrahigh precision photometry on bright stars already known to host planets. It will provide the unique capability of determining accurate radii for a subset of those planets for which the mass has already been estimated from ground-based spectroscopic surveys, providing on-the-fly characterisation for exoplanets located almost everywhere in the sky. It will also provide precise radii for new planets discovered by the next generation of ground- or space-based transits surveys (Neptune-size and smaller). By unveiling transiting exoplanets with high potential for in-depth characterization, CHEOPS will also provide prime targets for future instruments suited to the spectroscopic characterisation of exoplanetary atmospheres.

The main science objective of the CHEOPS mission will be to study the structure of exoplanets smaller than Saturn orbiting bright stars.

In particular, CHEOPS will:

- determine the mass-radius relation in a planetary mass range for which only a handful of data exist and to a precision not achieved before;
- identify planets with significant atmospheres in a range of masses, distances from the host star, and stellar parameters;
- place constraints on possible planet migration paths followed during the formation and evolution of planets;
- bring new constraints on the atmospheric properties of known hot Jupiters via phase curves;
- provide unique targets for detailed atmospheric characterisation by future ground- (e.g., E-ELT) and space-based (e.g., JWST) facilities with spectroscopic capabilities.

In addition, 20 % of the CHEOPS observing time will be made available to the community through a selection process carried out by ESA, in which a wide range of science topics may be addressed.

To reach these science objectives, CHEOPS will measure photometric signals with a precision (limited by stellar photon shot noise) of 20 ppm (goal: 10 ppm) in six hours of integration time. This corresponds to the transit of an Earth-sized planet orbiting a star of 0.9 R_{sun} in 50 days detected with an $S/N_{transit} > 5$ (100 ppm transit depth). This precision will be achieved by using a single frame-transfer, back-illuminated CCD detector at the focal plane assembly of an ~33.5 cm diameter, on-axis Ritchey-Chrétien telescope. The spacecraft will be 3-axis stabilized, with a pointing accuracy of 8 arcsec rms, and will allow for at least 1.2 Gbit/day downlink. The baseline orbit satisfying the science requirements is a 6-am/6-pm sun-synchronous orbit with an altitude in the range between 620 and 800 km, enabling to have the sun permanently on the backside of the spacecraft and minimising Earth stray light. The mass of the spacecraft (< 250 kg) is compatible with a launch as auxiliary payload or co-passenger on VEGA or Soyuz (baseline scenarios), as well as with other small launch vehicles. A mission duration of 3.5 years in orbit is foreseen to enable the execution of the proposed science observation programme.

Status

The CHEOPS mission has been adopted by ESA as the first small mission (S-misison) in the Science Programme of the Agency.

Publications

1. CHEOPS: A transit photometry mission for ESA's small mission programme, Broeg et al. 2013, EPJ conf, vol. 47 p. 3005

Method

Ultra-precise measurement of stellar brightness

Development and Construction of Instruments

Switzerland is responsible for the development of a 33 cm telescope as well as the mission's ground segment.

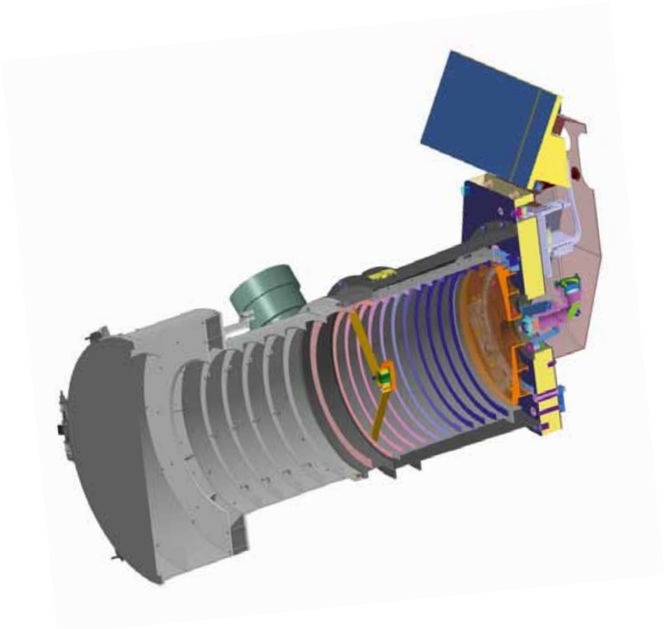
Industrial Hardware Contract to

RUAG Space, ITTs have been issued for other major items but the selection has not yet been made.

Abbreviations

CHEOPS CHaracterising ExOPlanet Satellite

Time-Line	From	To
Planning	March 2013	February 2014
Construction	March 2014	end 2017
Measurement Phase	2018	mid 2021



A cut through the CHEOPS instrument: a 33 cm aperture reflecting telescope. From left-to-right the following components are shown: Baffle cover, Primary and secondary stray light baffle (grey), Secondary mirror with spider mount (orange), Inner baffle (pink-blue) and telescope tube (dark grey), primary mirror (orange), Optical bench (yellow), back end optics (pink), folding mirror (green), focal plane assembly and detector (grey). The back end optics and focal plane are encapsulated in a hood against conamination and stray light, and are cooled using two radiators mounted on top of the optical bench (blue). A separate instrument electronics box will be mounted on the platform.

3.2 CubETH

Institute

Geodesy and Geodynamics Lab
ETH Zürich

In Cooperation with

Swiss Space Center

École Polytechnique Fédérale de Lausanne – EPFL, Lausanne

Department of Computer Science and Department of electrical Engineering, Hochschule Luzern

Hochschule Rapperswil

Haute école spécialisée de Suisse occidentale – HES-SO, Sion

Principal Investigator

Markus Rothacher

Hardware Development

Swiss Space Center

Method

Measurement

Research Based on Existing Instruments

GNSS Sensors developed and tested by u-blox AG.

Purpose of Research

CubETH is a project to evaluate low-cost GNSS sensors on a nano-satellite by following the Cubesat standard. GNSS sensors will be used for precise orbit determination and validation of attitude determination of the cube. The project shall verify in-space use of COTS GNSS detectors and novel algorithms for on-board data processing.

The main scientific goal of CubETH satellite is precision orbit determination using COTS GNSS sensors. Additionally, the aim is to characterize attitude determination using GNSS sensors. Programmatic goal is to implement this project in cooperation between ETHZ and EPFL schools, involving engineers and students from federal schools as well from HES/FH domain. This project will serve for education of new generations of highly qualified engineers.

The Geodesy and Geodynamics Lab of the ETHZ is responsible for this scientific instrument (payload). GNSS sensors are provided by Swiss company u-blox. The Swiss Space Center is working on the satellite bus (1U-Cubesat). In order to accelerate the development process and reduce the cost, the goal is to reuse as much as possible of the SwissCube design. Both main responsible entities (ETHZ and EPFL) work closely together with the different "Fachhochschulen" and industry partners of Switzerland. Final integration and testing will be performed at the Swiss Space Center. Science operations will be driven by ETHZ in close collaboration with ground stations for mission operations located at HS Luzern and HS Rapperswil.

Collaboration with industry is very important for this project. u-blox is supplying GNSS chips and knowledge on chip algorithms; RUAG Space is helping with testing procedures and analysis of test data; Saphyrion is helping with expertise in electrical system and beacon design.

In 2013 thirty people were involved in the project across five different schools ranging from students to senior sceintists and professors.

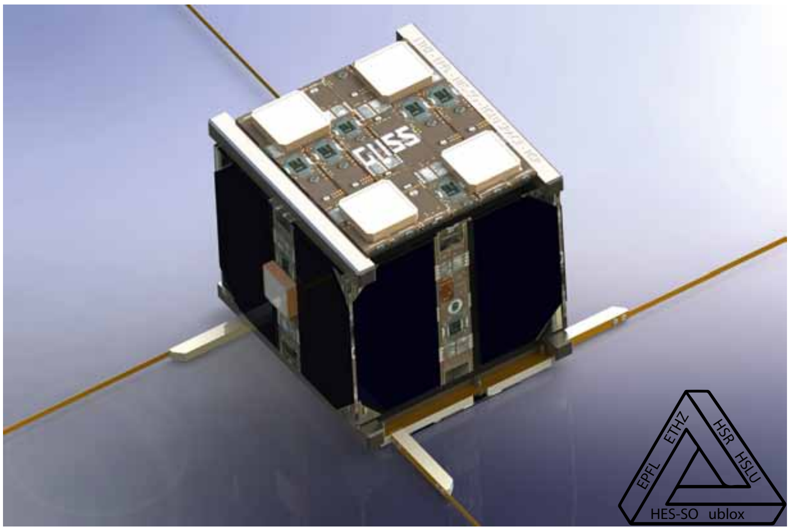
Status

PRR review was held in April 2013 and the project was in Phase B at the end of the year. The focus in 2013 was to examine options for CubETH implementation and qualifying individual components to validate design choices. The goal of phase B is to deliver an operational FlatSat model (electrical model), where all electrical and data interfaces will be verified. Payload, Control and Data Management, Electrical Power and Communication subsystems are now ready for integration on FlatSat. PDR is planned for Q3 2014. The goal is to demonstrate functioning FlatSat at the PDR.

The launch is targeted for 2016 and is still to be confirmed.

Publications

1. Software framework for measurement campaigns on a CubeSat Payload, 5th European Cubesat Symposium, June 2013, M. Klaper, M. Lussi, M. Jordan, M. Bucher, T. Rohrer, Y. Willener, C. Hollenstein, M. Rothacker, A. Ivanov, L. Kronig
2. CubETH Sensor Characterization: Sensor analysis required for a cubesat mission, 2nd IAA Conference on Dynamics and Control of Space Systems, Dycoss, Stefano Rossi, Anton Ivanov, Burri Gaetan, Volker Gass, Christine Hollenstein, Markus Rothacher



Artist view of CubETH.
© Swiss Space Center

Abbreviations

GNSS	global navigation satellite system
COTS	Commercial off the shelf
1U-CubeSat	Standard unit volume for Pico-Satellites 10 x 10 x 10 cm
FlatSat	Open version of the Satellite
PDR	Preliminary Design Review

Time-Line	From	To
Planning	Jan. 2013	Sept. 2014
Construction	Jan. 2014	Jan. 2015
Measurement Phase	2016	2017 TBC
Data Evaluation	2016 TBC	2018 TBC

Time-Line	From	To
Planning	Sept. 2012	Mar. 2016
Construction	Mar. 2016	2018
Measurement Phase	2018	2018
Data Evaluation	2018	2018

Institute

Swiss Space Center

In Cooperation with

Swiss Space Center members and external partners

Principal Investigator

Muriel Richard

Method

Measurement

Developments

Mission design, systems and subsystems validation.

3.3 Clean-mE/Active Debris Removal

Purpose of Research

China's demonstration of its capability to destroy an aging satellite in 2007, and the collision between the American satellite Iridium and the Russian Cosmos in 2009 brought a new emphasis on the orbital debris problem. Although most of the work had been concentrated on avoidance prediction and debris monitoring, all major space agencies are now claiming the need for active removal of debris. About 16000 debris above 10cm are catalogued. Roughly 2000 of these are remains of launch vehicles, 3000 belong to defunct satellites and the rest are either mission generated or fragmentation debris.

In addition, over the years, many studies have been performed to actively remove debris from LEO and GEO, and there is a vast pool of information on this topic. However, all solutions known at this point for removing debris are difficult to implement and require non-trivial resources (cost, mass…). Furthermore, all these solutions need new technology developments for efficient debris removal. Based on these observations, the Swiss Space Center has been involved in active debris removal research activities over the last four years in a program called "Clean-mE". Three major activities (involving students) were pursued in 2014 in this field.

The first activity was funded by EADS Astrium under a CNES contract. It had for purpose the evaluation of the most cost-effective way to remove 5–10 large debris (the ones with the most debris creation potential) per year. The Swiss Space Center in collaboration with Prof. O. De Weck, MIT (USA), created a mission and campaign analysis tool to feed the technical analysis. The tool optimizes the launch date and the debris selection path, the number of remover satellites per launch; it provides a conceptual design of the remover satellite and kits, and allows for technology trade-offs. The results of this activity were published at the 6th ESA Conference on Space Debris in Darmstadt, Germany.

A second activity started under ESA funding, which purpose is to evaluate if and which ADR technologies could be demonstrated in space using CubeSats (ranging from two units up to six units in size/mass). This activity involves academic and industrial partners of the Swiss Space Center. It is expected to finish late 2014.

The third activity of the Clean-mE program was the continuation of the CleanSpace One (CSO) project, which purpose will be to demonstrate the removal and de-orbiting of SwissCube. A first funding partner, Swiss Space Systems (S3), joined the project late 2014. Project management and mission scenario evaluations are on-going.

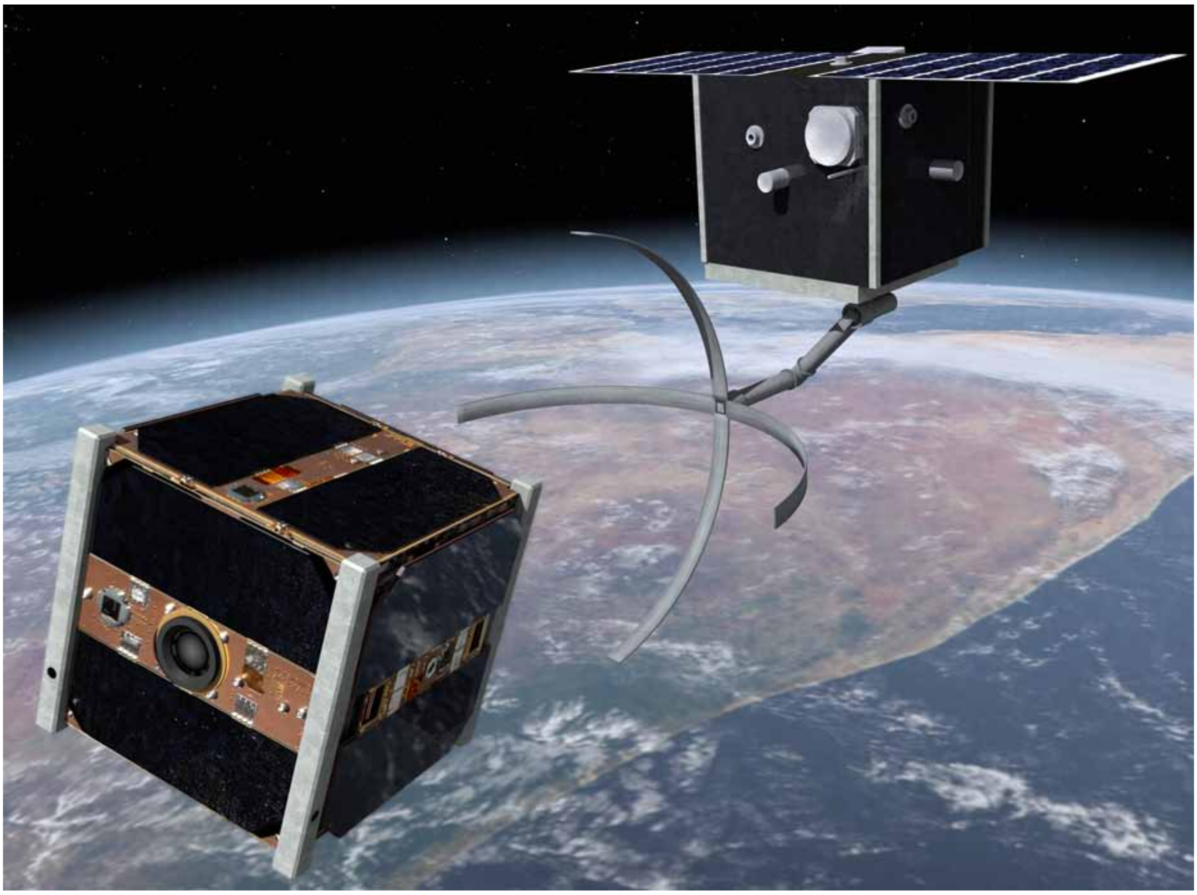
A press conference took place in Payerne on 10 September 2013, to announce this new partnership and present the satellite's new design. A large media coverage resulted from this event.

Status

The expected launch date for CleanSpace One by S3 is 2018. From 2014 to March 2016, the Phase A and B will be performed. Phase C and D, the construction the satellite and test of the various techonologies, will be spread over two years up to 2018.

Publications

1. M. Richard, L. Kronig, F. Belloni, S. Rossi, V. Gass: "Uncooperative Rendezvous and Docking for Micro Sats", RAST, Istanbul, June 2013



At close quarters CleanSpace One will very carefully perform the "Hug-Me" maneuver to catch the slowly rotating debris. These operations, may be partially done autonomously by CleanSpace One. The compliant grabbing system will utilize a MEMS based system to deploy and then wrap around the object in space. It will be inspired from nature's catching behaviors.

4 Astrophysics

4.1 POLAR

Institute

ISDC, DPNC (UNIGE)

PSI

In Cooperation with

IHEP Beijing China

NCBJ Poland

Principal Investigator

Martin Pohl

Co-Investigator

Nicolas Produit
Wojtek Hjdas

Method

Measurement

Development and Construction of Instruments

Polarimeter, front end electronic, trigger electronic, scintillating target, detector mechanics, on board software, on board firmware, ground segment software, analysis software.

Industrial Hardware Contract to

AOT Zurich

Purpose of Research

POLAR is a compact gamma ray polarimeter to be flown on-board of the Chinese space station Tiangong 2.

It is dedicated to the measurement of polarization of Gamma Ray Bursts (GRB) in hard X-ray energies. Gamma Ray Bursts belong to the most important subjects of the contemporary astrophysics. GRB are linked with explosive births of black holes. GRB are of cosmological origin. Polarization of GRB is one of the most important parameter to understand the GRB phenomenon. This parameter has not yet been measured with good statistics and controlled systematics.

POLAR is a wide field of view Compton polarimeter using light scintillation material. It cover an energy range from few tens up to several hundred keV. The polarization detection capability are 10 GRB per year with a polarization precision on the polarization degree better then 10 %.

POLAR is meant to be taking data for three years on board of Tiangong2 Chinese space station. Using this three year dataset, POLAR should be able to discriminate between the actual proposed models of primary emission of GRBs.

Status

During year 2013 two qualification models where built. One model was sent to China for conformance tests. The other one was used to perform all the space qualification. Tests of EMC, vibration, thermal, thermovacuum, static acceleration all passed with minor modifications. Unfortunately shock tests created internal damages to the qualification detector 2. Re-engineering of some parts of the detector and addition of shock dampers inflicted us a six months delay. Several shock tests have proven now that detector can eventually survive the very harsh shock test Chinese requirements. Flight model construction and acceptation tests will resume in 2014. Delivery of flight model has to take place during 2014.

In the mean time, on-board firmware, Monte-carlo and analysis software has improved. Discussions toward building of a European data center have started.

Important official papers where signed between ESA and China securing the 2015 POALR flight opportunity.

Publications

1. N. Produit et al. NUCL.INSTRUM. METH.A 550 616 (2005)

2. S. Orsi et al., NUCL.INSTRUM. METH.A 648 (2011)

3. Estella Suarez Doctorate thesis, 2010. University Geneva library

Polar Qualification Model 1 (QM1) arrived in China in December 2012.
On 25 January 2013 POLAR is being tested in IHEP Beijing. In front: upside down opened POLAR QM1.
From right to left: R. Marcinkowski, D. Rybka, W. Hajdas, all three from PSI. Picture taken by N. Produit ISDC.

Abbreviations

GRB	Gamma ray bursts
DPNC	Département de physique nucléaire et corpusculaire, University of Geneva
ISDC	Data Centre for Astrophysics, University of Geneva
PSI	Paul Scherrer Institute, Villigen
IHEP	High energy physics institute Beijing
NCBJ	Nuclear research institute of Poland

Time-Line	From	To
Planning	2009	2011
Construction	2012	2014
Measurement Phase	2015	2018
Data Evaluation	2015	2020

4.2 IBEX Interstellar Boundary Explorer

Institute

Space Research and Planetology, Physics Institute, University of Bern

In Cooperation with

Southwest Research Institute, Austin, TX, USA

Lockheed martin Advanced Technology Laboratory, Palo Alto, CA, USA

Space Research Centre PAS, Warsaw, Poland

University of New Hampshire, Durham, NH, USA

Principal Investigator

D. McComas, Southwest Research Institute, Austin, TX, USA

Co-Investigator

P. Wurz
D. Rodriguez
A. Galli
J. Scheer

Method

Measurement

Research Based on Existing Instruments

IBEX-Lo Instrument on IBEX.

Purpose of Research

The IBEX mission (NASA SMEX class) is designed to record energetic neutral atoms arriving from the interface of our heliosphere with the neighbouring interstellar medium in an energy range from 10 eV to 6 keV. This energy range is covered two sensors, IBEX-Lo measuring from 10 eV to 2 keV, and IBEX-Hi measuring from 500 eV to 6 keV. For each energy channel a full-sky map is compiled every half year, which allows to study the physical processes at the interface between the heliosphere and the interstellar medium.

Status

IBEX was successfully launched in October 2008 and brought into a highly elliptical orbit around the Earth. In June 2011 the orbit was changed into an orbit that is in resonance with the Moon, which tremendously extends the mission life to cover more than a solar cycle of eleven years with minimal fuel consumption. IBEX continues to take nominal measurements of ENAs originating from the interface region between our heliosphere and the surrounding interstellar matter.

Abbreviations

ENA	Energetic neutral Atom
IBEX	Interstellar Boundary Explorer
SMEX	Small Explorer

Publications

1. D.F. Rodríguez Moreno, P. Wurz, L. Saul, M. Bzowski, M.A. Kubiak, J.M. Sokół, P. Frisch, S.A. Fuselier, D.J. McComas, E. Möbius, and N. Schwadron "Evidence of direct detection of interstellar deuterium in the local interstellar medium by IBEX", Astron. and Astrophys. 557, (2013) A125, 1–13. DOI: 10.1051/0004-6361/201321420

2. S.A. Fuselier, F. Allegrini, H.O. Funsten, A.G. Ghielmetti, D. Heirtzler, H. Kucharek, O.W. Lennartsson, D.J. McComas, E. Möbius, T.E. Moore, S.M. Petrinec, L.A. Saul, J. Scheer, N. Schwadron, and P. Wurz, "Width and Variation of the ENA Flux Ribbon Observed by the Interstellar Boundary Explorer", Science, 326 (2009), 962–964

3. D.J. McComas, F. Allegrini, P. Bochsler, M. Bzowski, E.R. Christian, G.B. Crew, R. DeMajistre, H. Fahr, H. Fichtner, P. Frisch, H.O. Funsten, S.A. Fuselier, G. Gloeckler, M. Gruntman, J. Heerikhuisen, V. Izmodenov, P. Janzen, P. Knappenberger, S. Krimigis, H. Kucharek, M. Lee, G. Livadiotis, S. Livi, R.J. MacDowall, D. Mitchell, E. Möbius, T. Moore, N.V. Pogorelov, D. Reisenfeld, E. Roelof, L. Saul, N.A. Schwadron, P.W. Valek, R. Vanderspek, P. Wurz, and G.P. Zank, "First Global Observations of the Interstellar Interaction from the Interstellar Boundary Explorer", Science, 326 (2009), 959–962

Time-Line	From	To
Measurement Phase	on-going	
Data Evaluation	on-going	

4.3 DAMPE

Purpose of Research

The DAMPE (DArk Matter Particle Explorer) satellite is one of the five selected space missions in the Strategic Priority Research Program in Space Science of the Chinese Academy of Science.

The main scientific objectives of DAMPE are:

- To measure electrons and photons with much higher energy resolution and energy reach than achievable with existing space experiments in order to identify possible Dark Matter signatures.
- To advance the understanding of the origin and propagation mechanism of high energy cosmic rays by measuring their spectra and compositions.
- To extend the direct observation of high energy gamma sources.

DAMPE consists of a double layer of plastic scintillator strips detector that serves as anti-coincidence detector, followed by a silicon-tungsten tracker-converter (STK), which is made of six tracking double layers; each consists of two layers of single-sided silicon strip detectors measuring the two orthogonal views perpendicular to the pointing direction of the apparatus. Three layers of Tungsten plates with thickness of 1 mm are inserted in front of tracking layer 2, 3 and 4 for photon conversion. The STK is followed by an imaging calorimeter of about 31 radiation lengths thickness, made up of 14 layers of BGO bars in a hodoscopic arrangement. Finally a layer of neutron detectors is situated at the bottom of the calorimeter.

DAMPE will have unprecedented sensitivity and energy reach for electrons, photons and cosmic rays (proton and heavy ions). For electrons and photons, the detection range is 5 GeV–10 TeV, with an energy resolution of about 1 % at 800 GeV. For cosmic rays, the detection range is 100 GeV–100 TeV, with an energy resolution better than 40 % at 800 GeV. The geometrical factor is about 0.3 m^2 sr for electrons and photons, and about 0.2 m^2 sr for cosmic rays.

The DPNC is the proponent of the STK and is leading its design and construction, which is a collaborating effort between Switzerland (University of Geneva), Italy (INFN Perugia and INFN Bari) and China (Institute of High Energy Physics, Beijing). The STK consists of multiple layers of silicon micro-strip detectors interleaved with Tungsten converter plates. The principal purpose of the STK is to precisely measure the incidence direction of high energy cosmic rays, in particular gamma rays, as well as the charge of charged cosmic rays. The STK identifies gamma rays by their conversions to charged particles in tungsten plates and infer their incident direction by the measuring with great precision the path of the charged particles within the STK.

Status

The DAMPE payload has entered the construction phase and Engineering and Qualification Model (EQM) of the subsystems are being constructed. Prototypes of STK components have been produced and undergone space qualification tests in 2013. The STK EQM construction is in progress and will be completed in June 2014. The integration of all EQM models into a payload EQM is planned for summer

Institute

DPNC, University of Geneva

In Cooperation with

INFN Perugia
INFN Bari
IHEP Beijing
PMO Nanjing

Principal Investigator

Jin Chang, PMO, China

Swiss Principal Investigator

Xin Wu

Co-Investigator

Martin Pohl

Method

Measurement

Industrial Hardware Contract to

Composite Design Sàrl
Hybrid SA

2014, which will be tested for space qualification, and will be tested and calibrated with high energy particle beams at CERN. The Flight Model (FM) of the STK should be completed by the end of 2014 and the launch of DAMPE satellite is planned for the end of 2015. Ground segment and data reconstruction and analysis software are being developed. DPNC is coordinating the test beam activities, as well as the data reconstruction and analysis software implementation.

Abbreviations

DAMPE	DArk Matter Particle Explorer
STK	Silicon-Tungsten Tracker
BGO	Bismuth Germanium Oxide
DPNC	Département de physique nucléaire et corpusculaire, University of Geneva
IHEP	Inst. of High Energy Physics, Chinese Academy of Sciences, Beijing, China
PMO	Purple Mountain Observatory, Chinese Academy of Sciences, Nanjing, China
INFN	Istituto Nazionale di Fisica Nucleare, Italy
CERN	European Organization for Nuclear Research

Time-Line	From	To
Planning	2012	2013
Construction	2013	2015
Measurement Phase	2016	2018
Data Evaluation	2016	2020

4.4 Large Observation Programs with XMM-Newton

Purpose of Research

XMM-Newton is currently the work horse of high-energy astrophysics. This group is contributing very actively to the science exploitation of the mission through its participation in several very ambitious observing campaigns dedicated to the study of individual active galactic nuclei (AGN) or to the study of galaxy clusters and the large-scale structure of the Universe. The three main campaigns are:

- The Ultimate XMM Extragalactic Survey (XXL) is an XMM-Newton Very Large Programme aiming at surveying two extragalactic regions of 50 deg² in total with more than 6 Ms of observation. XXXL is a very large consortium of more than 100 scientists, led by Marguerite Pierre, CEA. XXL aims at discovering some 600 new galaxy clusters up to redshift about 2 and 10 000 AGN out to redshift 4. One of the main goal of XXL is the study of the equation of state of Dark Energy using the cluster mass function.

- A large (mostly) European consortium led by Jelle Kaastra, SRON, has been built to obtain one of the most intensive observation campaign on the Seyfert 1 galaxy Markarian 509, totalling 600 ks with XMM-Newton, and 1.2 Ms with INTEGRAL. These data have been used to characterize the outflowing winds that are typical of these objects and which may play a very significant role in the evolution of galaxies, by preventing gas and dust to fall towards the center of galaxies, quenching therefore star formation. The velocity, ionization degree and opacity of these winds have been determined thanks to the high-signal-to-noise ratio RGS grating observations. The campaign has been designed to allow the determination of their locations and densities, which are very difficult to disentangle, allowing to determine all the physical properties of these outflows. The very rich data set to constrain the physical mechanisms of high-energy emission in these objects, providing new insights into the physical conditions and processes in these objects, including the geometry of the emission and the existence of strong relativistic effects.

- Another XMM-Newton Large Program led by Jelle Kaastra, SRON, has been devoted to the study of the AGN NGC 5548, together with (in particular) Hubble Space Telescope (HST), INTEGRAL and NuSTAR observations. X-ray spectroscopy with XMM-Newton and UV spectroscopy with HST, plus all the supporting information necessary to constrain the continuum emission, shall be used to understand the geometry of the AGN through the characterization of the physical conditions and ionization structure of the gas in the immediate surroundings of the nucleus. The properties of outflows, which may play a very important role in the evolution of galaxies, is a key goal of this project. On larger distance scales, the UV spectroscopy shall be used to determine the dynamical properties of the so-called broad-line region, and its connection to the accretion flow.

Abbreviations

AGN	active galactic nucleus
HST	Hubble Space Telescope

Institute

Department of Astronomy,
University of Geneva

In Cooperation with

Many research institutes worlwide – more than one hundred scientists

Principal Investigator

Marguerite Pierre, CEA, FR
Jelle Kaastra, SRON, NL

Swiss Principal Investigator

Stéphane Paltani, UNIGE

Co-Investigator

R. Boissay, UNIGE
J. Coupon, UNIGE
D. Eckert, UNIGE
S. Fotopoulou, UNIGE
N. Fourmanoit, UNIGE

Method

Measurement

Research Based on Existing Instruments

XMM-Newton.

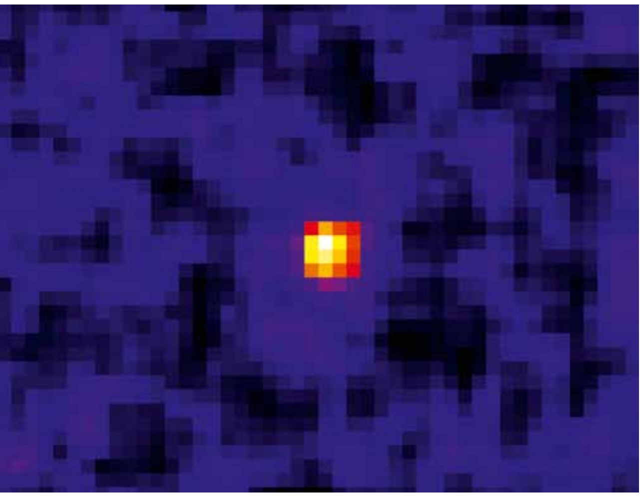
Publications

1. Pierre, M., “XXL – An overview of the ultimate XMM extragalactic survey”, Proceedings “The X-ray Universe”, Berlin, 2011

2. J.S. Kaastra et al., 2011, “Multiwavelength campaign on Mrk 509. I. Variability and spectral energy distribution”, Astronomy & Astrophysics, Volume 534, id.A36

3. J.S. Kaastra et al., 2014, “Discovery of a fast and massive outflow from the supermassive black hole in NGC 5548”, submitted

4.5 The HEAVENS High-Energy Data Analysis Service



The Crab nebula detected at 4 MeV by the INTEGRAL PICSIT detector. Such data are not available anywhere else.

Institute

ISDC Data Centre for Astrophysics, Astronomical Observatory of the University of Geneva

In Cooperation with

CAMK Poland
GSFC USA
FAU Germany
Univ. of Leicester Great Britain
CEA France

Principal Investigator

R. Walter

Method

Measurement

Development of Software for

The generation, provision and utilisation of customized high level data analysis products.

Publications

http://www.isdc.unige.ch/heavens/

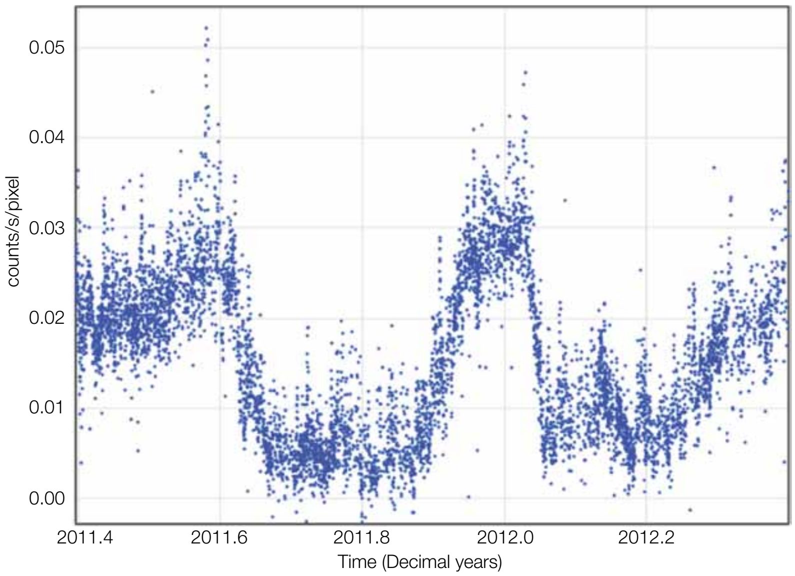
Purpose of Research

High-energy astrophysics space missions have pioneered and demonstrated the power of legacy data sets for generating new discoveries, especially when analyzed in ways the original researchers could not have anticipated. HEAVENS provides analysis services for a number of recent and important high-energy missions. These services allow any user to perform on-the-fly data analysis to produce straightforwardly scientific results for any sky position, time and energy intervals without requiring mission specific software or detailed instrumental knowledge. The ultimate goal is to ensure that the data of the present instruments can be effectively used by everyone and everywhere for the decades to come. By providing a straightforward interface to complex data and data analysis, HEAVENS makes the data and the process of generating science products available to the public and higher education. HEAVENS promotes the visibility of high-energy and multi-wavelengths astrophysics to the society at large and encourages the public to actively explore the data. This is a fundamental step to transmit the values of science and to evolve towards the knowledge society.

HEAVENS generates custom made high-level science data products that are unique and not available anywhere else, such as data from all INTEGRAL instruments, RXTE, Swift BAT etc.

Status

HEAVENS includes data from several major ESA and NASA missions. It is regularly enhanced with new instruments and capabilities, typically following important data analysis advances/campaign performed at the ISDC for scientific research. In 2013 HEAVENS served 300 requests for 140 different external users on average, every month. Data generated by the HEAVENS service are also used for scientific research at the University of Geneva.



Continuous hard X-ray lightcurve of Cyg X-1 with a resolution of 1 000 sec (flux uncertainties are as small as 0.001). Such lightcurves (here from Swift BAT) data are not available anywhere else.

4.6 High-Energy Astrophysics

Purpose of Research

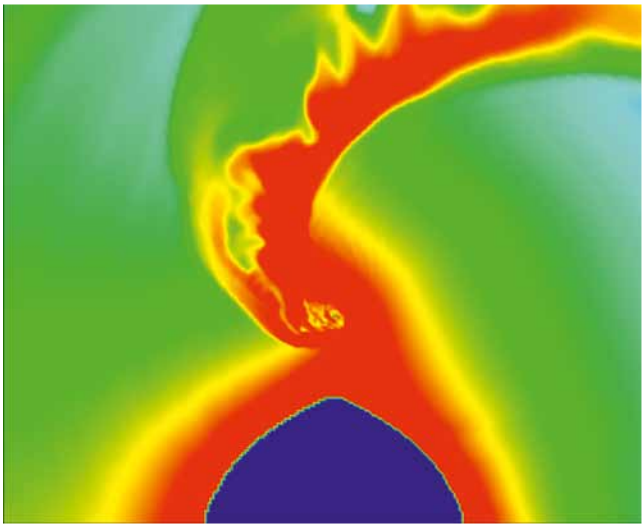
High-energy astrophysics studies astronomical objects emitting X-ray to gamma-rays photons, neutrinos and cosmic rays. ISDC scientists are using very diverse instruments (radio and mm telescopes, Planck, Hershel, optical telescopes, XMM, Chandra, Swift, Suzaku, NuStar, INTEGRAL, Fermi, MAGIC, FACT) covering all wavebands, together with archival data, to study black-holes, neutron stars and pulsars, isolated or in binary systems, pulsar winds, supernova and remnants, active galactic nuclei, galaxy clusters and gamma-ray bursts. The group at the ISDC includes four senior scientiststs, height postdocs and five PhD students. They published more than 60 papers in 2012/2013. Some highlights are summarized below.

A strong hard X-ray flare was discovered in the galaxy NGC 4845 by INTEGRAL in January 2011 and was also followed-up densely by XMM-Newton and Swift. The resulting lightcurve corresponds very well to the variability of the accretion flow predicted by hydrodynamic simulations of the tidal disruption of an object flying close to a giant black-hole at the center of the galaxy. Details of the observations indicate that a the unlucky object is light, a super-Jupiter, and that its internal structure corresponds to that of a planet or of a brown dwarf, not a normal star. In addition, the black-hole was found to be about 10 times lighter than Sgr A* at the center of our galaxy, a rather low mass, usually not detectable.

Jets are present in a vast majority of astrophysical objects, from young forming stars up to extremely massive black holes hidden in the core of active galaxies. However, the physics of these systems, as well as the unique characteristics that differentiate each of them, are still scarcely known. INTEGRAL, together with a vast multiwavelength follow-up campaign, led to the discovery of the longest jet ever observed in our Galaxy. This jet is formed, surprisingly, by an isolated neutron star, which is escaping at supersonic velocity from the place where it was born during a supernova explosion 10–20 kyr ago. The characteristics of the jet and the pulsar wind system, open up the possibilities to study the physics of jets in general. The association of the system with its parent, bright, supernova remnant, moreover, hints for a peculiar and still unknown core collapse mechanism that gave birth to the entire system.

Neutron stars are fundamental to probe the physics of matter at the highest density, where even atom nuclei are broken into quarks. New stellar systems, discovered by INTEGRAL, including a neutron star orbiting a massive companion, allow to weight the neutron star in an original manner, by measuring the gravitational deflection of the wind stream generated by the companion star. The gas stream is so dense that it absorbs the X-ray emission of the neutron star. X-ray observations along the orbit therefore allow to map its deflection and to evaluate the mass of the neutron star by comparison with hydrodynamic models.

A new transient pulsar, identified as IGR J18245-2452, was detected by INTEGRAL in March 2013 in the globular cluster M28. Observations by XMM-Newton determined the pulsar's spin period to be 3.9 milliseconds clearly identifying it as an



Focusing and bending of the stellar wind by a neutron star.

Institute

ISDC Data Centre for Astrophysics, Astronomical Observatory of the University of Geneva

Co-Investigator

T. Courvoisier
A. Neronov
S. Paltani
R. Walter

Method

Measurement

X-ray-bright millisecond pulsar powered by accretion of material from a nearby low-mass star companion. The spin period and other key characteristics was found to match perfectly those of a pulsar in M28 that had been observed in 2006, but only at radio wavelengths. This is then the first ever fast-spinning "millisecond pulsar" caught in a crucial evolutionary phase, as it swings between emitting pulses of X-rays and radio waves.

Galaxy clusters form from the largest inhomogeneities of the early Universe, and thus they are expected to retain their mass (both baryonic and dark matter) throughout cosmic time. We evaluated the baryon fraction of galaxy clusters in their entire volume by combining X-ray (ROSAT) and Sunyev-Zel'dovich (Planck) data. As expected, we find that the average baryon fraction reaches the cosmic value Ωb/Ωm in the outer regions, which shows that clusters are suitable targets for cosmological studies. The cosmic-ray content of galaxy clusters is expected to produce gamma-rays. Stacking the Fermi observations at the position of 53 known galaxy clusters could not detect the expected emission, indicating that the injection of cosmic rays by cosmological shocks is less efficient than expected.

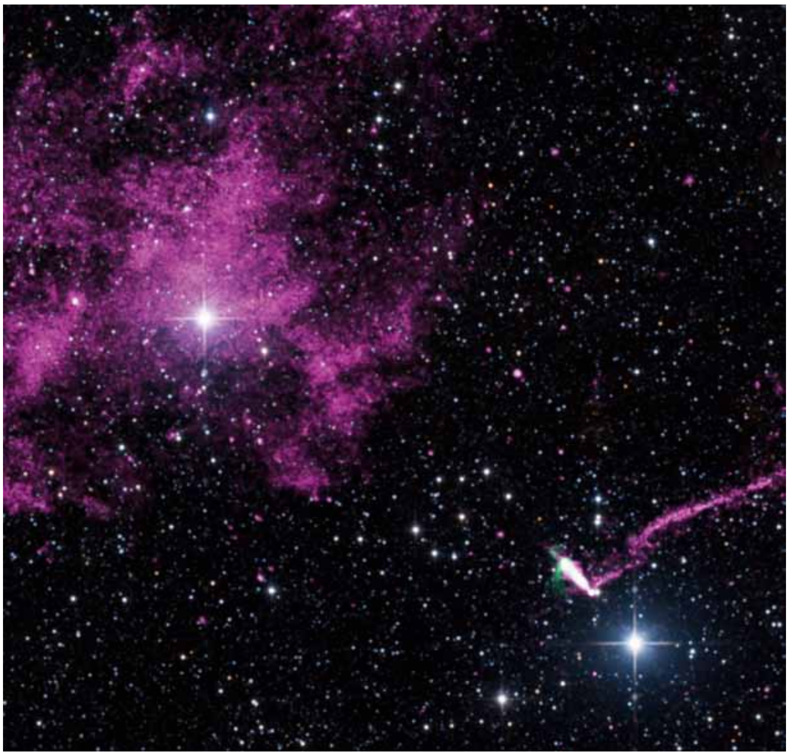
Publications

1. Nikolajuk M. & Walter R., 2013, A&A 552, 75

2. Papitto A. et al., 2013, Nature 501, 7468, pp. 517–520

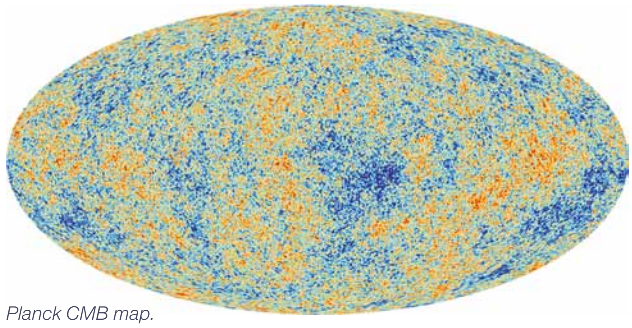
3. Pavan L. et al., 2014, A&A, 562, id.A122

4. Manousakis et al., 2012, A&A 547, 20



Hellical X-ray jet expelled by the run-away pulsar IGR J11014-6103 discovered by INTEGRAL.

4.7 Planck



Planck CMB map.

Purpose of Research

Planck is an ESA satellite launched in 2009, with an off-axis tilted Gregorian design, a primary mirror measuring 1.9 x 1.5 m and a 1.1 x 1.0 m secondary mirror. The satellite carried two scientific instruments, LFI (Low-Frequency Instrument), an array of radio receivers using high electron mobility transistor mixers and HFI (High-Frequency Instrument), an array of microwave detectors using spiderweb bolometers equipped with neutron transmutation doped germanium thermistors.

Planck mapped the anisotropies in the cosmic microwave background radiation (CMB) at an angular resolution of about 10 arc minutes and a temperature sensitivity of one part in one million, for 9 frequencies (from 30 GHz to 857 GHz), scanning the entire sky twice per year. Temperature fluctuations we observe, approximately 380 000 years after the Big Bang, correspond to primordial density fluctuations and give us insight on early stages of the Universe (and the theory of inflation) as well as on the evolution of fluctuations at later times. Planck has released in 2013 the first set of cosmological data and results, providing the best constraints on the cosmological parameters currently available. Results support the inflationary paradigm by detecting a small non-zero tilt of the primordial power spectrum at over 5 sigma.

Planck further detects the gravitational lensing of the CMB anisotropies by the large-scale structure in the Universe with a significance of 26 sigma, reconstructing also the lensing potential power spectrum. Moreover, it provides the most stringent constraints on primordial non-Gaussianity, topological defects and non-trivial topologies of the Universe. Overall it is in stunning agreement with the cosmological standard model, being consistent with spatial flatness to percent level. Planck has also provided an all-sky cluster catalog, a catalog of Extragalactic and Galactic compact sources, a map of different astrophysical and galactic “foregrounds” and a host of further science results.

Planck publications can be found at: http://www.sciops.esa.int/index.php?project=PLANCK&page=Planck_Published_Papers

Switzerland is involved on several levels in Planck. Since 2001, the ISDC Data Centre for Astrophysics was responsible for developing the first steps of the data processing for the LFI instrument of Planck. This Level 1 software has been defined as mission critical by ESA and ran smoothly throughout the Planck mission at the LFI Data Processing Centre in Trieste, Italy.

Several members of the Theory Department of the Université de Genève were and are directly involved in the ongoing cosmological science exploitation effort. This includes search for non-Gaussianities and topological defects, component separation analysis, extraction of power spectra and parameter estimation, with particular interest for Dark Energy investigation and comparison with Supernovae available data.

Overall, Planck as been a great success, working without interruption for over twice the intended period and meeting all performance requirements.

Institute

Université de Genève

In Cooperation with

ESA
about 100 institutes in Europe, USA, Canada
NASA

Principal Investigator

Jean-Loup Puget, IAS Orsay, Paris (HFI)

Reno Mandolesi, CNR Bologna (LFI)

Swiss Principal Investigator

Marc Türler, Université de Genève

Co-Investigator

Ruth Durrer, Université de Genève

Martin Kunz, Université de Genève

Valeria Pettorino, Université de Genève & Heidelberg

Marco Tucci, Université de Genève

Method

Measurement

Research Based on Existing Instruments

Planck/LFI and Planck/HFI.

Status

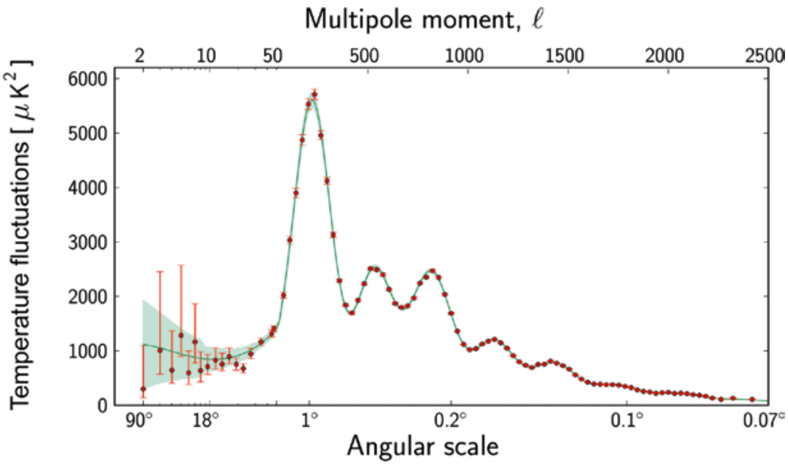
The Planck satellite was turned off on 23 October 2013 as planned. The collaboration is currently analyzing data on temperature and polarization relative to the whole mission time, which is twice the nominal mission and includes five full-sky surveys from HFI and eight full-sky surveys from LFI. Full-mission data are expected to give a further improvement in our cosmological understanding, and new results will come out in 2014. In particular, polarization data can improve current constraints on the possible contribution from primordial tensor fluctuations and on the optical depth of the Universe, and they are an important test for studies of non-Gaussianity and of anomalies in CMB data.

Publications

1. The Planck Collaboration, Planck 2013 results. I. Overview of products and results, submitted to A&A, arXiv: 1303.5062 (2013)
2. The Planck Collaboration, Planck 2013 results. XV. CMB power spectra and likelihood, submitted to A&A, arXiv: 1303.5075 (2013)
3. The Planck Collaboration, Planck 2013 results. XVI. Cosmological parameters, submitted to A&A, arXiv: 1303.5076 (2013)
4. The Planck Collaboration, Planck 2013 results. XXIV. Constraints on primordial non-Gaussianity, accepted by A&A, arXiv: 1303.5084 (2013)

Abbreviations

HFI	High-Frequency Instrument
LFI	Low-Frequency Instrument
CMB	Cosmic Microwave Background



Planck power spectrum of CMB fluctuations.

4.8 Cryogenic Receivers for the Herschel/HIFI Spectrometer

Purpose of Research

The Herschel Space Observatory reached successfully its location far away from Earth (Lagrangian point 2). It was ideal to search for water in star forming regions, protostellar envelopes and the rest of the universe. As a wide spectrum is completely covered at high spectral resolution for the first time, the HIFI instrument on board of Herschel has already discovered new molecules in a region of the spectrum that is inaccessible from the ground (from 0.5 to 1.9 THz or 150 to 800 microns). At ETH Zurich we have for instance discovered ionized water (H_2O^+) for the first time in star-forming regions. The HIFI spectrometer is the largest of three instruments on board.

The Swiss hardware contribution for the HIFI instrument grantees observing time on HERSCHEL (forth cornerstone of ESA). ETH Zurich has lead the production of some hardware and is now contributing to develop software in collaboration with FHNW Windisch.

The prime focus in Switzerland is on water and other hydrides in the envelopes of very young stellar objects of both high and low mass (ETH Zurich). The main goal is to study the effects on water and other molecules produced by the irradiation of far UV and X-rays. These reactions can destroy or form water, depending on irradiation, temperature and density. These molecules are also tracers for the physical conditions and processes in star-forming regions. In particular, we study the irradiation by protostellar far UV and X-ray emission.

A second project is the investigation of water in the atmosphere of Mars, using the high spectral resolution of HIFI to derive the water distribution from the line profile (University of Bern).

Status

The Herschel Space Observatory was launched successfully on 14 May 2009 and operated until the supply liquid Heliium coolant was exhausted on 29 April 2013. The HIFI instrument was operating according to specifications until the end of the mission. The hardware components we have contributed worked perfectly. We have also contributed software, in particular the pipeline, used by the whole community to prepare the data for scientific analysis.

The first results papers were published by Astronomy and Astrophysics in a dedicated issue in late 2010, including 4 first authored publications from the Institute of Astronomy at ETH. In the mean time more data are published using more detailed modelling and interpretations (see below).

Time-Line	From	To
Planning	1999	2000
Construction	2000	2008
Measurement Phase	2009	2013
Data Evaluation	2010	2014

Institute

Institute of Astronomy, ETH Zurich

In Cooperation with

ESA

Principal Investigator

F. Helmich (SRON)

Swiss Principal Investigator

A. O. Benz (ETH)

Co-Investigator

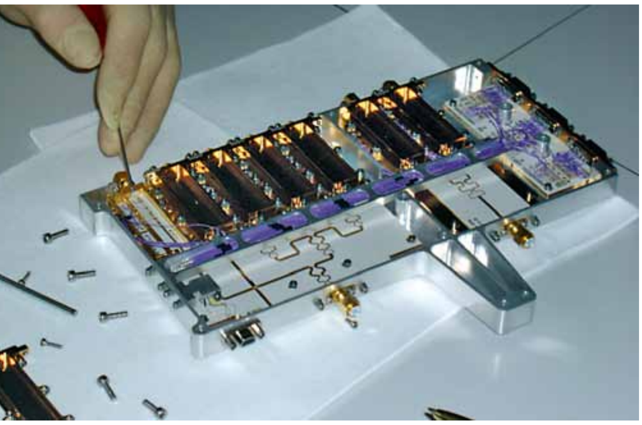
S. Bruderer (MPE)
E. van Dishoeck (Obs. Leiden)
S. Wampfler (Copenhagen)

Method

Measurement

Industrial Hardware Contract to

HTS Wallisellen
RUAG Oerlikon
Baumer Electronics Frauenfeld



The frequency amplification unit, including low-noise and low-power amplifiers (InP HEMTs), for the HIFI instrument on the Herschel Space Observatory. The unit was designed and constructed by the Laboratory for Electromagnetic Fields and Microwave at ETH Zurich. The figure shows the qualification model. The flight model was produced by RUAG Aerospace Oerlikon and Baumer Electronics, Frauenfeld.

Publications

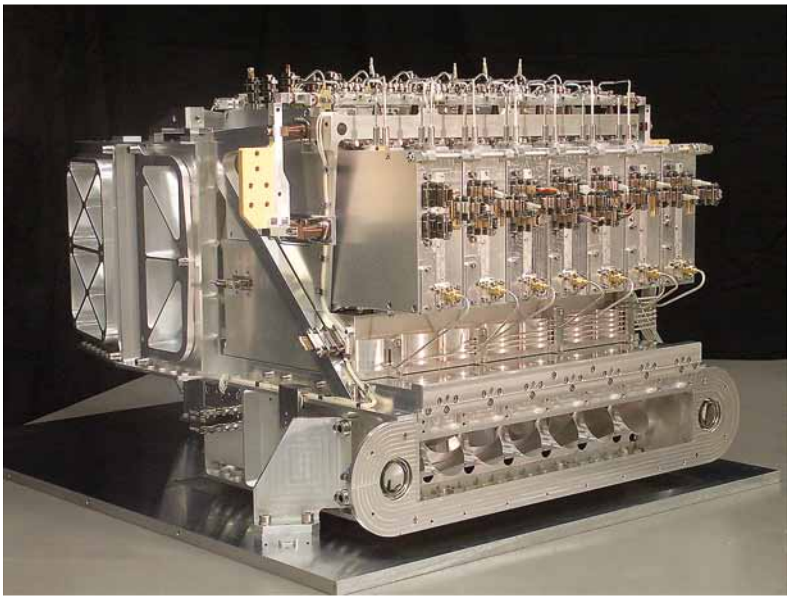
1. Benz, Arnold O.; Bruderer, Simon; van Dishoeck, Ewine F.; Stäuber, Pascal; Wampfler, Susanne F. "Neutral and Ionized Hydrides in Star-Forming Regions. Observations with Herschel/HIFI", 2013, The Journal of Physical Chemistry A, Vol. 117, Issue 39, p. 9840–9847

2. Wampfler, S. F.; Bruderer, S.; Karska, A.; Herczeg, G. J.; van Dishoeck, E. F.; Kristensen, L. E.; Goicoechea, J. R.; Benz, A. O.; Doty, S. D.; McCoey, C.; Baudry, A.; Giannini, T.; Larsson, B. "OH far-infrared emission from low- and intermediate-mass protostars surveyed with Herschel-PAC", 2013, Astronomy & Astrophysics, Volume 552, id.A56, 45 pp.

3. Wampfler, S. F.; Bruderer, S.; Kristensen, L. E.; Chavarría, L.; Bergin, E. A.; Benz, A. O.; van Dishoeck, E. F.; Herczeg, G. J.; van der Tak, F. F. S.; Goicoechea, J. R.; Doty, S. D.; Herpin, F. "First hyperfine resolved far-infrared OH spectrum from a star-forming region", 2011, Astronomy & Astrophysics, Volume 531, id.L16, 5 pp.

Abbreviations

HIFI Herschel Heterodyne Instrument for the Far Infrared



Common Optics Assembly of HIFI on the Herschel Space Observatory, an ESA space craft that operated at the Lagrangian Point L2, 1.5 million km from Earth. The mechanical structure and components were produced by RUAG Wallisellen.

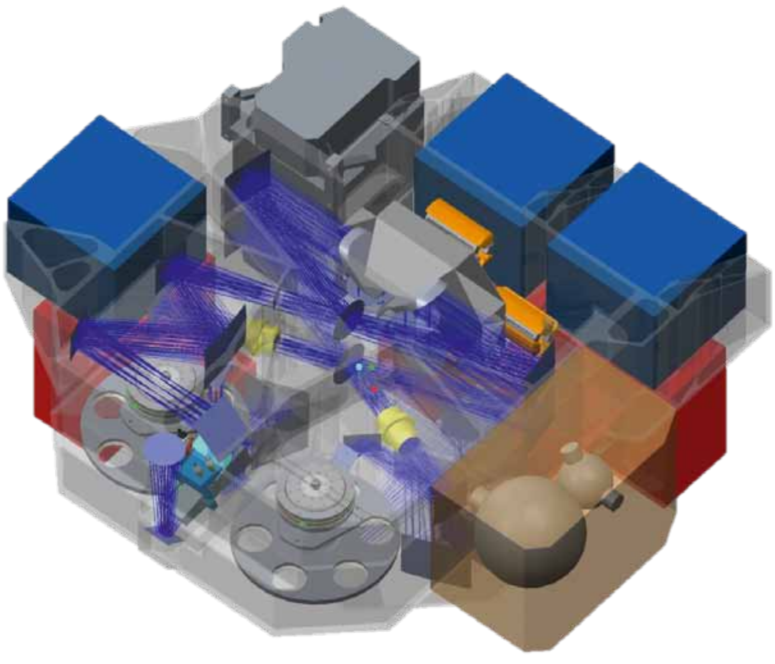
4.9 The SAFARI Instrument Control Center and the SPICA Mission

Purpose of Research

SAFARI is a far-infrared instrument to be launched on board of the Japanese SPICA mission. It is a Fourier-transform imaging spectrometer with an actively cooled, novel detector using the Transition Edge Sensor technology that allows high sensitivity. In addition, the SPICA telescope, to be provided by ESA, will be actively cooled down to about 6K, effectively suppressing most of the satellite's infrared thermal background, which will allow us to reach much deeper (up to a millions times fainter) fluxes in the SAFARI range. Science topics addressed by SPICA and SAFARI are, among others, the formation and evolution of stars and planets, and of galaxies. The University of Geneva was appointed by the SAFARI Heads of Nations as the lead institute to coordinate the development and operations of the SAFARI Instrument Control Center, in collaboration with members of the SAFARI Consortium. The ICC will be responsible for the calibration, software development, and routine operations tasks of the instrument. It will work In Cooperation with the ESA and JAXA ground segments. The University of Geneva participation in SAFARI and SPICA will complement the hardware efforts done at ETHZ. The SAFARI Consortium will have access to guaranteed time on board SPICA.

Status

Although SPICA has passed several reviews in Japan, SPICA has not yet undergone the JAXA phase-up review that would formally transform its status into an approved project. During the reporting period, the ICC System Design Team was formed and met several times to create and update the SAFARI Science Implementation Plan that describes the intended structure, development, and operations of the SAFARI ICC.



Reference design of SAFARI (September 2013).

Institute

Department of Astronomy, University of Geneva

In Cooperation with

SRON Groningen and the SAFARI Consortium

Principal Investigator

Peter Roelfsema, SRON

Swiss Principal Investigator

Marc Audard, UNIGE

Co-Investigator

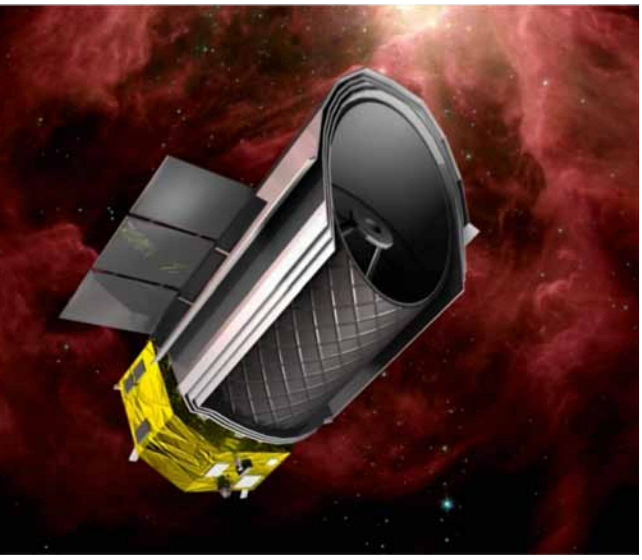
Daniel Schaerer, UNIGE
Stéphane Paltani, UNIGE

Method

Measurement

Development of Software for

Instrument Control Center for the SAFARI instrument onboard the Japanese SPICA mission.



The SPICA satellite.

The Science Implementation Plan and SPICA ground segment plans were presented at SAFARI consortia twice a year. In addition Swiss participants have contributed to the update of the Yellow Book.

In mid 2013, it became apparent that, due to the financial situation in Japan, the SPICA mission could not be launched without a stronger financial involvement by international partners. JAXA/ISAS and ESA/SRON agreed upon a stronger involvement of the European contribution to SPICA, including the SAFARI instrument and the European ground segment. Consequently, the SPICA consortium will propose a strong European contribution in SPICA via the upcoming M4 call. If selected, the final mission selection will take place in 2017, with a foreseen launch in late 2026.

Publications

1. T. Nakagawa, H. Matsuhara, Y. Kawakatsu, “The next-generation infrared space telescope SPICA”, Proceedings of the SPIE, Vol. 8442, art. id 84420O, 9pp (2012)

2. P. Roelfsema, M. Giard, F. Najarro, K. Wafelbakker, W. Jellema, B. Jackson, B. Swinyard, M. Audard, Y. Doi, M. Griffin, F. Helmich, F. Kerschbaum, M. Meyer, D. Naylor, H. Nielsen, G. Olofsson, A. Poglitsch, L. Spinoglio, B. Vandenbussche, K. Isaak, J. R. Goicoechea, “The SAFARI imaging spectrometer for the SPICA space observatory”, Proceedings of the SPIE, Vol. 8442, art. id 84420R, 15pp (2012)

3. J. R. Goicochea, M. Audard, C. Joblin, I. Kamp, M. R. Meyer, “The far-IR view of star and planet forming regions”, Proceedings of the SPICA’s New Window on the “Cool Universe” conference, arXiv: 1310.1683 (2013)

Abbreviations

ICC	Instrument Control Center
SPICA	Space Infrared Telescope for Cosmology and Astrophysics
SAFARI	SpicA FAR-infrared Instrument

Time-Line	From	To
Planning	2011	2014
Construction	2014	2026
Measurement Phase	2027	2032
Data Evaluation	2032	

4.10 Gaia Variability Analysis and Processing

Purpose of Research

Gaia is a cornerstone mission of the Astrophysics programme of the European Space Agency successfully launched in December 2013. Its goal is to measure repeatedly 1 billion objects in our Galaxy. Thanks to these measurements Gaia will deliver outstanding contributions on astrophysics, e.g. on galactic astrophysics, stellar astrophysics (stellar evolution and stellar variability), solar system body studies.

In order to face the major challenge represented by the processing of the huge data stream received from the spacecraft, the European community has organized itself initially into 8 Coordination Units (CUs), dividing the task into different thematics. Following a formal ESA selection process in 2007, two entities managed by the Geneva University were formed to support the variability processing and analysis of Gaia:

- the Coordination Unit 7 (CU7), which is an international consortium
- the Geneva Data Processing Centre (DPCG), which is responsible for operating the software developed by CU7

This activity directly builds upon the expertise gathered through the important participation of the University of Geneva in two other ESA missions: Hipparcos and INTEGRAL.

The CU7/DPCG group is in charge of the analysis of the variability of celestial objects: in particular, characterization and classification of these objects in different variability types.

The CU7 Geneva team also contributes to the work of other Coordination Units: in the CU6 multiple transits analysis work package and in the CU2 models of variable objects implemented in the Universe Model.

Our main goal is to produce parts of the intermediate and final Gaia catalogs which will be released by ESA (final release planned in 2021).

The Geneva team is also pursuing an active research program on stellar variability which will benefit from and contribute to the Gaia development and creates a synergy between software development and science.

The Geneva group consists of 17 people, contributing at different levels (scientists, software engineers, post-docs, PhD students, system administrators).

The ESA project related Gaia activities in Geneva are supported by the University of Geneva, funding provided by the Swiss Prodex Programme and the Swiss Federal Activités Nationales Complémentaires (ANC). The preparation of the scientific exploitation of Gaia data has been supported by FNRS and RTN-FP6/ITN-FP7 EU grants.

Time-Line	From	To
Planning	2006	2021
Construction	Cyclic development	2021
Measurement Phase	2013	2019
Data Evaluation	Cyclic	2021/2022

Institute

Department of Astronomy,
University of Geneva, Geneva

In Cooperation with

17 institutes mostly in Europe
(about 70 people)

Principal Investigator

ESA

Swiss Principal Investigator

Laurent Eyer

Co-Investigator

Nami Mowlavi
Berry Holl
Diego Ordonez
Richard Anderson
Fabio Barblan
Leanne Guy
Isabelle Lecoeur
Lovro Palaversa
Lorenzo Rimoldini
Sophie Saesen
Maria Süveges
François Bouchy
Laurent Douchy
Emmanuel Carrillo
& the Software company SixSQ

Method

Measurement

Development of Software for

The Gaia mission.

Launch of Gaia by a Soyuz rocket, operated by Arianespace, lauched from Europe's Spaceport in French Guiana at 6h12 local time (9h12 UTC). The drawing on the fairing was made by a Swiss student, Joël Schopfer, of EPAC in Saxon.

Status

Successful launch of Gaia: the Gaia spacecraft was admirably launched from French Guyana on 19 December 2013 and has started its commissioning phase which will be followed by a nominal five-year data collection period.

Preparation and execution of the Operation Rehearsals (ORs): the first CU7/OR is being performed on simulated data produced by CU2. It will be followed by another Operation Rehearsal on the real Gaia Ecliptic Pole data. These ORs test our CU7/DPCG interfaces with ESAC, CNES and Cambridge Data Processing Centers. It also tests the full integration of the software pipelines of all CUs.

Operations: the Coordination Units 1, 3, 5, 6 and part of CU4 are starting operations, while CU7 & 8 are relying on calibrated data. CU7/DPCG will enter into operations end of 2015.

Software development: the development process has been an iterative waterfall model common to all the eight coordination units of the Gaia DPAC and will continue during the whole mission until 2021/2022 in order to produce the iterative releases of the Gaia catalogue.

Publications

1. Anderson R.I. et al., Cepheids in open clusters: an 8D all-sky census, A&A 434, p. 2238–2261, 2013
2. Eyer L. et al., The Gaia mission, CEAB 37, p. 115–126, 2013
3. Rimoldini L. et al., Automated classification of Hipparcos unsolved variables, MNRAS 427, p. 2917–2937, 2012

Abbreviations

CU	Coordination Unit
CU4	Object Processing Coordination Unit
CU5	Photometric Processing Coordination Unit
CU6	Spectroscopic processing Coordination Unit
CU7	Variability Analysis and Processing Coordination Unit
DPAC	Data Processing and Analysis Consortium
DPC	Data Processing Center
DPCG	Data Processing Center of Geneva
OR	Operation Rehearsal

4.11 Euclid

Purpose of Research

Euclid is a mission of the European Space Agency designed to understand the origin and evolution of the Universe by investigating the nature of its most mysterious components: dark energy and dark matter, and by testing the nature of gravity. Euclid will achieve its scientific goal by combining a number of cosmological probes, among which the primary ones are weak gravitational lensing and baryonic acoustic oscillations.

The Euclid payload consists of a 1.2 m Korsch telescope designed to provide a large field of view. The Euclid survey will cover 15 000 deg^2 of the extragalactic sky with its two instruments: the VISual imager (VIS) and the Near-Infrared Spectrometer Photometer instrument (NISP), which includes a slitless spectrometer and a three-band photometer. Euclid is the second Medium Class mission of the ESA Cosmic Vision 2015–2025 programme, with a foreseen launch date in 2020.

Switzerland plays an important role in Euclid, with participation at all levels, from the science definition, to the building of space hardware, the development of analysis algorithms, the participation in the data processing and the science exploitation.

Several Swiss institutes are strongly involved in Euclid: the EPFL, the FHNW, UNIGE and UNIZH. On the science level, the EPFL (strong lensing), UNIGE (theory) and UNIZH (cosmological simulations) are co-coordinating the respective Science Working Groups. On the software and algorithms level, the EPFL is active in the development of algorithms for the measurement of the galaxy shear (weak lensing), as well as the detection of strong gravitational lenses, for which it plays a role of coordinator in the so-called Shear Organization Unit. FHNW contributes to the so-called system team, which provides the overall infrastructure binding the different components of the Euclid data centers.

UNIGE is in charge of the coordination of the development of algorithms and software for the determination of photometric redshifts. UNIGE also hosts the Swiss Euclid Science Data Center and is in charge of the determination of the photometric redshifts and the detection of strong lenses. The Euclid data processing is a large distributed effort, which will have to operate a multi-petabyte archive and a commensurate processing power. UNIGE also develops the RSU, a cryogenics shutter for the VIS instrument.

All participating institutes will partake in the science of Euclid, whether for the main science goals or for the very rich secondary science that will result from the huge Euclid survey.

Status

Euclid has concluded the Definition Phase (Phase A/B1) in spring 2012. It has entered Implementation Phase (Phase B2/C/D) in summer 2012. Phase B of the hardware development will be concluded in the first quarter of 2014, and a year later for the ground-segment activities. Phase C will be concluded in 2015/2016 for the hardware and the software respectively. The launch is currently schedule for the fourth quarter of 2020.

Institute

École Polytechnique Fédérale de Lausanne (EPFL)

Fachhochschule Nordwestschweiz (FHNW)

Université de Genève (UNIGE)

Universität Zürich (UNIZH)

In Cooperation with

ESA
about 100 European institutes
NASA
more than 1 000 astronomers and engineers worldwide

Principal Investigator

Yannick Mellier, Institut d'Astrophysique de Paris

Co-Investigator

Swiss consortium members with lead responsibilities only:

Frédéric Courbin, EPFL
Pierre Dubath, UNIGE
Jean-Paul Kneib, EPFL
Martin Kunz, UNIGE
Georges Meylan, EPFL
Stéphane Paltani, UNIGE
Anaïs Rassat, EPFL
Romain Teyssier, UNIZH

Method

Measurement

Developments

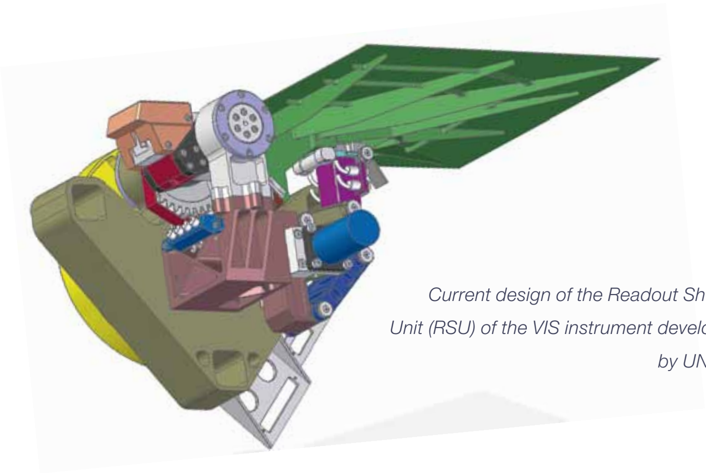
Development and construction of the Read-Out Shutter Unit (RSU) of the VIS instrument.

Development of algorithms for photometric redshifts, weak lensing and strong lensing.

Development of the Swiss Euclid Science Data Center.

Industrial Hardware Contract to

Ruag Space AG
(VIS RSU Phase B)



Current design of the Readout Shutter Unit (RSU) of the VIS instrument developed by UNIGE.

Publications

1. R. Laureijs, et al., 2011, "Euclid Definition Study Report", Euclid Red Book, ESA/SRE(2011)12, eprint arXiv: 1110.3193

2. L. Amendola, et al., 2013, "Cosmology and Fundamental Physics with the Euclid Satellite", Living Reviews in Relativity, vol. 16, no. 6

3. R. Joseph, et al., 2014, "A PCA-based automated finder for galaxy-scale strong lenses", submitted to Astronomy & Astrophysics

Abbreviations

NISP	Near-Infrared Spectrometer Photometer instrument
OU	Organization Unit
RSU	Read-out Shutter Unit
VIS	VISible imager

Time-Line	From	To
Planning		2012
Construction	2012	2017(HW)/2019(SW)
Measurement Phase	2020	2027
Data Evaluation	2020	2030

4.12 ASTRO-H

Purpose of Research

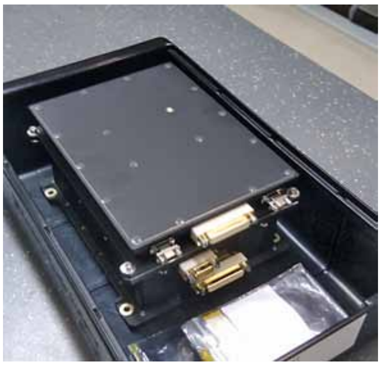
ASTRO-H is a mission of the Japan Aerospace Exploration Agency (JAXA) with a planned launch date in 2015. It is part of a very successful Japanese scientific program dedicated to high-energy astrophysics, the latest mission being Suzaku (2005), which is still in operation. ASTRO-H is an essential mission for high-energy astrophysics, between the current generation with XMM-Newton, INTEGRAL, Chandra and Suzaku, and the future Large Mission of ESA's Cosmic Vision program dedicated to the study of the hot and energetic Universe. UNIGE has been invited to participate in the ASTRO-H mission together with the Dutch space agency SRON, by developing a filter wheel for the Soft X-ray Spectrometer (SXS). The SXS is a cryogenics silicon detector working at 50 mK, aiming at providing excellent energy resolution (about 4 eV) in the 0.3–10 keV energy range, while preserving some imaging capabilities and high throughput. This instrument will be first operational cryogenics detector on an X-ray satellite. The purpose of the filter wheel is to select different optical elements, either to reduce X-ray count rate or optical load on the detector, as well as to protect the detector from micro-meteorites. It also supports and commands active calibration sources, which are provided by SRON, and assembled on top of the filter wheel.

The Filter Wheel consists of two separate units: the Filter Wheel Electronics (FWE) and the Filter Wheel Mechanism (FWM). The control and power electronics module, the FWE, has been designed by Micro-Cameras & Space Exploration and assembled and qualified by UNIGE. The filter wheel mechanism (FWM) has been built and qualified by Ruag Space. The Flight Models have been successfully delivered to SRON and then to JAXA in fall 2013.

UNIGE is now developing the European Science Support Center (ESSC). The ESSC is a part of the European user support activities for ASTRO-H. The other part, the Science Operations Centre (SOC), is located at ESAC (Spain) and is focussed on supporting the European user community in the use of the allocated time for ASTRO-H, through handling annual calls for observing proposals and related activities.

The ESSC provides direct support to European astronomers interested in submitting ASTRO-H proposals and in reducing and analyzing ASTRO-H data. In collaboration with the SOC, it will run a user helpdesk interface. The ESSC staff also contributes to the testing and validation of the ASTRO-H analysis software and its documentation. The ESSC will further train European astronomers and will contribute the technical support of the ESA Observing Time Allocation Committee process.

In addition, the ESSC staff is well integrated in the ASTRO-H collaboration thanks to the hardware involvement



Flight Model of the Filter Wheel Electronics (FWE).

Institute

Department of Astronomy, University of Geneva

In Cooperation with

Japan Aerospace Exploration Agency (JAXA)

Netherlands Institute for Space Research (SRON)

Principal Investigator

Tadayuki Takahashi, JAXA

Swiss Principal Investigator

Stéphane Paltani

Method

Measurement

Developments

Development and construction of the Filter Wheel Mechanism and Filter Wheel Electronics.

Development of user support activities.

Industrial Hardware Contract to

Ruag Space AG (FWM)

Micro-Cameras & Space Exploration (FWE)

for the SXS filter wheel. The staff is involved in the ASTRO-H Science Working Group and contributes to the definition of the target list to be proposed by the SWG for the performance verification phase.

Status

Hardware work has been completed. Post-delivery activities are on-going. The ESSC is being developed.

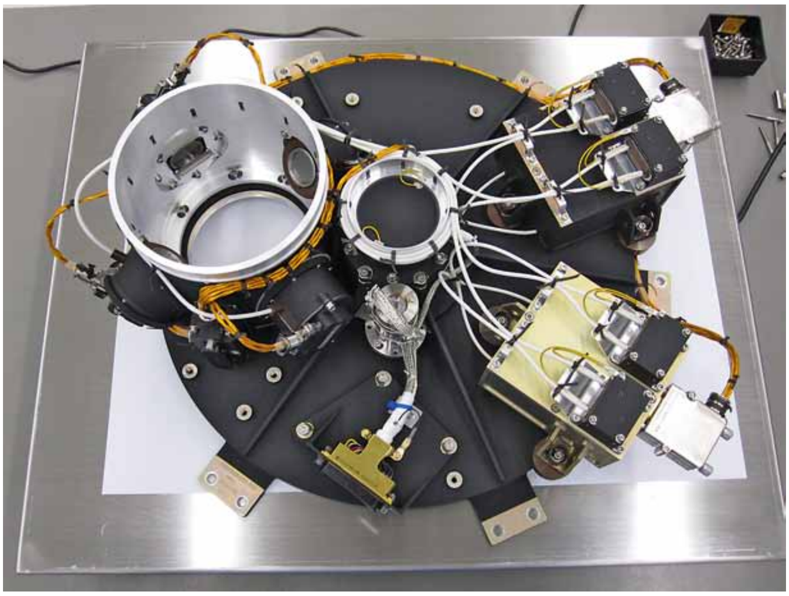
Publications

1. T. Takahashi, et al., 2012, "The ASTRO-H X-ray Observatory", Proceedings of the SPIE, Volume 8443, article id. 84431Z

Abbreviations

ESSC	European Science Support Center
FWE	Filter Wheel Electronics
FWM	Filter Wheel Mechanics
SXS	Soft X-ray Spectrometer

Time-Line	From	To
Planning		2010
Construction	2010	2013
Measurement Phase	2015	2020
Data Evaluation	2015	2025



Flight Model of the Filter Wheel Mechanics (FWM) equipped with active calibration sources and high-voltage power supplies provided by SRON.

4.13 Athena

Purpose of Research

ESA has recently selected "The Hot and Energetic Universe" as the science theme of the second Large Mission of the Cosmic Vision programme. A large European consortium is gathering to propose the Athena mission as a response to the upcoming ESA call.

Athena is an evolution of former proposals: XEUS, International X-ray Observatory and Athena, which is now in an excellent position to become Europe's next major X-ray astronomy mission, after ESA's cornerstone mission XMM-Newton. Athena will provide tremendous improvements over the current generation for high spatial and spectral resolution spectro-imaging. Athena will carry a large-field-of-view fast imager and a cryogenic imaging calorimeter. The calorimeter (X-ray Integral Field Unit, X-IFU) will allow imaging at electron-volt resolution, i.e. an improvement by a factor about 50 over current imaging instruments. It has to operate at cryogenic (50 mK) temperatures. This will be achieved by a complex, multi-stage mechanical cooling chain.

Switzerland is participating actively in the development of the X-IFU instrument for Athena. It is responsible for the development of the Filter Wheel subsystem. The filter wheel will allow to insert different optical and X-ray attenuating blocking filters to reduce optical light from bright objects (O, B stars) and to reduce the X-ray count rate for very bright objects in order to prevent degradation in detector performance. A beam diffuser and polarization sensitive filters shall also be placed in the optical beam. The filter wheel will also drive active X-ray sources, which can generate mono-energetic photons in order to perform gain calibrations of the detector. The filter wheel heavily relies on heritage from the Swiss contribution to ASTRO-H. Switzerland also develops a dewar door mechanism, which maintains air tightness until space is reached.

The Filter Wheel subsystem is strongly linked to the calibration of the instrument, so UNIGE will significantly contribute to the calibration effort.

Ground-segment activities for Athena are currently in discussion. UNIGE envisages a significant participation in the development phase and during scientific operations.

Status

The ESA call for a mission addressing the science theme "The Hot and Energetic Universe" in 2014. The Athena collaboration shall respond to this call. Formal selection of the mission will take place in 2015.

Publications

1. K. Nandra et al., 2013, "The Hot and Energetic Universe: A White Paper presenting the science theme motivating the Athena+ mission", arXiv: 1306.2307

2. D. Barret et al., 2013, "The Hot and Energetic Universe: The X-ray Integral Field Unit (X-IFU) for Athena+", arXiv: 1308.6784

Abbreviations

X-IFU	X-ray Integral Field Unit

Time-Line	From	To
Planning	2015	2018
Construction	2018	2026
Measurement Phase	2028	2038
Data Evaluation	2028	2048

Institute

Department of Astronomy, University of Geneva

In Cooperation with

Max-Planck-Institut für extraterrestrische Physik (MPE), Garching

Institut de Recherche en Astrophysique et Planétologie (IRAP), Toulouse

Principal Investigator

Kirpal Nandra (MPE), Chair of the Athena+ Coordination Group

Didier Barret (IRAP), P.I. of the X-IFU instrument

Swiss Principal Investigator

Stéphane Paltani

Method

Measurement

Developments

Development and construction of the Filter Wheel subsystem of the X-IFU instrument.

Development of data center activities.

5 Solar Physics

5.1 SOHO/CELIAS

Solar Wind and Suprathermal Particles. Abundances of Elements, Charge States and Isotopes and Kinetic Properties of Heavy Ions.

Institute

Space Science and Planetology, Physics Institute, University of Bern

In Cooperation with

Christian-Albrechts-Universität Kiel

Max-Planck-Institut für Extraterrestrische Physik, Garching, Germany

Max-Planck-Institut für Aeronomie, Lindau, Germany

University of Maryland, College Park, NH, USA

University of New Hampshire, Durham, NH, USA

Principal Investigator

R. Wimmer, Christian-Albrechts-Universität Kiel, Germany

Co-Investigator

H. Balsiger
P. Bochsler
P. Wurz

Method

Measurement

Research Based on Existing Instruments

CELIAS instrument on the SOHO spacecraft.

Purpose of Research

Investigation of the solar wind composition. Abundances of approximately 20 elements and their isotopes are studied in detail for different solar wind conditions. Diagnostics of coronal conditions with charge state distributions of heavy ions. Study of the temporal evolution of transient events (e.g. Coronal Mass Ejections) in the main energy range of the solar wind and for suprathermal particles.

Status

SOHO was launched on 2 December 1995 and is operating since then. In June 2013 ESA approved an additional mission extension of SOHO until December 2014, with an indicative extension until end of 2016. The CELIAS instrument is still operating and produces valuable data. Data analysis, interpretation, and modelling of solar wind measurements are in progress.

Publications

1. X. Wang, B. Klecker and P. Wurz, "Solar Wind Composition Associated with the Solar Activity", in Solar Wind Composition Associated with the Solar Activity, Exploring the Solar Wind, Dr. Marian Lazar (Ed.), ISBN: 978-953-51-0339-4, InTech – Open Access publisher, (2012) 49–68, DOI: 10.5772/35508

2. L. Saul, P. Wurz, and R. Kallenbach, "A measurement of the adiabatic cooling index for interstellar helium pickup ions in the inner heliosphere", Astrophys. Jou. 703 (2009) 325–329

3. C. Giammanco, P. Wurz, and R. Karrer, "Minor Ion Abundances in the Slow Solar Wind", Astrophys. Jou. 681 (2008), 1703–1707

4. P. Wurz, F.M. Ipavich, A.B. Galvin, P. Bochsler, M.R. Aellig, R. Kallenbach, D. Hovestadt, H. Grünwaldt, M. Hilchenbach, W.I. Axford, H. Balsiger, A. Bürgi, M.A. Coplan, J. Geiss, F. Gliem, G. Gloeckler, S. Hefti, K.C. Hsieh, B. Klecker, M.A. Lee, S. Livi, G.G. Managadze, E. Marsch, E. Möbius, M. Neugebauer, K.U. Reiche, M. Scholer, M.I. Verigin, B. Wilken, "Elemental Composition of the 6 January 1997, CME", Geophys. Res. Lett. 25(14) (1998), 2557—2560

Abbreviations

SOHO Solar and Heliospheric Observatory
CELIAS Charge, Element and Isotope Analysis System

Time-Line	From	To
Measurement Phase	since 1996	
Data Evaluation	on-going	

5.2 SOHO/VIRGO

Purpose of Research

VIRGO provides continuous high-precision measurements of the total and spectral solar irradiance (TSI and SSI).

The data are used for research in two areas:

- Evaluation of the direct and indirect solar influence on the terrestrial climate;
- MHD-investigations of the variable amplitude of solar acoustic eigenmodes.

Status

SOHO was launched in December 1995. The VIRGO experiment started observations in early 1996. VIRGO is still operational and keeps extending the longest time series of solar irradiance. Funding is secured until end of 2014 with a possible extension until 2016.

Publications

1. Wehrli, C., W. Schmutz, and A. I. Shapiro, 2013, Correlation of spectral solar irradiance with solar activity as measured by VIRGO, A&A 556, L3
2. Fröhlich, C., 2013, Total Solar Irradiance: What have we learned from the last three cycles and the recent minimum?, Space Science Reviews, 176, pp 237–252
3. Fröhlich, C., 2012, Total Solar Irradiance Observations, Surveys in Geophysics, 33, 453–473

Abbreviations

MHD	Magneto-Hydrodynamics
SSI	Spectral Solar Irradiance
SOHO	Solar and Heliospheric Observatory
TSI	Total Solar Irradiance
VIRGO	Variability of Solar Irradiance and Gravity Oscillations

Institute

Physikalisch-Meteorologisches Observatorium Davos und Weltstrahlungszentrum, PMOD/WRC, Davos

In Cooperation with

ESA/NASA

Principal Investigator

Claus Fröhlich, PMOD/WRC

Co-Investigator

Wolfgang Finsterle
Werner Schmutz
Christoph Wehrli

Method

Measurement

Research Based on Existing Instruments

VIRGO instrument on the SOHO spacecraft.

5.3 STEREO/PLASTIC

Solar Wind and Suprathermal Particles. Abundances of Elements, Charge States and Isotopes and Kinetic Properties of Heavy Ions.

Abbreviations

PLASTIC	PLasma and SupraThermal Ion Composition
STEREO	Solar Terrestrial Relations Observatory

Institute

Space Research and Planetology, Physics Institute, University of Bern

In Cooperation with

University of New Hampshire, Durham, NH, USA

Christian-Albrechts-Universität Kiel

Max-Planck-Institut für Extraterrestrische Physik, Garching, Germany

Principal Investigator

A. Galvin, University of New Hampshire, Durham, NH, USA

Co-Investigator

P. Bochsler
L. Blush
A. Optiz
P. Wurz

Method

Measurement

Research Based on Existing Instruments

The PLASTIC instruments on the STEREO spacecraft.

Purpose of Research

The STEREO mission consists of two spacecraft located at Earth orbit, with one spacecraft flying ahead of the Earth and one spacecraft flying behind the Earth, both with increasing distance to the Earth with time. STEREOs main focus is on transient events in the solar wind, for example coronal mass ejections, which will be observed from two vantage points, and from a third if SOHO is operating. The PLASTIC instrument (one on each spacecraft) will perform measurements of the solar wind elemental and charge composition. Measurements allow diagnostics of coronal conditions with charge state distributions of heavy ions. Study of the temporal evolution of transient events (e.g. Coronal Mass Ejections) in the main energy range of the solar wind and for suprathermal particles.

Status

The two STEREO spacecraft were successfully launched in October 2006 and operating since then. In June 2011 the STEREO spacecraft reached opposition (180° separation) which allowed viewing of the whole Sun. Since then the spacecraft are moving closer to each other until they meet in March 2014, in opposing position to the Earth. The PLASTIC instrument is operating nominally.

Publications

1. A. Opitz, A. Fedorov, P. Wurz, K. Szego, J-A. Sauvaud, R. Karrer, A.B. Galvin, S. Barabash, and F. Ipavich, “Solar wind bulk velocity throughout the inner heliosphere from multi-spacecraft measurements”, Solar Physics, 264 (2010) 377–382, DOI: 10.1007/s11207-010-9583-7

2. A. Opitz, J.-A. Sauvaud, A. Fedorov, P. Wurz, J.G. Luhmann, B. Lavraud, C.T. Russell, P. Kellogg, C. Briand, P. Henri, D.M. Malaspina, P. Louarn, D.W. Curtis, E. Penou, R. Karrer, A.B. Galvin, D.E. Larson, I. Dandouras, and P. Schroeder, “Temporal evolution of the solar wind electron core density at solar minimum by correlating the STEREO A and B SWEA measurements”, Solar Physics 266 (2010), 369–377

3. A.B. Galvin, L. Kistler, M. A. Popecki, C. J. Farrugia, M. Boehm, L. Ellis, S. Ellis, J.A. Gaidos, M. Granoff, D. Heirtzler, B. King, U. Knauss, M.A. Lee, S. Longworth, E. Möbius, K. Simunac, K. Singer, S. Turco, M. Vosbury, M. Widholm, L.M. Blush, R. Karrer, P. Bochsler, H. Daoudi, A. Etter, J. Fischer, J. Jost, A. Opitz, M. Sigrist, P. Wurz, B. Klecker, R.F. Wimmer-Schweingruber, M. Koeten, B. Thompson, and D. Steinfeld, “The Plasma and Suprathermal Ion Composition (PLASTIC) Investigation on the STEREO Observatories”, Space Science Reviews, 136 (2008) 437–486

Time-Line	From	To
Measurement Phase	ongoing	
Data Evaluation	ongoing	

5.4 High Energy Solar Physics Data in Europe (HESPE)

Purpose of Research

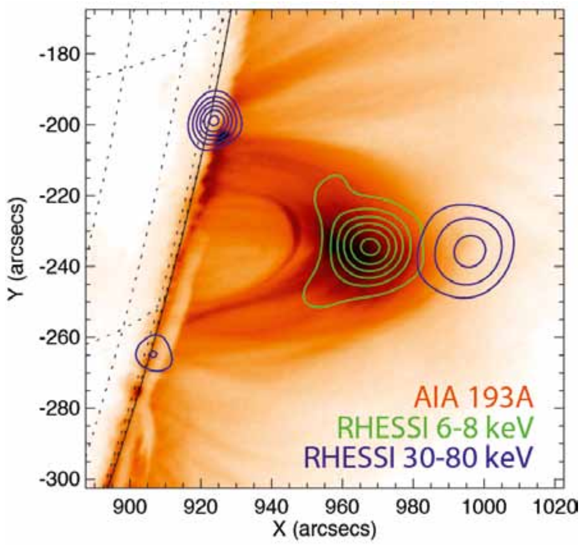
The Reuven Ramaty High Energy Solar Spectroscopic Imager (RHESSI) is a NASA Small Explorer (SMEX) mission with a significant Swiss contribution in hardware, software, and science. RHESSI was launched in 2002 and is currently still fully operational providing unique observations of our Sun in the hard X-ray and gamma-ray range. The European-funded HESPE project combines the experience of computer scientists and heliophysicists to exploit the RHESSI data base and software and make X-ray solar data readily available to the entire solar community.

Publications

1. M. Battaglia and E. P. Kontar 2012 ApJ 760 142
2. M. Battaglia and E. P. Kontar 2013 ApJ 779 107
3. Säm Krucker and Marina Battaglia 2014 ApJ 780 107

Abbreviations

HESPE	High Energy Solar Physics Data in Europe
RHESSI	Reuven Ramaty High Energy Solar Spectrocopic Imager
SDO	Solar Dynamic Observatory



Hard X-ray (RHESSI) and extrem UV (SDO) images of a solar flare occurring at the limb (from Krucker & Battaglia 2014). Thermal emissions (red-colored image and green contours) show the flare loop, while the blue contours highlight the acceleration region above the flare loop as well as the location where accelerated electrons slam into the solar surface (chromosphere). By combining these images with spectral information, the particle densities within the acceleration site could be derived revealing that a bulk acceleration process energizes the entire acceleration region to a non-thermal (non-Maxwellian) state.

Institute

i4Ds, FHNW

In Cooperation with

Universita di Genova

University of Glasgow

Uni Graz

Centre Nationale de la Recherche Scientifique, France

UC Berkeley

Principal Investigator

Michele Piana, UNIGE

Swiss Principal Investigator

Andre Csillaghy, FHNW

Co-Investigator

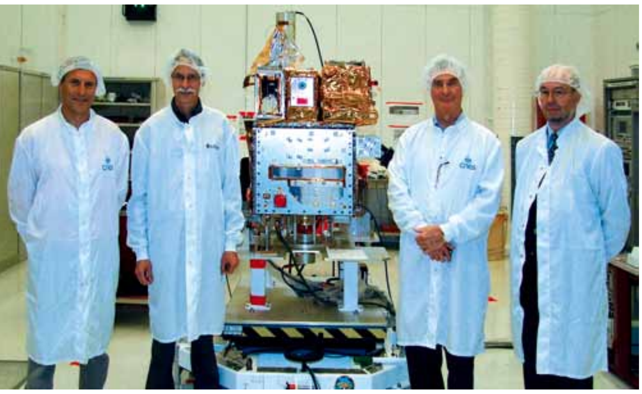
László István Etesi
Nicky Hochmuth
Marina Battaglia
Säm Krucker

Method

Measurement

Research Based on Existing Instruments

The High Energy Solar Physics Data in Europe (HESPE) project is a European funded study that develops and applies new tools to analyze hard X-ray and gamma-ray observations taken by the Reuven Ramaty High Energy Solar Spectral Imager (RHESSI) and make them accessible to solar community.



The PICARD mission PI, the CNES PICARD mission manager, and two instrument PIs in front of the PICARD space craft in the clean room of CNES Toulouse.
From left to right: F. Buisson, W. Schmutz, G. Thuillier, and M. van Ruymbeke.

5.5 PREMOS/PICARD

Institute

Physikalisch-Meteorologisches
Observatorium Davos
und Weltstrahlungszentrum,
PMOD/WRC, Davos

In Cooperation with

LATMOS, F
CNES, F

Principal Investigator

Werner Schmutz, PMOD/WRC

Co-Investigator

André Fehlmann
Wolfgang Finsterle
Gregor Hülsen
Eugene Rozanov
Markus Suter
Christoph Wehrli

Method

Measurement

Development and Construction of Instruments

The PREMOS experiment is PMOD/WRC's contribution to the French space mission PICARD. It compromises three 4-channel filter radiometers measuring at wavelengths of 212, 215, 268, 535, 607 and 782 nm, and two absolute radiometers to measure the Total Solar Irradiance (TSI). The PREMOS package has been developed and built in house at PMOD/WRC.

Purpose of Research

Space observations of the variations and trends in the TSI provide valuable information on changes to the total energy input to the Earth's climate system. The PREMOS absolute radiometers are the PMOD/WRC's latest contribution to maintain a continuous TSI data set. The PREMOS TSI measurements agree well with the results of the TIM/SORCE mission launched in 2003, both measuring a TSI value of about 1361 W/m^2. This value is 4.5 W/m^2 lower than the measurements of VIRGO/SOHO, which can be explained by stray light problems detected when calibrating the PREMOS instrument traceable to the International System of Units (SI).

Measurements of the Spectral Solar Irradiance (SSI) complement our set of information on the radiative output of the Sun. The results at four different wavelengths are used to study the fundamental physical processes on the Sun which drive phenomena's like sun spots or solar oscillations. Variations in the UV control the ozone processes in the middle atmosphere and thus indirectly influence the climate. The SSI results are currently used by PMOD/WRC scientists to investigate the correlation of spectral irradiance variations with TSI changes on a rotational cycle timescale.

Abbreviations

PREMOS PREcision MOnitoring Sensor (PMOD/WRC experiment on PICARD)

TSI Total Solar Irradiance

SSI Spectral Solar Irradiance

Status

The nominal mission duration of the PICARD satellite of two years has been expired in 2012; however, the mission was continued until March 2014 when the satellite and all instruments were finally shut down.

Publications

1. Fehlmann A., Kopp G., Schmutz W., Winkler R., Finsterle W., Fox N., 2011, Fourth World Radiometric Reference to SI radiometric scale comparison and implications to on-orbit measurements of the total solar irradiance, Metrologia 49, S34–S38, doi: 10.1088/0026-1394/49/2/S34

2. Schmutz W., Fehlmann A., Hülsen G., Meindl P., Winkler R., Thuillier G., Blattner P., Buisson F., Egorova T., Finsterle W., Fox N., Gröbner J., Hochedez J.-F., Koller S., Meftah M., Meisonnier M., Nyeki S., Pfiffner D., Roth H., Rozanov E., Spescha M., Wehrli C., Werner L., Wyss J.U., 2009, The PREMOS/PICARD instrument calibration, Metrologia 46, S202–S206, doi: 10.1088/00261394/46/4/S13

3. Thuillier G., Dewitte S., Schmutz W., The Picard Team, 2006, Simultaneous measurement of the total solar irradiance and solar diameter by the PICARD mission, Adv. Space Res. 38, 1792–1806, doi: 10.1016/j.asr.2006.04.034

Time-Line	From	To
Construction	2000	2009
Measurement Phase	27/07/2010	04/03/2014
Data Evaluation	2010	ongoing

5.6 Probing Solar X-ray Nanoflares with NuSTAR

Purpose of Research

The Nuclear Spectroscopic Telescope Array (NuSTAR) is a NASA Small Explorer satellite using true focusing optics and pixellated X-ray detectors to achieve unprecedented sensitivity in the medium-to-hard X-ray band (2–80 keV). While NuSTAR is an astrophysics mission, it can point at the Sun, and the NuSTAR program has dedicated three weeks of observing the Sun toward the end of the satellite's primary mission.

NuSTAR is 200 times more sensitive than RHESSI, the current state-of-the-art satellite for solar hard X-ray studies. With the extraordinary increase in sensitivity provided by NuSTAR, we will be able to test the so-called "nanoflare heating" theory predicting that many tiny explosions seen in X-rays provide enough energy to keep the solar atmosphere at that its extraordinary hot temperature in the million degree range.

Status

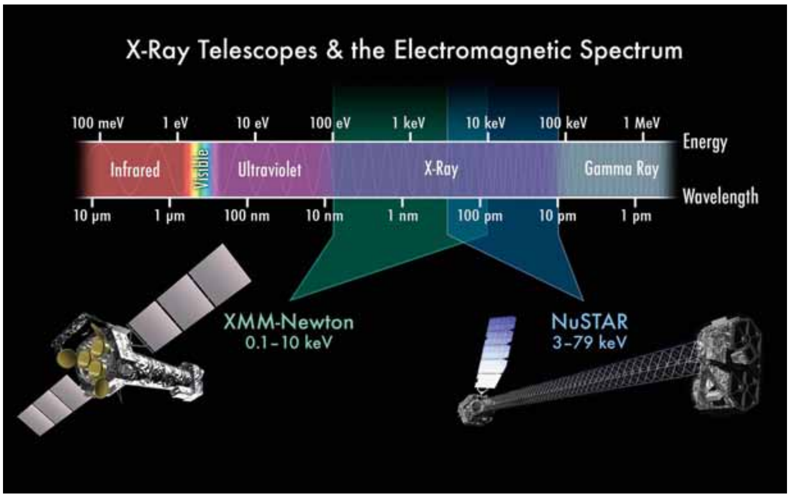
NuSTAR was successfully launched in June 2012; first solar observations are currently planed for spring 2014.

Publications

1. Fiona A. Harrison et al. 2013 ApJ 770 103

Abbreviations

NuSTAR	Nuclear Spectroscopic Telescope Array



NuSTAR energy range within the electromagnetic spectrum.

Institute

i4Ds, FHNW

In Cooperation with

Caltech, USA
UC Santa Cruz, USA
University of Glasgow, UK

Principal Investigator

Fiona Harrison, Caltech

Swiss Principal Investigator

Säm Krucker, FHNW

Co-Investigator

Marina Battaglia, FHNW

Method

Measurement

Research Based on Existing Instruments

NuSTAR is the next generation of X-ray observatory. It was successfully launched in June 2012. Nustar's unprecedented sensitivity opens up entirely new views on astrophysical X-ray objects including our Sun.

Institute

i4Ds, FHNW

In Cooperation with

SRC Poland
CEA Sacaly, France
Leibniz-Institut für Astrophysik Potsdam (AIP)
Czech Space Office
Uni Graz
Trinity College Dublin
LESIA, France
University of Genova

Principal Investigator

Säm Krucker, FHNW

Co-Investigator

J. Sylwester, SRC
O. Limousin, CEA
G. Mann, AIP
F. Farnik, CSO
A. Vernonig, Uni Graz
P. Gallagher, TCD
N. Vilmer, LESIA
M. Piana, Genova

Method

Measurement

Development and Construction of Instruments

STIX is a Swiss-lead instrument on board ESA's Solar Orbiter mission to be launched in 2017. STIX is based on a Fourier-imaging technique similar to that used successfully by the Hard X-ray Telescope (HXT) on the Japanese Yohkoh mission, and related to that used for the Reuven Ramaty High Energy Solar Spectroscopic Imager (RHESSI) NASA SMEX mission.

Industrial Hardware Contract to

Almatech
Art of Technology
Syderal

5.7 STIX: Spectrometer/Telescope for Imaging X-rays on Solar Orbiter

Purpose of Research

Solar Orbiter is a joint ESA-NASA collaboration that will address the central question of heliophysics: How does the Sun create and control the heliosphere? To achieve this goal, Solar Orbiter carries a set of ten instruments to perform joint observations. Through hard X-ray imaging and spectroscopy, the STIX instrument provides information of heated (> 10 MK) plasma and accelerated electrons that are produced as magnetic energy is released during solar flares. By using this set of diagnostics, STIX plays an important role in enabling Solar Orbiter to achieve two of its major science goals of (1) understanding the acceleration of electrons at the Sun and their transport into interplanetary space and (2) determining the magnetic connection of the Solar Orbiter back to the Sun. In this way, STIX provides a crucial link between the remote and in-situ instruments of the Solar Orbiter mission.

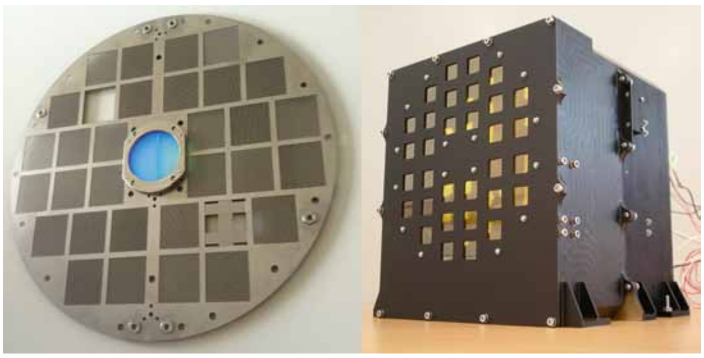
Status

In October 2012, Solar Orbiter was selected as the first medium-class mission of ESA's Cosmic Vision 2015–2025. STIX was previously selected as one of the ten instruments on board Solar Orbiter. STIX successfully passed the Preliminary Design Review (PDR) in 2012, and the Critical Design Review (CDR) has been scheduled for spring 2014. The Figure shows the Thermal Structural Model (STM) manufactured in fall 2013.

Publications

1. Benz, A. O.; Krucker, S.; Hurford, G. J.; Arnold, N. G.; Orleanski, P.; Gröbelbauer, H.-P.; Klober, S.; Iseli, L.; Wiehl, H. J.; Csillaghy, A.; and 50 coauthors: Space Telescopes and Instrumentation 2012: Ultraviolet to Gamma Ray. Proceedings of the SPIE, Volume 8443, article id. 84433L, 15 pp. (2012)

Time-Line	From	To
Planning	2010	2013
Construction	2014	2015
Measurement Phase	2017	2026
Data Evaluation	2017	2026



Structural Thermal Model of one of the two STIX tungsten grids with the blueish aspect lens (left) and the Detector Electroncis Module with the 32 openings behind each an X-ray detectors is placed (right). The two grids are placed in front of the X-ray detectors to produce a Moire pattern on the X-ray detectors so that the imaging information is stored in the relative count rate of the different pixles (i.e. each detector provides a Fourier component).

5.8 The Spectral Imaging of the Coronal Environment Instrument (SPICE) on Solar Orbiter

Purpose of Research

SPICE will significantly contribute to the key science question of Solar Orbiter: How does the Sun create and control the heliosphere?

For this purpose SPICE is designed to study the structure, dynamics and composition of the corona by observing key emission lines on the solar disk on timescales from seconds to tens of minutes. A key aspect of the SPICE observing capability is the ability to quantify the spatial and temporal signatures of temperature and density tracers to explain the interrelationship between the chromosphere, coronal structures, coronal mass ejections, the solar wind.

The EUV wavelength region from 70.4 nm to 105 nm observed by SPICE is dominated by emission lines from a wide range of ions formed in the solar atmosphere at temperatures from 10000 to 10 million K. SPICE will measure plasma densities and temperatures, flow velocities, the presence of plasma turbulence and composition of the source region plasma of the solar wind. It will be observing, at all latitudes, the energetics, dynamics and fine-scale structure of the Sun's magnetized atmosphere.

Status

SPICE successfully passed the Preliminary Design Review in 2013. The Critical Design Review has started in 2013 and is still ongoing at the time of writing of this report. The launch of Solar Orbiter is scheduled for July 2017.

Publications

1. A. Fludra, D. Griffin, M. Caldwell, P. Eccleston, J. Cornaby, D. Drummond, W. Grainger, P.Greenway, T. Grundy, C. Howe, C. McQuirk, K. Middleton, O. Poyntz-Wright, A. Richards, K. Rogers, C. Sawyer, B. Shaughnessy, S. Sidher, I. Tosh, S. Beardsley, G. Burton, A. Marshall, N. Waltham, S. Woodward, T. Appourchaux, A. Philippon, F. Auchere, E. Buchlin, A. Gabriel, J.-C. Vial, U. Schühle, W. Curdt, D. Innes, S. Meining, H. Peter, S. Solanki, L. Teriaca, M. Gyo, V. Büchel, M. Haberreiter, D. Pfiffner, W. Schmutz, M. Carlsson, S.V. Haugan, J. Davila, P. Jordan, W. Thompson, D. Hassler, B. Walls, C. Deforest, J. Hanley, J. Johnson, P. Phelan, L. Blecha, H. Cottard, G. Paciotti, N. Autissier, Y. Allemand, K. Relecom, G. Munro, A. Butler, R. Klein, A. Gottwald, 2013: SPICE EUV spectrometer for the Solar Orbiter mission, Proceedings of SPIE, Vol. 8862 88620F, doi 10.1117/12.2027581

Time-Line	From	To
Planning	2008	2011
Construction	2011	2017
Measurement Phase	2020	2029
Data Evaluation	2020	2029 and beyond

Institute

Physikalisch-Meteorologisches Observatorium Davos und Weltstrahlungszentrum, PMOD/WRC, Davos

In Cooperation with

Rutherford Appleton Laboratory (RAL), UK

Goddard Space Flight Center (GSFC), USA

Institut d'Astrophysique Spatiale (IAS), France

Institute for Theoretical Astrophysics (ITA), Norway

Max Planck Institute for Solar System Research (MPS), Germany

Southwest Research Institute (SwRI), USA

ESA

NASA

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Mats Carlsson, Viggo Hansteen (ITA, Norway)

Udo Schühle, Sami Solanki, Werner Curdt, Eckart Marsch, Hardi Peter, Luca Teriaca, Davina Innes (MPS, Germany)

Margit Haberreiter (PMOD/WRC, Switzerland)

Nick Waltham, Richard Harrison (RAL, UK)

Susanna Parenti (ROB, Belgium)

Method

Measurement

Development and Construction of Instruments

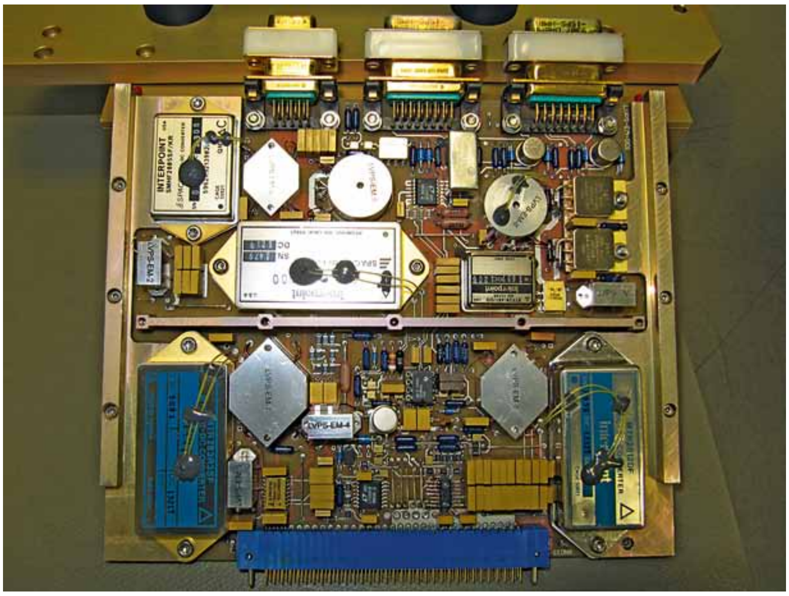
SPICE is a payload on ESA/NASA M-class mission Solar Orbiter. The hardware, electronics and software will be developed and manufactured by many different institutes and industry partners located in the USA and Europe. PMOD/WRC is responsible for the development and manufacturing of the contamination door, the slit change mechanism (SCM) and the low voltage power supply (LVPS) for SPICE.

Industrial Hardware Contract to

APCO Technologies and Almatech, Switzerland

Abbreviations

AU	Astronomical Unit
ESA	European Space Agency
EUV	Extreme Ultra Violet
GSFC	Goddard Space Flight Center
IAS	Institut d'Astrophysique Spatiale
ITA	Institute for Theoretical Astrophysics
IO	Institut d'Optique
MPS	Max Planck Institute for Solar System Research
PMOD	Physikalisch Meteorologisches Observatorium Davos
RAL	Rutherford Appleton Laboratory
ROB	Royal Observatory Belgium
SPICE	Spectral Imaging of the Coronal Environment Instrument
SwRI	Southwest Research Institute
WRC	World Radiation Center



Engineering Model (EM) of the Low Voltage Power Supply (LVPS) for the SPICE instrument built at PMOD/WRC. The EM of the LVPS has been integrated into the SPICE Electronic Box and undergone thermal and vibrational tests. The functional, electronic and magnetic cleanliness tests of SPICE at full instrument level are currently being carried out at RAL.

5.9 Extrem Ultraviolet Imager (EUI) on Solar Orbiter

Purpose of Research

EUI is designed to investigate the dynamics in the solar corona. During the mission phase, the spacecraft will approach the Sun as close at 0.28 AU at perihelion, while the aphelion will between 0.78 to 1.13 AU. Furthermore, about 3 years after launch, the spacecraft will begin an out-of ecliptic phase, with an inclination increasing toward the maximum value of about 33° with respect to the equatorial plane.

The scientific objectives of Solar Orbiter rely ubiquitously on the EUV Imager (EUI), a suite of imaging telescopes to observe the upper solar atmosphere. The suite is composed of 1 Full Sun Imager (FSI) working alternatively at the two 174 Å and 304 Å passbands and 2 High Resolution Imagers (HRI), one observing the hydrogen Lyman-α line (1216 Å) and one the Extreme Ultra-Violet (EUV) band 174 Å.

EUI will significantly contribute to the following four major Solar Orbiter science themes:

- What are the origins of the solar wind streams and the heliospheric magnetic field?
- What are the sources, acceleration mechanisms, and transport processes of solar energetic particles?
- How do coronal mass ejections evolve in the inner heliosphere?
- Explore, at all latitudes, the energetics, dynamics and fine-scale structure of the Sun's magnetized atmosphere.

Status

The prelimanary design review was finished in April 2012. The instrument CDR co-location was successfully passed end of 2013. The close-out is still on-going and will be finished with the success of the CDRs of some remaining part. The OBS-CDR is scheduled for spring 2014. The launch of Solar Orbiter is planned for July 2017.

Publications

1. Halain J.-P., Rochus P., Renotte E., Appourchaux T., Berghmans D., Harra L., Schühle U., Schmutz W., Auchère F., Zhukov A., Dumesnil C., Delmotte F., Kennedy T., Mercier R., Pfiffner D., Rossi L., Tandy J., BenMoussa A., Smith P., "The EUI instrument on board the Solar Orbiter mission: from breadboard and prototypes to instrument model validation", Space Telescopes and Instrumentation 2012: Ultraviolet to Gamma Ray. Proceedings of the SPIE, Volume 8443, 21 pp. (2012)

2. Halain J.-P., Houbrechts Y., Auchère F., Rochus P., Appourchaux T., Berghmans D., Schühle U., Harra L., Renotte E., Zukhov A., "The Solar-Orbiter EUI Instrument Optical Developments", International Conference on Space Optics (ICSO 2010)

3. Rochus P., Halain J.P., Renotte E., Berghmans D., Zhukov A., Hochedez J.F., Appourchaux T., Auchère F., Harra L.K, Schühle U., Mercier R., "The Extreme Ultraviolet Imager (EUI) onboard the Solar orbiter Mission", 60th International Astronautical Congress (2009)

Institute

Physikalisch-Meteorologisches Observatorium Davos und Weltstrahlungszentrum, PMOD/WRC, Davos

In Cooperation with

Centre Spatiale de Liège (CSL), Belgium

Royal Observatory of Belgium (ROB), Belgium

Institut d'Astrophysique Spatiale (IAS), France

Institut d'Optique (IO), France

UCL Mullard Space Science Laboratory (MSSL), UK

Max Planck Institute for Solar System Research (MPS), Germany

ESA

NASA

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Method

Measurement

Development and Construction of Instruments

The Extrem Ultraviolet Imager (EUI) is a payload on ESA/NASA M-class mission Solar Orbiter. The hardware, electronics and software will be developed and manufactured by many different institutes and industry partners located in Europe. The instrument consortium lead is held by the Centre Spatiale de Liège (CSL) in Belgium. PMOD/WRC together with swiss industry is responsible for the optical bench structure (OBS) of the EUI instrument. This structure will be disigned with a aluminium honeycomb with carbon fiber face sheets sandwich panels.

Industrial Hardware Contract to

APCO Technologies

Abbreviations

AU	Astronomical Unit
CDR	Critical Design Review
CSL	Centre Spatiale de Liège
ESA	European Space Agency
EUI	Extrem Ultraviolet Imager
EUV	Extrem Ultraviolet
FSI	Full Sun Imager
HRI	High Resolution Imager
OBS	Optical Bench Structure

Time-Line	From	To
Planning	2008	2010
Construction	2011	2017
Measurement Phase	2020	2029
Data Evaluation	2020	2029 and beyond

Group Photo taken during the 12th EUI Consortium Meeting held 4–6 December 2013 at CSL, Liège, Belgium. Shown in the front is the Structural and Thermal Model (STM) of EUI being prepared for the Thermal Vaccuum Test in the clean room at CSL.
Front row left to right: C. Dumesnil, V. Bommier, R. Mercier, S. Guissot, D. Innes, L. Teriaca, F. Auchère, P. Smith, J.P. Halain, A. Zhukov, M. Gyo, U. Schühle, O.G. Obadia, A. Debaize, E. Renotte, D. Berghmans, L. Jacques; middle row: A. Hermans; back row left to right: D. Beluz, L. Rossi.

5.10 Compact Lightweight Absolute Radiometer (CLARA) on NORSAT-1

Purpose of Research

Space Climate

The CLARA absolute solar radiometer will measure the total solar irradiance (TSI) with high accuracy and cadence. The TSI is the fundamental driver for all climate processes on earth (Haigh, J.D., 2001, Science 294). Past climate changes can be related to variations of the TSI (Shapiro et al. 2011, AA 529, A67). Over the past ~150 years human activity had an increasing effect on the earth's climate. The high-accuracy TSI measurements from CLARA will help to assess the solar forcing on global temperatures in order to distinguish between anthropogenic and natural climate change.

Radiometry

Recently, an explanation for the puzzling difference between the "solar constant" measured by PMO6-, DIARAD-, and ACRIM-type radiometer and the more advanced TIM/SORCE experiment was proposed and tested in laboratory experiments (Fehlmann et al. 2012, Metrologia 49, S34 ; Suter et al., 2012, WMO-CIMO/TECO-2012). The CLARA absolute solar radiometer is designed to validate the laboratory results in space. Furthermore, full traceability to ground based irradiance standards will provide the highest level of confidence in the "solar constant" measured by CLARA.

Space Weather

We will model the TSI variations by a 4-component composite of solar atmospheres which represent different activity states of the Sun (quiet sun, sunspots, network, and active regions). A successful model reproduction of the TSI variability will also yield a spectral reconstruction that includes the UV.

UV radiation has a direct influence on the composition of the terrestrial middle and upper atmosphere. Unfortunately, UV measurements suffer from serious long-term stability issues (both filter radiometers and spectrometers). On the other hand are TSI variations highly correlated with the UV intensity variations and in fact, models predict that the TSI variations are dominated by the contribution from the UV. The highly accurate TSI measurements thus can serve not only as a proxy for UV (through modeling) but also offer the possibility to assess the long-term stability of UV measurements, if those are available.

Status

The preliminary mechanical and thermal design is finished. Mathematical simulation and analyses will be performed as a next step for design verification. In parallel the electronics part was developed and is now in manufacturing for the engineering model.

The industry tasks are almost defined and will then be published by the ESA Prodex Office for tender.

Time-Line	From	To
Planning	spring 2013	April 2014
Construction	February 2014	December 2014
Measurement Phase	early 2016	not yet defined
Data Evaluation	early 2016	

Institute

Physikalisch-Meteorologisches Observatorium Davos und Weltstrahlungszentrum, PMOD/WRC, Davos

In Cooperation with

Norwegian Space Centre, Norway

University of Toronto UTIAS-SFL, Canada

Principal Investigator

Werner Schmutz, PMOD/WRC

Co-Investigator

Bo Anderson (NSC, Norway)
Torbe Leifsen (UiO, Norway)
Greg Kopp (LASP, USA)
André Fehlmann (IAF, USA)
Wolfgang Finsterle (PMOD/WRC)

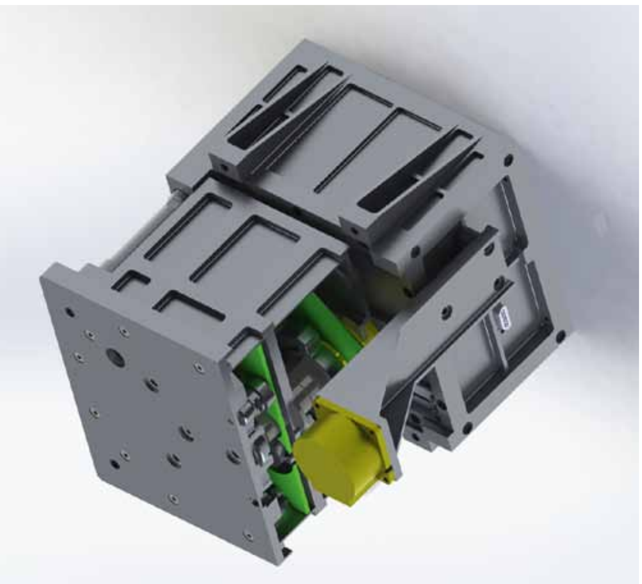
Method

Measurement

Industrial Hardware Contract to

Industry tasks will be contracted during 1st quarter, 2014.

CLARA CAD image.



Development and Construction of Instruments

The Norwegian satellite NORSAT-1 will investigate solar radiation, space weather and detect ship traffic. The science payload will cover several aspects of scientific research focusing on the sun, including measuring Total Solar Irradiation (TSI) with one instrument, and measuring electron plasma from the sun with a Langmuir probe.

The TSI instrument CLARA will be developed and built by PMOD/WRC.

CLARA is a new generation absolute radiometer. It involves a new thermal design concept and digital signal processing, which permits higher cadence measurements, compared to previous absolute radiometers.

The University of Toronto will provide the platform for the nano-satellite, which will measure 20x20x40cm.

PMOD/WRC will build one engineering- and two flight units of the instrument. The institute provides the mechanical and thermal design. Further the complete electronics will be developed and manufactured in-house. Swiss industry is responsible for software development, mechanical and thermal simulations, some hardware manufacturing tasks and environmental testing. CLARA will be assembled at PMOD and calibrated at PMOD/WRC and LASP.

Publications

1. Finsterle et al., AGU Fall Meeting 2013 Session GC54A Talk 07

Abbreviations

CLARA	Compact Lighweight Absolute Radiometer
ESA	European Space Agency
LASP	Laboratory for Atmospheric and Space Physics (Boulder, CO)
NSC	Norwegian Space Centre
PMOD	Physikalisch-Meteorologisches Observatorium Davos
TSI	Total Solar Irradiance
UiO	University in Oslo
UTIAS-SFL	University of Toronto – Institute for Aerospace Studies Space Flight Laboratory
WRC	World Radiation Center

5.11 Digital Absolute Radiometer (DARA) on PROBA-3

Purpose of Research

DARA on PROBA-3 will explore the remaining difference between the absolute measurements of the Total Solar Irradiance (TSI) between the two most accurate absolute radiometers presently measuring TSI: PREMOS/PICARD and TIM/SORCE. The measurements of the two experiments differ by 0.03 %, which is a difference within the experiment's uncertainties. A confirmation or falsification of the new solar constant value of 1361 W/m² by a new independent experiment is a must in order to progress in the assessment of the absolute Total Solar Irradiance. The DARA experiment will be fully SI traceable calibrated and realizes several new concepts in radiometry in order to achieve higher accuracy and long-term stability. The DARA measurements will lead to an improvement of the uncertainty of the solar constant, but the more important result than the solar constant value itself is its uncertainty with full traceability to SI. A major goal of the DARA experiment is also to extend the TSI data record with unprecedented accuracy and sensitivity. Various space experiments have been monitoring the TSI continuously since 1978, covering three solar minima. It is still a matter of debate whether or not the minima levels of the TSI have changed, and whether the changes of the solar constant are climate effective. The nominal mission time of PROBA-3 is two years, which seems little in view of extending the TSI time series. However, as the degradation of the instruments in space is extremely difficult to assess, the finally highly accurate absolute value of DARA would allow TSI comparisons of future experiments on an absolute level, which will break the dependency on a continuous, uninterrupted monitoring on a relative level.

Development and Construction of Instruments

The digital absolute Radiometer DARA is a scientific payload experiment on PROBA-3, an ESA's Technology Demonstration microsatellite. PROBA-3 will be the world's first precision formation flying mission. A pair of satellites will fly together maintaining a fixed configuration as a "large rigid structure" in space, representing a coronograph configuration, to prove formation flying technologies. The DARA experiment will be placed on the front space craft.

The prototype development phase for DARA was supported by ESA's Prodex Programm in 2010. In this context the new radiometer design was established and successfully tested. An enhanced flight instrument is now in phase C/D for the NORSAT-1 mission. A continuation of the DARA development is planned to start this year, depending on the PROBA-3 schedule.

Status

In 2013 ESA has announced a project continuation of PROBA-3 to phase C/D for the Spacecraft. The Kick-off meeting for the S/C prime contractor is planned early 2014.

Abbreviations

DARA	Digital Absolute Radiometer
EM	Engineering Model
ESA	European Space Agency
FM	Flight Model
PROBA	Project for On-Board Autonomy
S/C	Spacecraft
TSI	Total Solar Irradiance

The DARA prototype in the lab at PMOD/WRC.

Time-Line	From	To
Planning	end of 2013	early 2015
Construction	end of 2014 (EM)	May 2016 (FM)
Measurement Phase	2017	open
Data Evaluation	2017	open

Institute

Physikalisch-Meteorologisches Observatorium Davos und Weltstrahlungszentrum, PMOD/WRC, Davos

Principal Investigator

Werner Schmutz, PMOD/WRC

Co-Investigator

Wolfgang Finsterle, PMOD/WRC
Benjamin Walter, PMOD/WRC
Andrei Zhukov, ROB

Method

Measurement

Industrial Hardware Contract to

Industry tasks will be contracted at a later project stage.

6 Earth Observation, Remote Sensing

6.1 Multi-Beam Limb Sounder STEAMR for Earth Explorer PREMIER

Institute

Institute of Applied Physics

In Cooperation with

ESA

Omnisys, Sweden

Rutherford Appleton Laboratory, UK

Almatech, Switzerland

TK Instruments, UK

High Altitude Research Stations Jungfraujoch+Gornergrat, Switzerland

Principal Investigator

Urban Frisk (Omnisys, Sweden)

Swiss Principal Investigator

Axel Murk

Co-Investigator

Mark Whale

Method

Measurement

Development and Construction of Instruments

Optical design of the STEAMR instrument, breadboard model development and test of its focal plane array optics, characterization and field campaign with prototype receivers.

Industrial Hardware Contract to

Almatech, Lausanne

Purpose of Research

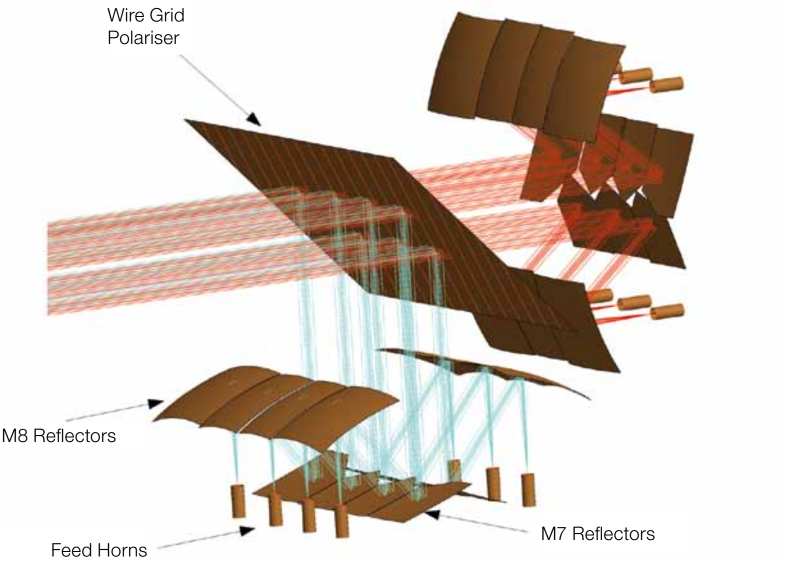
STEAMR is a 340 GHz multi-beam limb sounder for the ESA Earth Explorer Mission candidate PREMIER. Its scientific objectives are to study the chemical composition and dynamical processes in the Earth's Upper Troposphere / Lower Stratosphere by remote sensing observations with high spatial and temporal resolution.

The STEAMR optics consists of an off-axis dual reflector telescope with elliptical aperture, astigmatic imaging optics and a focal plane array (FPA) with fourteen receivers. The complete optical chain has been optimized at IAP using Gaussian beam-mode analysis and the software package GRASP.

The FPA optics includes interleaved facet reflectors and ultra-gaussian corrugated feed horns. In order to validate the numerical GRASP simulations and the feasibility of the monolithical machining of the facet reflectors a breadboard model of the FPA has been built and characterized by near-field antenna measurements with a submillimeter wave vector network analyzer.

Other critical components of STEAMR are the 325–360 GHz receivers and the broadband digital autocorrelation spectrometers of the Swedish instrument prime Omnisys. Prototypes of these components were characterized at IAP by laboratory tests and first light atmospheric observations from the alpine research stations Jungfraujoch and Gornergrat.

A breadboard model of the FPA has been manufactured and characterized by near field antenna measurements.



Focal Plane Array (FPA) optics for the multi-beam limb sounder STEAMR on the ESA Earth Explorer Mission PREMIER. The ray tracing model shows how the signal path of fourteen 340 GHz receivers is combined using a polarized beam splitter and a set of interleaved facet reflectors.

Status

PREMIER was one of the three final candidates for the next Earth Explorer Mission. In the last mission downselection in 4/2013 it was not selected for flight. The STEAMR instrument concept is currently revised to fit on alternative flight opportunities.

Publications

1. Axel Murk, Mark Whale, Matthias Renker, “STEAMR Focal Plane Array Optics: Executive Summary”, IAP Research Report No. 2013-05-MW, Sep. 2013

2. Matthias Renker, Mark Whale, and Axel Murk, “Antenna simulations and measurements of focal plane array facet reflectors”, IEEE Transactions on Antennas and Propagation, 61(4): 1–11, 2013

3. Mark Whale et al., “A Compensating Anastigmatic Submillimeter Array Imaging System for STEAMR”, IEEE Transactions on Terahertz Science and Technology, 3(1):110–119, 2013

Abbreviations

STEAMR — Stratosphere-Troposphere Exchange And Climate Monitor Radiometer

PREMIER — Process Exploration by Measurements of Infrared and millimetre-wave Emitted Radiation

FPA — Focal Plane Array

Time-Line	From	To
Planning	2010	2012
Construction	2011	2012
Measurement Phase	2012	2013
Data Evaluation	2013	2014

6.2 Airborne Prism Experiment Instrument and Uncertainty Model

Purpose of Research

The goal of the research project (EMRP ENV-04 REG02) is twofold:

- Measurement biases caused by a suboptimal sensor model applied during the estimation of calibration coefficients and for the data calibration of digital numbers to radiance values are addressed by improving the APEX sensor model.
- The provision of accurate measurements for the quantitative estimation of bio-geophysical variables requires the definition of an uncertainty budget, such that final products are made traceable with a known uncertainty.

Status

The APEX calibration information system and level1 processor have been upgraded to implement the refined APEX sensor model. Work on the uncertainty budget is currently ongoing.

Publications

1. A. Hueni, J. Biesemans, K. Meuleman, F. Dell'Endice, D. Schläpfer, S. Adriaensen, S. Kempenaers, D. Odermatt, M. Kneubuehler, J. Nieke, and K. Itten, "Structure, Components and Interfaces of the Airborne Prism Experiment (APEX) Processing and Archiving Facility", IEEE Transactions on Geoscience and Remote Sensing, vol. 47, pp. 29–43, 2009

2. A. Hueni, K. Lenhard, A. Baumgartner, and M. Schaepman, "The APEX (Airborne Prism Experiment – Imaging Spectrometer) Calibration Information System", IEEE Transactions on Geoscience and Remote Sensing, vol. 51, pp. 5169–5180, 2013

3. A. Hueni, D. Schlaepfer, M. Jehle, and M. E. Schaepman, "Impacts of Dichroic Prism Coatings on Radiometry of the Airborne Imaging Spectrometer APEX", Appl. Opt. (submitted)

Institute

Remote Sensing Laboratories (RSL)
Dept. of Geography
University of Zurich-Irchel
Winterthurerstrasse 190
8057 Zurich

In Cooperation with

NPL (UK)

DLR (GER)

Principal Investigator

Andreas Hueni

Method

Measurement

Research Based on Existing Instruments

Improvement of the APEX sensor model and establishment of an uncertainty budget.

6.3 APEX – Airborne Prism Experiment

Purpose of Research

Based on the present demand for airborne and spaceborne imaging spectroscopy data in remote sensing, the European Space Agency (ESA) has built a new generation airborne hyperspectral imager named APEX. APEX is a pushbroom imager with 300–500 spectral bands, operational in the spectral region from 380 to 2 500 nm, and with 1 000 pixels across track. It is flown in an aircraft at operating altitudes between 2 and 8 km having a spatial resolution of 1–5 m.

The mission objectives of APEX are mainly being a simulator, calibrator, and validator for spaceborne multispectral and hyperspectral instruments (such as ENMAP). APEX shall also foster the application development for hyperspectral imaging in Europe and worldwide. The project shall be a European answer to the scientific success of American hyperspectral instruments. Its specifications are state-of-the-art in resolution and overall radiometric performance.

Status

RSL is responsible for the scientific management of the project, for added value within the calibration chain of the APEX instrument, the product generation, and for extending and maintaining the Processing and Archiving Facility. The latter is a universal, database driven system supporting the processing and distribution of all APEX raw data acquisitions. Sophisticated information technology tools are used for a versatile processing system, which is designed to be persistent throughout the operational phase of the instrument.

ESA EOEP has taken the lead within APEX by providing the SWIR detector technology, the calibration home base, and the technical management.

After an extensive measurement and instrument characterization campaign in summer 2010 the APEX instrument was accepted by ESA in December 2010. Since then the project is in its operational phase E where in 2011 VITO together with RSL have successfully accomplished two more flight campaigns all over Europe. In 2012 and 2013 again, new and extended flight campaigns (increased flight window, additional testsites) took place. In 2013 RSL successfully acquired 88 flightlines over 20 testsites covering ~4 000 km² mainly located in Switzerland.

Publications

1. D'Odorico, P., et al., 2011: Performance assessment of onboard and scene-based methods for Airborne Prism Experiment spectral characterization. Applied Optics, 50(23): 4755–4764, 2011

2. Itten, K.I., et al., 2008: APEX – the hyperspectral ESA Airborne Prism Experiment, Sensors, (8)10: 6235–6259

3. Jehle, M., et al., 2010: APEX – current status, performance and product generation. IEEE Sensors 2010, Waikoloa (HI), pp. 533–537, 2010

4. Hueni, A., Lenhard, K., Baumgartner, A., & Schaepman, M.E., 2013: The APEX (Airborne Prism Experiment – Imaging Spectrometer) Calibration Information System. IEEE Transactions on Geoscience and Remote Sensing, 51 (11), pp. 5169–5180

Abbreviations

APEX	Airborne Prism Experiment
ESA	Eurpoean Space Agency
EOEP	Earth Observation Envelope Programme
PRODEX	PROgramme de Developement d'EXperiences Scientifiques
RSL	Remote Sensing Laboratories
SWIR	Short Wave InfraRed
ENMAP	ENvironmental Mapping and Analysis Program
VITO	Vlaamse Instelling voor Technologisch Onderzoek

Time-Line	From	To
Planning	1997	2000
Construction	2002	2010
Measurement Phase	2011	2016
Data Evaluation	2011	2016

Institute

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In Cooperation with

European Space Agency/PRODEX

European Space Agency/EOEP

VITO (Belgium)

Principal Investigator

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Co-Investigator

Koen Meuleman (VITO)
Michael Jehle (RSL)

Method

Measurement

Research Based on Existing Instruments

Exploitation of the APEX instrument during extensive measurement campaigns in the calbration home base and in the field.

6.4 SPECCHIO Spectral Information System

Purpose of Research

Scientific efforts to observe the state of natural systems over time, allowing the prediction of future states, have led to a burgeoning interest for organized storage of spectral field data and associated metadata, seen as being key to the successful and efficient modeling of such systems. A centralised system for such data established for the remote sensing community aims to standardise storage parameters and metadata thus fostering best practice protocols and collaborative research. The development of a spectral information system will not only ensure the long-term storage of data but support scientists in data analysis activities, essentially leading to improved repeatability of results, superior reprocessing capabilities, and promotion of best practice.

Status

SPECCHIO remains under active development. Major contributions have been made to the system in the past year via funding provided by the Australian National Data Service and the EuroSpec COST action.

SPECCHIO is installed in some 30 research institutions world wide and is as well used in teaching activities at the Remote Sensing Laboratories, University of Zurich.

SPECCHIO is today the most advanced spectral information system within the domain of Earth observing remote sensing.

Publications

1. A. Hueni, J. Nieke, J. Schopfer, M. Kneubühler, and K. Itten, "The spectral database SPECCHIO for improved long term usability and data sharing", Computers & Geosciences, vol. 35, pp. 557–565, 2009
2. A. Hueni, T. Malthus, M. Kneubuehler, and M. Schaepman, "Data Exchange between distributed Spectral Databases", Computers & Geosciences, vol. 37, pp. 861–873, 2011
3. A. Hueni, L. Chisholm, L. Suarez, C. Ong, and M. Wyatt, "Spectral Information System Development for Australia", in Geospatial Science Research Symposium Melbourne, Australia, 2012

Institute

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In Cooperation with

ANDS
(Australian National Data Service)

EuroSpec COST Action

Specnet

Principal Investigator

Andreas Hueni

Co-Investigator

Laurie Chisholm (UoW, Australia)

Method

Measurement

Development of Software

Development of a Spectral Information System for the storage of spectral field and laboratory data and associated metadata.

6.5 HYLIGHT – Integrated Use of Airborne Hyperspectral Imaging Data and Airborne Laser Scanning Data

Purpose of Research

The Joint Research Activity (JRA) HYLIGHT (FP7-EUFAR2) will develop methodologies and tools for the integrated use of airborne hyperspectral imaging (HSI) data and airborne laser scanning (ALS) data in order to produce improved HSI and ALS products. The developed methodologies, prototypes and tools will be tested by the involved data processing facilities to improve the quality of both HSI and ALS data products for the scientific users. HYLIGHT tools will be made freely available via the EUFAR toolbox and the EUFAR handbook. EUFAR (www.eufar.net) is an Integrating Activity funded by the 7th Framework Programme of the European Commission. The activity was recently extended as EUFAR2 to run from 2014–2018 (24 partners). It aims at providing and improving the access to airborne facilities (i.e. aircraft, airborne instruments, data processing centers) for researchers in environmental and geo-sciences through Networking Activities (NA), Trans-national Access (TA) Activities and Joint Research Activities (JRA). The long term objectives of EUFAR are to lay the groundwork of a European distributed infrastructure for airborne research in environmental and geo-sciences for each European scientist to get access at “equal terms” to the airborne facility the most suited to his scientific objectives.

Status

EUFAR2-HYLIGHT will start in 2014.

Publications

1. Bachmann, M., Adar, S., Ben-Dor, E., Biesemans, J., Briottet, X., Grant, M., Hanus, J., Holzwarth, S., Hueni, A., Kneubühler, M., Meuleman, K., de Miguel, E., Perez Gonzalez, I., Reusen, I., Richter, R., Ruhtz, T., Schaale, M., Weide, S., 2011: EUFAR FP7 HyQuaPro (JRA-2) Report on Quality Layers for VITO, DLR, INTO and PML. Toulouse, EUFAR

2. Koetz, B., Sun, G., Morsdorf, F., Ranson, K.J., Kneubühler, M., Itten, K.I., & Allgöwer, B., 2007: Fusion of Imaging Spectrometer and LIDAR Data over Combined Radiative Transfer Models for Forest Canopy Characterization. Remote Sensing of Environment, 106, pp. 449–459

3. Reusen, I., Bachman, M., Beekhuizen, J., Ben-Dor, E., Biesemans, J., Brenguier, J L., Brown, P., Chabrillat, S., Eisele, A., Gomez-Sanchez, J.A., Grant, M., Groom, S., Hanus, J., Heuvelink, G.B.M., Holzwarth, S., Hueni, A., Kaufmann, H.C., Knaeps, E., Kneubühler, M., Malthus, T., Meuleman, K., de Miguel Llanes, E., Mueller, A., Pimstein, A., Prado Ortega, E., Purcell, P., Ruhtz, T., Schaale, M., Schaepman, M.E., Wendisch, M., 2009: EUFAR goes hyperspectral in FP-7. In: Workshop on hyperspectral image and signal processing: evolution in remote sensing, Grenoble, France, 26–28 August 2009, 1–4

Time-Line	From	To
Measurement Phase	2014	2018
Data Evaluation	2014	2018

Abbreviations

APEX	Airborne Prism Experiment
HYLIGHT	FP7/EUFAR2 Joint Research Activity on Integrated use of airborne hyper spectral imaging data and airborne laser scanning data
EUFAR2	FP-7 Integrating Activity “European Framework for Airborne Research”, 2014–2018

Institute

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INTA (Spain)
PML (UK)
CVGZ (Czech Republic)
TAU (Israel)
TU Wien (Austria)

Principal Investigator

Ils Reusen (VITO)

Swiss Principal Investigator

Felix Morsdorf (RSL)

Co-Investigator

Andreas Hüni (RSL)
Mathias Kneubühler (RSL)
Michael E. Schaepman (RSL)

Method

Simulation

Research Based on Existing Instruments

Airborne hyperspectral sensors and laser scanners.

6.6 Wet Snow Monitoring with Spaceborne SAR

Institute

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8057 Zurich

In Cooperation with

European Space Agency (ESA)

Canadian Space Agency (CSA)

WSL Institute for Snow and Avalanche Research (SLF)

Principal Investigator

David Small

Co-Investigator

Erich Meier
Adrian Schubert

Method

Measurement

Development of Software for

Sentinel-1
ENVISAT ASAR
ALOS PALSAR
TerraSAR-X
RADARSAT-2
COSMO-SKYMED

Purpose of Research

The University of Zurich Remote Sensing Laboratories (UZH-RSL) works with ESA and other partners to develop a new kind of spaceborne SAR image product whereby many of the effects of topography on radar image brightness are modelled and corrected before estimating the backscatter coefficient at each image coordinate.

The new type of product offers several benefits. Comparisons of backscatter from image acquisitions made from differing orbital tracks become possible. Flattening the terrain-induced effects on radar brightness enables significantly more frequent revisits to a given point on the Earth, particularly given the availability of a wide swath mode such as C-band ASAR WS, RADARSAT-2 SCN & SCW and Sentinel-1, L-band ALOS PALSAR WB (wide beam), or the wide ScanSAR modes from the X-band sensors CosmoSkymed, TSX, TDX, and (soon) PAZ.

Use of the new products enables a great improvement in "temporal resolution", a parameter of critical importance in land cover monitoring to lower the probability of missing the cusp of an event. Data-rich time-series can be built up for a chosen area much more quickly from a single sensor given a wider variety of tracks (even combinations of ascending and descending passes). It is then also much easier to integrate backscatter measurements from a diversity of sensors. Each sensor is typically characterized by the single orbital repeat period chosen at launch and the set of beam modes on offer. Different sensors therefore almost always implies differing tracks, modes, and nominal incident angles, triggering (in the absence of terrain-flattening) incompatibility with meaningful short-term comparisons or quick revisits when monitoring large regions. Only terrain-flattened backscatter, a product we call terrain-flattened gamma nought, offers the possibility of combining data from multiple SAR sensors acquired over rolling terrain.

The ESA Sentinel-1 satellites, the first of which was launched on 3 Apr 2014, offer the promise of multiple observations of the territory of Switzerland within a single week. Given the severe topography in the country, construction of backscatter time-series requires rigorous radiometric calibration that accounts for track-dependent terrain-induced effects. If a standard terrain-flattened backscatter product could be offered by ESA, that would simplify interpretation of SAR imagery not only in Switzerland, but throughout the world.

Status

A terrain-normalisation method for SAR imagery covering steep terrain has been developed and tested using data from the major spaceborne SAR sensors. Tests have been performed and published using data from ENVISAT ASAR, ALOS PALSAR, RADARSAT-2, and TerraSAR-X. In the case of wide-swath C-band data covering Switzerland, seasonal trends have been established. Springtime melting in the Swiss Alps generates a strong signal: terrain-flattened backscatter makes monitoring the snow melt theoretically possible with multiple observations per week using data from Sentinel-1 satellites.

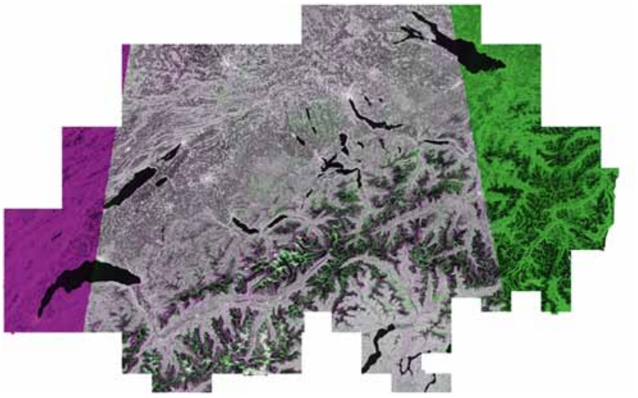
Wet snow measurements have been evaluated qualitatively and are being compared with state-of-the-art operational methodologies. Harmonized data acquisition strategies for the different spaceborne SAR sensors are being coordinated through the World Meteorological Organisation Polar Space Task Group (WMO-PSTG). Tools are in development for integration of wide swath C-band Radarsat-2 and Sentinel-1, L-band ALOS2 PALSAR2, and X-band CSK, TSX, TDX, and PAZ data.

Publications

1. Small D., Miranda N., Ewen T., Jonas T., Reliably flattened backscatter for wet snow mapping from wide-swath sensors, Proc. ESA Living Planet Symposium, Sept. 2013, 8p

2. Small D., Zuberbühler L., Schubert A., Meier E., Terrain-flattened gamma nought Radarsat-2 backscatter, Canadian Journal of Remote Sensing, Oct. 2011, Vol. 37, No. 5, pp. 493–499, doi: 10.5589/m11-059

3. Small D., Flattening Gamma: Radiometric Terrain Correction for SAR Imagery, IEEE Trans. on Geoscience & Remote Sensing, Aug. 2011, Vol. 49, No. 8, pp. 3081–3093, doi: 10.1109/TGRS.2011.2120616



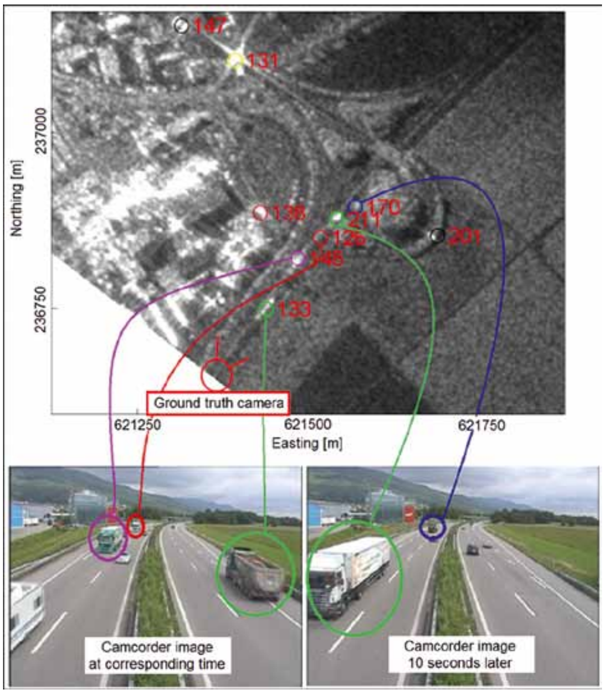
Ascending/Descending overlay of Radarsat-2 C-band SCNB radiometrically terrain corrected backscatter covering Switzerland – Data obtained via CSA/MDA SOAR programme (project 1985) – RADARSAT-2 Data and Products.
© MacDONALD, DETTWILER AND ASSOCIATES LTD. (2010) – All Rights Reserved. The digital height model DHM25 from swisstopo was used for terrain geocoding and radiometric corrections.

Abbreviations

ALOS	Advanced Land Observation Satellite (L-band)
ASAR	Advanced Synthetic Aperture Radar (C-band)
CSA	Canadian Space Agency
ESA	European Space Agency
JAXA	Japanese Space Agency
PALSAR	Phased Array L-band Synthetic Aperture Radar
RSL	Remote Sensing Laboratories
S1A	Sentinel-1 SAR Satellite (C-band)
SAR	Synthetic Aperture Radar
SCN	RADARSAT ScanSAR Narrow
SCW	RADARSAT ScanSAR Wide
TSX/TDX/PAZ	TerraSAR-X satellites (X-band)
UZH	University of Zurich
WB	ALOS PALSAR Wide Beam
WMO	World Meteorological Organization
WS	ENVISAT ASAR Wide Swath

Time-Line	From	To
Planning	ongoing	
Measurement Phase	2002	ongoing
Data Evaluation	2010	ongoing

6.7 Moving Target Tracking in SAR Images



Tracking moving vehicles in an X-band SAR image over Oensingen, Switzerland.

Institute

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In Cooperation with

armasuisse (CH)

German Aerospace Center DLR (Germany)

Principal Investigator

Erich Meier (RSL)

Co-Investigator

Daniel Henke (RSL)
Michael Schaepman (RSL)

Method

Measurement

Research Based on Existing Instruments

Airborne SAR sensors.

Purpose of Research

Ground moving target indication (GMTI) in Synthetic Aperture Radar (SAR) data addresses the task of extracting information about moving objects. Compared to other GMTI systems, SAR sensors can indicate moving objects while simultaneously imaging the area of interest. Furthermore, SAR data can be acquired almost independently of weather conditions and daylight. These SAR-specific properties enable their deployment over a wide range of target tracking applications from traffic monitoring to surveillance in uncharted areas.

Investigations into moving target tracking were conducted for both single- and multi-channel airborne SAR systems. Both approaches, based on hidden state-based modeling, rely on image statistics and multitarget unscented Kalman filtering. Their goal is to robustly detect and track continuously moving objects (such as motor vehicles) over time, providing information not only about the existence of moving targets but additionally about their trajectories in the image space while illuminated by the radar beam.

The methods were successfully applied to experimental single- and multi-channel data sets from two airborne SAR sensors: one a high-frequency Ka-band (35 GHz) SAR and the other an X-band (9.6 GHz) system. In both cases, it was possible to accurately characterize the movement of vehicles on a highway section in the radar image space, as validated by measurements on the ground (portable speedometer stations from the Swiss Federal Institute of Metrology, video cameras).

Status

Ongoing.

Publications

1. Henke D., Magnard C., Frioud M., Small D., Meier E., & Schaepman M. E. (2012). Moving-Target Tracking in Single-Channel Wide-Beam SAR. IEEE Transactions on Geoscience and Remote Sensing, 50(11), 4735–4747

2. Henke D., Mendez Dominguez E., Small D., Schaepman M.E., & Meier E. (2013). Moving target tracking in single- and multichannel SAR. IEEE Transactions on Geoscience and Remote Sensing, submitted

3. Henke D., & Meier E. (2012). Moving target tracking in single-channel SAR. In IEEE International Geoscience and Remote Sensing Symposium (IGARSS), 2012, 6813–6816

Abbreviations

GMTI	Ground Moving Target Indication
SAR	Synthetic Aperture Radar

6.8 ESA STSE "3D Vegetation Laboratory"

Purpose of Research

The up-coming generation of ESA operational missions – the Sentinels – will enhance the capability to observe the vegetated surfaces of the Earth. Nevertheless the quantitative interpretation of the Earth Observation (EO) signal is a challenging task because vegetation is a complex and dynamic medium. Effects of horizontal and vertical heterogeneities and asymmetrical structures of vegetation as well as their high temporal dynamics are often neglected in the algorithm development, calibration and validation procedures.

To better understand the scientific basis as well as the potential of future and upcoming missions we need detailed knowledge about the observed medium and the processes governing the radiative transfer. The combination of a realistic description of the medium in high detail together with a validated radiative transfer model will create a virtual lab mimicking reality which is capable to assess the potential of novel observation systems as well as to develop new algorithms and understand scaling issues from point measurements to the landscape.

The advancement of ground based LiDAR systems now provides information that helps describing and reconstructing forest stands in 3D down to the leaf/shoot level. Such detailed representations of the canopy structure and the distribution of leaves/branches within a 3D radiative transfer model will thus allow the simulation of current and future missions in a controlled but realistic environment. It would thus offer an opportunity to test and develop dedicated applications to integrate EO into Earth system modeling. The 3D-VegtationLab will develop a concept for land surface reference sites, which will be demonstrated for two selected pilot super-sites as a scientific support tool. The tool will include a standardized and comprehensive multi-temporal and multi-scale benchmark dataset together with a scientific toolbox based on a radiative transfer model. The 3D-Vegetation Lab will provide the scientific community with a common benchmarking tool to develop, validate and compare biophysical EO products from space-borne missions with special attention to prepare for upcoming Sentinels.

Status

Project started in 2010 and will finish early 2014.

Publications

1. Eysn, L.; Pfeifer, N.; Ressl, C.; Hollaus, M.; Grafl, A. & Morsdorf, F., A Practical Approach for Extracting Tree Models in Forest Environments Based on Equirectangular Projections of, Terrestrial Laser Scans, Remote Sensing, 2013, 5, 5424–5448

Time-Line	From	To
Measurement Phase	2010	2014
Data Evaluation	2010	2014

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Co-Investigator

Felix Morsdorf (RSL)

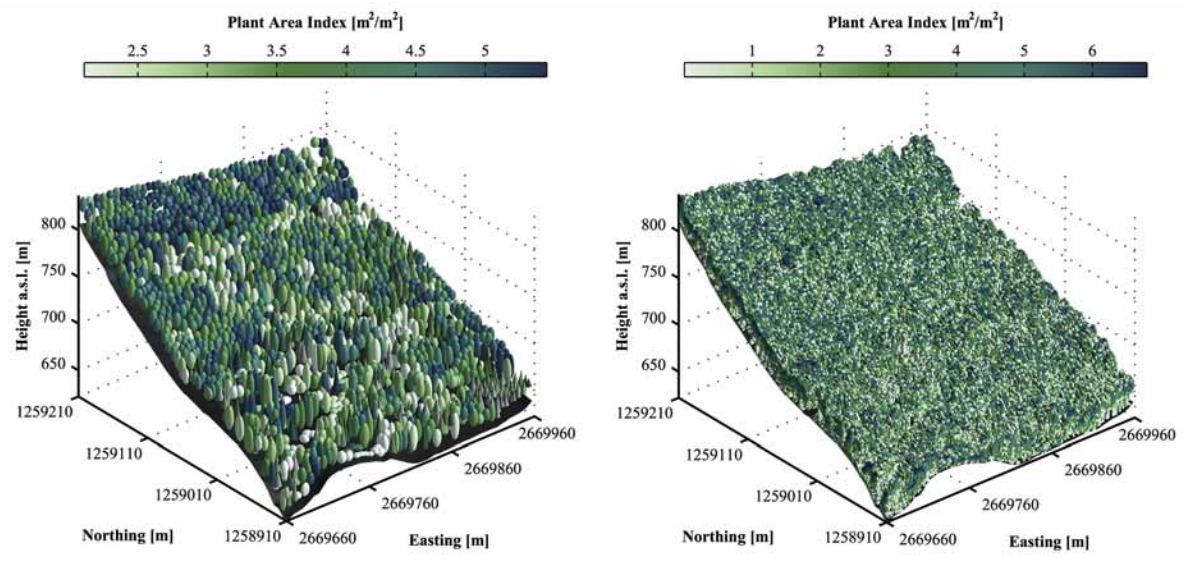
Method

Simulation

Research Based on Existing Instruments

3D modeling toolbox for sensor and data and methods prototyping.

2. Morsdorf, F.; Leiterer, R.; Schaepman, M. E.; Pfeifer, N.; Hollaus, M.; Disney, M.; Lewis, P.; Gastellu-Etchegorry, J.-P.; Brazile, J. & Koetz, B., 3D-Vegetation Laboratory: Science and modeling support for accuracy assessment and prototyping of EO data and products, ForestSat, Corvallis, Oregon, USA, 11.-14.9.2012, 2012
3. Schneider, F. D.; Leiterer, R.; Morsdorf, F.; Gastellu-Etchegorry, J.-P.; Lauret, N.; Pfeifer, N. & Schaepman, M. E. Simulating imaging spectrometer data: 3D forest modeling based on LiDAR and in situ data Remote Sensing of Environment, in review



Airborne laser scanning based single tree (left) and voxel grid (right) reconstruction of plant area index values of Lägeren scene for the use with the radiative transfer model DART. From Schneider et al. (2013).

6.9 Swiss Earth Observatory Network (SEON)

Purpose of Research

The Swiss Earth Observatory Network (SEON), funded by the Swiss University Conference (SUK) and ETH-board, is a competence centre to monitor status and functioning of Swiss ecosystems in a changing environment. An increasing demand for natural resources impacts important biotic and physical processes within the Earth system and causes complex interactions within terrestrial ecosystems. SEON pursues a holistic Earth system science approach to assess environmental change impacts on ecosystem functioning and considers complex feedback mechanisms between the Earth spheres, including the human impact.

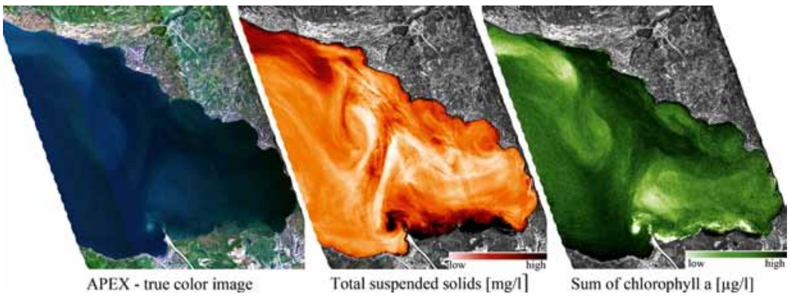
Complex interactions between the Earth's spheres and underlying physical processes will be assessed using coupled models and observations in a holistic fashion. Backbone of the SEON approach are state-of-the-art observatories, in-situ measurements, and models. The project consortium focuses on several research topics:

- Spatio-temporal quantification of ecosystem processes (i.e., NPP)
- Energy and gas exchange of terrestrial ecosystems
- Resource utilization and -efficiency of major crop species
- Exchange processes of aquatic ecosystems and mapping of IOP/AOP
- Air quality and atmospheric transport processes of NO_2
- Dynamic of the cryosphere and monitoring of snow/ice parameters
- Modelling trends of agricultural management and impact on soil functions

SEON actively supports young academics and contributes to regular curricula to educate next generation professionals in Earth System Science.

Status

The project started in January 2013, monitoring activities using the airborne imaging spectrometer APEX (Airborne Prism Experiment) and in-situ instrumentation were initialized in many Swiss test sites.



APEX Chlorophyll-a and total suspended solids in Lake Geneva, 14 May 2013. Left: APEX True color image. Middle: Total suspended solids (TSS) [mg/l], dark colors represent high TSS-concentrations, bright colors low TSS-concentrations. Right: Chlorophyll a concentration (Chl-a) [µg/l] dark colors represent high Chl-a concentrations, bright colors low Chl-a concentrations.

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Aquatic Physics, Eawag, Kastanienbaum, Switzerland

Laboratory for Air Pollution and Environmental Technology, EMPA, Duebendorf, Switzerland

Institute of Agricultural Science – Grassland Science, ETH Zurich, Switzerland

Institute of Agricultural Science – Crop Science, ETH Zurich, Switzerland

Principal Investigator

Michael E. Schaepman (RSL)

Co-Investigator

Alexander Damm

Method

Measurement

Research Based on Existing Instruments

Backbone of the SEON approach are state-of-the-art observatories (e.g., APEX imaging spectrometer), in-situ measurements, and models.

6.10 SpaceCam

Artist view of the SpaceCam.
© Swiss Space Center.

Institute

Swiss Space Center (SSC), Switzerland

In Cooperation with

School of Astronautics, Beihang University (BUAA), China

Principal Investigator

Gilles Feusier, SSC

Method

Measurement

Development and Construction of Instruments

Adaptation of a commercial off-the-shelf (COTS) industrial smart camera.

Time-Line	From	To
Planning	2013	2015
Construction	January 2014	June 2014
Measurement Phase	end 2014	end 2015
Data Evaluation	end 2014	end 2015

Purpose of Research

In the frame of the Active Debris Removal (ADR) activities, the Swiss Space Center is seeking for solutions permitting the in-flight identification of debris and the determination of their attitude. Vision system is a key element of this goal. An ADR mission will therefore require autonomous vision system, making use of smart cameras, with their own processing power permitting in-orbit image analysis and data extraction. In-orbit data analysis and extraction permits to overcome the limitation of the data communication bandwidth and access time between the spacecraft and the ground station.

The objective of the Swiss Space Center is to test in-orbit a modified COTS industrial smart camera and to verify the camera computing power in space environment. Image acquisition and stress tests will be performed on the camera as well as data communication between the camera and the spacecraft. Algorithms and communication protocol are being developed for that purpose and will be implemented into the smart camera.

A collaboration with the Beihang University of Aeronautics and Astronautics (BUAA) in Beijing, China, has started and gave the opportunity for the Swiss Space Center to fly a smart camera on the BUAA-SAT academic satellite that is targeted to be launched end 2014. One of the missions of the SpaceCam on BUAA-SAT will be to verify the proper deployment of the spacecraft coiled gravity-gradient stabilization mast. The project is also a stepping-stone towards collaboration between EPFL and BUAA.

Status

A Structural and Thermal Model (STM) of the camera has already been developed by the Swiss Space Center and sent to BUAA for implementation into BUAA-SAT test platform.

In parallel, the Swiss Space Center developed a communication protocol between the camera and the satellite as well as the on-board software that will be tested with the Electrical Model, delivered by end of December 2013 to BUAA.

The Critical Design Review (CDR) of the camera was successfully performed in December 2013 and the manufacturing of the Qualification Model (QM) and Flight Model (FM) is in progress.

The qualification of the camera will be performed at SSC in spring 2014. The FM will be delivered before end of Q2 2014.

Abbreviations

ADR	Active Debris Removal
BUAA	Beihang University of Aeronautics and Astronautics
CDR	Critical Design Review
COTS	Commercial Off-The-Shelf
FM	Flight Model
QM	Qualification Model
SSC	Swiss Space Center
STM	Structural and Thermal Model

6.11 GOCE: Precise Orbit Determination

Purpose of Research

The Gravity field and steady-state Ocean Circulation Explorer (GOCE) was ESA's first Earth explorer core mission of the Living Planet Programme. It was launched on 17 March 2009 into a very low Earth orbit and has been intended to serve solid Earth physics, oceanography, geodesy, and glaciology by measuring the stationary part of the Earth's gravity field with the highest possible accuracy and spatial resolution. The mission officially ended after more than four very successful years of operations on 21 October 2013 when the fuel was depleted.

The core instrument of the mission was a three-axis gravity gradiometer for inferring the small-scale structures of the Earth's gravity field with an unprecedented accuracy of 1 mGal (1 cm in terms of geoid heights) down to a spatial resolution of 100 km. For the derivation of the long wavelength part of the Earth's gravity field and for precise orbit determination, the satellite was equipped with a dual-frequency Global Positioning System (GPS) receiver. The satellite has been orbiting the Earth at a very low orbital altitude of only 255 km down to 225 km to be most sensitive to the Earth's gravity field. An ion propulsion assembly was required to maintain the low orbital altitude with a drag-free flight by compensating non-gravitational forces acting on the satellite in flight direction (mainly atmospheric drag).

The scientific data processing from Level 1b to Level 2 is performed by the High-level Processing Facility (HPF) of the European GOCE Gravity Consortium (EGG-C), which consists of ten European institutions and universities. Precise orbit determination of the GOCE satellite based on the measurements of the onboard GPS receiver is an integral part of the HPF tasks. The Astronomical Institute of the University of Bern (AIUB) is in charge of computing the precise science orbit (PSO) product with a stringent accuracy requirement of 2 cm 1-D RMS and a latency of about 2 weeks.

The GOCE PSO product is used for the final Level 2 processing within the HPF and primarily serves the most accurate geolocation of the measured gravity gradients from the core instrument and the recovery of the long wavelength part of the Earth's gravity field. The GOCE PSO product is generated with the Bernese GPS Software developed at AIUB.

Status

Starting in August 2012 the orbital height of the satellite has been lowered step-wise to 225 km to get measurements at an even lower altitude than before. On 21 October 2013 the fuel for the ion engine was depleted and the satellite re-entered the Earth's atmosphere on 11 November 2013.

The excellent quality of the PSO product has been confirmed by validation with independent Satellite Laser Ranging (SLR) measurements: reduced-dynamic PSO solutions used for the most accurate geolocation exhibit an accuracy of about 1.8 cm SLR RMS, kinematic PSO solutions used for long wavelength gravity field recovery exhibit an accuracy of about 2.4 cm SLR RMS.

Mid of 2014 the Release 5 gravity fields covering the entire mission will be published.

Institute

Astronomical Institute of the University of Bern (AIUB)

In Cooperation with

GOCE High-level Processing Facility (HPF)

Principal Investigator

Adrian Jäggi

Co-Investigator

Heike Bock
Ulrich Meyer

Method

Measurement

Publications

1. Bock, H., A. Jäggi, U. Meyer, P. Visser, J. van den IJssel, T. van Helleputte, M. Heinze, U. Hugentobler, "GPS – derived orbits for the GOCE satellite", Journal of Geodesy, 85 (2011), 807–818, DOI: 10.1007/s00190-011-0484-9
2. Jäggi, A., H. Bock, L. Prange, U. Meyer, G. Beutler, "GPS – only gravity field recovery with GOCE, CHAMP, and GRACE", Advances in Space Research, 47 (2011), 1020–1028, DOI: 10.1016/j.asr.2010.11.008

Abbreviations

GOCE	Gravity field and steady-state Ocean Circulation Explorer
EGG-C	European GOCE Gravity Consortium
HPF	High-level Processing Facility

ESA Gravity field and steady-state Ocean Circulation Explorer (GOCE) satellite.

7 Comets, Planets

7.1 ROSINA

Purpose of Research

The Rosetta Orbiter Spectrometer for Ion and Neutral Analysis (ROSINA) will answer important questions posed by the mission's main objectives. After Giotto this will be the first time that the volatile part of a comet will be analyzed in situ. This is a very important investigation, as comets, in contrast to meteorites, have maintained most of the volatiles of the solar nebula. To accomplish the very demanding objectives through all the different phases of the comet's activity, ROSINA has unprecedented capabilities, including very wide mass range (1 amu to >300 amu); very high mass resolution (m/dm >3000, i.e. the ability to resolve CO from N_2 and 13C from 12CH); very wide dynamic range and high sensitivity; as well as the ability to determine cometary gas velocities, and temperature.

ROSINA consists of two mass-spectrometers for neutrals and primary ions with complementary capabilities and a pressure sensor.

Scientific Goals

As part of the core payload of the Rosetta mission, the Rosetta Orbiter Spectrometer for Ion and Neutral Analysis (ROSINA) is designed to answer outstanding questions posed by the Rosetta mission's main objectives. The spectrometer's primary objective is to determine the elemental, isotopic and molecular composition of the comet's atmosphere and ionosphere, as well as the temperature and bulk velocity of the gas and the homogenous and inhomogeneous reactions of the gas and ions in the dusty cometary atmosphere and ionosphere. In determining the composition of the atmosphere and ionosphere, the following prime scientific objectives, also set by the Rosetta Science Definition Team, will be achieved:

- Determination of the global molecular, elemental, and isotopic composition and the physical, chemical and morphological character of the cometary nucleus. Determination of the processes by which the dusty cometary atmosphere and ionosphere are formed, and characterization of their dynamics as a function of time, heliocentric and cometocentric position.
- Investigation of the origin of comets, the relationship between cometary and interstellar material and the implications for theories on the origin of the Solar System.
- Investigation of possible asteroid outgassing and establishing the relationships between comets and asteroids.

Status

Successful exit from hibernation on 20 January 2014.

Time-Line	From	To
Planning	1995	1996
Construction	1996	2002
Measurement Phase	launch 2004, asteroid flyby's 2008 & 2010	
Comet phase	2014	2015
Data Evaluation	2014	?

Institute

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Universität Bern
Sidlerstr. 5
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In Cooperation with

ESA, MPS, TUB, BIRA, CESR, IPSL, LMM, UMich, SwRI

Principal Investigator

Kathrin Altwegg

Co-Investigator

Hans Balsiger
Martin Rubin
Ernest Kopp
Annette Jäckel
Peter Wurz

Method

Measurement

Industrial Hardware Contract to

Contraves (Ruag) Space
APCO
Montena etc.

Publications

1. H. Balsiger, et al. (2007), ROSINA – ROSETTA ORBITER SPECTROMETER FOR ION AND NEUTRAL ANALYSIS,, Space Sci Rev, 128/1, 745–801

2. Schläppi B., K. Altwegg, H. Balsiger, M. Hässig, A. Jäckel, P. Wurz, B. Fiethe, M. Rubin, S. A. Fuselier, J. J. Berthelier, J. De Keyser, H. Rème and U.Mall, “The influence of spacecraft outgassing on the exploration of tenuous atmospheres by in situ mass spectrometry”, JGR, VOL. 115, A12313, 14 pp., 2010

3. K. Altwegg, H. Balsiger, U. Calmonte, M. Hässig, L. Hofer, A. Jäckel, B. Schläppi, P. Wurz, J.J. Berthelier, J. De Keyser, B. Fiethe, S. Fuselier, U. Mall, H. Rème, and M. Rubin, In situ mass spectrometry during the Lutetia flyby, 2012, PSS, 66,1,pp. 173–178

Abbreviations

ROSINA	Rosetta Orbiter Sensor for Ion and Neutral Analysis

Wake-up event (reception of the first signal from Rosetta after 30 months in hibernation) at the Physics Institute in Bern, 20 January 2014 with the PI emer. Hans Balsiger and the actual PI Kathrin Altwegg.

7.2 HiRISE – High Resolution Imaging Science Experiment

Purpose of Research

Uni Bern specializes in the understanding and modelling of Mars surface processes connected to volatiles (CO_2 and H_2O) using data from the HiRISE camera. This includes topics such as the dynamics of sublimation and dessication. We take advantage of our co-investigator status to participate in the programme both scientifically and in the target planning. Developments of these tools will also contribute to the CaSSIS programme.

Status

Instrument currently in extended Phase E.

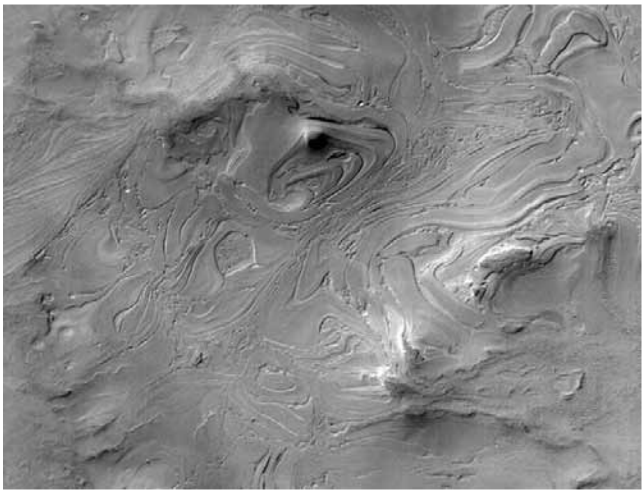
Publications

1. McEwen, A.S., L. Ojha, C.M. Dundas, S.S. Mattson, S. Byrne, J.J. Wray, S.C. Cull, S.L. Murchie, N. Thomas, and V.C. Gulick, (2011), Seasonal Flows on Warm Martian Slopes, Science, Science, 333, 740

2. Thomas, N., G. Portyankina, C. J. Hansen, and A. Pommerol (2011), Sub-surface CO_2 gas flow in Mars' polar regions: Gas transport under constant production rate conditions, Geophys. Res. Lett., 38, L08203, doi: 10.1029/2011GL046797

3. El Maarry, M.R., J.M. Dohm, G. Michael, N. Thomas, S. Maruyama, (2013), Morphology and evolution of the ejecta of Hale crater in Argyre basin, Mars: Results from high resolution mapping, Icarus, 226, 905–922 doi: 10.1016/j.icarus.2013.07.014

Time-Line	From	To
Planning	1999	2000
Construction	2000	2004
Measurement Phase	2007	2016
Data Evaluation	2007	2016



The NW part of Hellas Basin on Mars contains some remarkable structures which may be caused by the flow of ice-rich material. It produces so-called banded terrain. The figure gives an example. This is currently under investigation by students at the Center for Space and Habitability in Bern.

Institute

Space Research and Planetology Division, Physikalisches Institut, University of Bern

In Cooperation with

University of Arizona, Tucson

Principal Investigator

A.S. McEwen

Co-Investigator

Nicolas Thomas

Method

Measurement

Research Based on Existing Instruments

HiRISE instrument for NASA's Mars Reconnaissance Orbiter.

Abbreviations

ASPERA-3	Analyzer of Space Plasmas and Energetic Atoms
ENA	Energetic Neutral Atoms
MEX	Mars Express
NPD	Neutral Particle Detector

Institute

Space Research and Planetology Physics Institute
University of Bern

In Cooperation with

Swedish Space Research Institute, Kiruna, Sweden
(R. Lundin, S. Barabash)

Max-Planck-Institut für Aeronomie, Lindau, Germany
(M. Fränz, J. Woch)

Applied Physics Laboratory, John Hopkins University, laurel, MD, USA
(P. Brandt)

Principal Investigator

R. Lundin, Swedish Space Research Institute, Kiruna, Sweden

Swiss Principal Investigator

P. Wurz

Co-Investigator

P. Bochsler

Method

Measurement

Research Based on Existing Instruments

The ASPERA-3 instrument on the Mars Express Spacecraft.

7.3 ASPERA-3/Mars Express: Remote Particle Sensing of Ion Populations in Mars' Extended Atmosphere

Purpose of Research

The general scientific objective of the ASPERA-3 instrument is to study the solar wind – atmosphere interaction and characterise the plasma and neutral gas environment in the near-Mars space through energetic neutral atom (ENA) imaging and in situ plasma measurements. The main scientific objectives of the ASPERA-3 instrument are to

- Determine the instantaneous global distributions of plasma and neutral gas near the planet,
- Study the atmospheric escape induced by the highly variable solar wind and solar UV irradiation,
- Investigate the modification of the atmosphere through the solar wind ion bombardment,
- Investigate the energy deposition from the solar wind to the ionosphere.

The Neutral Particle Detector (NPD) provides measurements of the ENA flux, resolving velocity and mass (H and O) of the coming particles with a coarse angular resolution.

Status

The Mars Express spacecraft and the ASPERA-3 experiment still perform fine. The Mars Express (MEX) mission was extended five times by ESA, the latest extension is until the end of 2014. At Bern, data analysis concentrates on NPD data where the neutral exosphere, martian atmospheric loss via energetic neutral atoms, and energetic atoms of interstellar origin are investigated in detail.

Publications

1. A. Galli, P. Wurz, P. Kollmann, P.C. Brandt, M. Bzwoski, J.M. Sokół, M.A. Kubiak, A. Grigoriev, and S. Barabash, "Heliospheric Energetic Neutral Hydrogen measured with ASPERA-3 and ASPERA-4", Astrophys. Jou. 775 (2013) 1–24

2. A. Galli, P. Wurz, E. Kallio, A. Ekenbäck, M. Holmström, S. Barabash, A. Grigoriev, Y. Futaana, M.-C. Fok, and H. Gunell, "The Tailward Flow of Energetic Neutral Atoms Observed at Mars", Jou. Geophys. Res. 113 (2008) E12012

3. A. Galli, P. Wurz, H. Lammer, H.I.M. Lichtenegger, R. Lundin, S. Barabash, A. Grigoriev, M. Holmström, and H. Gunell, "The Hydrogen Exospheric Density Profile Measured with ASPERA-3/NPD", Space Science Rev. 126 (2006) 447–467

4. R. Lundin, D. Winningham, S. Barabash, R. Frahm, M. Holmström, J.-A. Sauvaud, A. Fedorov, K. Asamura, A.J. Coates, Y. Soobiah, K.C. Hsieh, M. Grande, H. Koskinen, E. Kallio, J. Kozyra, J. Woch, M. Fraenz, D. Brain, J. Luhmann, S. McKenna-Lawler, R.S. Orsini, P. Brandt, and P. Wurz, "Plasma Acceleration Above Martian Magnetic Anomalies", Science 311 (2006) 980–983

Time-Line	From	To
Measurement Phase	on-going	
Data Evaluation	on-going	

7.4 ASPERA-4/Venus Express: Remote Particle Sensing of Ion Populations in Venus' Extended Atmosphere

Purpose of Research

The general scientific objective of the ASPERA-4 instrument is to study the solar wind-atmosphere interaction and characterize the plasma and neutral gas environment in the near-Venus space through energetic neutral atom (ENA) imaging and local plasma measurements. ASPERA-4 is an almost identical copy of the ASPERA-3 instrument on Mars Express. The main scientific objectives of the ASPERA-4 instrument are to

- Determine the instantaneous global distributions of plasma and neutral gas near the planet,
- Study the atmospheric escape induced by the highly variable solar wind and solar UV irradiation,
- Investigate the modification of the atmosphere through the solar wind ion bombardment,
- Investigate the energy deposition from the solar wind to the ionosphere.

The Neutral Particle Detector (NPD) provides measurements of the ENA flux, resolving velocity and mass (H and O) of the coming particles with a coarse angular resolution.

Status

Venus Express was successfully launched on 9 November 2005 from Baikonur / Kazakhstan, followed by an interplanetary cruise of 153 days. Successful insertion of spacecraft into an orbit around Venus was on 11 April 2006. Final operational orbit was attained in May 2006. The mission was extended several times, at latest extension is until end of 2014. At Bern, data analysis concentrates on NPD data where the neutral exosphere, martian atmospheric loss via energetic neutral atoms, and energetic atoms of interstellar origin are investigated in detail.

Publications

1. A. Galli, P. Wurz, P. Kollmann, P.C. Brandt, M. Bzwoski, J.M. Sokół, M.A. Kubiak, A. Grigoriev, and S. Barabash, "Heliospheric Energetic Neutral Hydrogen measured with ASPERA-3 and ASPERA-4", Astrophys. Jou. 775 (2013) 1–24

2. A.G. Wood, S.E. Pryse, M. Grande, I.C. Whittaker, A.J. Coates, K. Husband, W. Baumjohann, T. Zhang, C. Mazelle, E. Kallio, M. Fränz, S. McKenna-Lawlor, and P. Wurz, "The transterminator ion flow at Venus at Solar Minimum", Planet. Sp. Sci. 73 (2012) 341–346

3. A. Galli, M.-C. Fok, P. Wurz, S. Barabash, A. Grigoriev, Y. Futaana, M. Holmström, A. Ekenbäck, E. Kallio, and H. Gunell, "The Tailward Flow of Energetic Neutral Atoms Observed at Venus", Jou. Geophys. Res. 113 (2008) E00B15

4. A. Galli, P. Wurz, P. Bochsler, S. Barabash, A. Grigoriev, Y. Futaana, M. Holmström, et al., "First observation of energetic neutral atoms in the Venus environment", Planet. Space Science 56 (2008) 807–811

Time-Line	From	To
Measurement Phase	on-going	
Data Evaluation	on-going	

Abbreviations

ASPERA-4	Analyzer of Space Plasmas and Energetic Atoms
ENA	Energetic Neutral Atoms
NPD	Neutral Particle Detector

Institute

Space Research and Planetology
Physics Institute
University of Bern

In Cooperation with

Swedish Space Research Institute, Kiruna, Sweden
(S. Barabash, R. Lundin, H. Anderson)

Max-Planck-Institut für Aeronomie, Lindau, Germany
(M. Fränz, J. Woch)

Applied Physics Laboratory, John Hopkins University, Laurel, MD, USA
(P. Brandt)

Principal Investigator

S. Barabash, Swedish Space Research Institute, Kiruna, Sweden

Swiss Principal Investigator

P. Wurz

Co-Investigator

A. Galli
P. Bochsler

Method

Measurement

Research Based on Existing Instruments

The ASPERA-4 instrument on the Venus Express Spacecraft.

7.5 Investigation of the Chemical Composition of Lunar Soils (Luna-Glob and Luna-Resurs Missions)

Institute

Space Research and Planetology
Physics Institute
University of Bern

In Cooperation with

Institute of Space Research, IKI,
Moscow, Russia
((G. Managadze, M. Gerasimov,
A. Chumikov, A. Sapgir)

Université Pierre et Marie Curie,
Paris, France
(M. Cabane)

Principal Investigator

G. Managadze (LASMA PI),
Institute of Space Research, IKI,
Moscow, Russia

P. Wurz (NGMS PI, LASMA Co-PI),
University of Bern, Switzerland

Swiss Principal Investigator

P. Wurz

Co-Investigator

M. Tulej

Method

Measurement

Development and Construction of Instruments

Laser ablation mass spectrometer, LASMA, for the direct measurements of the elemental composition of solid materials.

Neutral Gas Mass Spectrometer, NGMS, to measure the chemical composition volatiles.

Purpose of Research

The Russian Space Agency will launch two lunar landers to land on the lunar south and north poles, Luna-Glob and Luna-Resurs. LASMA, a laser ablation mass spectrometer, which is part of the scientific payload of these landers, will perform direct elemental analysis of soil samples collected in the vicinity of the spacecraft landing site. Elemental and isotopic analysis will be performed on 12 soil samples.

On Luna-Resurs there is a gas-chromatography mass spectrometer complex, GC-MS, which will perform detailed investigations of the volatile content of soil samples collected in the vicinity of the spacecraft landing site. The GC-MS consists of a thermal differential analyzer, a gas chromatograph and a mass spectrometer (NGMS), which is provided by the University of Bern.

Status

Spacecraft and scientific instruments are currently under development. Launch of Luna-Glob is foreseen for mid 2016, and Luna-Resurs will launch in 2019. Instrument development is ongoing. The LASMA instrument is a copy of the LASMA instrument that was part of the Phobos-Grunt mission.

Publications

1. M. Tulej, A. Riedo, M. Iakovleva, and P. Wurz, “On applicability of a miniaturized laser ablation time of flight mass spectrometer for measurements of trace elements”, Int. Jou. Spectrosc. (2012) Article ID 234949, doi: 10.1155/2012/234949

2. P. Wurz, D. Abplanalp, M. Tulej, M. Iakovleva, V.A. Fernandes, A. Chumikov, and G. Managadze, “Mass Spectrometric Analysis in Planetary Science: Investigation of the Surface and the Atmosphere”, Sol. Sys. Res. 46 (2012) 408–422

3. M. Tulej, M. Iakovleva, I. Leya, and P. Wurz, “A miniature mass analyser for in situ elemental analysis of planetary material: performance studies”, Analytical and Bioanalytical Chemistry 399 (2011) 2185–2200, doi: 10.1007/s00216-010-4411-3

4. U. Rohner, J. Whitby, P. Wurz, and S. Barabash, “A highly miniaturised laser ablation time-of-flight mass spectrometer for planetary rover”, Rev. Sci. Instr., 75(5), (2004), 1314–1322

Abbreviations

NGMS — Neutral Gas Mass Spectrometer

Time-Line	From	To
Planning	09-2010	02-2011
Construction	03-2011	end 2014
Measurement Phase	mid 2016	end 2020
Data Evaluation	mid 2016	2021

7.6 SARA/Chandrayaan-1 Investigation of the Solar Wind Interaction with the Lunar Surface

Purpose of Research

The Sub-keV Atom Reflecting Analyzer (SARA) experiment was flown on the first Indian lunar mission Chandrayaan-1. The SARA instrument consists of three major subsystems: a LENA sensor (CENA), a solar wind monitor (SWIM), and a digital processing unit (DPU).

SARA was used to image the solar wind-surface interaction to study primarily solar wind reflection and surface sputtering, and surface magnetic anomalies and associated mini-magnetospheres. SARA is the first LENA imaging mass spectrometer of its kind that has been flown on a space mission. A replica of SARA has been built to fly to Mercury onboard the BepiColombo mission.

Status

Chandrayaan-1 was launched on 22 October 2008, went successfully in lunar polar orbit (first at 100 km orbit and later at 200 km orbit), and operated until 28 August 2009. The Sub-keV Atom Reflecting Analyzer (SARA) experiment operated nominally on the first Indian lunar mission Chandrayaan-1. The SARA is a low energy neutral atom (LENA) imaging mass spectrometer, which performed remote sensing of the lunar surface via detection of neutral atoms in the energy range from 10 eV to 3 keV.

The University of Bern participated in the design and development of the instrument and contributed hardware to the two sensors of SARA, SWIM and CENA.

Publications

1. A. Vorburger, P. Wurz, S. Barabash, M. Wieser, Y. Futaana, M. Holmström, A. Bhardwaj, and K. Asamura, “Energetic Neutral Atom Observations of Magnetic Anomalies on the Lunar Surface”, Jou. Geophys. Res. 117 (2012), A07208, doi: 10.1029/2012JA017553

2. A. Schaufelberger, P. Wurz, S. Barabash, M. Wieser, Y. Futaana, M. Holmström, A. Bhardwaj, M.B. Dhanya, R. Sridharan, and K. Asamura, “Scattering function for energetic neutral hydrogen atoms off the lunar surface”, Geophys. Res. Lett. 38 (2011) L22202, doi: 10.1029/2011GL049362, 2011

3. C. Lue, Y. Futaana, S. Barabash, M. Wieser, M. Holmström, A. Bhardwaj, M.B. Dhanya, and P. Wurz, “Strong influence of lunar crustal fields on the solar wind flow”, Jou. Geophys. Res. 38, (2011) L03202, doi: 10.1029/2010GL046215

4. M. Wieser, S. Barabash, Y. Futaana, M. Holmström, A. Bhardwaj, R. Sridharan, M.B. Dhanya, A. Schaufelberger, P. Wurz, and K. Asamura, “First observation of a mini-magnetosphere above a lunar magnetic anomaly using energetic neutral atoms”, Geophys. Res. Lett., 37 (2010) L05103, doi: 10.1029/2009GL041721

Abbreviations

CENA	Chandrayaan Energetic Neutral Atom
SARA	Sub-keV Atom Reflecting Analyzer
SWIM	Solar Wind Measurement

Institute

Space Research and Planetology
Physics Institute
University of Bern

In Cooperation with

Swedish Space Research Institute, Kiruna, Sweden
(S. Barabash, M. Wieser, H. Anderson)

Space Physics Laboratory, Vikram Sarabhai Space Centre, Trivandrum, India
(A. Bhardwaj, M. B. Dhanya)

Principal Investigator

S. Barabash, Swedish Space Research Institute, Kiruna, Sweden

Swiss Principal Investigator

P. Wurz

Co-Investigator

A. Vorburger

Method

Measurement

Research Based on Existing Instruments

The SARA instrument on the Chandrayaan-1 spacecraft.

7.7 CaSSIS – Colour and Stereo Surface Imaging System

Institute

Space Research and Planetology Physics Institute
University of Bern

In Cooperation with

Fachhochschule Nordwestschweiz, Windisch

Space Research Center, Warsaw

INAF, Italy

Principal Investigator

Nicolas Thomas

Co-Investigator

G. Cremonese (Co-PI)
Astronomical Observatory, Padova, Italy, and

24 other scientists from Europe and the US

Method

Measurement

Industrial Hardware Contract to

RUAG Space, Zurich (telescope)

nanoTRONIC, Biel (flight software)

SELEX-ES, Campi Bisenzio (focal plane assembly)

Purpose of Research

CaSSIS will fly on the ExoMars Trace Gas Orbiter (TGO) in 2016 and is designed to be the main imaging system on the mission. The primary objectives of CaSSIS are

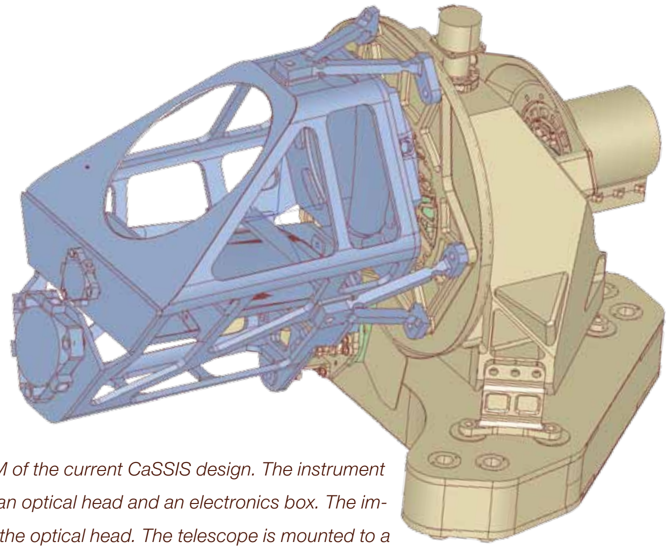
- to characterize sites which have been identified as potential sources of trace gases
- to investigate dynamic surface processes (e.g. sublimation, erosional processes, volcanism) which may contribute to the atmospheric gas inventory
- to certify potential future landing sites by characterizing local slopes, rocks, and other potential hazards.

CaSSIS will provide < 5 m/px imaging of the surface of Mars in 4 colours and in stereo. The instrument will weigh around 17.7 kg and have an orbit-averaged power consumption of < 25 W. The imaging technique to be used is a “push-frame” where small 2D-images are taken rapidly using a hybrid CMOS detector and matched together on the ground during post-processing.

CaSSIS has been developed as a replacement for the HiSCI experiment which was originally slated for the TGO mission.

Status

CaSSIS completed PDR successfully in October 2013 and will undergo CDR at the beginning of April 2014.



A CAD/CAM of the current CaSSIS design. The instrument comprises an optical head and an electronics box. The image shows the optical head. The telescope is mounted to a rotation drive which allows production of stereo images by rotating the telescope through 180 deg to produce a stereo convergence angle of 22 deg.

Time-Line	From	To
Planning	2012	2013
Construction	2013	2015
Measurement Phase	2017	2019
Data Evaluation	2017	2022

7.8 SERENA and ENA – Mass spectrometers for BepiColombo

Composition of Crust, Exosphere, Surface Evolution, Formation and Evolution of Planet Mercury.

Purpose of Research

The European Space Agency (ESA) has defined the Cornerstone Mission, named BepiColombo, for the detailed exploration of planet Mercury. Because of observational difficulties Mercury is a largely unknown planet and therefore a high scientific return is expected from such an exploratory mission. Launch of BepiColombo is foreseen for August 2016 and the transfer to Mercury will take until 2022. Thus the dataphase will start late in 2022, the earliest, and will last for one year with a possible extension of an additional year.

We participate, within an international collaboration, in the BepiColombo mission by developing two mass spectrometers. One mass spectrometer is on BepiColombo/MMO spacecraft to perform Energetic Neutral Atom (ENA) imaging of the space around Mercury, the second instrument will go on the BepiColombo/MPO spacecraft to measure the elemental, chemical, and isotopic composition of Mercury's exosphere with a sensitive neutral gas mass spectrometer. With these two instruments we would substantially contribute to three out of the six main scientific goals set for BepiColombo.

Status

The BepiColombo spacecraft are currently under development with launch scheduled for August 2016. Scientific instruments shall be delivered for integration on the spacecraft by the end of 2014.

Publications

1. P. Wurz, J.A. Whitby, U. Rohner, J.A. Martín-Fernández, H. Lammer, and C. Kolb, "Self-consistent modelling of Mercury's exosphere by sputtering, micro-meteorite impact and photon-stimulated desorption", Planet. Space Science 58 (2010) 1599–1616

2. A. Mura, P. Wurz, H.I.M. Lichtenegger, H. Schleicher, H. Lammer, D. Delcourt, A. Milillo, S. Massetti, M.L. Khodachenko, and S. Orsini, "The sodium exosphere of Mercury: Comparison between observations during Mercury's transit and model results", Icarus 200 (2009) 1–11

3. P. Wurz and H. Lammer, "Monte-Carlo Simulation of Mercury's Exosphere", Icarus, 164(1), (2003), 1–13

Abbreviations

ENA	Energetic neutral Atom
MMO	Mercury magnetospheric Orbiter
MPO	Mercury Planetary Orbiter
SERENA	Search Exopheric Refilling and Emitted Natural Abundances
STROFIO	Start from a Rotating FIeld mass spectrOmeter

Time-Line	From	To
Measurement Phase	Jan 2022	Jan 2023
Data Evaluation	Jan 2022	2025

Institute

Space Research and Planetology
Physics Institute
University of Bern

In Cooperation with

Instituto di Fisica dello Spazio Interplanetari, Rome, Italy
(S. Orsini, A. Milillo)

Swedish Space Research Institute, Kiruna, Sweden
(S. Barabash, M. Wieser)

Southwest Research Institute, San Antonio, TX, USA
(S. Livi)

Principal Investigator

S. Orsini, Instituto di Fisica dello Spazio Interplanetari, Rome, Italy

S. Barabash, Swedish Space Research Institute, Kiruna, Sweden

Swiss Principal Investigator

P. Wurz

Co-Investigator

J. Scheer

Method

Measurement

Development and Construction of Instruments

The University of Bern participates in two instruments for the mission.

1) The SERENA instrument on the MPO spacecraft of BepiColombo, for which Bern provides substantial hardware for the STROFIO mass spectrometer and for the MIPA ion sensor.
2) The MPPE instrument package on the MMO spacecraft of BepiColombo, for which Bern provides substantial hardware for the ENA instrument.

7.9 BELA – BepiColombo Laser Altimeter

Institute

Space Research and Planetology
Physics Institute
University of Bern

In Cooperation with

DLR Institute for Planetary Research (DLR), Berlin-Adlershof, Germany

Max-Planck-Institut für Sonnensystemforschung (MPS), Göttingen, Germany

Instituto de Astrofisica de Andalucia (IAA), Granada, Spain

Principal Investigator

Nicolas Thomas (Co-PI)
Tilman Spohn (Co-PI)

Co-Investigator

30 leading geophysicists from Europe

Method

Measurement

Industrial Hardware Contract to

RUAG Space (CH)
Syderal (CH)
FISBA Optik (CH)

Cassidian Optronik (D)

CRISA (E)

Purpose of Research

BepiColombo laser altimeter (BELA) is a joint Swiss-German project with a smaller involvement from Spain. The scientific objectives of the experiment are to measure the

- figure parameters of Mercury to establish accurate reference surfaces
- topographic variations relative to the reference figures and a geodetic network based on accurately measured positions of prominent topographic features
- tidal deformations of the surface
- surface roughness, local slopes and albedo variations, also in permanently shaded craters near the poles

BELA will form an integral part of a larger geodesy and geophysics package, incorporating radio science and stereo imaging. Although standalone instruments in their right, only the synergy between these will make full use of present-day technology and scientific capability. The synergy will cover the problems of planetary figure and gravity field determination, interior structure exploration, surface morphology and geology, and extend into the measurements of tidal deformations. The reference surfaces and the geodetic network will provide the coordinate system for any detailed exploration of the surface, geological, physical, and chemical. The topography is needed to develop digital terrain models that allow quantitative explorations of the geology, the tectonics, and the age of the planet surface. The topography is further needed for a reduction of the gravity field data because topographical contributions to gravity must first be removed before using gravity anomalies for the investigation of sub-surface structures. The use of topography together with gravity data will constrain, by an admittance analysis between the two and with the help of a flexure model for the lithosphere, lithosphere and crust properties. Examples here would include the lithosphere elastic thickness (essential for the reconstruction of the thermal history of Mercury) and the crustal density (essential for the construction of a Hermean internal model). In addition to the moments of inertia which will be provided by the radio science experiment, the tidal deformations measured by BELA and the radio science instrument will place further constraints of global models of the interior structure. BELA will contribute by providing the deformation of the surface while the radio science package will measure the mass relocations.

Under favorable conditions, it will even be possible to constrain the rheology of the interior of the planet by measuring the time lag between the motion of the tidal bulge and the disturbing potential.

The instrument (Figure) comprises a transmitter producing a 50 mJ laser

Time-Line	From	To
Planning	2004	2008
Construction	2008	2014
Measurement Phase	2024	2026
Data Evaluation	2024	2028

pulse at 1 064 nm. The laser passes through a beam expander to collimate the beam before exiting to the planet through a baffle. The return pulse is captured by a 20 cm beryllium telescope which is protected by a novel reflective baffle. The light then passes through a transfer optic containing a 1 064 nm filter before collection on an avalanche photodiode detector. Conversion to a range is performed using a time of flight electronics within an electronics box which also houses the instrument computer and power supply.

Status

EM, STM and EQM programmes completed. Flight model build in progress.

Publications

1. Gunderson, K. and N.Thomas, (2010) BELA receiver performance modeling over the BepiColombo mission lifetime, Planetary and Space Science, 58, 309–318

2. Seiferlin, K., Chakraborty, S., Gunderson, K., Fischer, J., Luethi, B.S., Piazza, D., Rieder, M., Sigrist, M., Thomas, N., Weigel, T. (2007) Design and manufacture of a lightweight reflective baffle for the BepiColombo Laser Altimeter, Optical Engineering, 46(4), 043003-1

3. Thomas, N., T. Spohn, J.-P. Barriot, W. Benz, G. Beutler, U. Christensen, V. Dehant, C. Fallnich, D. Giardini, O. Groussin, K. Gunderson, E. Hauber, M. Hilchenbach, L. Iess, P. Lamy, L.-M. Lara, P. Lognonne, J.J. Lopez-Moreno, H. Michaelis, J. Oberst, D. Resendes, J.-L. Reynaud, R. Rodrigo, S. Sasaki, K. Seiferlin, M. Wieczorek, and J. Whitby, (2007) The BepiColombo Laser Altimeter (BELA): Concept and baseline design, Planetary and Space Science, 55, 1398–1413

The BELA EQM instrument in the thermal vacuum chamber at the University of Bern. To the top, the beryllium telescope structure can be seen mounted to the optical bench (an aluminium honeycomb). In the foreground, the laser head box is mounted to the same optical bench. The electronics unit specifically for the laser electronics is to the lower right. The necessary baffles for the telescope and the laser are not mounted in this configuration.

7.10 Jupiter and Icy Moons Explorer (JUICE)

Institute

Space Research and Planetology Physics Institute
University of Bern

In Cooperation with

Swedish Space Research Institute, Kiruna, Sweden

Applied Physics Laboratory, John Hoppkins University, Laurel, MD, USA

Max-Planck-Institut für Sonnensystemforschung, Katlenburg-Lindau, Germany

University of Wales Aberystwyth, Wales, UK

Finnish Meteorological Institute, Helsinki, Finland

Principal Investigator

S. Barabash, Swedish Space Research Institute, Kiruna, Sweden

Swiss Principal Investigator

P. Wurz

Co-Investigator

M. Tulej
A. Vorbure
A. Galli
N. Thomas

Method

Measurement

Development and Construction of Instruments

Particle Environment Package (PEP)

Purpose of Research

The JUICE mission (ESA L-class) is dedicated to explore the Jupiter system, visit the moons Europa, Ganymede, and Callisto with several flybys and it will finish its mission in orbit of Ganymede. JUICE will study the moons in detail, their composition, interior and atmosphere, the magnetosphere of Jupiter, as well as Jupiter's atmosphere. The article Environment Package (PEP) will measure all particle populations in the Jupiter system, which are electrons, ions and neural particles in the energy range from thermal energies all the way to relativistic particles.

Status

The Particle Environment Package (PEP) is one of the 10 selected experiments for the JUICE missions. The Swedish Institute for Space Physics is the PI institution, the University of Bern is Co-PI institution for this experiment. At mission level the industrial partner is currently selected, with a decision expected for fall 2014. Experiments are in Phase A/B1 to define all technical and scientific requirements. Mission adoption by ESA for Phase C/D is forseen for November 2014.

Abbreviations

ENA	Energetic neutral Atom
JUICE	Jupiter and Icy Moons Explorer

Time-Line	From	To
Planning	May 2013	Nov 2014
Construction	2015	2020
Measurement Phase	2030	2032
Data Evaluation	2030	2035

7.11 Submillimeter Wave Instrument (SWI) for JUICE

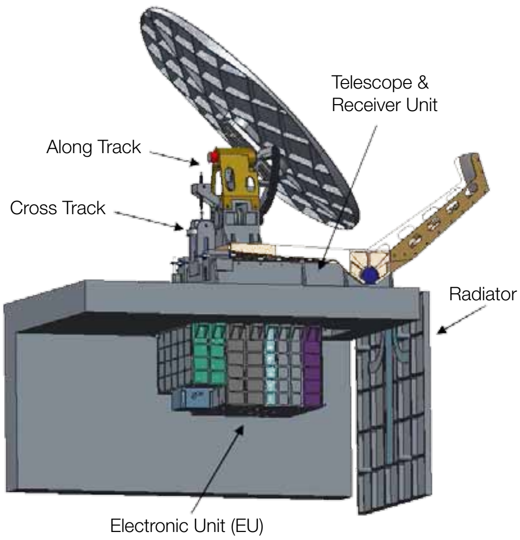
Purpose of Research

The JUpiter ICy moons Explorer (JUICE) is a L-class mission of the ESA Cosmic Vision 2015–2025 program to investigate Jupiter and its Galilean satellites as planetary bodies and potential habitats for life. The Submillimeter Wave Instrument (SWI) on JUICE will study the chemical composition, wind speeds and temperature variability of the Jovian atmosphere, as well as the exosphere and surface properties of its icy moons.

SWI consists of two heterodyne receivers tunable between 530–630 GHz, high resolution and broadband spectrometers, and a steerable off-axis telescope with 30 cm aperture. The Institute of Applied Physics is responsible for the optical design and the development and test of the receiver unit.

Status

The SWI instrument has been selected in 2/2013 and is currently in Phase A/B1. JUICE is scheduled for launch in 2022 and will arrive in the Jupiter system in 2032.



Submillimeter Wave Instrument (SWI) for the ESA mission JUICE to Jupiter and its icy moons. The instrument consists of a radiometer/spectrometer operating between 530 and 630 GHz and a telescope with 30 cm aperture.

Abbreviations

SWI	Submillimeter Wave Instrument
JUICE	Jupiter Icy Moons Explorer

Institute

Institute of Applied Physics (IAP)
University of Bern

In Cooperation with

MPS, Germany
Omnisys, Sweden
LERMA, France
RPG, Germany
NICT, Japan

Principal Investigator

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Swiss Principal Investigator

Axel Murk

Co-Investigator

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Method

Measurement

Development and Construction of Instruments

Optics and Receiver Unit for the SWI instrument on the Jupiter Mission JUICE.

Industrial Hardware Contract to

TBD

7.12 GALA – Ganymede Laser Altimeter

Institute

Space Research and Planetology Physics Institute
University of Bern

In Cooperation with

DLR Institute for Planetary Research (DLR), Berlin-Adlershof, Germany

Chiba Institute of Technology, Japan

Instituto de Astrofisica de Andalucia (IAA), Granada, Spain

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Method

Measurement

Industrial Hardware Contract to

TBD

Purpose of Research

GALA will measure the topography of the Jovian moon, Ganymede from onboard ESA's JUICE mission. Uni Bern will contribute the rangefinder electronics to the laser altimeter system. This will be a derivative of the BELA rangefinder which has been successfully implemented for BepiColombo. The rangefinder will mostly be constructed in industry.

The rangefinder measures the time of flight of the laser pulse, and the laser pulse energy and pulse shape. These three quantities are the only immediate science result from a laser altimeter, and are used to compute

- the altitude of the S/C above the surface
- the topography of the surface (taking into account orbit data)
- the albedo of the surface at the laser wavelength
- the slope of the surface (from shot-to-shot altitude data)
- the roughness of the surface inside the laser footprint, determined from the pulse shape.

The BELA range finder module is a novel type of digital signal processing module for laser altimetry. The signal from the detector is digitized prior to the pulse detection and pulse/time of flight analysis. The digitation of the signal is done using two phase shifted 40 MHz ADC's which are combined to produce sampling at 80 MHz. This way of signal analysis has several advantages to previously used analogue detection systems. The system is fully programmable and so can be adapted to expected pulse shapes even during flight. The improvement of the detection limit is significant because digital matched filtering can be applied.

Status

Instrument currently in Phase A.

Time-Line	From	To
Planning	2012	2016
Construction	2016	2019
Measurement Phase	2025	2033
Data Evaluation	2031	2035

8 Life Science

8.1 Yeast Bioreactor Experiment

Network biology of stress responses and cell flocculation of Saccharomyces cerevisiae grown in a continuous bioreactor under microgravity conditions.

Purpose of Research

The project is focused on the effect of microgravity on the physiology of S. cerevisiae (yeast). Studies have shown that simulated microgravity results in a disturbed physiology. The expression of a significant number of genes (1372) was changed when yeast cells were cultured for 5 or 25 generations in a low-shear simulated microgravity environment. The relevance of gravity on S. cerevisiae cell-cell and cell-surface interactions is best shown by the fact that S. cerevisiae cells grow in clusters in microgravity conditions compared to cells grown on earth. In addition, it was found that continuous cultivation of S. cerevisiae in microgravity had an influence on the bud scar positioning, a critical factor in cell adhesion and invasion.

In this experiment different S. cerevisiae strains will be used to investigate the effect of microgravity on non-interacting and cell-cell interacting (flocculation) yeast growth, and on induced stress responses by applying a heat and osmotic shock in microgravity.

An integrative-experimental approach will be used to assess the effect of microgravity. Therefore, various -omics technologies, i.e. fluxomics, transcriptomics, proteomics and genomics and specific cell analysis methods will be used to analyse the samples. This will lead to insight into how gravity influences global regulation of energy metabolism, (stress) signaling transduction pathways, transcriptional regulatory networks, gene regulatory networks, protein-protein interaction networks, and metabolic networks.

Yeast cultivation will be performed in a specifically designed continuous bioreactor. The use of a continuous cultivation mode (chemostat) gives defined and controlled conditions over time (i.e. growth at one specific growth rate) permitting the repetition of an experiment, without having different starting conditions except for the elapsed microgravity time, and easily interpretable results.

Status

The projects status is a delta B phase where scientific requirements for the hardware development are established. The hardware is undergoing development and extensive tests will be carried out to analyze the chosen solution in terms of performance, robustness and maintainability.

Time-Line	From	To
Planning	2013	2013
Construction	2014	2018

Institute

Lucerne School of Engineering and Architecture
Centre of Competence in Aerospace Biomedical Science & Technology
Hergiswil, Switzerland

In Cooperation with

Vrije Universiteit Brussel
Lab. Structural Biology Brussels
Dept. Bioengineering Sciences
Brussels, Belgium

Univ. Gent
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Method

Measurement

Development and Construction of Instruments

Bioreactor for continuous cultivation of yeast.

8.2 SPHEROIDS

Institute

Lucerne School of Engineering and Architecture
Centre of Competence in Aerospace Biomedical Science & Technology
Hergiswil, Switzerland

In Cooperation with

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Department of Biomedicine and Pharmacology
8000 Aarhus C
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Daniela Gabriele Grimm

Swiss Principal Investigator

Marcel Egli

Method

Measurement

Development and Construction of Instruments

Bioreactor for cultivating human cells.

Industrial Hardware Contract to

RUAG Space, Nyon

Purpose of Research

The "SPHEROIDS" project is focused on human endothelial cells. The goal of our study is to investigate three dimensional cell assembly under the condition of microgravity while emphasizing proliferation, differentiation and induction of apoptosis (programmed cell death). Extensive studies have been performed on cultured endothelial cells over the last few years using the Random Positioning Machine (RPM). These studies have shown that cultured endothelial cells are highly sensitive to simulated hypogravity, which induced three-dimensional cell aggregation, as well as up-regulation of several growth factors and of extracellular matrix components. It also initiated apoptosis in the EA.hy926 human endothelial cell line. The flight experiment will enable the science team to distinguish the effects, which are caused by the technique of the RPM from those which are due to the influence of real microgravity.

Status

The hardware for the "SPHEROIDS" experiment has been designed, developed and built by RUAG Space.

Publications

In preparation.

Time-Line	From	To
Planning	2008	2012
Construction	2012	2014
Measurement Phase	2015 (TBD)	
Data Evaluation	2015	2016

9 Swiss Space Industries Group

ESA, the Key Account

The world space industry is a strategically important growth sector of high value-creating potential and great economic importance. If Europe is to compete globally and secure a leading position, the resources available must be efficiently deployed and activities pooled.

These tasks are handled by the European Space Agency (ESA). It coordinates and promotes the development of European space technology and ensures that the investment made goes to the lasting benefit of all Europeans. The EU aims to utilise the benefits of its space policy in its security, environment, transport, economic and social policy.

ESA has an annual budget of around three billion euros. Switzerland contributes around 155 million francs annually. As one result, funds flow into research and enable Swiss scientists to participate in significant ESA missions, while the manufacturer benefit as a supplier to the research sector or directly through contracts awarded by ESA.

Swiss Collaboration

While the Swiss space market cannot match the biggest European countries for size, it can definitely keep up with them in terms of quality and innovation. The Ariane and Vega launchers, the Automated Transfer Vehicle (ATV), the space astrometry mission Gaia or the Sentinel satellites for Copernicus, Europe's Global Monitoring for Environment and Security system are just some examples of important space programmes in which Swiss manufacturers have played a major role. Hardly a European mission takes place today which does not incorporate technologies from Switzerland.

None of this would be possible without Switzerland's early commitment to the European Space Agency, right from the day one. ESA's ambitious programmes enable the Swiss space companies to acquire the expertise that underpins its excellent reputation and promising position on the global growth market for space technology. Strengthening and further expanding this position has to be the goal for the coming years. This means not only overcoming technological and economic challenges but also dealing with difficult political issues. The leading players – science, politics and the industry – have to work seamlessly together.

The Engagements within the Space Industry

Swissmem unites the Swiss electrical and mechanical engineering industries and associated technology-oriented sectors. The space industry is an important division among them.

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Swiss Space Industries Group

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Integration of the EarthCARE (Earth Clouds, Aerosols and Radiation Explorer) satellite.

Integration of a an alignment-mechanism. used for the electrical power transmission of a satellite.

SSIG Members

Apco Technologies SA
www.apco-technologies.com

Art of Technology AG
www.art-of-technology.ch

Boa AG
www.boa.ch

Clemessy (Switzerland) AG
www.clemessy.ch

CSEM
www.csem.ch

EPFL, Swiss Space Center
www.epfl.ch

Fisba Optik AG
www.fisba.ch

Meggitt SA, Sensing Systems
www.meggittsensingsystems.com

Micos Engineering GmbH
www.micos.ch

Orolia Switzerland SA
www.spectratime.com

Precicast SA
www.precicast.com

RUAG Schweiz AG, RUAG Space
www.ruag.com/space

WEKA AG
www.weka-ag.ch

Even though, having a membership with ESA, the international competitiveness is not self-evident. The ability to compete internationally is not a matter of course – it must be worked on. A location able to compete is the basis of success. The commitment of Swissmem applies to Switzerland, the context for work and thought, for this reason. Continuous basic work has made Swissmem into a centre of strategic commercial and employer skills. This allows the association to represent the concerns of the sector to politicians, national and international organizations, representatives of employees and the public.

Apart from this, Swissmem offers to the companies numerous practice-oriented services, which help them to maintain their ability to compete and to meet new challenges successfully.

The Specialists: SSIG, Swiss Space Industries Group

Within Swissmem the SSIG ("Swiss Space Industries Group") is organized as a technology group. The SSIG includes companies that are significantly involved in the wide-ranging, competitive Swiss space technology environment. Those companies play a prominent role in the broadly faceted, competitive Swiss space industry. These manufacturers and engineering companies develop solutions for all areas of space business: structures for rockets, satellites, space transporters, components for propulsion engines and scientific instruments.

As established specialists in mechatronics, optics, sensors, electronics and software, our companies participate in various ESA projects and earn themselves a merited high place in the fiercely competitive European market by delivering quality, expertise, flexibility and on-time reliability. Space research is a driving force of innovation. Space engineering brings together virtually all the strategic technologies. The sector therefore stands out as a future-oriented, innovative and attractive employer.

Jobs and Training

The Swiss Space companies of SSIG currently engage approximately 800 employees in the Space sector, but other thousands of professionals are also indirectly connected with the space industry. Many of them are university graduates who find attractive jobs in the diverse areas of the production of space components and systems and contribute specialist expertise to the companies concerned.

The employees of those companies concerned not only come from a broad spectrum of educational and training backgrounds but also represent a wide range of disciplines and therefore help to create a highly diversified store of expertise. This includes specialist knowledge in the fields of computer science, mechanics, electronics, optics, aerodynamics and tribology.

This very broadly based expert knowledge enables the companies to provide innovative solutions to the complex challenges arising in the space sector.

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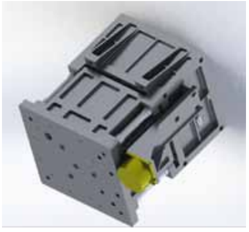

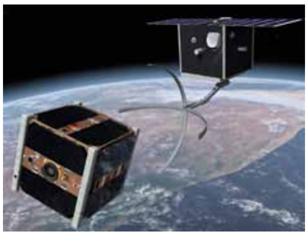

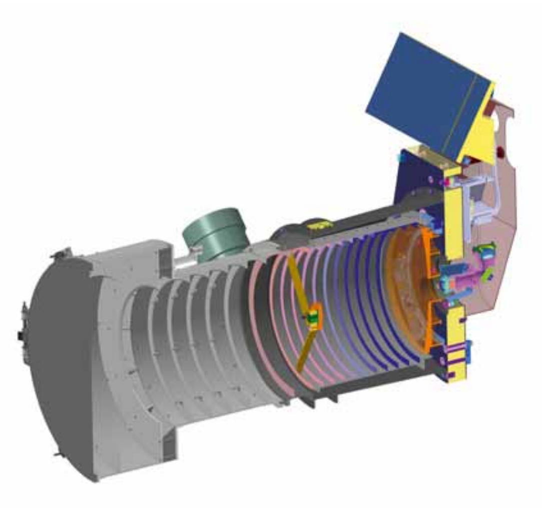

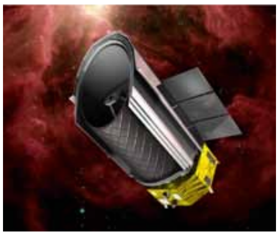

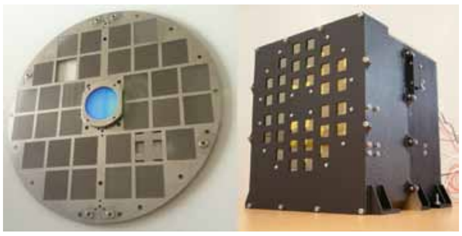

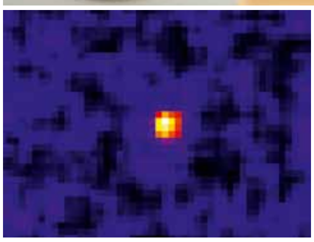

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www.spaceresearch.scnatweb.ch

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www.geo.uzh.ch/microsite/skf

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