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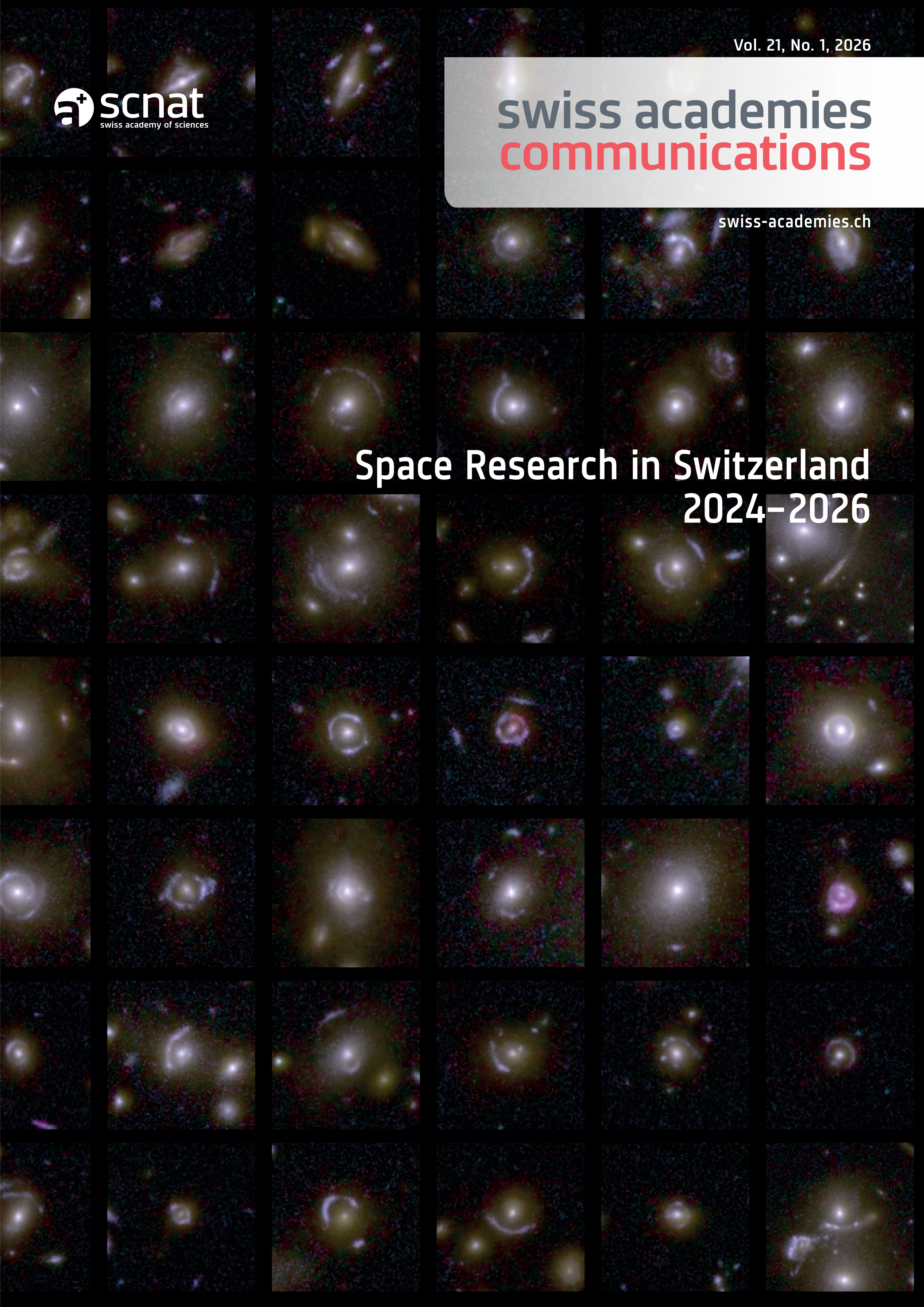

Space Research in Switzerland 2024–2026

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COVER PHOTO
A collage of images from Euclid containing examples of gravitational lenses. Each example typically comprises a bright centre with smears of stars in an arc or multiple arcs around it as a result of light travelling towards Euclid from distant galaxies being bent and distorted by normal and dark matter in the foreground. In some rare cases the smearing is in a complete ring, creating a so-called Einstein Ring. Image credit: ESA/Euclid/Euclid Consortium/NASA, image processing by M. Walmsley, M. Huertas-Company, J.-C. Cuillandre.

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1 Foreword

The Committee on Space Research (COSPAR) was established in 1958 to promote open collaboration at the international level in the domain of space research. Switzerland is a member of COSPAR through the Swiss Committee on Space Research (CSR) of the Swiss Academy of Sciences (SCNAT). The 46th Scientific Assembly in Florence, Italy, this summer is an occasion for delegations to showcase their activities in this domain. The present report is a compilation of projects that have been conducted in Swiss research institutes over the period 2024 – 2026.

Space research in Switzerland benefits from very strong support from the Swiss Space Office, the national agency for space matters at both the national and international levels. Thanks to this support, Swiss research institutions have been able to participate in a large number of high-profile scientific missions. Most projects in which Switzerland is involved are led by the European Space Agency (ESA). This long-term commitment to ESA originates from its very foundation and remains a tenet of Swiss space policy. Bilateral collaborations with international partners are nevertheless common, including successful collaborations with NASA in the USA, JAXA in Japan, CMSA and CAS in China, and ISRO in India, among others.

Space research in Switzerland is mostly conducted at the Swiss Federal Institutes of Technology in Zürich (ETH) and Lausanne (EPFL), the Universities of Bern, Geneva, and Zürich, and the Universities of Applied Sciences in Windisch, Luzern, and Locarno, as well as at semi-independent research centres such as the Physical and Meteorological Observatory of Davos. Most space research domains are covered, from the Sun and the heliosphere to Solar System exploration and astrophysics, as well as more applied space science domains such as Earth observation, space situational awareness, satellite navigation systems, and life sciences in space. Swiss industries play a fundamental and enabling role in all space activities, and the CSR therefore maintains close contacts with the Swiss Space Industries Group, a body regrouping most of the Swiss industries active in the space domain.

The period 2024 – 2026 has been quite remarkable for several space missions with significant Swiss involvement. In 2025, both ESA's INTEGRAL and Gaia spacecrafts concluded their scientific journeys. While INTEGRAL operations are now essentially terminated, several more years of data analysis will be needed for Gaia to deliver its full potential. The Swiss and ESA-led CHEOPS mission continues to reveal new stellar systems and make significant discoveries. The mission is still performing beautifully and is being considered for extension until at least 2029. The Solar Orbiter probe has started its journey towards the Sun's poles, already producing stunning images of these regions. The XRISM mission has delivered incredible views of the X-ray sky thanks to its unprecedented combination of spectral resolution and sensitivity at these energies, leading to an avalanche of landmark results, while Euclid has started its six-year program to map the extragalactic sky in exquisite detail. The complete PLATO payload has been delivered and integrated into the spacecraft, which is now awaiting launch. The year 2026 will also mark the arrival of BepiColombo at Mercury, finally reaching its final orbit after eight years of extremely complex operations.

Following a long tradition, Switzerland is always eager to engage in collaborations with international partners. However, external factors continue to hamper these collaborations. In addition, budget uncertainties pose a new challenge to the space community, especially for international collaborations, which are not fully offset by ESA's historic success in obtaining the largest budget increase ever in 2025, particularly for its science programme. The greatest scientific successes in space research have been built on trustful international collaborations, and it is the wish of the Swiss space community that such collaborations become the norm again.

The above list does not intend to provide an exhaustive account of Swiss achievements over the last two years. We invite the reader to peruse the following compilation of Swiss projects related to space research to gain a more comprehensive picture of the dynamism of this research sector in Switzerland.

Stéphane Paltani

2 National Initiatives

2.1 Space Exchange Switzerland (SXS)

Space eXchange Switzerland

Mission

Let's promote Space in Switzerland!

Space Exchange Switzerland (SXS) is a national platform for the promotion of space in Switzerland funded by the Swiss Space Office (SSO) of the State Secretariat for Education, Research and Innovation (SERI).

SXS unites five leading Swiss institutions, with EPFL at its core alongside ETH Zürich, the University of Zurich, Università della Svizzera Italiana, and the FHNW, forming a strong national consortium and implementing activities benefiting the whole Swiss space ecosystem.

Fields of Action

- **Industry & Ecosystem Coordination**: Connecting companies, universities, and institutions, and strengthening Switzerland's competitiveness through the European Harmonisation process participation (THAG) and the organisation of national events for professionals.
- **Talent Development**: Guiding students and young professionals toward ESA and space related career opportunities.
- **Scientific Support**: Providing expertise through the scientific National Point of Contact (NPOC) to advance the use of Earth Observation data in research and applications.
- **International Representation**: Coordinating Swiss pavilions and delegations at major global space conferences such as the International Astronautical Congress (IAC).
- **Public Outreach**: Engaging the broader public through booths, events, and Space Clubs to promote space science across generations.

Our Impact

Since 2022, SXS has strengthened Switzerland's scientific and industrial footprint in the global space field. Through its scientific NPOC, it has delivered **over 200 consultations** supporting research teams in the use of Earth Observation data. By yearly coordinating the **Swiss pavilions at the IAC (International Astronautical Congress)**, SXS has ensured high visibility opportunities for students, institutions, big industries and start-ups to showcase their innovations internationally in Paris, Milan and Sydney.

Its facilitation of **49 Swiss actors in the European Harmonisation process** helps align national capabilities with European priorities and keeps the Swiss space industry competitive and technologically relevant. During the Community Days, SXS reunites the Space Community each second year with over 250 participants for two days to foster synergies, business opportunities and to update the community on the latest information and updates.

SXS also plays a key role in building talent: Swiss applications to ESA entry programmes have increased six-fold, reaching nearly 700, supported by around 80 Movetia grants. Public engagement continues to grow, with 11 outreach booths at events such as Fantasy Basel, Air and Space Days Lucerne, Mint-Vaud and TUN-Basel.

Over 100 Space Club sessions have been organised, enabling direct exchanges between scientists, engineers, students, and the public. In 2025, SXS had the honour of organising the 50th celebration of ESA in Lausanne, a milestone to confirm Switzerland's close relations with ESA.

Director:
Grégoire Bourban

Funded by:
Swiss Space Office SERI

Consortium made of:
EPFL (Leading house), UZH, ETHZ, USI, FHNW

Staff
13 people in 5 Universities

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https://www.space-exchange.ch

Outlook for 2026 – 2028

In the years ahead, Space Exchange Switzerland (SXS) will further strengthen its role as a national connector within the Swiss space ecosystem, with a strong focus on international visibility, scientific coordination, and community development. A major milestone will be Switzerland's participation at IAC 2026 in Antalya, where SXS will support universities, research groups, and industry partners in showcasing Swiss excellence and reinforcing Switzerland's candidacy for IAC 2029 in Geneva.

Nationally, SXS will intensify its engagement with the scientific community as the new cycle of the European Harmonisation process unfolds, ensuring that Swiss institutions and companies remain fully aligned with European priorities and maintain high competitiveness. The public outreach programme will also expand, with the Cosmos Club network extending into new Swiss regions such as Solothurn and Sion, strengthening SXS's mission to bring space science closer to local communities across the country.

On the educational and career side, SXS will build on the strong momentum of previous years by reinforcing the talent pool it has developed since 2022, offering closer guidance to students throughout their ESA selection processes, and fostering stronger networking between young talents, industry partners, and research institutions. Public engagement will remain a priority, supported by outreach booths and hands-on activities that introduce space science to all generations.

Altogether, SXS is set for dynamic and impactful years ahead focused on international representation, scientific coordination, talent development, and public outreach – continuing to act as a catalyst for a vibrant, innovative, and well-connected Swiss space ecosystem.

GROW the next generation of space experts.

ENGAGE with the public.

BOOST the Swiss space ecosystem keeping it competitive and efficient.

2.2 ISSI – International Space Science Institute

INTERNATIONAL SPACE SCIENCE INSTITUTE

Mission

The International Space Science Institute (ISSI) is a scientifically independent and neutral Space and Earth Science institute that advances science by facilitating open multi-disciplinary discourse in a stimulating environment, reaching out towards new scientific horizons.

Introduction

ISSI is a prominent, independent, non-profit institute of advanced study in Bern, Switzerland, established in 1995 to foster multidisciplinary research in space sciences, including heliophysics, astrophysics, planetary sciences and Earth sciences. ISSI hosts International Teams, Workshops, Fora, Working Groups and individual scientists, to gather in Bern and discuss compelling scientific questions and publish the results of their deliberations in the professional literature. ESA, the Swiss Space Office (SSO), and the Swiss Academy of Sciences (SCNAT) provide most of the financial resources of ISSI's operations. The Univ. Bern contributes a Director position and infrastructure. The Institute of Space and Astronautical Science (ISAS, JAXA, Japan) also supports ISSI with an annual financial contribution.

Scientific Activities at ISSI in 2024 and 2025

ISSI welcomed 1940 individual scientists to its facilities in 2024 – 2025. They attended 81 activities in 2024 and 69 in 2025. ISSI offers a portfolio of scientific activities to suit the community needs, described here:

Breakthrough Workshops: Breakthrough Workshops are designed to address key questions in science, by gathering the main experts on the topic, invite them to spend a week in a neutral and welcoming environment, discuss, and produce one high visibility, high impact, open access peer-reviewed paper providing the community consensus on the topic in question, including what there is agreement on, and where there is not, to be submitted within three months from the completion of the Workshop. The number of participants is capped at ~45 scientists. ISSI typically organises one Breakthrough Workshop per year.

Two Breakthrough Workshops were implemented in 2024 and 2025: The chronology of the very early Universe according to JWST: the first billion years (11-15 March 2024) and Life Beyond Earth: The Missing Link (16-20 June 2025).

Workshops: Workshops host up to 50 scientists, meeting for a week to address key open questions in a scientific field of broad interest. A key element of ISSI workshops is to gather experts with diverse backgrounds and views of the topic, to ensure an interdisciplinary perspective and synthesis of the overarching research question(s). ISSI Workshops generally lead to a special issue of typically ~8-15 peer reviewed open access papers in the journals Space Science Reviews or Surveys in Geophysics, which are also printed as volumes of the Space Science Series of ISSI (SSSI). In 2024 and 2025, ten Workshops took place: i) Physical links between weather and climate in space and the lower Atmosphere, ii) Geoscience of (exo)planets: Going beyond habitability, iii) Electron Kinetic Physics: The Next Frontier in Space and Astrophysical Plasmas, iv) 50 years of accretion disks, v) Exocomets: bridging our understanding of minor bodies in solar and exoplanetary systems, vi) What's under the H0od? Towards consensus on the lo-

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cal value of the Hubble constant, vii) Stellar Magnetism and its Impact on (Exo)Planets, viii) Unsolved Mysteries of the Uranian System, ix) Eclipses and Beyond: Unveiling the Mysteries of the Sun's Visible Corona, x) Opening up Earth Observations for Climate Adaptation.

Fora: Fora serve the purpose of enabling free-ranging debates and brainstorming on future directions, challenges and/or innovations, related mostly to open research questions. Fora involve ~25 participants who meet for 2-3 days at ISSI in Bern. They generally lead to the publication of white papers, or informal reports, but may also generate scientific papers where appropriate. Eleven Fora took place in 2024 and 2025: i) Cosmic Footprint, large Scale Space Ethics, ii) Coastal Blue Carbon from Space, iii) International Cooperation in Space to Advance Science, iv) Scientific measurement disparities in imaging spectroscopy of terrestrial ecosystems, v) Using Earth Observation Systems to Improve Climate Adaptation Policy and Action, vi) Towards building a European Heliophysics Community and Advancing the Multi-Disciplinary Field of Heliophysics Research, vii) Network of Oceanic LIDARs for the Validation of Ocean Color Satellite Missions, viii) Observational Tests of the Dynamical Models for Outer Solar System Formation, ix) Exploring the Synergies between Space and Laboratory Plasma Physics, x) Climate Extremes in Our Warming World and xi) Forest Genetic Resources and the Future Biomass in Forests.

International Teams: International Teams consist of up to 15 researchers with complementary scientific expertise, affiliated with institutions in at least four different countries worldwide. International Teams include a minimum of 20% Early Career Researchers (ECRs; within 5 years of PhD). They hold a series of two one-week meetings over a period of 24 months, with the possibility of a third meeting in well-justified cases. The aim of the International Teams is to carry out a focused research project leading to publications in peer reviewed scientific journals. An open call for proposals for International Teams is released every year mid-January, with a deadline of mid-March and the evaluation by the Science Committee in June.

Working Groups: Working Groups (WGs) are set up to enable science by technical means. They are proposed by the community in consultation with the ISSI directorate. Each WG consists of up to 15 researchers and the results are published as a Scientific Report or in scientific literature. In 2024 and 2025, the following Working Groups were active: 'Global Terrestrial Water Storage Product', 'Auroral Research Coordination: Towards Internationalised Citizen Science (ARCTICS)', 'Disentangling Pulse Profiles of (Accreting) Neutron Stars', 'Global Assessment of Limnological, Estuarine and Neritic Ecosystems (GALENE)', 'Towards a Universal Tracers Portal in Astrobiology', 'The Variability of the Airglow for the Detection of Atmospheric Dynamics', 'Solar Forcings for CMIP 7', and 'Incoherent Scatter – An Invaluable Tool in the Field of Space and Plasma Physics'.

Online Seminar Series: the Game Changers

ISSI has continued its series of webinar talks, inaugurated in August 2020, the Game Changers Online Seminars, with speakers from all over the world. The seminars are currently held with a monthly cadence: www.issibern.ch/results/game-changers-webinars, and are also disseminated to a broader audience via the ISSI YouTube channel.

Publications

Scientific activities at ISSI result in 300-400 peer-reviewed papers in international journals each year. All results can be found in ISSI's Annual Reports 28 (2023) and 29 (2024). In collaboration with Springer, ISSI releases the Space Sciences Series of ISSI (SSSI), to gather the collections of review papers arising from ISSI workshops and ISSI Scientific Reports (SR), and to capture the output of other selected activities. Published in 2024 and 2025 were:

SSSI Vol. 84: **Surface-Bounded Exospheres and Interactions in the Inner Solar System**.
SSSI Vol. 87: **Venus: Evolution Through Time**.
SSSI Vol. 90: **Solar and Stellar Dynamos: A New Era**.
SSSI Vol. 93: **Earth's Changing Water and Energy Cycle**.
SSSI Vol. 94: **Tipping Elements in the Earth's Climate System**.
Scientific Reports Vol. 18: **ESA Science Progr. Missions – Contributions and Exploitation**.

Outlook

Through its yearly Call for International Team proposals ISSI selects approximately 30 new Teams. The following Workshops and Fora are currently scheduled to take place in 2026, with more to be recommended at the upcoming meeting of the ISSI Science Committee: 1) Multi-Spacecraft Observations and their Importance for Understanding Particle Dynamics in the Inner Heliosphere (12-16 Jan. 2026), 2) Connecting Chemical Abundances to their Generative Stellar Populations in Distant Galaxies (29 Jun. – 3 Jul. 2026), 3) A Multidisciplinary Path Toward a Unified Understanding of the Outer Solar System (30 Nov. – 4 Dec. 2026) 4) Global Navigation Satellite Systems (GNSS) for Monitoring Earth Deformation: Challenges in Resolving Subtle Ground Motion in Climate and Tectonics (6-18 Mar. 2026), 5) Challenges and Advances in Remote Sensing of Coastal Sea Level with GNSS-IR (27-29 May 2026).

3 Institutes and Observatories

3.1 ISDC – INTEGRAL Science Data Centre

Institute
Dept. Astronomy, Univ. Geneva (UNIGE)
Versoix, Switzerland

In cooperation with
European Space Agency (ESA);
German Aerospace Centre (DLR)

Principal/Swiss Investigator(s)
C. Ferrigno (UNIGE)

Contribution
Research based on existing instruments:
INTErnational Gamma-Ray Astrophysics Laboratory (INTEGRAL)

Website(s)
https://www.isdc.unige.ch

https://mmoda.io

Purpose of Research

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

ISDC processed spacecraft telemetry to generate a set of widely usable products, as well as performing a quick-look analysis to assess the data quality and discover transient astronomical events. Data are distributed to guest observers and archived at ISDC, which is the only complete source of INTEGRAL data. ISDC also has the task of integrating and distributing software for the offline analysis of INTEGRAL data together with handbooks, and of giving support to users. Only as a result of the ISDC contribution are INTEGRAL data available to the astronomy community. INTEGRAL terminated science operations in February 2025. Thereafter, only house-keeping data have been transmitted on ground for about 15 % of the orbit time. These still include the rate of the anti-coincidence that can be used to detect gamma-ray transients above 100 keV. The presence of the ISDC has guaranteed Swiss scientists a central role in the exploitation of INTEGRAL data. To date, ISDC members have participated in about 20 % of the publications based on INTEGRAL data.

Past Achievements and Status

INTEGRAL was launched in October 2002 and its data were not only used for research papers and PhD theses, but also as a near-real time monitor: several astronomical telegrams per month were published and, every second day, an automatic alert for a gamma-ray burst (GRB) was sent to robotic telescopes within seconds of the detection so that GRBs could be localised.

In 2020, an anomaly to the propulsion system revealed that the onboard fuel was exhausted. The mission operation center at ESA found an ingenious way to operate the spacecraft without loss of scientific performance: they implemented a pointing strategy that prevents excessive accumulation of angular momentum, induced by Solar wind pressure. Solar panel and battery aging, and orbital evolution would have allowed the mission to be prolonged until the foreseen re-entry in February 2029, but science operations ended in February 2025 to free ESA resource for upcoming missions. Since then, the contact with the satellite are limited to short passages (15 % of the orbit) just to keep a stable attitude through appropriate pointing and therefore thermal control.

INTEGRAL carries the most sensitive all-sky monitor for GRBs without a localisation capability, and it is an essential tool to discover a gamma-ray counterpart of a gravitational wave event (Savchenko et al., 2016). During full satellite operation, the INTEGRAL team has produced stringent upper limits on 85 % of the double black-hole mergers detected by LIGO and on the neutrino events detected by IceCUBE. Together with the gamma-ray monitor onboard the Fermi observatory, it found a flash of gamma-rays two seconds after the arrival on Earth of gravitational waves, originating as a result of a binary neutron star merger (Savchenko et al., 2017). This historical achievement has opened the era of multi-messenger astronomy with the subsequent observation of a kilonova in the optical, X-ray, and radio bands. Data from the gamma-ray monitor are still available, but just for the time during which there is contact with the spacecraft.

ISDC is an essential pillar of the mission and is currently funded by the Swiss Space Office, Univ. of Geneva, and ESA, with contributions from the German Aerospace Center through the Inst. Astronomy and Astrophysics, Tübingen. ISDC counts on the contribution of about five software engineers and scientists who work in synergy with other space missions within the Univ. of Geneva and EPFL. Post-operations started in 2025 and will end in February 2027. During this period, ISDC is devoted to ensure the decoding and distribution of available telemetry, the consolidation of calibration, and of the archive, as well as the support to the Legacy archive by populating a gallery of standard observational products.

ISDC has developed a Multi-Messenger online analysis tool (MMODA, https://mmoda.io) to allow any inexperienced user to obtain high-level data products from the IBIS/ISGRI, JEM-X, and SPI-ACS instruments for any data selection and a wide range of parameter choices (SPI data analysis is provided by the SPI PI institute). The user can explore the platform capability anonymously, while, upon login and acceptance of the terms of service, one can easily obtain images, spectra and light curves from the web interface for a larger dataset. This platform runs on the computing infrastructure at the University of Geneva nested into virtual access to European research infrastructures (see https://www.acme-astro.eu) and it provides the capability to perform customised analysis with state-of-the-art methods without installing software and downloading raw data: the barrier to exploit INTEGRAL data is greatly lowered for new-comers, the access facilitated for experienced users, and legacy is preserved. The studies performed at ISDC are mainly in the field of high-energy astrophysics. Although, a significant fraction of the research topics are linked to areas in which INTEGRAL makes a significant contribution, a variety of other observation facilities, such as XMM-Newton, XRISM, Chandra, IXPE, and Fermi have also been exploited.

Publications

Mereghetti S, Savchenko V, Ferrigno C et al. (2020) **INTEGRAL discovery of a burst with associated radio emission from the Magnetar SGR 1935+2154**, Astrophys. J. Lett. 898(2): id.L29.

Savchenko V, Ferrigno C et al. (2016) **INTEGRAL upper limits on gamma-ray emission associated with the gravitational wave event GW150914**, Astrophys. J. Lett. 820(2): L36, 5 pp.

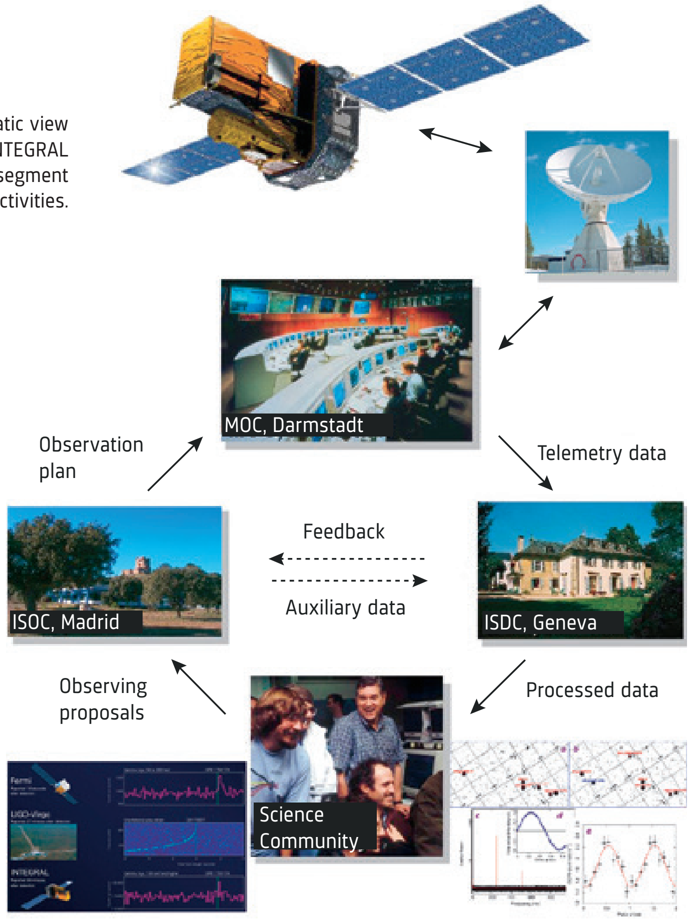
Savchenko V, Ferrigno C et al. (2017) **INTEGRAL detection of the first prompt gamma-ray signal coincident with the gravitational-wave event GW170817**, Astrophys. J. Lett. 848(2): L15, 8 pp.

Abbreviations

INTEGRAL	Int. Gamma-Ray Astrophys. Lab.
ISDC	INTEGRAL Science Data Centre

Further Information

Multi-Messenger online analysis tool (MMODA)
https://mmoda.io



Schematic view of the INTEGRAL ground segment activities.

3.2 EPFL Space Center

EPFL Space Center

Institute
EPFL Space Center

Academic Director
J.-P. Kneib

Executive Director
E. David

Staff
2 Engineers,
1 PhD,
5 Administrative & Support Staff
2 Affiliated Researchers
3 Technical staff members and industry liaison specialists

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Description

The mission of the EPFL Space Center is to promote space-related research and education at EPFL, support space-affiliated professors, coordinate the Minor in Space Technologies, manage EPFL student space teams, and connect the Swiss space innovation ecosystem with academic, industrial, and international partners.

Past Achievements and Status

One Unified Space Center: The most significant institutional development of this period is the full integration of the Space Innovation Network into the EPFL Space Center, creating a single, unified entity. This consolidation – validated by a formal EPFL institutional review in 2023 – 2024 – strengthens the Center's role as the federating platform for the Swiss space community. EPFL management renewed the Center's mandate and budget for 2025 – 2028, and the Center formally established its Advisory Board and Steering Committee for the first time.

Education: The Minor in Space Technologies enrolled 83 students in 2024, and 73 in 2025, marking over twenty years of continuous operation. The curriculum was significantly refreshed: the foundational course transitioned to a new instructor (Thibault Kuntzer) following astronaut Prof. Claude Nicollier's retirement, and the Spacecraft Design and Systems Engineering course was relaunched with new mission scenarios and a first-ever cleanroom visit. Daniel Neuenschwander, former ESA Director of Human and Robotic Exploration and former head of the Swiss Space Office, was appointed Professor of Practice at EPFL's School of Engineering. The Center's professional continuing education course on space sustainability launched successfully in March 2024 and was expanded to four days in 2025.

Student Teams – Key Wins:

- The EPFL Rocket Team completed a custom test-bench for engines up to 15 kN, and conducted the maiden flight of Firehorn, its first cryogenic bi-liquid rocket (see figure).
- The EPFL Spacecraft Team successfully launched a second In-Orbit Demonstration (Twocan onboard computer, SpaceX Falcon, 9 January 2025), and was selected for the ESA Fly Your Satellite! Design Booster programme – a major competitive recognition.
- Xplore: The Team won the Presentation Task Excellency prize at the European Rover Challenge 2024 with rover Onyx and drone Dragonfly. In 2025, they secured first place with their rover Phoenyx and drone Zephyr !

Research – Space Sustainability: Space sustainability is the Center's primary research focus. Key 2024 achievements include: leading the development of the ESA Zero Debris Charter Technical Booklet, contributing to Product Footprint environmental category rules, and securing integration into IAU working

The maiden flight of the Firehorn rocket.

groups. The REACT project, successor to the completed RISSL initiative, was successfully achieved with a consortium including the University of Stuttgart and ISAE-SUPAERO, developing a life-cycle assessment tool for space transportation systems. The Center produced over 30 scientific contributions and supported 11 major research proposals in 2024 – 2025.

Space Innovation – Industry Network: Following integration into the unified Center, the network delivered strong results in 2024 – 2025: 60+ new industry connections, 32 technical information services, 2 commercial transactions, 6 supports on ESA billing, and test facility access for 10 projects. The Space Innovation website now hosts a new extranet: a new collaborative tool dedicated to network members, accessible through restricted access. It offers a growing library of conference reports prepared by the Space Innovation team, providing members with key takeaways from major events without having to attend. Members can also find curated summaries of funding opportunities relevant to the Swiss space ecosystem, as well as a comprehensive database listing test equipment and facilities available across Switzerland and Europe. This tool is designed to enhance collaboration throughout the network.

Publications

2024

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Billot N, Hellmich S, Benz W (2024) **In-situ observations of resident space objects with the CHEOPS space telescope**, J. Space Safety Eng.

Fischer J-S et al. (2024) **Pathway for Closing the Knowledge Gaps for a Comprehensive Life Cycle Assessment and Ecodesign of Space Transportation Systemisation Systems**, Whitepaper/position paper.

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2025

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Irureta-Goyena B et al. (2025) **A method for asteroid detection using convolutional neural networks on VST images,** Journal paper.

Rachith E, Hellmich S, Kneib J-P (2025) **Detection and Characterization of Space Debris Using VST/OmegaCAM Archival Data**, 9th Euro. Conf. Space Debris.

Renis F et al. (2025) **Leveraging light-curve inversion for kinematic state estimation of uncooperative targets**, 9th Euro. Conf. Space Debris.

Udriot M et al. (2025) **REACT Final Presentation – The Assessment and Comparison Tool (ACT), Simplified, spacespecific, prospective LCA**, Presentation, class 1, releasable to public (ESA).

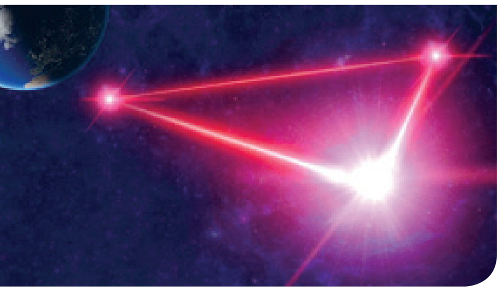
Udriot M (2025) **SpaceMAKEr Environmental Sustainability Strategies**, Handbook.

Udriot M et al. (2025) **Space sustainability in systems engineering and design processes – Industry overview and case study at EPFL**, 11th EUCASS Conference.

Verkammen M, Udriot M (2025) **Inclusion d'une ACV dans la conception de missions spatiales : premières applications de l'outil ACT, développé au EPFL Space Center**, Conference presentation: MCV – Congrès Management du Cycle de Vie 2025.

Verkammen M, Udriot M (2025) **The Assessment and Comparison Tool (ACT) – simplified, space-specific, prospective LCA**, Conference presentation, Ecodesign Days 2025.

3.3 ETH Zurich | SPACE



LISA (Laser Interferometer Space Antenna).
Image credit: ESA.

Director
T. H. Zurbuchen

R. Kornfeld (Managing Director)
S. Stähler (Education)
F. Kehl (Research)
N. Strecker (Entrepreneurship)
F. Seidel (GeoLab)
S. Quanz (LIFE)

Staff
25 Scientific, Technical and Administrative

Contact Information
ETH Zurich | Space
Sonneggstrasse 5,
CH-8092 Zurich, Switzerland

Contact Information
https://space.ethz.ch

Mission

ETH Zurich | Space boosts space activities to establish ETH Zurich as one of the leading universities in space research, Earth observation, education, and entrepreneurship within Europe and beyond.

ETH Zurich | Space is an initiative of the ETH Presidential Office designed to strengthen and coordinate space-related activities across the university. It connects researchers, students, young entrepreneurs, industry partners, and international space agencies to enable ambitious scientific missions, technological innovation, and educational excellence. The initiative is structured around five strategic pillars: Education, Research & Innovation, Industry & Entrepreneurship, and the Swiss GeoLab.

Education

The Education initiative centres on the Master of Science in Space Systems, the first programme of its kind in Switzerland. Hosted by the Department of Earth and Planetary Sciences (D-EAPS) in collaboration with the Departments of Mechanical and Process Engineering (D-MAVT), Information Technology and Electrical Engineering (D-ITET), and Physics (D-PHYS), the program started in 2024 with a diverse inaugural cohort of 27 Swiss students from engineering, science, and mathematics backgrounds.

Since 2025, the programme has been open to international applicants and has grown to 37 students in the 2nd cohort, with a goal of 50 students per year in 2026. The curriculum emphasises systems engineering, data literacy, and sustainability awareness, preparing students to contribute to the rapidly evolving space economy and to lead future scientific and technological space missions. The programme combines interdisciplinary coursework with hands-on projects and collaboration with industry and space agencies.

Research and Innovation

The Research and Innovation initiative supports ambitious faculty-led space missions across ETH Zurich. Its core instrument is the Project Hub, which provides a shared pool of experienced project managers, systems engineers, and technical specialists. By offering expertise that individual research groups typically cannot maintain independently, the Hub lowers the barrier for principal investigators to engage in complex space missions. The Project Hub supports projects throughout their lifecycle, from early mission concepts and proposal preparation to implementation and mission operations.

Complementing this structure is the π Innovation Hub, which enables the early exploration of high-risk, high-reward ideas through rapid prototyping and feasibility studies. Promising concepts can mature within this framework before transitioning into the Project Hub for structured development and mission implementation.

Industry and Entrepreneurship

The Industry and Entrepreneurship initiative fosters startups emerging from ETH Zurich and the broader Swiss innovation ecosystem that commercialise technologies related to space.

ETH Zurich | Space hosts the ESA Business Incubation Centre Switzerland (ESA BIC CH), which supports early-stage companies through funding, technical / business support, and access to industry and agency networks. Through this programme and additional partnerships with industry, ETH Zurich helps translate academic research into scalable commercial ventures, strengthening Switzerland's role in the European space economy.

Swiss GeoLab

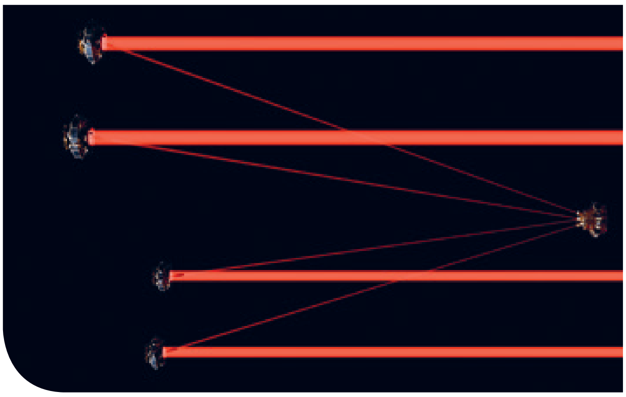
Launched in 2026, Swiss GeoLab aims to transform the rapidly growing availability of Earth observation data into practical solutions, addressing natural hazards and environmental challenges. Switzerland's well-characterised geological/geophysical risks provide an ideal natural laboratory for developing innovative monitoring and mitigation strategies. The initiative focuses on integrating data from satellites, drones, ground-based monitoring stations, and other sources into a unified technological platform capable of analysing and interpreting large datasets. The resulting tools are intended to generate economic value, support national resilience against natural hazards, and provide scalable solutions applicable worldwide. The GeoLab platform will also be accessible to other research institutions and industry partners.

LIFE (Large Interferometer for Exoplanets)

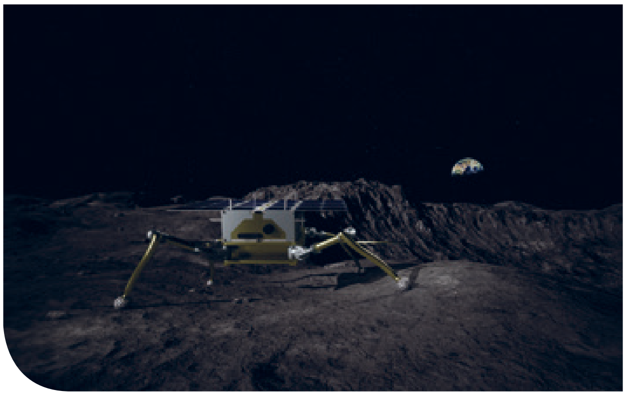
Spearheaded by ETH Zurich, the LIFE Space Mission aspires to become the world's leading search for life beyond Earth – shifting perspectives, and re-imagining our place in the universe. By deploying a formation-flying, mid-infrared nulling interferometer, LIFE will directly detect hundreds of exoplanets in our galactic neighbourhood. This includes an unprecedented sample of dozens of terrestrial worlds with Earth-like radii and temperatures. By measuring their intrinsic thermal emission spectra, LIFE will determine their atmospheric composition and possibly identify the first definitive signatures of exoplanetary biospheres. The LIFE Mission is currently in the concept definition phase.

ETH Zurich | Space contributions to Faculty Missions

ETH Zurich | Space supports space missions led by ETH faculty by providing project management and systems engineering expertise that complements scientific leadership within departments. Current activities include contributions to ESA's LISA gravitational-wave observatory, the Lunar Leaper legged exploration mission concept, and SpaceChip, an early lab-on-a-chip concept study for life-detection instrumentation in planetary missions. ETH Zurich | Space also supports mission concepts of other institutions, such as the M-MATISSE proposal of PMOD/WRC in Davos, offering coordination, technical support, and liaison with space agencies and industry partners.



LIFE Space Mission.



LunarLeaper.

ETH Master's programme in Space Systems.

3.4 Satellite Laser Ranging (SLR) at the Swiss Optical Ground Station and Geodynamics Obs. Zimmerwald (SwissOGS)

Laser beam transmitted from the 1-meter ZIMLAT telescope to measure mm-accuracy distances of artificial satellites.

Institute
Astronomical Institute, Univ. Bern (AIUB), Bern

In cooperation with
Bundesamt für Landestopographie (swisstopo), Wabern, Switzerland

Principal/Swiss Investigator(s)
L. Kleint (AIUB)

Co-Investigator(s)
A. Jäggi (AIUB)
P. Lauber (AIUB)
A. Villiger (swisstopo)

Website(s)
https://www.aiub.unibe.ch

Purpose of Research

The Zimmerwald Geodynamics Observatory, part of the SwissOGS (Swiss Optical Ground Station), is a station of the global tracking network of the International Laser Ranging Service (ILRS). Satellite Laser Ranging (SLR) observations to satellites equipped with laser retro-reflectors are acquired with the monostatic 1-m multi-purpose Zimmerwald Laser and Astrometric Telescope (ZIMLAT). The system is operated 24 hours a day and 7 days per week.

The collected data are delivered in near real-time to the global ILRS data centers, and official products are generated by the ILRS analysis centers using SLR measurements to the geodetic satellites, in particular LAGEOS 1 and 2 (Laser Geodynamics Satellite), and LARES (Laser Relativity Satellite). Products derived from these SLR observations include precise satellite ephemerides, station positions and velocities of sites in the ILRS network, as well as Earth Orientation Parameters (EOPs, i.e., polar motion and rates, length-of-day).

The contribution of SLR measurements to the definition of the origin of the International Terrestrial Reference Frame (ITRF) (the so-called geocenter coordinates), the global scale, precise orbit parameters, and low-degree spherical harmonics of the Earth's gravity field (especially the dynamic oblateness term) is essential due to the unique orbit precision of geodetic satellites and the precision of laser observations at a level of a few millimetres per normal point. The latter are derived from raw measurement data by averaging over a short time interval.

Past Achievements and Status

The Zimmerwald SLR station provides high quality range data to the scientific community on a 24/7 basis. The efforts are embedded in the larger context of the Global Geodetic Observing System (GGOS) of the International Association of Geodesy (IAG). In order to achieve the GGOS science goals, the accuracy and amount of SLR measurements needed to be further improved.

The SwissOGS therefore carried out a major upgrade in 2025 from the old 100 Hz SLR system, established in 2008, to a new 1 kHz system. Higher repetition rates are beneficial for improving the quality of the SLR normal point generation. But higher repetition rates also require significant upgrades to the processing software and hardware. On the hardware side, transmit/receive switching techniques such as mechanical rotating shutters, as they were used for the old SLR system at the SwissOGS, are particularly critical elements as their rotational speed cannot easily be increased. When transmitting and receiving in the telescope Coudé path, it is necessary to prevent the outgoing laser pulse from directly hitting the detector.

A special feature of the new SLR system at the SwissOGS is that the same transmit and receive path is used. This was achieved in 2025 by using a special mirror and beam divergence, such that the transmit path goes through a small hole in the mirror, while the receive path with a larger beam diameter is reflected off its surface. The new 1 kHz system therefore does not need separate optical systems for the transmit and receive path as is the case for most other kHz SLR systems.

In May 2025, the new 1 kHz SLR system fulfilled the requirements of the International Laser Ranging Service (ILRS) and started to provide SLR normal point data on a regular basis. It was verified that the normal point data are of similar quality as for other kHz SLR stations, which are using similar screening methods and ranging schemes. Together with the highly autonomous management of the SLR operations by the in-house developed control software, the Zimmerwald Observatory is one of the most productive SLR stations worldwide. This achievement is remarkable when considering the fact that weather conditions in Switzerland only allow operations about two thirds of the time.

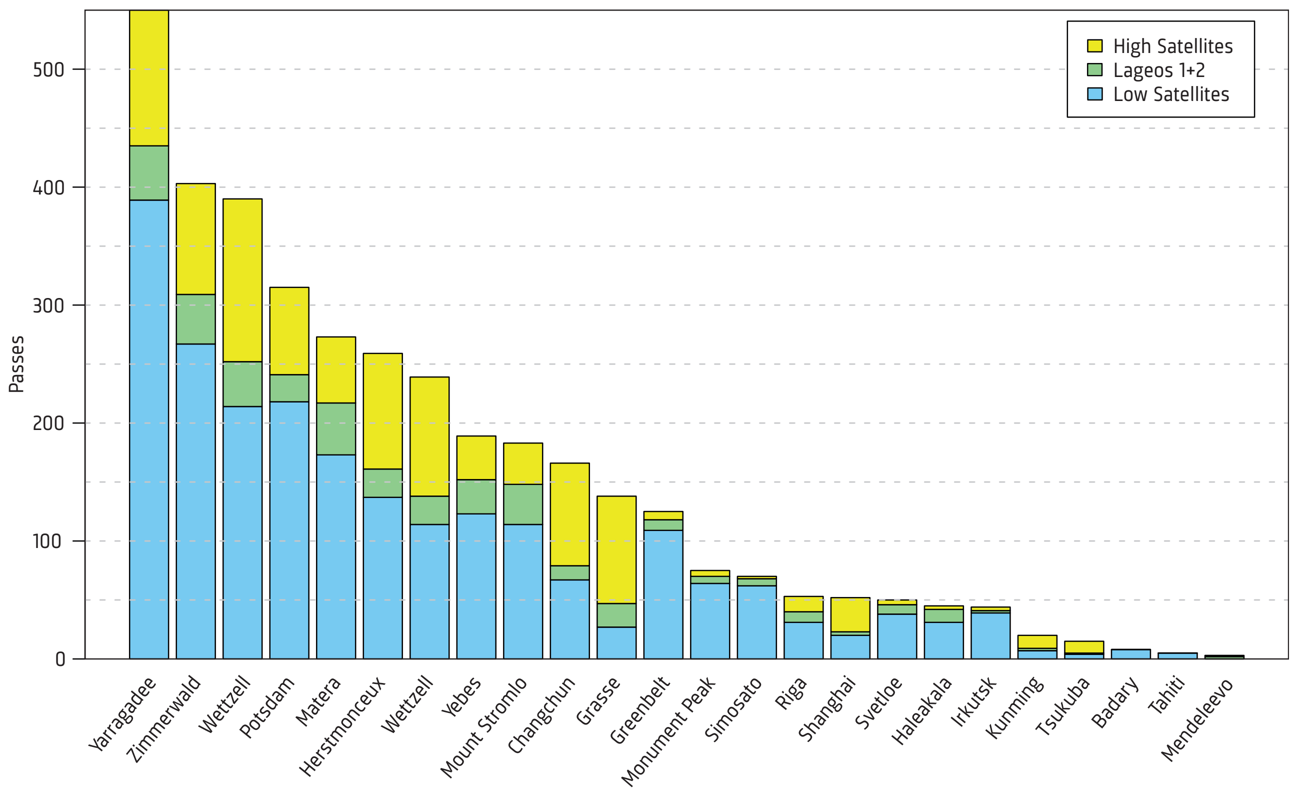
Although a complete characterisation of the new kHz system is still ongoing, e.g. in terms of RMS and range biases of the normal points over longer time spans, it can already be stated that the inauguration of the new 1 kHz SLR system has been successfully performed.

Publications

Lauber P et al (2026) **The new 1kHz Zimmerwald SLR system – Transmit and Receive from Telescope Coudé, IAG Symposia Series**, doi.org/10.1007/ 1345_2026_322, in press.

Abbreviations

GGOS	Global Geodetic Observing System
ILRS	International Laser Ranging Service
ITRF	International Terrestrial Reference Frame
LAGEOS	Laser Geodynamics Satellite
LARES	Laser Relativity Satellite
SLR	Satellite Laser Ranging
ZIMLAT	Zimmerwald Laser and Astrometry Telescope



Number of passes observed by the ILRS station network within one week in August 2025.

3.5 CODE – Centre for Orbit Determination in Europe

Institute
Astronomical Inst., Univ. Bern (AIUB), Bern, Switzerland

In cooperation with
Bundesamt für Landestopographie (swisstopo), Wabern, Switzerland; Bundesamt f. Kart. u. Geodäsie (BKG), Frankfurt a. M., Germany; Inst. Astronom. u. Physikal. Geodäsie (IAPG), Technische Universität München, Germany

Principal/Swiss Investigator(s)
R. Dach (AIUB)

Co-Investigator(s)
A. Jäggi (AIUB)
A. Villiger (swisstopo)
D. Thaller (BKG)
U. Hugentobler (IAPG)

Contribution
Research based on existing instruments: GNSS data analysis and software development.

Website(s)
https://www.aiub.unibe.ch/code

Purpose of Research

Using measurements from Global Navigation Satellite Systems (GNSS) is (among many other applications) well-established for the realisation 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) was established 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: i) the Astronomical Institute of the University of Bern (AIUB; Bern, Switzerland), ii) the Bundesamt für Landestopographie (swisstopo; Wabern, Switzerland), iii) the Bundesamt für Kartographie und Geodäsie (BKG; Frankfurt a. M., Germany), and iv) the Institut für Astronomische und Physikalische Geodäsie (IAPG) of the Technische Universität München (Munich, Germany).

Since the early pilot phase of the IGS (21 June 1992), CODE has continuously contributed to the IGS. The operational processing is located at AIUB using the Bernese GNSS Software package that has been developed and maintained at AIUB for many years.

Nowadays, data from more than 300 globally distributed IGS tracking stations are processed every day in a rigorous combined multi-GNSS (currently the American Global Positioning System (GPS), the Russian counterpart GLONASS, and the European Galileo system) processing scheme 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. For five years, it was the only one following this approach. Meanwhile, other IGS analysis centers have also started to follow this strategy. In addition, the inclusion of Galileo in the operational product chains of the IGS was started by CODE in September 2019 as the first of the analysis centers.

In a separate processing line, a fully integrated five-system solution is developed, including not only the established GNSS, GPS, GLONASS, and Galileo systems, but also the Chinese BeiDou (since March 2021 also those of the third generation), and the Japanese QZSS as additional systems. The resulting solution is generated in the frame of the IGS multi-GNSS extension (IGS MGEX).

Past Achievements and Status

The main products are precise GNSS satellite 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 to study vertical and horizontal site displacements and plate motions, and to provide information for the realisation 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 are determined for each day, and are 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 modelling standards. Members of the CODE group contribute or chair different IGS product committees, e.g., on Bias and Calibration or on GNSS antennas. Since 2023, Rolf Dach – another member of the CODE team – became the elected chair of the Governing Board.

CODE is contributing in a series of satellite antenna calibration computations in order to also include the Asian satellite systems (Beidou and QZSS) consistently into the legacy product series. Other activities are focusing on the preparation to ESA's Genesis mission where several geometric space-geodetic techniques will be combined via a space-tie.

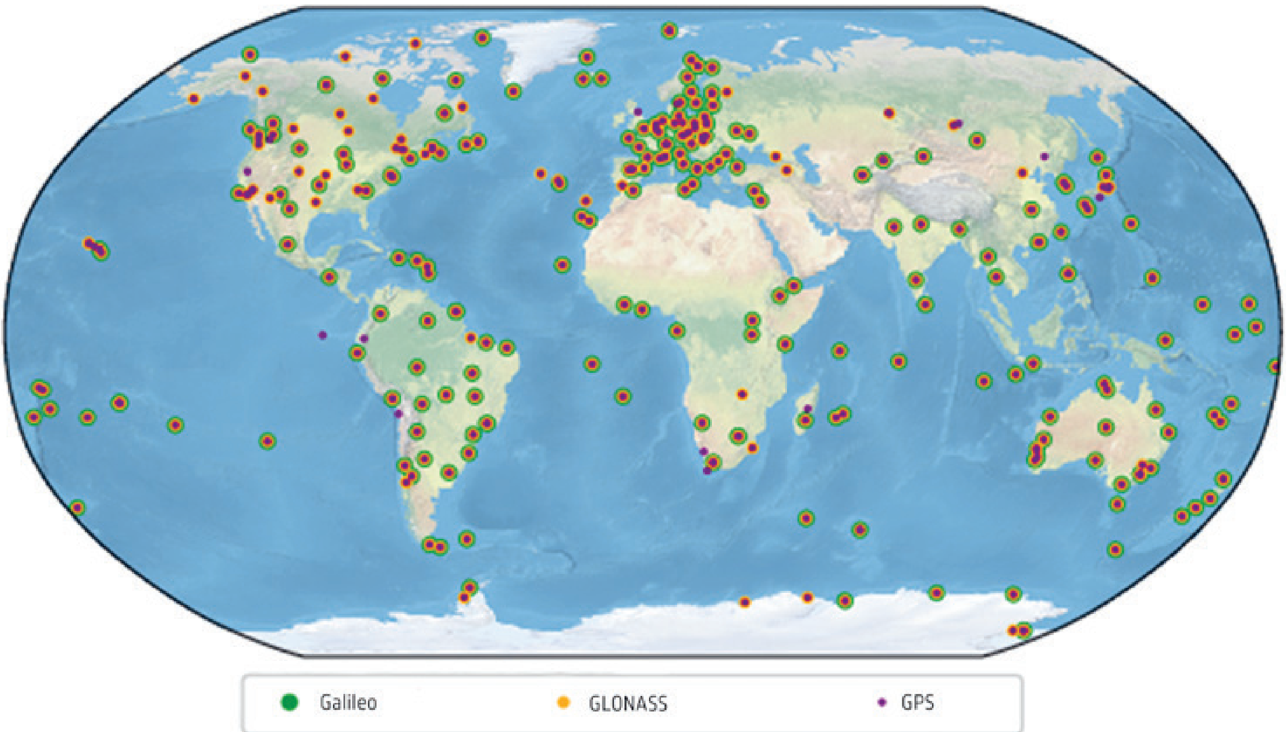
Abbreviations

Beidou	BeiDou Navigation Satellite System
CODE	Centre for Orbit Determination in Europe
GLONASS	Globalnaja Nawigazionnaja Sputnikowaja Sistema
GNSS	Global Navigation Satellite Systems
GPS	Global Positioning System
IERS	International Earth Rotation & Reference Systems Service
IGS	International GNSS Service
ITRF	International Terrestrial Reference Frame
LEO	Low Earth Orbit
QZSS	Quasi-Zenith Satellite System

Publications

A list of recent publications is available at:

https://www.bernese.unibe.ch/publist



Station network as currently used for CODE's final product generation for the International GNSS Service (IGS).

3.6 Geodetic Prediction Center

ETH zürich

Geodetic Prediction Center

Institute
Chair of Space Geodesy, Inst. Geodesy and Photogrammetry, Dept. Civil, Environ. Geomatic Eng., ETH Zurich (ETH), Zurich, Switzerland

In cooperation with
European Space Agency (ESA)

Principal/Swiss Investigator(s)
B. Soja (ETH)

Co-Investigator(s)
L. Crocetti, J. Gou, M. Iten, S. Mao, M. Schartner; (all ETH Zurich)

Contribution
Development of software for: Prediction of geodetic variables using machine learning.

Website(s)
https://gpc.ethz.ch/

Purpose of Research

The Geodetic Prediction Center (GPC) at ETH Zurich serves as a specialised platform dedicated to the spatio-temporal prediction of Essential Geodetic Variables (EGVs). As modern science and society become increasingly dependent on real-time geodetic products for navigation and geohazard monitoring, the GPC aims to overcome data latency by providing robust temporal predictions. Furthermore, the GPC addresses gaps in geodetic observations through advanced spatio-temporal interpolation. The research focuses on developing and implementing state-of-the-art machine learning (ML) frameworks to provide optimal predictive performance.

For several EGVs, the center benefits from assimilating heterogeneous data sources, including geodetic measurements from Global Navigation Satellite Systems (GNSS), environmental models, and auxiliary datasets. Ultimately, these high-accuracy products are made openly available to the scientific community via gpc.ethz.ch, supporting a wide variety of applications on both global and regional scales.

Past Achievements and Status

Since its establishment in 2021, the GPC has continuously expanded the range of EGVs that are operationally predicted. Initially, the center focused on Earth Orientation Parameter (EOP) predictions and successfully participated in the 2nd EOP Prediction Comparison Campaign. Our success helped drive the ML revolution in the field, motivating a dedicated campaign specifically for ML models. Notably, our Celestial Pole Offset predictions performed best among all participants (Kiani Shahvandi et al., 2024).

Following these achievements, we added operational Effective Angular Momentum (EAM) predictions and conducted scientific studies related to station coordinate and orbit predictions using ML. We then utilised ML to improve real-time global ionospheric maps (GIMs) and developed spatio-temporal predictions for ionospheric Vertical Total Electron Content (VTEC; Mao et al., 2025), tropospheric Zenith Wet Delay (ZWD; Crocetti et al., 2024), and atmospheric turbulence.

Supported by ESA, we are currently developing probabilistic predictions of tropospheric and ionospheric variables within the framework of the project: Probabilistic Neural Network Models for Accurate Atmospheric Modelling.

Publications

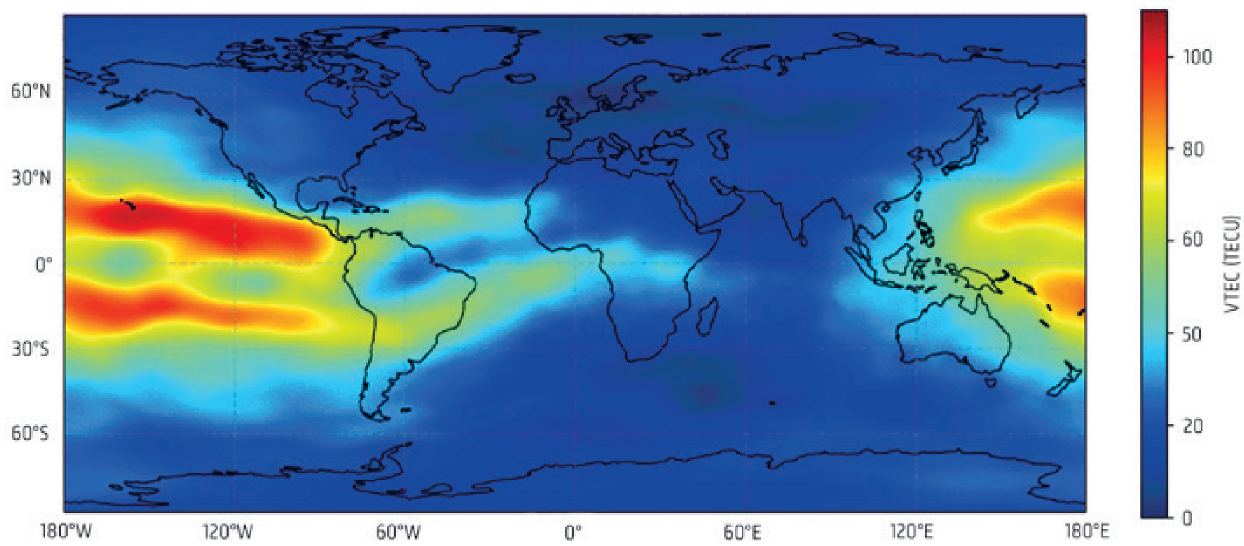
Crocetti L, et al. (2024) **Global, spatially explicit modelling of zenith wet delay with XGBoost**, J. Geodesy 98(4): 23, doi.org/10.1007/s00190-024-01829-2

Kiani Shahvandi M, Belda S, Karbon M, Mishra S, Soja B (2024) **Deep ensemble geophysics-informed neural networks for the prediction of celestial pole offsets**, Geophys. J. Int. 236(1): 480-493, doi.org/10.1093/gji/ggad436

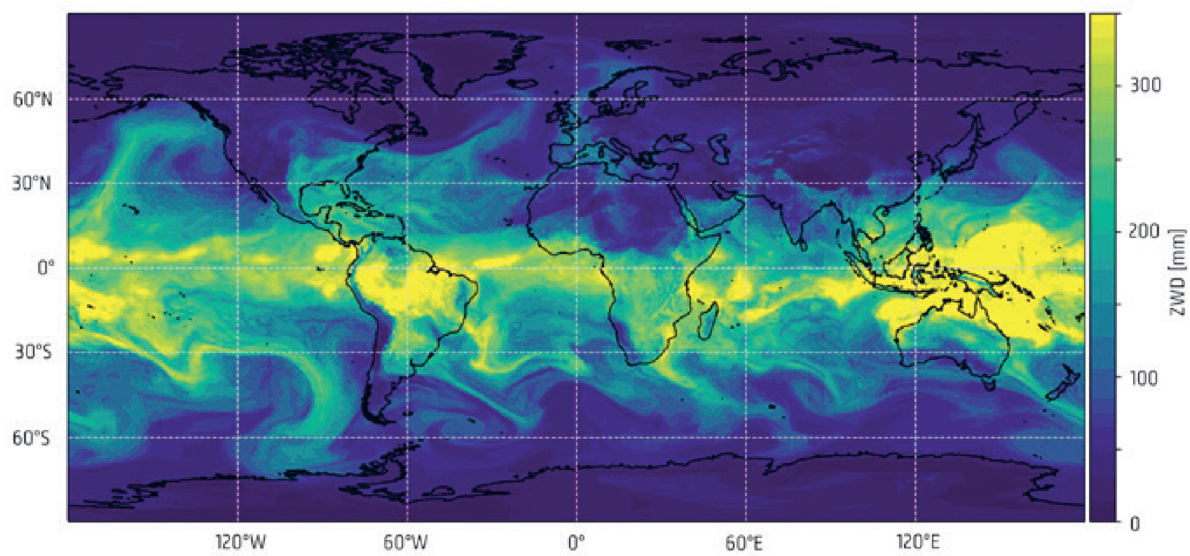
Mao S, Pan Y, Kłopotek G, Schartner M, Krásná H, de Witt A, Soja B (2025) **Enhanced Global Ionospheric Mapping Using Deep Ensemble Neural Networks With Uncertainty Quantification**, Space Weather 23(7): e2025SW004446, doi.org/10.1029/2025SW004446

Abbreviations

EAM	Effective Angular Momentum	GPC	Geodetic Prediction Center
EGVs	Essential Geodetic Variables	ML	Machine Learning
EOP	Earth Orientation Parameter	VTEC	Vertical Total Electron Content
GIMs	Global Ionospheric Maps	ZWD	Zenith Wet Delay
GNSS	Global Navigation Satellite Sys.		



Neural network-based Global Ionospheric Map on 12 November 2025 at 00:00 UTC.



Zenith wet delay (ZWD) predicted by XGBoost on 6 March 2026 at 00:00 UTC.

3.7 Swiss Data Cube

Swiss Data Cube

Institute
Inst. Envrionmental Sciences, University of Geneva (UNIGE), Switzerland

Principal/Swiss Investigator(s)
G. Giuliani (UNIGE)

Contribution
The Swiss Data Cube provides a routine, reliable and operational service, using openly accessible and freely available Earth Observations (EO) data to deliver decision-ready products enabling policy-makers, scientists, the private sector and civil society to address social, environmental and economic changes at the national scale.

Website(s)
https://www.swissdatacube.org

Purpose of Research

The Swiss Data Cube (SDC) aims to provide a routine, reliable and operational service, using Earth Observations (EO) to deliver decision-ready products enabling policy makers, scientists, the private sector and civil society to address social, environmental and economic changes at the national scale and develop an ecosystem for innovation across sectors.

The SDC processes, on a daily basis, openly accessible and freely available data to produce decision-ready products. Working closely with different stakeholders' communities (administrations, industry, scientists…), the Swiss Data Cube will be responsive to the information needs, challenges, and priorities of the Swiss institutions. It will ultimately leverage and build on existing capacity to enable the use of EO data to address key challenges across the country. The SDC delivers a unique capability to track changes across Switzerland and to process, interrogate, and present Earth observation data in response to environmental issues in Switzerland. This near real-time information can be readily used as an evidence base for the design, implementation, and evaluation of national policies. It will also support innovation and growth in the digital economy; improve the management of natural resources; and improve efficiency and effectiveness of government investments.

Past Achievements and Status

The SDC, launched in 2016 under the Swiss Federal Office for the Environment with UNEP/GRID-Geneva and the University of Geneva, made Switzerland the second country in the world to adopt an Earth Observation Data Cube approach. It has provided Analysis Ready Data since 1984, updated daily, covering optical (Sentinel-2, Landsat 5/7/8) and radar (Sentinel-1) imagery.

Since then, partners including the University of Zurich and WSL (Swiss Federal Institute for Forest, Snow and Landscape Research) have joined the initiative, expanding its environmental monitoring capabilities. Key achievements include 35-year vegetation and snow cover analyses, glacier retreat tracking, lake water quality monitoring, and archaeological potential mapping in the Alps. The SDC also developed SwissEnvEO for FAIR-compliant data publishing and built strong international collaborations with CEOS, GEO, and Geoscience Australia, cementing Switzerland's role as a global pioneer in EO data infrastructure.

Snow cover monitoring: One of its most prominent applications has been the monitoring of snow cover. Poussin et al. (2025) developed an approach to map snow cover from four decades of Landsat and Sentinel-2 imagery across Switzerland, and this was extended into a comprehensive open dataset spanning 1984 – 2021. Past and future trends in Swiss snow cover were further analysed using the Snow Observation from Space algorithm (Poussin et al., 2025). These time-series have documented the progressive decline of snow on the Swiss Plateau and support climate change adaptation assessments.

Vegetation monitoring – has been another key use case. Honeck et al. used three decades of Earth observations to track forest trends across Switzerland, translating a vegetation index into an indicator aligned with the Sustainable Development Goals. A 35-year Landsat trend analysis of vegetation water content was also conducted to assess drying conditions across the country. More recently, Obuchowicz et al. (2023) documented long-term greening trends across Switzerland using an NDVI time-series spanning three decades, and Charrière et al. compared NDVI and PPI indices for monitoring vegetation dynamics in mountainous areas.

Land cover and land use: The SDC has also been applied to land cover and land use change analysis. Giuliani (2024, doi.org/10.1080/20964471.2024.2323241) demonstrated a time-first approach for land cover mapping using Big Earth Observation data time-series applied to the Lake Geneva region, while Thomas & Giuliani explored land use change dynamics at the national scale. Downscaling methods were additionally developed to improve the spatial resolution of national land use datasets. Beyond vegetation and snow, the SDC has contributed to mapping Local Climate Zones in Switzerland's five largest cities and to identifying areas of archaeological potential through satellite-derived snow cover time-series.

Collectively, these applications demonstrate the SDC's growing role as a foundational platform for reproducible, multi-decadal environmental monitoring in support of national policy and international sustainability frameworks.

Abbreviations

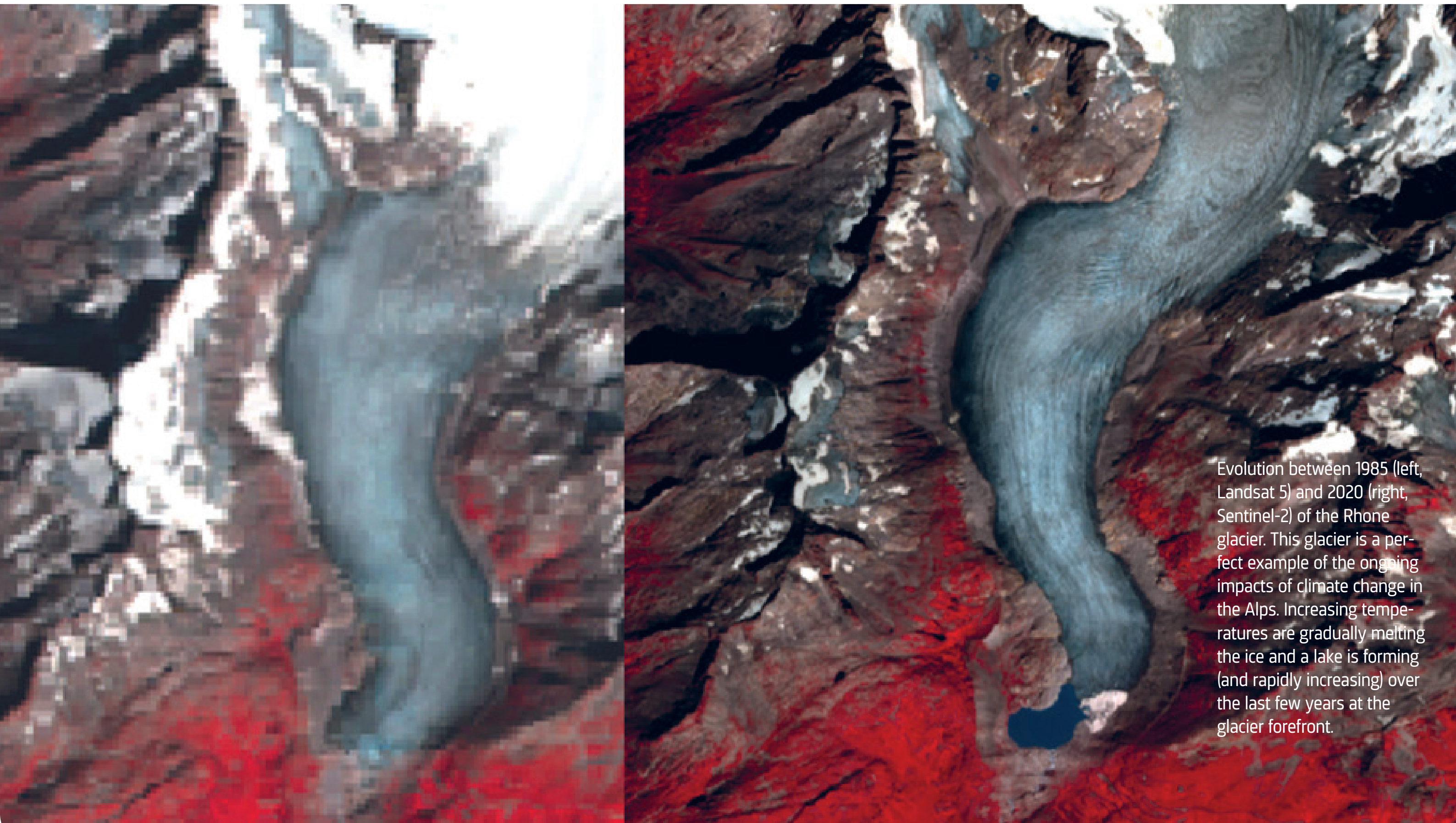
EO	Earth Observation
SDC	Swiss Data Cube

Publications

Chatenoux B et al. (2021) **The Swiss Data Cube: Analysis Ready Data archive using Earth Observations of Switzerland**, Nature Scientific Data. 8: 295, doi.org/10.1038/s41597-021-01076-6

Obuchowicz C, Poussin C, Giuliani G (2023) **Change in observed long-term greening across Switzerland – Evidence from a three decades NDVI time-series and its relationship with climate and land cover factors**, Big Earth Data, doi.org/10.1080/20964471.2023.2268322

Poussin C et al. (2025) **Past and future trends in Swiss snow cover: Multi-decades analysis using the snow observation from space algorithm**, Fron. Rem. Sens. 6: 1542181, doi.org/10.3389/frsen.2025.1542181



Evolution between 1985 (left, Landsat 5) and 2020 (right, Sentinel-2) of the Rhone glacier. This glacier is a perfect example of the ongoing impacts of climate change in the Alps. Increasing temperatures are gradually melting the ice and a lake is forming (and rapidly increasing) over the last few years at the glacier forefront.

4 Swiss Space Missions

4.1 CHEOPS – CHaracterising ExOPlanet Satellite

Artist's impression of CHEOPS in orbit.
Image credit: ESA.

Institute
Center for Space & Habitability,
Univ. Bern (UNIBE),
Bern, Switzerland

In cooperation with
Institut für Weltraumforschung Graz, Austria;
Center Spatial de Liege, Belgium;
Obs. de Genève, Genève, Switzerland;
Lab. d'Astrophys., Marseille, France;
DLR Inst. Planetary Res., Germany;
DLR Inst. Opt. Sensor Sys., Germany;
Konkoly Observatory, Hungary;
INAF Osserv. Astrofisico di Catania, Italy;
INAF Osserv. Astro. di Padova, Italy;
Centro de Astro. da Univ. do Porto, Portugal;
Deimos Engenharia, Portugal;
Onsala Space Observatory, Sweden;
Stockholm Univ., Sweden;
Univ. Warwick, Univ. Cambridge, UK;
Univ. Vienna, Austria

Principal/Swiss Investigator(s)
C. Broeg (UNIBE)

Co-Investigator(s)
The CHEOPS team includes more than 100 scientists and engineers from 40 institutions in 11 ESA Member States. See: https://cheops.unibe.ch/about-us/core-science-team

Purpose of Research

CHEOPS is the first mission dedicated to search for transits of exoplanets by means of ultra-high precision photometry on bright stars already known to host planets. It provides 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 of exoplanets located almost everywhere in the sky. It will also continue to provide precise radii for new planets and validate new planet candidates discovered by space or ground-based missions such as TESS.

By unveiling transiting exoplanets with high potential for in-depth characterisation, CHEOPS also provides prime targets for future instruments suited to the spectroscopic characterisation of exoplanetary atmospheres.

In particular, CHEOPS will continue to:

- Determine the mass-radius relation in a planetary mass range for which only a handful of data exist and to a precision not previously achieved.
- 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. By unveiling transiting exoplanets with high potential for in-depth characterisation, CHEOPS is also providing prime targets for future instruments suited to the spectroscopic characterisation of exoplanetary atmospheres.
- Bring new constraints on the atmospheric properties of known hot Jupiters via phase curves.
- Explore synergies with other space missions via a dedicated programme (SoM: synergies with other missions).
- Provide unique targets for detailed atmospheric characterisation by ground (e.g. the European Extremely Large Telescope, E-ELT) and space-based (e.g. the James Webb Space Telescope, JWST) facilities with spectroscopic capabilities.

Since the beginning of the mission extension in September 2023, 30 % of CHEOPS observing time has been made available to the community through a selection process carried out by ESA.

Past Achievements and Status

- Mission selection: Oct. 2012.
- Mission adoption: Feb. 2014.
- Instrument Critical Design Review: Dec. 2015.
- Telescope shipped to ADS Madrid for integration: Apr. 2018.
- Satellite ready for launch, and placed in storage at ADS: May 2019.
- CHEOPS was successfully launched from Kourou as a secondary passenger on a Soyuz- Fregat rocket: 18 Dec. 2019.
- Successful completion of the in-orbit commissioning review: 25 Mar. 2020.
- Hand-over of the responsibility for CHEOPS operations from ESA to the Consortium: Apr. 2020.
- Apr. 2020 – Sep. 2023: Nominal mission successfully completed.
- Nov. 2021 – Mar. 2022: Mission extension operations review.
- May 2022: Mission extension science case presented to SSAC.
- Jun. 2023: In-orbit performance review and lessons learned.
- September 2023: Beginning of the first mission extension.
- Nov. 2025: successful MEOR for 2nd extension.

Publications

Benz W, Broeg C, Fortier A, et al. (2021) **The CHEOPS Mission**, Exp. Astron. 51: 109-151.

CHEOPS publications derived from the Guest Observer programme can be obtained here: http://ui.adsabs.harvard.edu/public-libraries/Do7dSW94QiefOrgZt5YwbA

Scientific results: CHEOPS publications derived from the Guaranteed Time Observing (GTO) programme can be obtained here: https://ui.adsabs.harvard.edu/user/libraries/cx-JTRv4OTV2SHn_p_xpl2Q

Abbreviations

CHEOPS	CHaracterising ExOPlanet Satellite
MEOR	Mission Extension Operations Review (ESA)

Time-Line	From	To
Planning	2013	2014
Construction	2014	2019
Measurement phase	Apr. 2020	open
Data evaluation	Apr. 2020	open

Contribution
Switzerland was responsible for the development, assembly, and verification of a 32 cm diameter telescope as well as the development of the mission's ground segment. Currently, it leads the mission operations and scientific organisation. It is responsible for the Science Operations Center and the monitoring and characterisation of the instrument as it ages.

Industrial hardware contract(s)
Major contracts with: Airbus Defense & Space (ADS), Almatech, Connova AG, Pfeiffer Vacuum AG, P&P, RUAG Space

Website(s)
www.cheops.unibe.ch

Artist's impression of the planetary system around the star LHS 1903: Scientists discovered that the planetary system around the star LHS 1903 challenges current planet formation theories with the unusual order of its planets. Surprisingly, the most distant outer planet might be rocky and seems to have formed later – in a different environment than the other planets around the star. From 'Gas-depleted planet formation occurred in the four-planet system around the red dwarf LHS 1903' by T. Wilson et al., which was published in *Science* on 12 February 2026, DOI:10.1126/science.adl2348.

5 Solar Physics

5.1 SPICE and EUI on Solar Orbiter

Artist's impression of Solar Orbiter.
Image credit: ESA.

Institute
Phys. Met. Observatorium Davos/ World Radiation Centre (PMOD/WRC), Davos, Switzerland

In cooperation with
Centre Spatiale de Liège (CSL), Belgium; Royal Observatory Belgium (ROB), Belgium; Mullard Space Science Lab. (MSSL), UK ; Rutherford Appleton Lab. (RAL), UK; Institut d'Astrophysique Spatiale (IAS), France; Max Planck Institut f. Sonnensystemforschung (MPS), Germany; University of Oslo (UiO), Norway; South West Research Institute (SWRI), USA

Principal Investigator(s)
D. Berghmans (ROB), Belgium (EUI)
F. Auchère (IAS), France (SPICE)

Swiss Principal Investigator(s)
L. Harra (PMOD/WRC)

Co-Investigator(s)
There are 62 EUI and 59 SPICE co-Investigators with international representation

Industrial hardware contract(s)
APCO Technologies, Switzerland
Almatech, Switzerland

Website(s)
https://www.pmodwrc.ch

Purpose of Research

The EUV Imager (EUI) and Spectral Imaging of the Coronal Environment (SPICE) are two instruments onboard the ESA/NASA Solar Orbiter mission. The mission was successfully launched on 9 February 2020 from Cape Canaveral, USA. The mission's over-arching goals are to understand how the Sun creates and controls the heliosphere. The spacecraft used gravity assists from Venus and the Earth to slowly place the spacecraft into a 180-day orbit around the Sun. One set of instruments was designed to measure, in-situ, the solar plasma and magnetic fields – these are operated continuously. The other set of instruments remotely sense the Sun, measuring the dynamics and plasma parameters of solar wind sources.

The remote sensing instruments mostly operate intensively during the closest points of the orbit to the Sun (perihelia). The EUI instrument provides both full Sun images in the extreme UV (EUV) through the Full Sun Imager (FSI) and two high resolution imagers (HRIs) that provide high resolution data of a smaller field-of-view – one telescope measuring in the corona and the second in the chromosphere. Due to Solar Orbiter's inclined orbit, reaching about 17° in March 2025, it became possible to look inside the solar polar region for the first time.

Solar Orbiter also coordinates observations with other space-based and ground-based instruments. The first successful coordinated campaign involving Solar Orbiter, the largest ground-based telescope DKIST, and the space-based instruments IRIS and Hinode was conducted in 2022 (Barczynski et al., 2025). These coordinated observations are being continued and provide a unique opportunity to investigate processes in the solar atmosphere from two different vantage points with the highest currently achievable spatial and temporal resolutions.

The quiet Sun corona and coronal holes show phenomena ranging from rapid, small-scale brightenings to slowly evolving large structures, offering key clues to coronal heating and solar wind formation. The Solar Orbiter mission, together with instruments on Solar Dynamics Observatory (SDO), Hinode, and IRIS (Interface Region Imaging Spectrograph), now provides high-resolution EUV imaging, spectroscopy, and magnetic-field measurements to study these regions. The first five years of Solar Orbiter operations have produced numerous publications on the physics of the quiet Sun and coronal holes. Harra et al. (2025) provided a review of recent findings and placed them in the broader context of understanding how the corona is heated and how the solar wind originates.

Solar Orbiter's combined remote-sensing and in-situ instruments also allow detailed studies of solar energetic electrons (SEEs) and their connections to flares, coronal mass ejections (CMEs), and radio emissions. These results are compiled and analysed in the Comprehensive Solar Energetic Electron event Catalogue (CoSEE-Cat), which records SEE events and their solar counterparts using measurements from eight Solar Orbiter instruments, including EUI, along with magnetic-connectivity modelling. The first release (Warmuth et al., 2025), containing 303 events from 2020 – 2022, shows clear differences between impulsive and gradual events and indicates that observed delays between SEEs and associated solar emissions are partly due to propagation effects.

SPICE provides EUV spectroscopic measurements of solar atmospheric emissions from the chromosphere to the corona (log T = 4 – 7) for both remote-sensing window and synoptic observations. Its main goal is to study the physical state and composition of solar atmospheric plasma, with a focus on the source regions of outflows and ejection processes that connect the solar surface, corona, and heliosphere.

By providing information about the first ionisation potential (FIP) effect, SPICE helps to link the solar surface and the heliosphere (Varesano et al., 2024). Measurements of spectral line intensities and Doppler velocities, combined with coordinated observations, provide new insights into active-region upflows and their coupling to the lower atmosphere, supporting reconnection-driven, continuous upflows above ~0.6 MK (Zhu et al., 2025).

Past Achievements and Status

The SPICE Low Voltage Power Supply (LVPS) was built at PMOD/WRC. Together with APCO Technologies, PMOD/WRC was responsible for the EUI Optical Bench Structure (OBS). In addition, the SPICE Slit Change Mechanism (SCM) was provided by Almatech, and the SPICE contamination door (SCD) by APCO Technologies, both managed by PMOD/WRC.

Abbreviations

EUI	Extreme Ultraviolet Imager
SPICE	Spec. Imaging of the Coronal Environ.

Time-Line	From	To
Planning	2008	2010
Construction	2010	2017
Measurement phase	2021	2029
Data evaluation	2021	2030

Publications

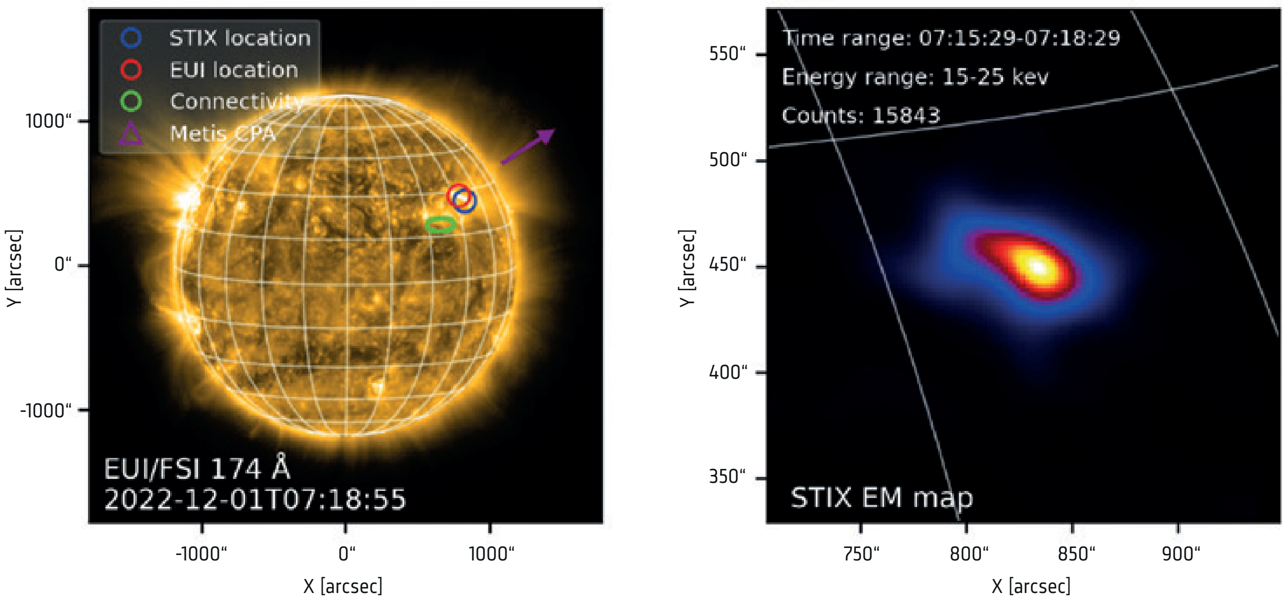
Barczynski K, Janvier M, Nelson CJ et al. (2025) **First coordinated observations between Solar Orbiter and the Daniel K. Inouye Solar Telescope**, A&A 701: A77, doi.org/10.1051/0004-6361/202554396

Harra L, Barczynski K, Auchère F et al. (2025) **The dynamics of the extreme ultraviolet quiet sun and coronal holes in the Solar Orbiter era**, Space Sci. Rev. 221, 50, doi.org/10.1007/s11214-025-01177-3

Varesano T et al. (2024) **SPICE connection mosaics to link the Sun's surface and the heliosphere**, A&A 685: A146, doi.org/10.1051/0004-6361/202347637

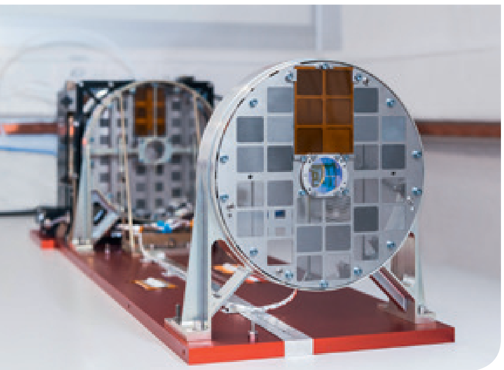
Warmuth A., Schuller F., Gomez-Herrero R. et al. (2025) CoSEE-Cat: **A comprehensive solar energetic electron event catalogue obtained from combined in situ and remote-sensing observations from Solar Orbiter**, A&A 701: A20,.

Zhu Y et al. (2025) **Active region upflows in various coronal structures and their coupling to the lower atmosphere**, A&A 701: A205, doi.org/10.1051/0004-6361/202555618



An example of flare identification using EUI FSI and STIX instruments onboard Solar Orbiter.

5.2 STIX – Spectrometer/Telescope for Imaging X-rays on Solar Orbiter



The STIX Flight Model.

Institute
Inst. for Data Science, Fachhochschule Nordwestschweiz (FHNW), Windisch, Switzerland

In cooperation with
SRC, Poland; CEA Sacaly, France; Leibniz-Institut für Astrophysik Potsdam (AIP), Germany; Czech Space Office, CZ; Univ. Graz, Austria; Trinity College, Dublin; LESIA, France; Univ. Genova, Italy

Principal/Swiss Investigator(s)
S. Krucker (FHNW)

Co-Investigator(s)
J. Sylwester (SRC); O. Limousin (CEA); G. Mann (AIP); F. Farnik (CSO); A. Veronig (Uni Graz); P. Gallagher (TCD) N. Vilmer (LESIA); M. Piana (Univ. Genova)

Contribution
Development & construction of instrument(s): STIX is a Swiss-led instrument onboard Solar Orbiter to study magnetic energy release and particle acceleration in solar flares.

Industrial contract(s) to
Almatech, Ateleris, SYDERAL, Art of Technology; Switzerland

Website(s)
https://stix.i4ds.net

Purpose of Research

Solar Orbiter is a joint ESA-NASA collaboration that addresses the central question of heliophysics: How does the Sun create and control the heliosphere? To achieve this goal, Solar Orbiter carries a set of 10 instruments to perform joint observations. Through hard X-ray imaging and spectroscopy, the Spectrometer/Telescope for Imaging X-rays (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 a crucial role in enabling Solar Orbiter to achieve two of its major science goals of:

– understanding the acceleration of electrons at the Sun and their transport into interplanetary space.
– determining the magnetic connection of 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.

Past Achievements and Status

Solar Orbiter was launched on 9 February 2020, and the commissioning of STIX was successfully completed in June 2020. In the nominal science phase, STIX has been continuously observing the Sun, and more than 100,000 solar flares have been recorded so far.

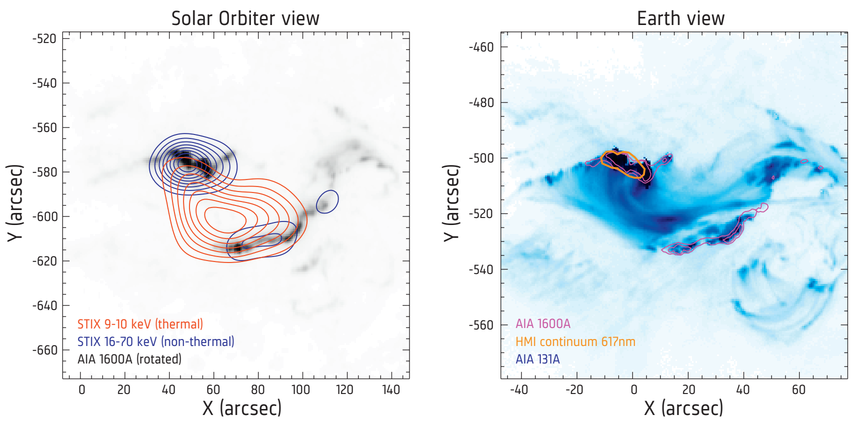
Publications

Krucker S et al. (2020) Astron. Astrophys. 642: id. A15, 21 pp.

Abbreviations

STIX Spectr./Telescope for Imaging X-rays

Time-Line	From	To
Planning	2010	2014
Construction	2014	2017
Measurement phase	2020	2030
Data evaluation	2020	open



STIX imaging results of the largest solar flare observed to date, an X-class flare on 28 October 2021. Images derived from STIX are shown revealing that the thermal emission is coming from a loop connecting the flare ribbons, while the non-thermal emissions are from the flare ribbons, produced by flare-accelerated electrons as they enter the dense ribbons.

5.3 SWA – Solar Wind Plasma Analyser on Solar Orbiter

Purpose of Research

Solar Orbiter was launched on 10 February 2020 to examine how the Sun creates and controls the heliosphere, the vast bubble of charged particles blown by the solar wind into the interstellar medium.

The spacecraft combines in-situ and remote sensing observations to gain new information about the solar wind, the heliospheric magnetic field, solar energetic particles, transient interplanetary disturbances and the Sun's magnetic field.

The Solar Wind Plasma Analyser (SWA), which is part of the science payload, consists of a suite of plasma sensors (Electron Analyser System (EAS), a Proton and Alpha Particle Sensor (PAS) and a Heavy Ion Sensor (HIS). These instruments measure the ion and electron bulk properties (including density, velocity, and temperature) of the solar wind, thereby characterising the solar wind at a distance of between 0.28 and 1.4 AU from the Sun.

In addition to determining the bulk properties of the wind, SWA provides measurements of the solar wind ion composition for key elements.

Past Achievements and Status

We calibrated the HIS instrument of the SWA experiment with highly charged ions as they are found in the solar wind, e.g. the C, N, O group and Fe, Si or Mg.

Solar Orbiter was successfully launched on 10 February 2020 from Cape Canaveral, USA, and is on its trajectory to a closer proximity to the Sun.

Publications

Gruchoła S, Galli A, Vorburger A, Wurz P (2021) **Future Venus missions and flybys: A collection of possible measurements with mass spectrometers and plasma instruments**, Adv. Sp. Res., 68(8): 3205-3217, doi.org/10.1016/j.asr.2021.07.024

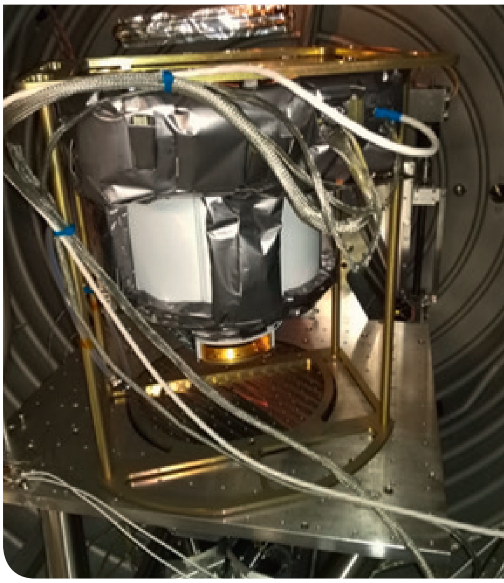
Livi S et al. (2023) **First results from the Solar Orbiter Heavy Ion Sensor**, Astron. Astrophys. 676: A36, 14 pp, doi.org/10.1051/0004-6361/202346304

Owen CJ, Bruno R, Livi S et al. (2020) **The Solar Orbiter Solar Wind Analyser (SWA) Suite**, Astron. Astrophys. 642(A16): 36 pp, doi.org/10.1051/0004-6361/201937259

Abbreviations

EAS	Electron Analyser System
HIS	Heavy Ion Sensor
MEFISTO	MEsskammer für Flugzeit-InStrumente u. Time-Of-Flight
PAS	Proton and Alpha Particle Sensor
SWA	Solar Wind Plasma Analyser

Time-Line	From	To
Planning	2007	2010
Construction	2010	2020
Measurement phase	2021	2029
Data evaluation	2021	2030



Heavy Ion Sensor (HIS) during calibration in the MEFISTO facility for highly charged ion beams at the Univ. of Bern.

Institute
Space Res. & Planet., Physics Inst., Univ. Bern (UNIBE), Bern, Switzerland

In cooperation with
Mullard Space Science Lab. (MSSL), Univ. College, London, UK; Southwest Research Institute, USA

Principal Investigator(s)
C. J. Owen (MSSL)

Swiss Principal Investigator(s)
P. Wurz (UNIBE)

Co-Investigator(s)
A. Galli (UNIBE)

Contribution
Development & construction of instrument(s): The Heavy Ion Sensor (HIS) of the Solar Wind Plasma Analyser (SWA)

Website(s)
www.esa.int/Science_Exploration/Space_Science/Solar_Orbiter

5.4 DARA – Digital Absolute Radiometer on PROBA-3

The PROBA-3 stack on its way into orbit.
Image credit: ESA.

Institute
Phys. Met. Observatorium Davos/
World Radiation Center (PMOD/WRC)

In cooperation with
European Space Agency (ESA)

Principal/Swiss Investigator(s)
W. Finsterle (PMOD/WRC)

Co-Investigator(s)
J.-P. Montillet, M. Haberreiter, D. Pfiffner (PMOD/WRC)
G. Kopp, Lab. Atmos. & Space Phys. (LASP), USA
A. Zhukov, Royal Obs. Belgium (ROB), Belgium

Contribution
Development & construction of instrument(s):
DARA experiment on the PROBA-3 spacecraft.

Industrial contract(s)
Almatech, dlab GmbH, Astorcast SA; Switzerland

Website(s)
www.esa.int/Enabling_Support/Space_Engineering_Technology/Proba_Missions/Proba-3_Mission3

https://www.pmodwrc.ch

Purpose of Research

DARA is a three-channel active cavity Electrical Substitution Radiometer (ESR) representing the latest advances in radiometry from PMOD/WRC. Engineered for high accuracy and long-term stability, DARA provides measurements of Total Solar Irradiance (TSI). Its calibration against the NIST-traceable TSI Radiometer Facility (TRF) and the World Radiometric Reference (WRR) ensures full SI-traceability. Through the PROBA-3 mission, DARA continues PMOD/WRC's legacy of contributing to the contiguous record of spaceborne TSI measurements maintained since 1978.

Past Achievements and Status

The ESA-PROBA3 spacecraft was successfully launched on 5 December 2024, onboard a PSLV-XL rocket from the Satish Dhawan Space Centre in Sriharikota, India. The payload includes the Digital Absolute Radiometer (DARA) from PMOD/WRC, which is dedicated to measuring Total Solar Irradiance (TSI) in orbit. At the onset of the commissioning phase, DARA recorded its first TSI data (first light), marking the beginning of its scientific mission in space. Following a successful commissioning period that concluded in mid-July 2025, PMOD/WRC transitioned to routine analysis of the DARA data. DARA can also operate in high-cadence mode to monitor TSI variability up to 0.3 Hz. The spacecraft operates in a highly elliptical orbit (600 x 60,530 km; 59° inclination), a trajectory that enables long, continuous observation windows of up to 19 hours. Technical teams are currently finalising the data pipeline to convert raw instrument telemetry (Level 0) into high-fidelity irradiance data (Level 2).

Publications

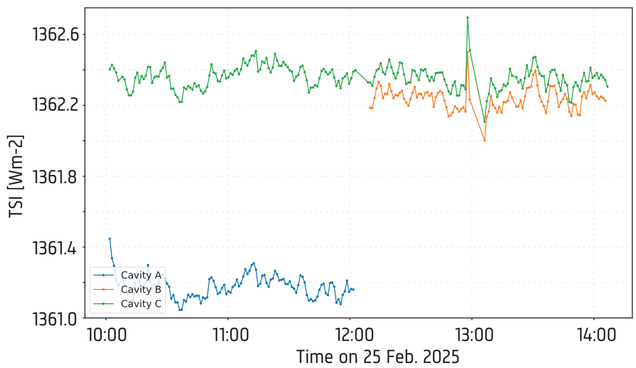
Montillet J, Schmutz W, Finsterle W et al. (2023) **The DARA/PROBA-3 radiometer: results from the preflight calibration campaign**, EGU, Vienna, Austria, EGU23-9007, doi.org/10.5194/egusphere-egu23-9007

Montillet J-P, Finsterle W, Haberreiter M et al. (2025) **Initial Results of Total Solar Irradiance Measurements by DARA-PROBA3**, EGU, Vienna, Austria, EGU25-18737, doi.org/10.5194/egusphere-egu25-18737

Abbreviations

DARA	Digital Absolute Radiometer
PROBA-3	Project for On-Board Autonomy-3

Time-Line	From	To
Planning	2013	2016
Construction	end 2013	end 2020
Measurement phase	2025	ongoing
Data evaluation	2025	ongoing



The Total Solar Irradiance (TSI) is shown on 25 Feb. 2025 for each cavity when first-light measurements began. Results for the main cavity (cavity B), the backup cavity (cavity C), and the reference (cavity A).

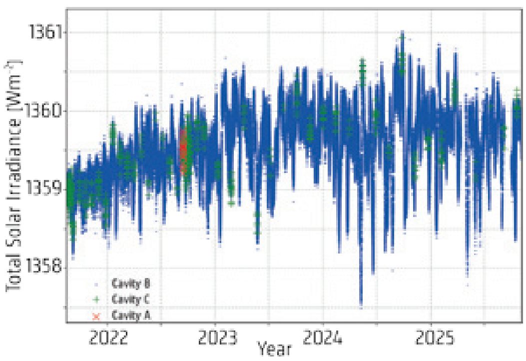
5.5 JTSIM-DARA on FY-3E

Purpose of Research

Continuous and precise Total Solar Irradiance (TSI) measurements are indispensable to evaluate the influence of short and long-term solar radiative emission variations on the Earth's climate. The Joint Total Solar Irradiance Monitor – Digital Absolute Radiometer (JTSIM-DARA) instrument on the Chinese FY-3E satellite is one of PMOD/WRC's current contributions to the almost seamless series of spaceborne TSI measurements since 1978.

Past Achievements and Status

JTSIM-DARA on FY-3E performs TSI measurements since 2021. The data pipeline is still being optimised together with project partners to automate the level transformation from raw observations (Level-0) to irradiance measurements (Level-2). Level-2 observations are corrected for all a-priori known factors (e.g., aperture area, reflectance, diffraction) and calibrated against the World Radiometric Reference (normalised to 1 AU). Radiative losses of the black-body receiver cavity are regularly calibrated against dark space and the TSI measurements are corrected accordingly. TSI is measured with all three JTSIM-DARA cavities at different intervals to estimate the degradation of the cavity absorptance. The first TSI data product (JTSIM-DARAv1) is publicly available in the public repository Astromat (https://repo.astromat.org/view.php?id=3105&system=astro). This is updated four times a year. Regular checks are ongoing to look at the degradation of the instrument due to exposure to UV/EUV.



Total Solar Irradiance (TSI) measurements from JTSIM-DARA showing results from cavities A, B and C.

Publications

Montillet J-P et al. (2025) **Assessment of instrument performance of the FY3E/JTSIM/DARA radiometer through the analysis of TSI observations**, Rem. Sens., 17(23): 3902, doi.org/10.3390/rs17233902

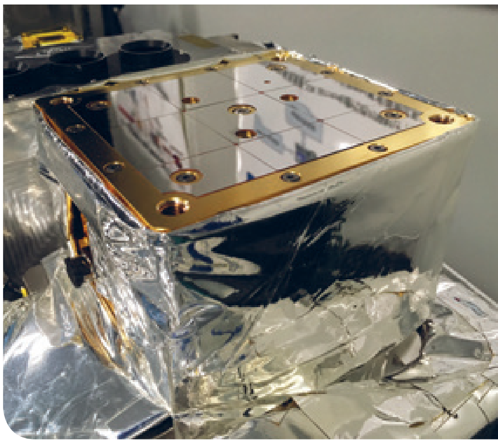
Song B et al. (2021) **The Fengyun-3E/Joint Total Solar Irradiance Absolute Radiometer: Instrument design, characterization, and calibration**, Solar Phys., 296: doi.org/10.1007/s11207-021-01794-5

Zhu P et al. (2025) **The first light from the joint total solar irradiance measurement experiment onboard the FY-3E meteorological satellite**, Earth & Space Sci. 12: e2023EA003064, doi.org/10.1029/2023EA003064

Abbreviations

DARA Digital Absolute Radiometer
JTSIM Joint TSI Monitor
TSI Total Solar Irradiance

Time-Line	From	To
Planning	2014	2015
Construction	2015	2018
Measurement phase	2021	ongoing
Data evaluation	2021	ongoing



A close-up of the DARA front-shield. The three cavity apertures can be seen close to the centre of the instrument.

Institute
Phys. Met. Observatorium Davos/
World Radiation Center (PMOD/WRC),
Davos, Switzerland

In cooperation with
Changchun Inst. Optics, Fine Mechanics & Physics (CIOMP)/Chinese Acad. Sci. (CAS), China;
Chinese Met. Administration (CMA), China

Principal Investigator(s)
W. Fang (CIOMP)

Swiss Principal Investigator(s)
W. Finsterle (PMOD/WRC)

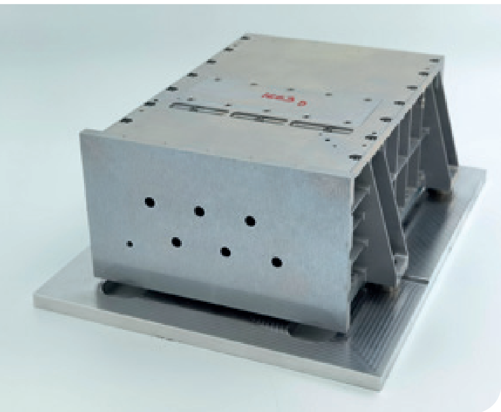
Co-Investigator(s)
J.-P. Montillet (PMOD/WRC),
D. Pfiffner (PMOD/WRC)

Contribution
Research based on existing instruments:
JTSIM-DARA experiment on the FY-3E spacecraft

Industrial hardware/software contract(s) to
dlab GmbH, Switzerland

Website(s)
https://www.pmodwrc.ch

5.6 SoSpIM – Solar Spectral Irradiance Monitor on Solar-C



SoSpIM housing, representing the mechanical and thermal interface of the instrument, mounted on a representative spacecraft baseplate for verification activities.

Institute
Phys. Met. Observatorium Davos/ World Radiation Center (PMOD/WRC), Davos, Switzerland

In cooperation with
JAXA;
ESA;
NASA

Principal Investigator
T. Shimizu (ISAS, JAXA)

Swiss Principal Investigator
L. Harra (PMOD/WRC)

Co-Investigator(s)
Marie Dominique (ROB)
Säm Krucker (FHNW)
K. Barczynski (PMOD/WRC)

Industrial hardware contract(s)
dlab GmbH; MICOS GmbH; Nanotronic

Website(s)
https://www.pmodwrc.ch

Purpose of Research

Solar-C_EUVST is the next JAXA solar physics mission. The mission carries an EUV imaging spectrometer with a slit-jaw imaging system called EUVST (EUV High-Throughput Spectroscopic Telescope) as the main mission payload, to take a fundamental step towards understanding how the Sun influences the Earth and other planets in our solar system.

A second, smaller instrument provides spectral irradiance capability through a Solar Spectral Irradiance Monitor (SoSpIM). This provides both scientific and calibration capabilities. SoSpIM and EUVST will work together. EUVST will provide spectral observations from the chromosphere to the corona, tracking the energy flow on small spatial scales. SoSpIM will provide 'Sun-as-a-star' measurements in two wavelength bands also covered by EUVST. This provides measurements of all solar flares visible from Earth, not only those within the EUVST field-of-view. The SoSpIM instrument provides the connectivity between the flare processes captured in detail on the Sun by EUVST and the impact of irradiance changes in different layers of Earth's atmosphere.

The SoSpIM instrument aims to specifically address two aspects:
– Understand how the solar atmosphere becomes unstable, releasing the energy that drives solar flares – achieved through probing fast time cadence solar flare variations.
– Measuring solar irradiance that impacts the Earth's thermosphere and the mesosphere, linking to spatially resolved measurements of the solar atmosphere with EUVST.

In order to achieve these goals, the SoSpIM instrument will monitor the spectrally resolved solar irradiance with a sub-second time cadence. There will be two channels with redundancy in the following bands:
– Channel 1: covering 170 – 215 Å (Al/Zr/Al filter combination).
– Channel 2: covering 1115 – 1275 Å (MgF_2 filter).

A key advantage of having a 'Sun-as-a-star' instrument onboard the mission is that all solar flares visible from Earth can be observed. SoSpIM will allow the direct connection to the impact on the Earth. The two channels on SoSpIM will probe the effects on the ionosphere/thermosphere (mainly with Channel 1) and the mesosphere and stratosphere (with Channel 2).

Past Achievements and Status

The Preliminary Design Review (PDR) successfully took place in autumn 2023 for SoSpIM. The Critical Design Review (CDR) will take place at the beginning of 2026.

Publications

A spectral solar irradiance monitor (SoSpIM) on the JAXA Solar-C mission, https://scostep.org/wp-content/uploads/2021/04/SCOSTEP_PRESTO_Newsletter_Vol27_high_reso.pdf

Abbreviations

EUVST	Extreme UV High-Throughput Spectroscopic Telescope
SoSpIM	Solar Spectral Irradiance Monitor

Time-Line	From	To
Planning	2019	2020
Construction	2020	2026
Measurement phase	2029	open
Data evaluation	open	open

5.7 CLARA – Compact Lightweight Absolute Radiometer on NorSat-1

Purpose of Research

The CLARA instrument onboard the Norwegian micro-satellite NorSat-1 is one of PMOD/WRC's operational absolute radiometers that has measured Total Solar Irradiance (TSI), one of the essential climate variables. CLARA continues to be operational and measures the Longwave Outgoing Radiation (OLR) at the top of the Earth's atmosphere from the night-side of Earth. These measurements are the first SI-traceable measurements of TSI and OLR with one single instrument and as such, serve as an important step towards determining the components of the Earth Radiation Budget with absolute measurements from space.

Past Achievements and Status

CLARA onboard NorSat-1 was launched on 14 July 2017 and after a successful commissioning phase, began measurements on 25 Aug. 2017. At the of 2019 CLARA started taking measurements of the Earth's outgoing longwave radiation from the night-side of Earth. In May 2018, an instrumental failure of the first reaction wheel occurred. The second reaction wheel failed in August 2021. While the first occurrence was a permanent failure, this time the interruption was caused by the wheel software. Fortunately, UTIAS in collaboration with the wheel supplier were able to solve the problem. The updated firmware was uploaded to the spacecraft in Feb. 2022 and the reaction wheel became functional again.

Due to the permanent failure of the reaction wheel from Sep. 2023 onwards, solar pointing of NorSat-1 was no longer possible. The positive news, however, is that the CLARA instrument status is nominal. As a result, terrestrial measurements of the OLR can continue. The analysis of the CLARA TSI dataset has been completed (see below figure), while OLR data analysis is ongoing on a routine basis (see opposite figure). Finally, a mapping routine has been developed, which allows spatial and temporally overlapping CERES Single Scanner Footprint data with the CLARA OLR measurements to be identified. Acknowledgement: MH acknowledges support by the Swiss Space Office and Karbacher Funds.

Publications

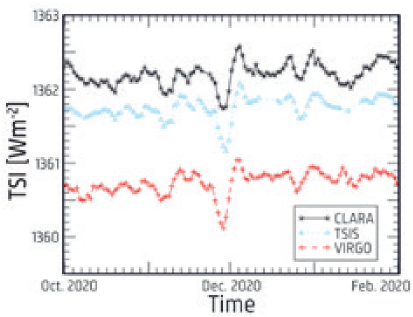
Haberreiter M, Reiter M, Finsterle W, Montillet J-P (2025), EGU25-11228, doi.org/10.5194/egu-sphereegu25-11228

Walter B, Andersen B, Beattie A et al. (2020), Astronomy in Focus, Proc. IAU, 358-360, doi.org/10.1017/S1743921319004617

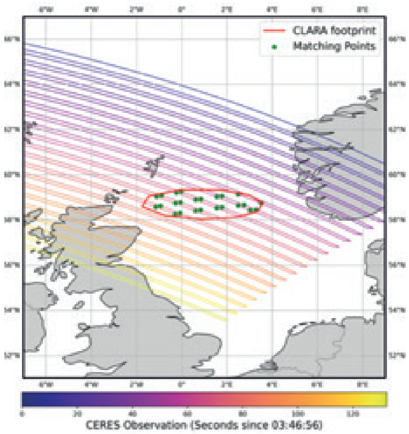
Abbreviations

CERES Clouds and Earth's Radiant Energy System
CLARA Compact Lightweight Abs. Rad.
OLR Outgoing Longwave Radiation

Time-Line	From	To
Planning	2013	2013
Construction	2014	2016
Measurement phase	Jun. 2017	TSI ended Sep. 2023; since then OLR
Data evaluation	2017	ongoing



Example of the degradation-corrected CLARA daily TSI values compared with VIRGO (red) and TSIS (blue).



The boundary of the CLARA footprint (red line) and the ground track of the CERES instrument (yellow to violet lines) is shown. The green dots correspond the overlapping observation of CERES within the CLARA footprint.

Institute
Phys. Met. Observatorium Davos/
World Radiation Center (PMOD/WRC),
Davos, Switzerland

In cooperation with
Norwegian Space Center (NSC), Oslo, Norway;
UiO, Norway;
UTIAS-SFL, Toronto, Canada;
Lab. Atmos. Space Phys. (LASP), Boulder, USA

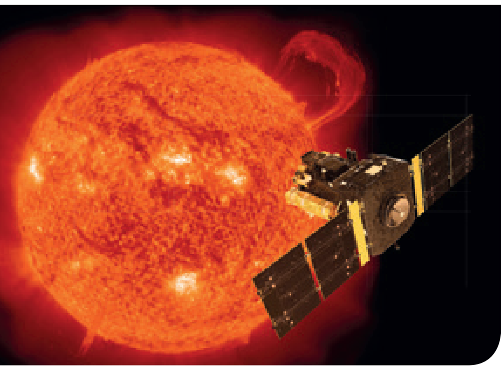
Principal/Swiss Investigator(s)
W. Finsterle (PMOD/WRC)

Co-Investigator(s)
M. Haberreiter, J.-P. Montillet (PMOD/WRC)
B. Andersen (UiO)
G. Kopp (LASP)

Contribution
Research based on existing instruments:
CLARA was developed and constructed by PMOD/WRC from 2013 to 2015

Website(s)
https://www.pmodwrc.ch

5.8 VIRGO on SOHO



VIRGO on the SOHO spacecraft. Image credit: ESA.

Institute
Phys. Met. Observatorium Davos/ World Radiation Center (PMOD/WRC), Davos, Switzerland

In cooperation with
ESA;
NASA;
Inst. Royal Met. Belgique (IRMB), Brussels, Belgium;
European Space Res. & Tech. Centre (ESTEC), Nordwijk, The Netherlands;
Instituto de Astrofísica de Canarias (IAC), Spain

Principal/Swiss Investigator(s)
W. Finsterle (PMOD/WRC)

Co-Investigator(s)
J.-P. Montillet (PMOD/WRC)
S. Dewitte (IRMB)
T. Appourchoux (CNRS, France)
A. Jimenez (IAC)

Contribution
Research based on existing instruments: VIRGO experiment on the SOHO spacecraft

Website(s)
https://www.pmodwrc.ch

Purpose of Research

The Variability of Irradiance and Global Oscillations (VIRGO) instrument onboard the Solar and Heliospheric Observatory (SOHO) provides continuous high-precision measurements of the Total and Spectral Solar Irradiance (TSI, SSI). TSI measurements are used to estimate a potential solar influence on terrestrial climate change and to determine the Earth's energy imbalance. The spectral solar irradiance (SSI) measurements contribute to the SSI database, which is used to model the chemistry and dynamics in the upper atmosphere of the Earth.

Past Achievements and Status

VIRGO has provided the longest continuous time-series of TSI and SSI. Sensor degradation is regularly assessed and corrected, based on a machine learning algorithm. SSI measurements are strongly affected by filter degradation.

New TSI data are published every four months.

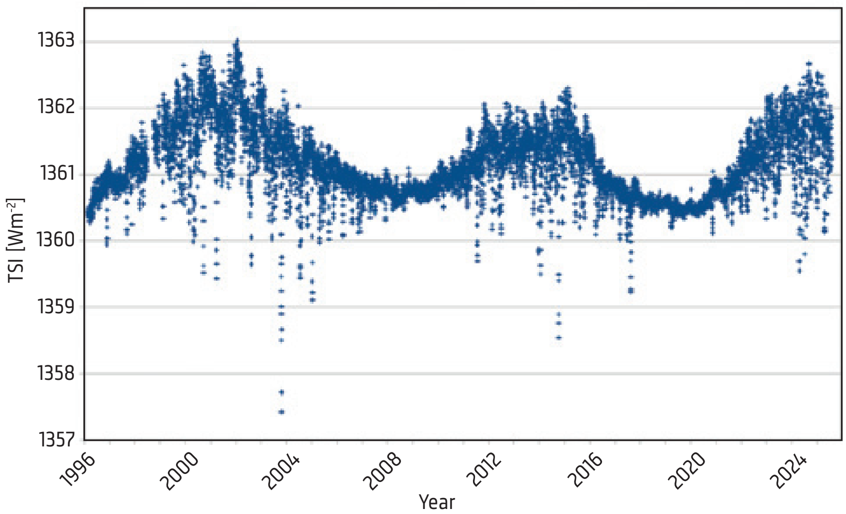
Publications

Montillet JP, Finsterle W, Kermarrec G, Šikonja R, Haberreiter M, Schmutz W, Dudok de Wit T (2022) **Data fusion of Total Solar Irradiance composite time series using 41 years of satellite measurements**, J. Geophys. Res. Atmos. 127: 13, e2021JD036146, doi.org/10.1029/2021JD036146

Abbreviations

SOHO	Solar and Heliospheric Observatory
SSI	Spectral Solar Irradiance
TSI	Total Solar Irradiance
VIRGO	Variability of Solar Irradiance and Gravity Oscillations

Time-Line	From	To
Planning	~1985	~1990
Construction	~1990	1995
Measurement phase	1996	ongoing
Data evaluation	1996	ongoing



The Total Solar Irradiance (TSI) time-series measured by VIRGO spans 30 years and continues to be measured.

5.9 PADRE – The Solar Polarization And Directivity X-Ray Experiment

Purpose of Research

PADRE is a 12-unit cubesat funded by NASA to make joint observations with FHNW's STIX (Spectroscope/Telescope for Imaging X-Rays) instrument onboard ESA's Solar Orbiter mission. PADRE flies four STIX spare detectors to make joint observations with STIX to measure X-ray directivity, taking advantage of Solar Orbiter's unique orbit, away from the Earth-Sun line. Directivity measurements allow us to measure the pitch angle distribution (beam or cloud) of flare-accelerated electrons. The MeDDEA (Measuring Directivity to Determine Anisotropy) instrument on PADRE, uses four STIX flight spare detectors (see Figure), and is led by S. Christe at the Goddard Space Flight Center (USA). FHNW has been involved from the start of the proposal phase, and we are currently closely involved in the cross-calibration of MeDDEA and STIX.

Past Achievements and Status

PADRE was launched in May 2025 and commissioning concluded in November 2025. First joint solar flare observations between PADRE and STIX occurred as of 28 Nov. 2025 (see below Figure).

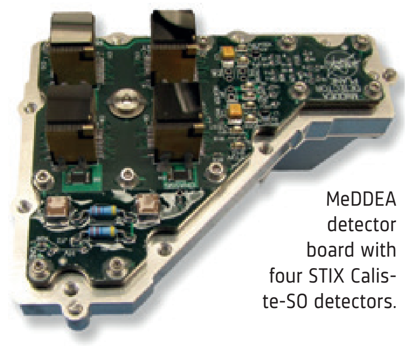
Publications

Krucker S et al. (2020) **The Spectrometer/Telescope for Imaging X-rays (STIX)**, Astron. Astrophys. 642: id. A15, doi.org. 10.1051/0004-6361/201937362

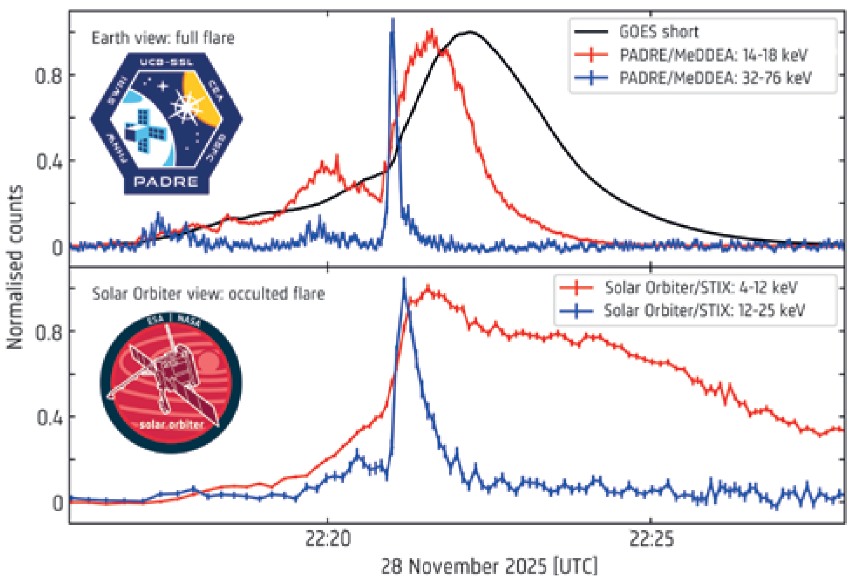
Abbreviations

FHNW	Fachhochschule Nordwestschweiz, Windisch, Switzerland
MeDDEA	(Measuring Directivity to Determine Anisotropy)
PADRE	The Solar Polarization And Directivity X-Ray Experiment
STIX	Spectr./Telescope for Imaging X-Rays

Time-Line	From	To
Planning	2021	2022
Construction	2022	2025
Measurement phase	2025	2026
Data evaluation	2025	open



MeDDEA detector board with four STIX Caliste-SO detectors.



First PADRE and STIX solar flare X-ray observations. PADRE observes the entire flare located on the solar disk. For STIX, the flare is occulted by the solar limb and only the much fainter (~1%) emission from the escaping coronal mass ejection (CME) is seen.

Institute
Inst. for Data Science, Fachhochschule Nordwestschweiz (FHNW), Windisch, Switzerland

In cooperation with
Univ. California (UC), Berkeley, USA; Goddard Space Flight Center (GSFC), USA; CEA, France

Principal Investigator(s)
J. Martinez Oliveros (UC)

Swiss Principal Investigator(s)
S. Krucker (FHNW)

Contribution
FHNW is involved in PADRE operation and leading the cross-calibration between PADRE and STIX.

Website(s)
https://padre.ssl.berkeley.edu

6 Heliospheric Physics

6.1 LIA – Light Ion Analyser on the Solar-wind-Magnetosphere-Ionosphere-Link-Explorer (SMILE) Mission

SMILE Mission logo. Image credit: ESA/CAS.

Institute
Space Res. & Planet., Physics Inst., Univ. Bern, (UNIBE), Bern, Switzerland

In cooperation with
National Space Science Center (NSSC), Chinese National Space Science Centre, Chinese Academy of Sciences (CAS), China

Principal Investigator(s)
L. Dai (NSSC)

Swiss Principal Investigator(s)
P. Wurz (UNIBE)

Co-Investigator(s)
A. Galli (UNIBE)

Contribution
Development & construction of instrument(s): Participation in the design and calibration of the Light Ion Analyser (LIA)

Website(s)
www.esa.int/Science_Exploration/Space_Science/Smile

Purpose of Research

The Solar wind Magnetosphere Ionosphere Link Explorer (SMILE) mission is a joint mission between ESA and the Chinese Academy of Sciences (CAS). SMILE was successfully launched on 19 May 2026 from Europe's Spaceport. SMILE aims to build a more complete understanding of the Sun-Earth connection by measuring the solar wind and its dynamic interaction with the terrestrial magnetosphere. We are participating in the Light Ion Analyser (LIA) instrument to investigate the interaction of the solar wind and magnetosheath under various conditions.

The LIA instrument will determine the plasma properties of the solar wind and magnetosheath ions under various solar wind conditions by measuring the three-dimensional velocity distribution of protons and alpha particles. LIA comprises of two top-hat-type electrostatic analysers, each mounted on opposite sides of the spacecraft platform. LIA is capable of sampling the full 4π three-dimensional distribution of the solar wind, and can measure ions in the energy range from 0.05 to 20 keV at a temporal resolution of up to 0.5 s.

Past Achievements and Status

The LIA instrument was fabricated, calibrated and successfully installed on the spacecraft.

Publications

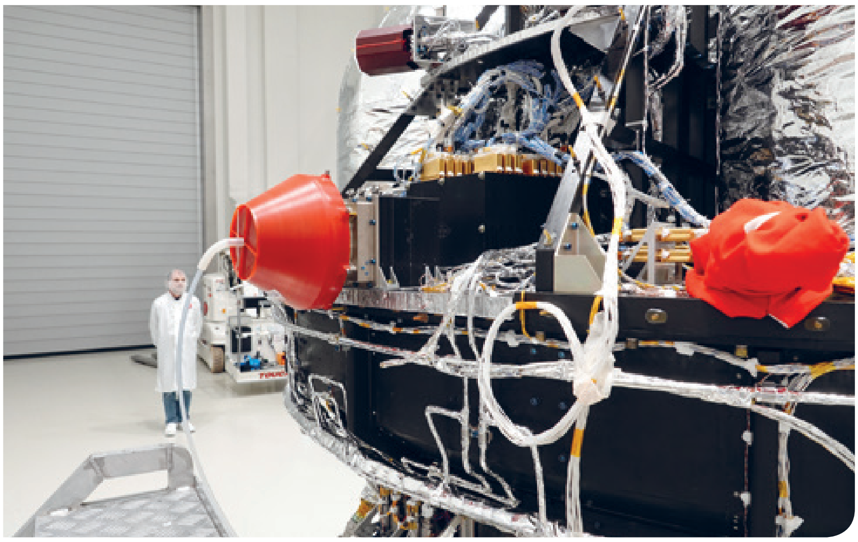
Dai L, Kong L, Zhang A et al. (2025) **The Light Ion Analyzer (LIA) for the SMILE Mission**, Sp. Sci. Rev., 221: 109, 27 pp, doi.org/10.1007/s11214-025-01235-w

Wurz P, Balogh A, Coffey V et al. (2007) **Calibration Techniques**, in Calib. of Particle Instr. in Space Physics, (eds. Wüest M, Evans DS, von Steiger R), ESA Comm., ISSI Sci. Rep., SR-007, 117-276.

Abbreviations

LIA Light Ion Analyser
SMILE Solar Wind Magnetosphere Ionosphere Link Explorer

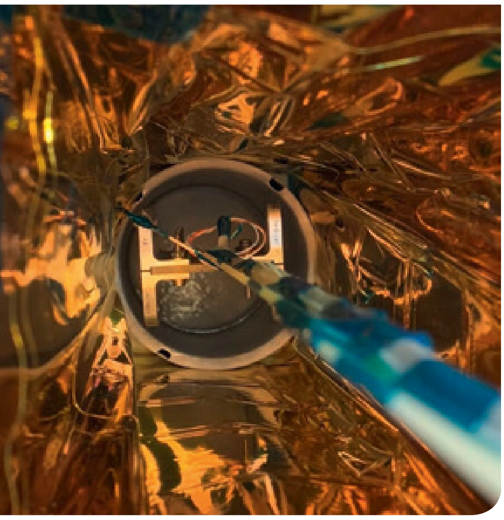
Time-Line	From	To
Planning	2015	2017
Construction	2017	2025
Measurement phase	2026	2028
Data evaluation	2026	2031



The LIA 2 instrument, covered by a red purging hood, mounted on the SMILE spacecraft.

The Smile spacecraft (gold) was fixed to a Vega-C rocket adaptor (black cone) on 25 March 2026, in preparation for liftoff from Europe's Spaceport in French Guiana. Image credit: ESA-M. Pédoussaut.

6.2 SXI – Soft X-Ray Imager on SMILE



Picture taken during the thermal cycling test of the SXI support assembly breadboard to verify the durability of the selected materials (fibre-reinforced plastic and aluminium) at ZHAW. Image credit: ZHAW.

Institute
Univ. Applied Sciences & Arts Northwestern Switzerland (FHNW), Switzerland

In cooperation with
Univ. Leicester (UoL), UK

Principal Investigator(s)
S. Sembay (UoL)

Swiss Principal Investigator(s)
S. Krucker (FHNW)

Co-Investigator(s)
H.-P. Gröbelbauer (FHNW)
G. Peikert (ZHAW, Switzerland)
W. Hajdas (PSI, Switzerland)

Contribution
Development & construction of instrument(s): Thermal design and radiator assembly

Industrial hardware contract(s)
KOEGL Space, Dielsdorf, Switzerland
Space Acoustics, Rafz, Switzerland

Website(s)
https://astro-helio.ch/project/sxi

Purpose of Research

The Solar wind Magnetosphere Ionosphere Link Explorer, or SMILE, is a joint mission between ESA and the Chinese Academy of Sciences. SMILE aims to build a more complete understanding of the Sun-Earth connection by measuring the solar wind and its dynamic interaction with the magnetosphere. While previous magnetospheric studies were mainly driven by single or multi-point in-situ observations from within or around the Earth's magnetosphere, SMILE's novel approach will take images and movies from outside the magnetosphere, thus revealing the global picture of the solar wind's interaction with the magnetosphere. With these global and time-dependent images, SMILE will revolutionise magnetospheric physics. In collaboration with Swiss industry, FHNW was in charge of the thermal design, and the design and manufacture of the radiator assembly of the Soft X-ray Imager (SXI). FHNW is also part of the SXI software and data analysis team.

Past Achievements and Status

The Flight Model of the SXI radiator was delivered in 2023. The SMILE mission was successfully launched from Europe's Spaceport on 19 May 2026.

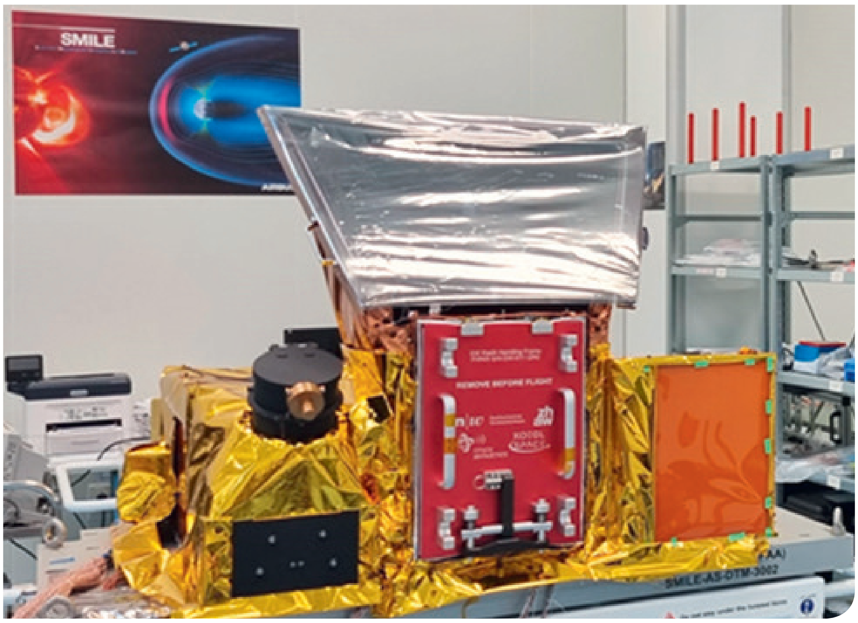
Publications

Raab W et al. (2016) **SMILE: a joint ESA/CAS mission to investigate the interaction between the solar wind and Earth's magnetosphere**, SPIE: 9905E, 02R.

Sembay S et al. (2024) **The Soft X-ray Imager (SXI) on the SMILE Mission**, Earth & Planet. Phys. 8: 1, 5-14, doi.org/ 10.26464/epp2023067

Abbreviations

FHNW	Univ. Applied Sciences & Arts NW Switzerland
SMILE	Solar wind Magnetosphere Ionosphere Link Explorer
SXI	Soft X-Ray Imager



Structural Thermal Model of the SMILE payload module before delivery to China in March 2022. The SXI instrument is seen in the center with the silver top. The Swiss contribution is the radiator (a red cover plate has been put over the radiator for transport).

6.3 IBEX – Interstellar Boundary Explorer

Purpose of Research

The IBEX mission (NASA SMEX class) is designed to record energetic neutral atoms (ENA) 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 by two ENA cameras, 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 the study of the plasma physical processes at the interface between the heliosphere and the interstellar medium, located at a distance of about 100 AU.

Past Achievements and Status

IBEX was successfully launched in October 2008 and was first 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 has significantly extended the orbital lifetime of the IBEX spacecraft and thus allows the mission to cover more than a solar cycle of 11 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. IBEX is still operating, to allow an overlap in operation with the successor mission, Interstellar Mapping and Acceleration Probe (IMAP). This allows cross-calibration between the ENA cameras on both spacecraft. Moreover, performing measurements at two vantage points will open new possibilities for investigations of the boundary region.

Publications

Galli A, Wurz P, Rahmanifard F, Möbius E, Schwadron NA, Kucharek H, Heirtzler D, Fairchild K, Bzowski M, Kubiak MA, Kowalska-Leszczynska I, Sokół JM, Fuselier SA, Swaczyna P, McComas DJ (2019) **Model-free maps of interstellar neutral hydrogen measured with IBEX between 2009 and 2018**, Astrophys. J, 871: 52, 18 pp., doi.org/10.3847/1538-4357/aaf737

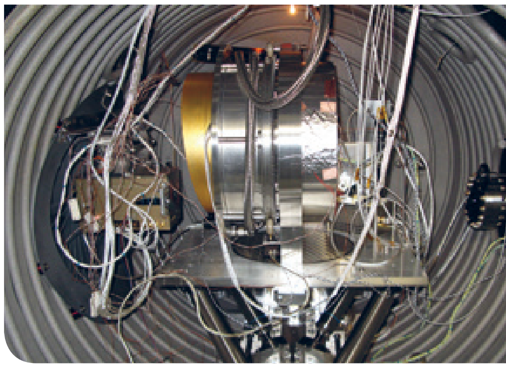
Galli A, Swaczyna P, Bzowski M, Kubiak MA, Kowalska-Leszczynska I, Wurz P, Rahmanifard F, Schwadron NA, Möbius E, Fuselier SA, Sokol JM, Gasser J, Heerikhuisen J, McComas DJ (2025) **15 years of interstellar neutral hydrogen observed with the Interstellar Boundary Explorer**, Astron. Astrophys. 278: 1, 14 pp, doi.org/10.3847/1538-4365/adc451

Rodríguez Moreno DF, Wurz P, Saul L, Bzowski M, Kubiak MA, Sokół JM, Frisch P, Fuselier SA, McComas DJ, Möbius E, Schwadron N (2013) **Evidence of direct detection of interstellar deuterium in the local interstellar medium by IBEX**, Astron. Astrophys. 557: A125, 1-13, doi.org/10.1051/0004-6361/201321420

Abbreviations

ENA	Energetic Neutral Atom
IBEX	Interstellar Boundary Explorer
IMAP	Interstellar Mapping and Acceleration Probe
MEFISTO	MEsskammer für Flugzeit-InStrumente u. Time-Of-Flight

Time-Line	From	To
Planning	2005	2006
Construction	2006	2008
Measurement phase	2008	2026
Data evaluation	2008	2030



IBEX-Lo flight instrument in the MEFISTO calibration facility, Univ. Bern.

Institute
Space Research and Planetology, Physics Inst., Univ. Bern (UNIBE), Bern, Switzerland

In cooperation with
Southwest Res. Inst., Austin, USA;
Lockheed Martin, Palo Alto, USA;
Space Res. Centre PAS., Warsaw, Poland;
Univ. New Hampshire, Durham, USA

Principal Investigator(s)
D. McComas, Princeton Univ., Princeton, USA

Swiss Principal Investigator(s)
P. Wurz (UNIBE)

Co-Investigator(s)
A. Galli (UNIBE)

Contribution
We conducted the ion-optical design, and participated in development and the manufacturing of the IBEX-Lo ENA camera. Moreover, we performed the entire IBEX-Lo calibration with ENAs over the full energy range from 10 eV to 2 keV, and for all species of interest.

Industrial hardware contract(s)
Sulzer Innotec

6.4 IMAP – Interstellar Mapping and Acceleration Probe

The IMAP-Lo instrument is shown installed on the Interstellar Mapping and Acceleration Probe (IMAP) at the Johns Hopkins Applied Physics Laboratory in Laurel, Maryland, USA. The IMAP-Lo entrance is covered by a red protection cover. Image Credit: NASA, Johns Hopkins APL, Princeton, Ed Whitman.

Institute
Space Res. & Planetology, Physics Institute, Univ. Bern (UNIBE), Bern, Switzerland

In cooperation with
Princeton Univ., Princeton, USA; SW Res. Inst., Austin, USA; Univ. New Hamp., Durham, USA; Los Alamos Nat. Lab., USA

Principal Investigator(s)
D. McComas (Princeton Univ.)

Swiss Principal Investigator(s)
P. Wurz (UNIBE)

Co-Investigator(s)
A. Galli (UNIBE)

Contribution
Development & construction of instrument(s):
Participation: ion-optical design, development, manufacture IMAP-Lo ENA camera.
Calibration: IMAP-Lo calibration with ENAs.

Industrial hardware contract(s)
SMC Mould Innovation AG, Hallau; MECHA Eng. & Maschinenbau, Belp Switzerland

Website(s)
https://science.nasa.gov/mission/imap

Purpose of Research

The NASA Interstellar Mapping and Acceleration Probe (IMAP) mission is a heliophysics mission that will simultaneously investigate two important and coupled science topics in the heliosphere: the acceleration of solar energetic particles and the interaction of the solar wind plasma with the local interstellar medium. These science topics are coupled because particles accelerated in the inner heliosphere play crucial roles in the outer heliospheric interaction.

IMAP was selected by NASA in 2018, and was successfully launched on 24 September 2025 from the NASA Kennedy Space Center (Florida, USA). IMAP is a Sun-tracking spin-stabilised satellite in orbit around the Sun–Earth L1 Lagrange point since 10 January 2026. The science phase started on 1 February 2026, and the primary mission will extend until February 2028.

The IMAP science payload comprises 10 scientific instruments. IMAP will also continuously broadcast real-time in-situ data that can be used for space weather prediction. Part of the scientific instrumentation are Energetic Neutral Atoms (ENA) cameras for the observation of the interface between the heliosphere and the interstellar medium. The University of Bern (Switzerland) is participating in the IMAP-Lo camera, covering the energy range from 10 eV to 1 keV.

Past Achievements and Status

Since the calibration of the IMAP-Lo ENA camera is one of our contributions to the IMAP project, we have developed a novel Absolute Beam Monitor (ABM) for the precise determination of the flux of energetic neutral particles of the neutral atom beam used for the IMAP-Lo calibration.

Publications

Gasser J, Galli A, Wurz P (2023) **Calibration beam fluxes of a low-energy neutral atom beam facility**, Rev. Sci. Instr. 94: 053302, 7 pp, doi.org/10.1063/5.0140759

Schwadron N, Shen MM, Amaya C, Begley S, Bower J, Brody J, Bzowski M, Cardarelli G, Christian ER, Clark G, Collura C, Cook C, Cortinas S, Crosier R, Cully M, De Los Santos A, Dominico J, Dutton N, Ellis S, Fairchild K, Ford J, FrostC, Funsten HO, Fuselier SA, …Wurz P (2025) **The IMAP-Lo instrument**, Sp. Sci. Rev. 221, 121 40 pp, https:/doi.org/10.1007/s11214-025-01234-x

Abbreviations

ABM	Absolute Beam Monitor
ENA	Energetic Neutral Atoms
IMAP	Interstellar Mapping and Acceleration Probe

Time-Line	From	To
Planning	Jan. 2018	Dec. 2018
Construction	Jan. 2019	Dec. 2024
Measurement phase	Feb. 2026	Feb. 2028
Data evaluation	Feb. 2026	Dec. 2030

6.5 Plasma Observatory

Purpose of Research

Plasma energization and energy transport are ubiquitous in space plasma. The Earth's Magnetospheric System is a key example of a complex and highly dynamic cosmic plasma environment where massive energy transport and plasma energization occur and can be directly studied through in-situ spacecraft measurements. In-situ observations, theory and simulations suggest that the key physical processes driving plasma energization and energy transport occur where plasma on fluid scales couple to the smaller ion kinetic scales, at which the largest amount of electromagnetic energy is converted into energized particles. Remote observations currently cannot access these scales, and existing multi-point in-situ observations do not have a sufficient number of observation points.

Plasma Observatory will be the first mission having the capability to resolve scale coupling in the Earth's Magnetospheric System through parallel measurements at seven points in space, simultaneously covering the ion and the fluid scales where the strongest plasma energization and energy transport occurs: the foreshock, bow shock, magnetosheath, magnetopause, magnetotail current sheet, and transition region. The mission website is accessible at https://plasma-observatory.inaf.it.

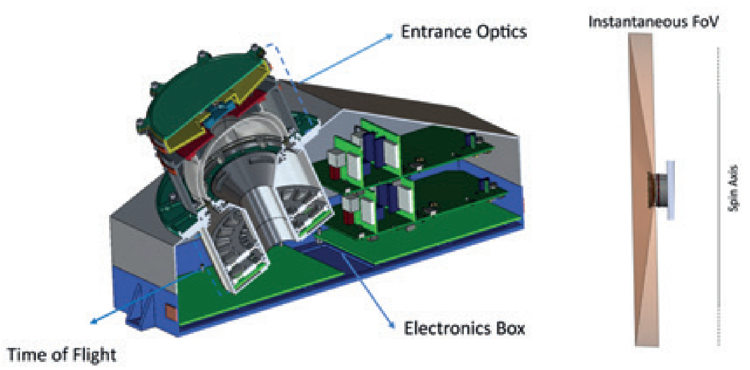
Past Achievements and Status

The Plasma Observatory is an ESA M7 mission candidate, currently under evaluation with two other candidates (THESEUS and M-MATISSE). ESA's decision on the adoption of one of these three candidates is expected in June 2026. The Plasma Observatory mission concept consists of seven identical spacecraft with complete suites of plasma instrumentation to monitor Earth's magnetosphere at high temporal and spatial resolution. Each measurement suite includes a magnetometer, wave instruments, an electron spectrometer, and an ion mass spectrometer (Ion Mass Composition Analyzer (IMCA). The University of Bern will contribute with their expertise in ion space instruments and space instrument calibration to IMCA.

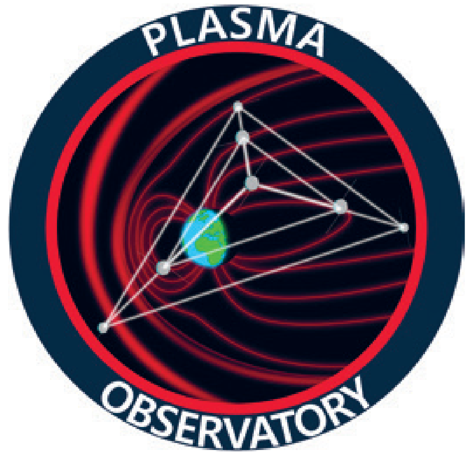
Publications

Please refer to: https://plasma-observatory.inaf.it/publications

Time-Line	From	To
Planning	Jul. 2026	Aug. 2028
Construction	Sep. 2028	2036
Measurement phase	2037	2039
Data evaluation	2037	2039



IMCA CAD model showing the main subsystems (left) and instantaneous Field-of-View (FoV; right).



Institute
Space Res. & Planetology, Physics Institute, Univ. Bern (UNIBE), Bern, Switzerland

In cooperation with
Inst. Space Astrophysics and Planetology (INAF-IAPS), Rome, Italy;
Max Planck Institute for Solar System Research (MPS), Göttingen, Germany;
Inst. Space and Astronautical Science (ISAS), Sagamihara, Japan;
Univ. New Hampshire (UNH), Durham, USA;
Lab. de Physique des Plasmas (LPP), Palaiseau, France;
Budapesti Műszaki és Gazdaságtudományi Egyetem and Inst. Earth Physics and Space Science (BME&EPSS), Budapest, Hungary;
Royal Belgian Inst. Space Aeronomy (BIRA-IASB), Brussels, Belgium

Principal Investigator(s)
Lead: M.F. Marcucci (INAF-IAPS)
Co-Lead: A. Retino (LPP-CNRS)

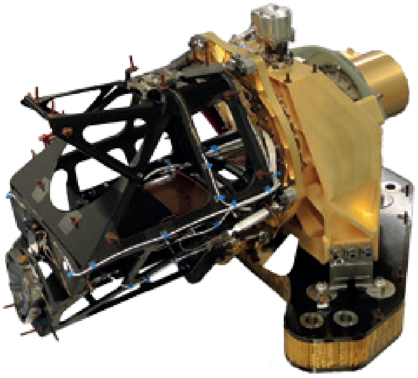
Swiss Principal Investigator(s)
A. Galli (Co-I of IMCA; UNIBE)

Contribution
Ion Mass Composition Analyzer (IMCA)

Website(s)
https://plasma-observatory.inaf.it

7 Comets, Planets

7.1 CaSSIS – The Colour and Stereo Surface Imaging System



The CaSSIS instrument onboard the ESA Trace Gas Orbiter (TGO) at Mars. Image credit: UNIBE.

Institute
Inst. Space Res. & Planetology Div., Univ. Bern (UNIBE), Bern, Switzerland

In cooperation with
INAF-Padova, Italy;
Space Research Centre, Warsaw, Poland;
Univ. Arizona, USA

Principal/Swiss Investigator(s)
N. Thomas (UNIBE)

Co-Investigator(s)
G. Cremonese (Co-PI), M. Banaskiewicz, J.C. Bridges, S. Byrne, V. Da Deppo, S. Diniega, M.R. El-Maarry, E. Hauber, A. Ivanov, L. Keszthelyi, R. Kirk, R. Kuzmin, N. Mangold, L. Marinangeli, M. Massironi, A.S. McEwen, C. Okubo, P. Orleanski, A. Pommerol, L.L. Tornabene, P. Wajer, J.J. Wray

Contribution
Development & construction of instrument(s): The hardware for CaSSIS was built and completed in 2015 by UNIBE. It has been operating at Mars since 2018 from onboard ESA's ExoMars Trace Gas Orbiter and continues to be operated through the UNIBE under a PRODEX contract.

Industrial hardware contract(s)
Thales-Alenia Space Switzerland, Zurich

Website(s)
https://www.cassis.unibe.ch

Purpose of Research

The Colour and Stereo Surface Imaging System (CaSSIS) is onboard ESA's ExoMars Trace Gas Orbiter (EMTGO) mission, launched in March 2016. The imaging system has the following main objectives:

1. Image and analyse surface features possibly related to trace gas sources and sinks in order to better understand the broad range of processes that might be related to trace gases. The science team will compile and prioritise a list of observation targets needed to test specific hypotheses concerning active surface processes on Mars. We will begin to address this objective early in the mission, prior to new trace-gas discoveries from EMTGO. CaSSIS can also investigate mineralogical diversity through colour variations in older terrains.

2. Map regions of trace gas origination as determined by other experiments to test hypotheses. EMTGO experiments are designed to discover trace gases and study atmospheric dynamics to trace the gases back to their source regions (perhaps to tens of km). Once these discoveries are made (if that goal is realised), CaSSIS will place top priority on imaging these regions to formulate and test specific hypotheses for the origin and/or release of trace gases.

3. Search for and help certify the safety of new candidate landing sites driven by EMTGO discoveries. The discovery of methane has helped stimulate exploration plans in Europe and the U.S. A portion of NE Syrtis Major has recently been approved for priority Mars Reconnaissance Orbiter (MRO) coverage as a candidate landing site; this site is at the margin of the Syrtis Major methane plume identified by Mumma et al. (2009).

It is likely that a pair of NASA/ESA landers will also consider methane areas for landing sites in the 2020s and later. At the workshop 'Habitability and Landing Sites' held in the UK, the surfaces associated with methane plumes were identified as high priority exploration targets. CaSSIS will play a role in defining new landing sites.

Past Achievements and Status

The instrument entered its prime mission in April 2018 and has since returned over 56,000 images of the surface of Mars in colour and more than 2300 stereo pairs. The high signal to noise has made it an excellent instrument for identifying subtle changes in surface mineralogy. The instrument has obtained numerous images of the ExoMars Rover landing site in Oxia Planum and is supporting the development of operational plans. It has also supported studies of the InSight and Perseverance landing sites.

Images showing spectral diversity and active processes have been obtained as well as images of Phobos. Images are placed within ESA's Planetary Science Archive 6 months after acquisition.

The instrument will run until at least the end of 2028 and possibly beyond.

Publications

Bilder vom Mars (2022) Nicolas Thomas and the CaSSIS Team, ISBN-13: 9783039221516, Pub. Werd & Weber, Thun.

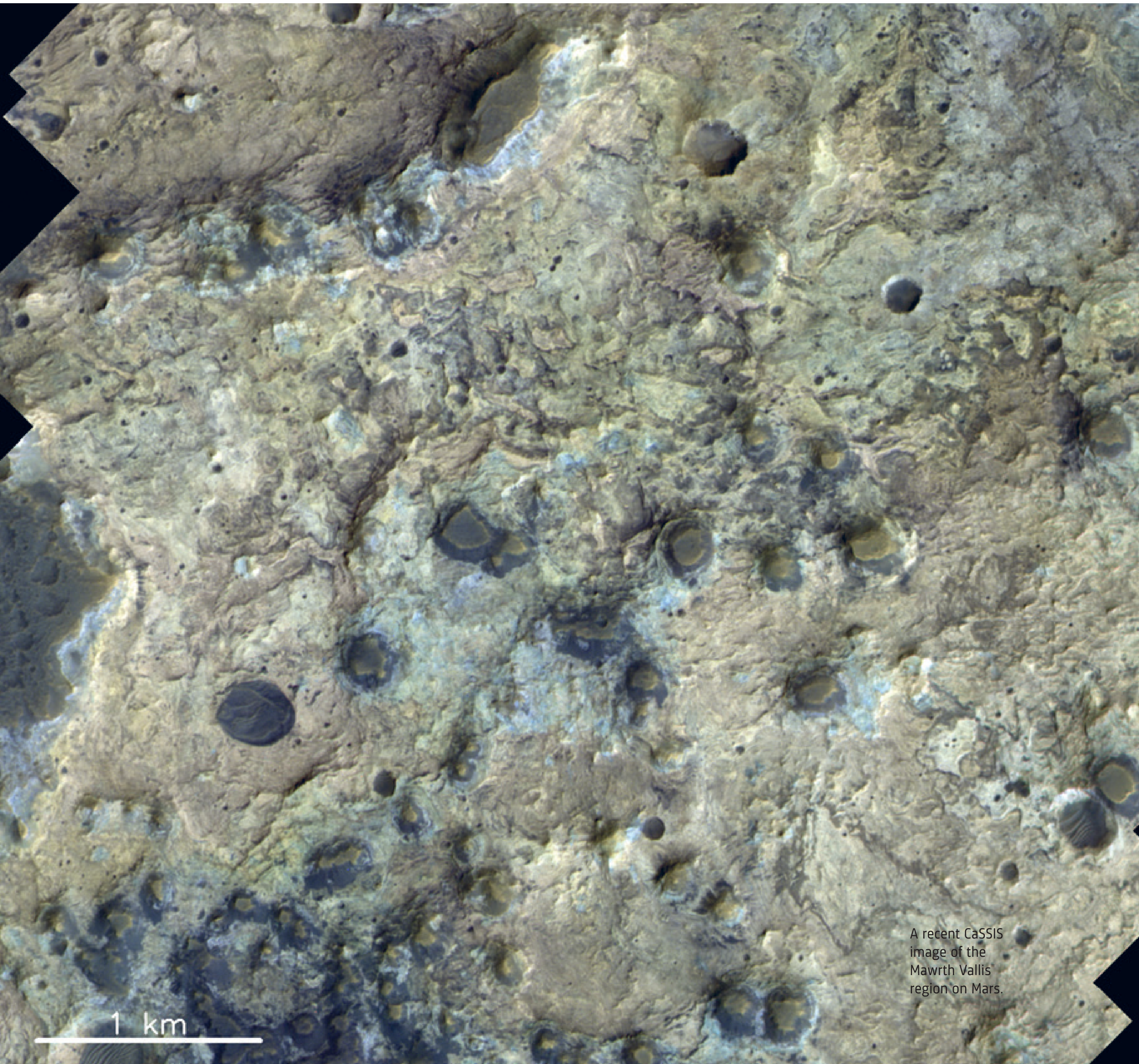
Roloff V, and 24 colleagues (2017) **On-ground performance and calibration of the ExoMars Trace Gas Orbiter CaSSIS Imager**, Space Science Reviews 212: 1871-1896.

Thomas N, and 60 colleagues (2017) **The Colour and Stereo Surface Imaging System (CaSSIS) for the ExoMars Trace Gas Orbiter**, Space Science Reviews 212: 1897-1944.

Abbreviations

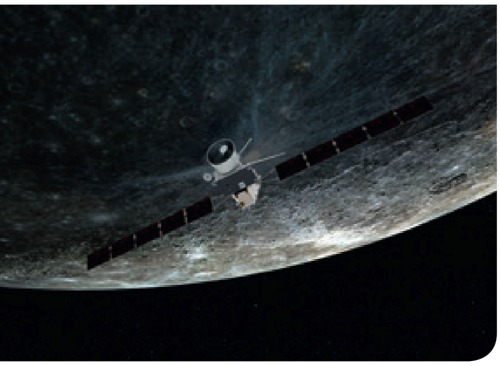
CaSSIS	Colour and Stereo Surface Imaging System
EMTGO	ExoMars Trace Gas Orbiter
MRO	Mars Reconnaissance Orbiter

Time-Line	From	To
Planning	Apr. 2010	Oct. 2013
Construction	Oct. 2013	Nov. 2015
Measurement phase	Apr. 2018	2028 at least
Data evaluation	2018	2029, poss. beyond



A recent CaSSIS image of the Mawrth Vallis region on Mars.

7.2 BELA – BepiColombo Laser Altimeter



Artist's impression of BepiColombo during a gravity assisted flyby of Mercury. Multiple flybys of Earth, Venus and Mercury will have occured before orbit insertion at Mercury in Nov. 2026. Image credit: ESA.

Institute
Space Res. & Planetology Div., Univ. Bern, (UNIBE), Bern, Switzerland

In cooperation with
DLR Institute for Planetary Res. (DLR), Berlin-Adlershof, Germany; Max-Planck-Inst. Sonnensystemforsch. (MPS), Katlenburg-Lindau, Germany

Principal Investigator(s)
N. Thomas (Co-PI, UNIBE), H. Hussmann (Co-PI, DLR)

Swiss Principal Investigator(s)
N. Thomas (UNIBE)

Co-Investigator(s)
30 geophysicists from Europe

Contribution
Development & construction of instrument(s): UNIBE developed and built BELA with parts supplied by Germany and Spain.

Industrial hardware contract(s)
Thales-Alenia Space Switzerland; SYDERAL SWISS SA; FISBA Optik; Cassidian Optronik, Germany

Website(s)(s)
https://www.bela.space.unibe.ch

www.esa.int/Science_Exploration/Space_Science/BepiColombo

Purpose of Research

The 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 on 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 favourable 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 comprises a transmitter producing a 50 mJ laser pulse at 1064 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 1064 nm filter before collection on an avalanche photodiode detector. Conversion to a range is performed using time-of-flight electronics within an electronics box, which also houses the instrument computer and power supply.

Past Achievements and Status

The flight model was delivered to ESA and integrated on the spacecraft in 2016. Performance analyses (e.g. Steinbruegge et al., 2018) indicate excellent results should be obtained with the present instrument status. The spacecraft was launched in 2018 and is currently in flight to Mercury. Testing of BELA has proceeded nominally and the instrument appears to be fully functional. Orbit insertion is foreseen at the end of 2026 and the prime mission will start in April 2027 for, nominally, a minimum of 1 Earth year.

Abbreviations

BELA BepiColombo Laser Altimeter

Publications

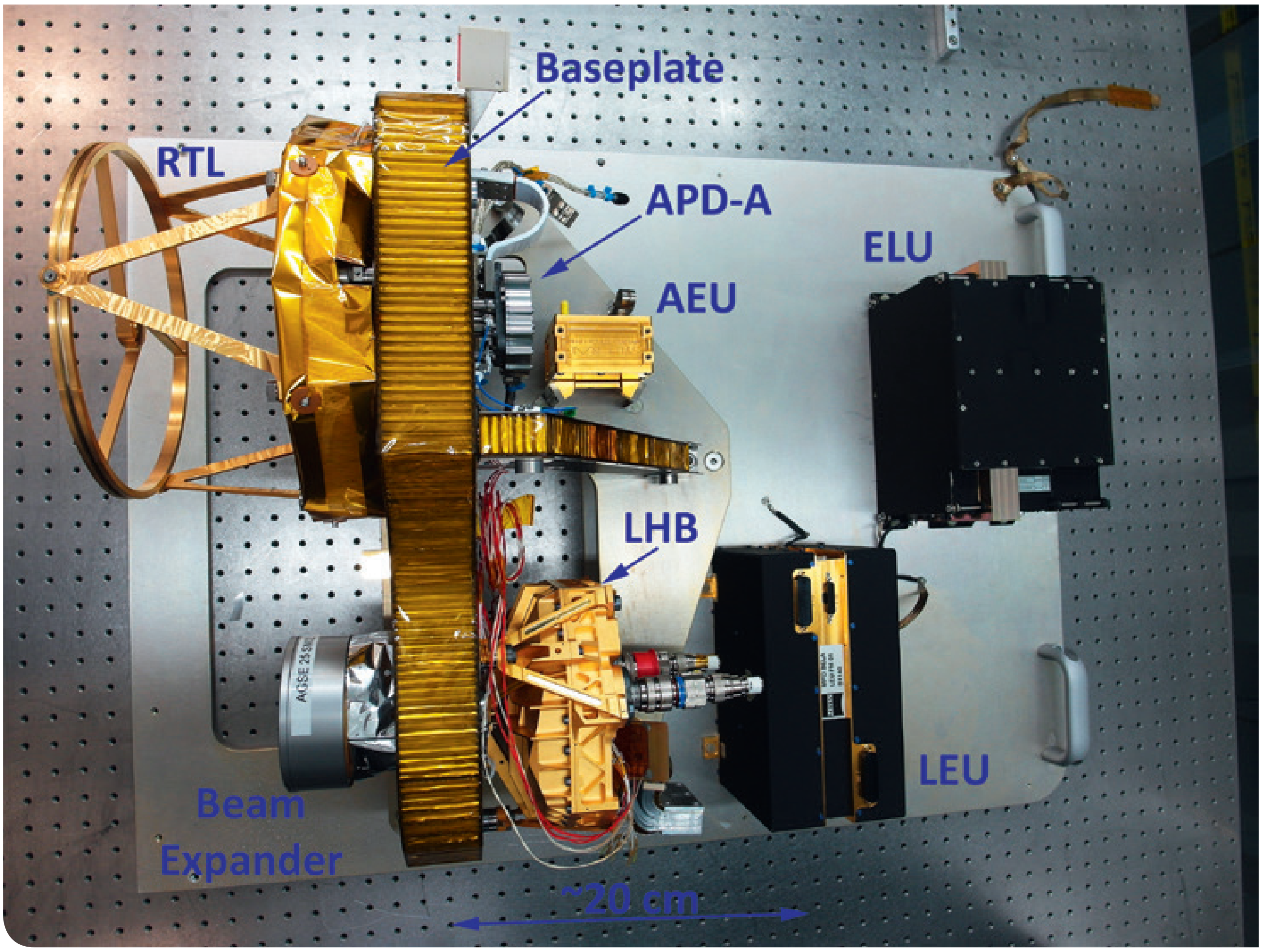
Gunderson K, Thomas N (2010) **BELA receiver performance modeling over the BepiColombo mission lifetime**, Planetary and Space Science 58: 309-318.

Steinbrügge G et al. (2018) **The performance of the BepiColombo Laser Altimeter (BELA) prior launch and prospects for Mercury orbit operations**, Plan. Space Sci. 159: 84, doi:10.1016/j.pss.2018.04.017.

Thomas N et al. (2007) **The BepiColombo Laser Altimeter (BELA): Concept and baseline design**, Planetary and Space Science 55: 1398-1413.

Thomas N, Hussmann H, Lara LM (2019) **The BepiColombo Laser Altimeter (BELA): A post-launch summary**, CEAS Space J. 11: 371.

Time-Line	From	To
Planning	2004	2008
Construction	2008	2016
Measurement phase	2027	2029
Data evaluation	2027	2030



The BELA system on the bench (without cabling). The transmitter comprises the LHB (laser head box), the beam expander and the LEU (laser electronics unit). The receiver comprises the RTL (receiver telescope), the avalanche photodiode (APD), and associated electronics. The electronics unit (ELU) houses boards for the rangefinder, the on-board computer and the power supply.

7.3 CLUPI – CLose-UP Imager for ExoMars Rover 2028

Exomars/RFM mission logo. Image credit: ESA/NASA.

Institute
Space Exploration Institute (SEI), Neuchâtel, Switzerland

In cooperation with
F. Westall (Co-PI; CNRS, Orléans, France); B.A. Hofmann (Co-PI; NHM, Bern)

Principal/Swiss Investigator(s)
J.-L. Josset (SEI)

Co-Investigator(s)
T. Bontognali, M. Josset, D. Koschny, O. Rüsch, T. Kurz (Co-I; SEI); N. Kuhn, (Univ. Basel) K. Foelmi †, E. Verreccia, S. Erkman (Univ. Lausanne); L. Diamond (Univ. Bern) and 15 other scientists from Canada, France, Italy, Germany, Austria, The Netherlands, Belgium, and United Kingdom

Contribution
Development & construction of instrument(s): High Res. Imaging instr. for colour close-up obs. of Martian rocks, surfaces, and samples.

Industrial hardware contract(s)
TAS-CH; CSEM; Fisba AG; Petitpierre SA; SYDERAL SWISS SA; e2v (funded by CNES)

Website(s)
https://www.space-x.ch

Purpose of Research

The ExoMars mission aims to land a rover on Mars, dedicated to search for signs of life. The ExoMars rover is equipped with a drill to collect material from outcrops up to 2 m deep and a set of scientific payloads. CLUPI, the CLose-UP Imager, is a high-performance colour imaging system as part of this payload. It plays an important role in achieving mission objectives.

The two main scientific objectives are:

- Geological context for establishing habitability:
  - Identification of the lithologies.
  - Identification of eventual structures/textures (primary or secondary alteration features) that could provide information to interpret habitability.
- Identification of biosignatures:
  - Observation of structural features.
  - Observation of concentrations of carbon (EXM looking for carbonaceous biosignatures).

CLUPI is a miniaturised, low-power, efficient and highly adaptive imaging system of less than 1 kg, with specific micro-technical innovations regarding its sensor and focus mechanism.

The imager has the ability to focus from about 11 cm to infinity (about 16 µm/pixel at 20 cm from the target), with colour imaging achieved using a detector with three layers of pixels (red, green, and blue). CLUPI can also perform auto-exposure, auto-focus, binning, windowing, and z-stacking to send a flexible amount of data and increase the scientific return. A calibration target is used to colour calibrate images during science operations.

CLUPI will be accommodated on the drill box of the rover and use mirrors to observe in three different fields-of-view. Taking advantage of both the rover's mobility and the degrees of freedom of the drill, CLUPI will carry out specific science operations:

- Geological environment survey, for the area immediately in front of the rover.
- Close-up observation of outcrops, to obtain geological information on rock texture and structure, possible alterations, etc., to allow the geological history of targets to be established as well as appraising the potential preservation of biosignatures.
- Drilling area observation.
- Drilling operation observation, to monitor the process, observe the generated mound of fines with potential colour and textural variations, and obtain information on the mechanical properties of the soil.
- Drill hole observation (with deposited fines).
- Drilled core sample observation collected by the drill up to 2 m below the Martian surface.

Past Achievements and Status

This mission should have been launched in September 2022 but due to political reasons, the Russian collaboration, through its space agency Roscosmos, with the European Space Agency (ESA) was suspended. As a consequence, the launch of the mission was cancelled. The ExoMars mission has now been approved in a new configuration with a launch planned in 2028 to allow for the replacement of the Russian components of the mission. A new collaboration agreement with NASA was signed in April 2024 in order to contribute key elements.

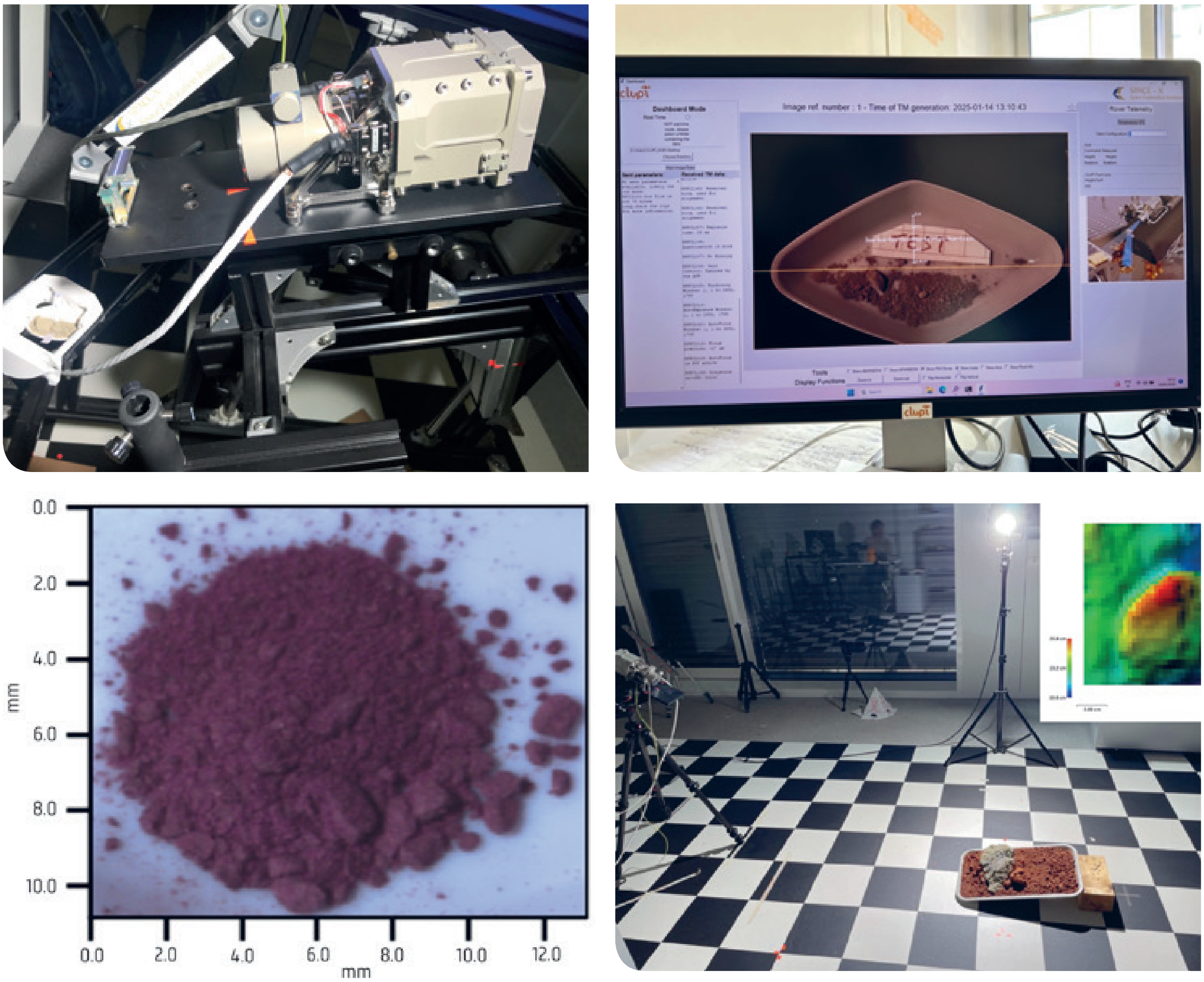
The instrument has been built but the 'new' mission requires maintenance and updates / refurbishment of the instrument to be compliant with the new mission configuration, in order to satisfy the operations optimisation and operations safety. The launch is now scheduled for 2028. A science validation phase with operation preparation is planned up to the arrival on the surface of Mars in 2030.

Publications

Josset J-L et al. (2017) **The Close-Up Imager (CLUPI) on board the ESA ExoMars Rover: Objectives, description, operations, and science validation activities**, Astrobiology 17: 595-611.

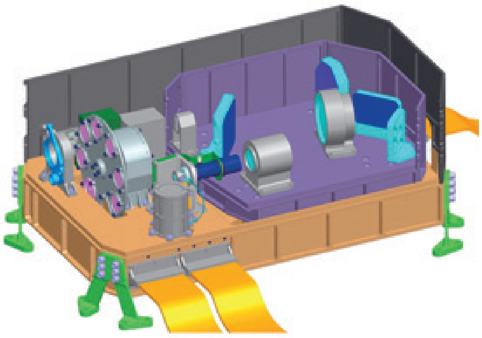
Vago J et al. (2017) **Habitability on early Mars and the search for biosignatures with the ExoMars Rover**, Astrobiology 17: 471-510.

Time-Line	From	To
Planning	2003	2010
Construction	2011	2026
Measurement phase	2028	2031
Data evaluation	2030	2032



Top left: CLUPI Flight Model Representative on a Drill/Rover simulator taking images of samples. Top right: Dashboard for CLUPI operations and data acquisition. Bottom left: Image data acquired by CLUPI of a representative rock powder. Bottom right: Operation simulations with inset showing colour-coded 3D topography from CLUPI stereo imagery of a representative rock sample. All these activities are performed in the CLUPI Science Operations Lab. of SEI in EPFL/Microcity (Neuchâtel, Switzerland). Image credits: SEI.

7.4 EnVision VenSpec-H: Venus Spectrometer with High Resolution



The VenSpec-H instrument box (optical bench).

Institute
Inst. Geophysics, Dept. Earth & Planetary Sciences, ETH Zurich, Switzerland

In cooperation with
Fachhochschule Nordwestschweiz (FHNW)
Hochschule Luzern (HSLU);
KOEGL Space GmbH;
Space Acoustics GmbH;
Royal Belgian Inst. Space Aeronomy, (BIRA-IASB), Belgium;
OIP (Industrial Prime);
ESA;
other international VenSpec partners

Principal Investigator(s)
S. Robert (BIRA-IASB)

Swiss Principal Investigator(s)
P. Tackley (ETH Zurich)

Co-Investigator(s)
(Co-Instrument Lead Scientists)
L. Lara (IAA/IDR, Spain), M. Ferus (JHI-CAS, Czechia)

Contribution
Development & construction of instrument(s):
Co-development of the VenSpec-H spectrometer of EnVision Venus orbiter including structural and thermal engineering, delivery of mathematical models, and Filter Wheel Mechanism development.

Website(s)
www.cosmos.esa.int/web/envision/venspec-h

Purpose of Research

EnVision is an orbital mission to Venus being developed by the European Space Agency (ESA). Its overall science goals are:

– To decipher the sequence of tectono-magmatic events that generated the regional and global surface features of Venus, and understand the geodynamics framework that controls the release of internal heat over Venus history.

– To search for ongoing geological processes and determine which parts of the planet are active in the present era.

– To characterise regional and local geological units, to better assess whether Venus once had condensed liquid water on its surface and was thus perhaps hospitable for life in its early history.

The result of these will be to provide a holistic view of the planet from its inner core to upper atmosphere to determine how and why Venus and Earth evolved so differently. The Swiss contribution to EnVision consists of co-developing VenSpec-H (Venus Spectrometer with High resolution). VenSpec-H will monitor the composition of minor species in the lower atmosphere on the night-side and above the clouds on the day-side, to enable characterisation of volcanic plumes and other sources of gas exchange with the surface of Venus, complementing VenSAR and VenSpec-M (Venus Spectrometer Multispectral imager) surface and SRS subsurface observations.

VenSpec-H will focus on the volcanic and cloud forming gases, and search for composition anomalies potentially related to volcanic activity.

The Swiss team is responsible for the mechanical and thermal engineering of the instrument box, and for the development and industrial implementation of the Filter Wheel Mechanism (FWM). In 2025, activities focused on iPDR preparation, thermal model correlation and validation, and the development of the FWM by the industrial partner, Almatech (Switzerland).

EnVision will carry a total of five instruments: the VenSAR synthetic aperture radar, the SRS Subsurface Radar Sounder, and three VenSpec spectrometers; additionally, the satallite radio link will be used for the RSE Radio Science Experiment. The VenSpec instrument suite consists of three channels: VenSpec-M, VenSpec-H, VenSpec-U (Venus Spectrometer Ultraviolet), and the Central Control Unit (CCU). All three channels have their independent optics due to the very different imaging concepts and wavelength ranges covered.

Past Achievements and Status

Instrument Mechanical Engineering – Mechanical activities focussed on preparation of the iPDR (Instrument Preliminary Design Review) structural mathematical model, development of the Structural Analysis Report, Structural Model Description, and Fracture Control Plan. FEM modelling was performed, based on updated CAD data. Dynamic testing of the contamination cover was performed.

Thermal Engineering – The thermal breadboard test was completed and formally reviewed in 2025. Model correlation was achieved according to ECSS standards without requiring fundamental model assumption changes. A new detailed PDR-loop thermal model was developed, including updated layout, straylight baffle integration, and Venus orbital hot/cold cases. Transient analyses covered operational, non-operational, calibration, and aerobraking scenarios.

Filter Wheel Mechanism (FWM) – FWM activities concentrated on supporting the handover to the industrial partner, Almatech. Based on the advancements of the Breadboard activities in Phase B, development of the FWM progressed in 2025 to EQSR. The Critical Design Review (CDR) is currently being prepared for 2026.

Science Activities – The Swiss team actively participated in the VenSpec Science Working Team, including Region of Interest (ROI) definition. Multiple international conference presentations were given in 2025, and key Venus science publications were published, including Bussmann et al. (2025; see further below). Research focused on Venus interior dynamics, rifting processes, impact history, and volatile evolution in preparation for EnVision data exploitation.

Publications

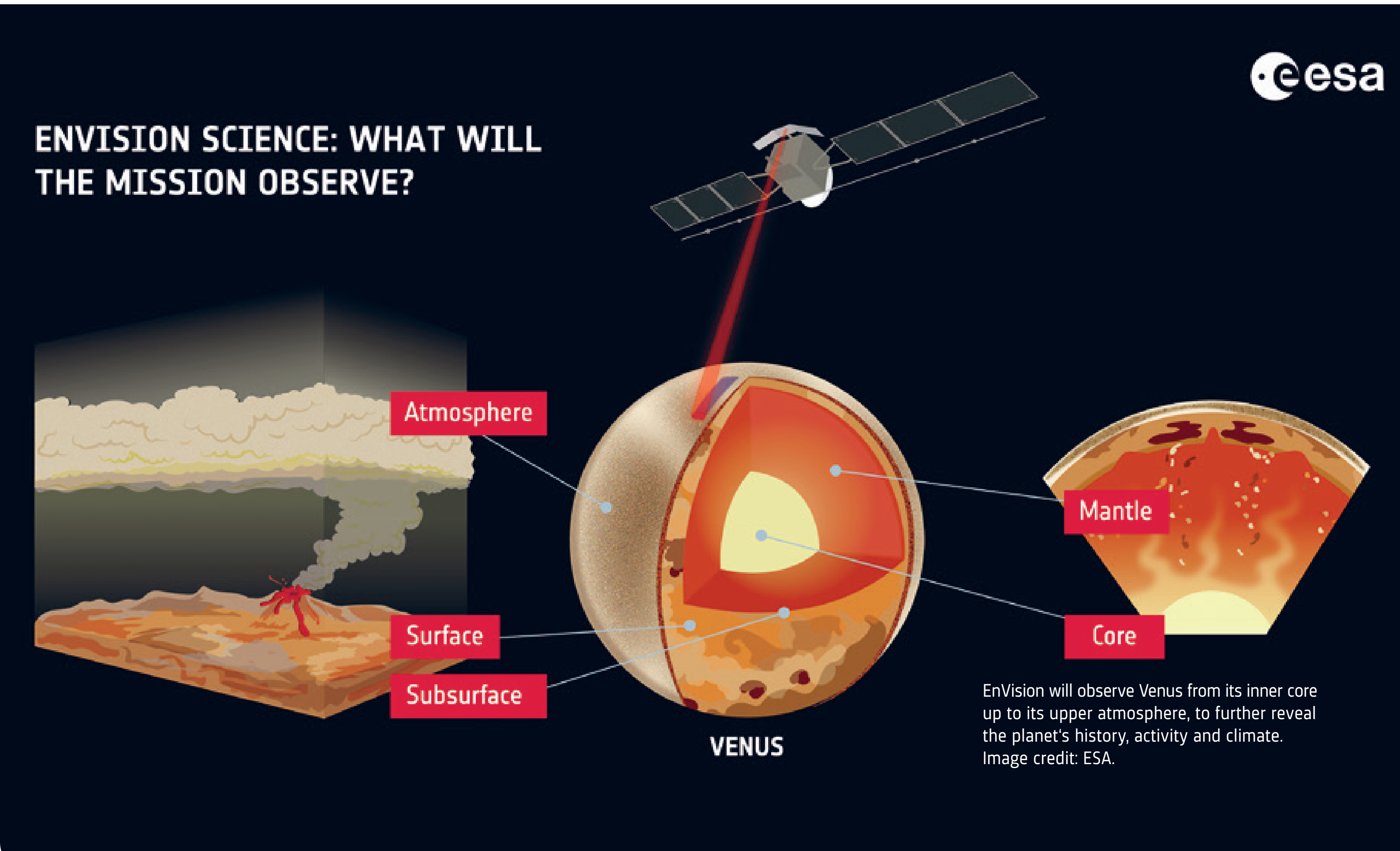
Bussmann M, Reinhardt C, Gillmann C, Meier T, Stadel J, Tackley P, Helled R (2025) **The possibility of a giant impact on Venus**, Astron. Astrophys.: 702, A106, doi.org/10.1051/0004-6361/202555802

De Cock R et al. (2025) **Design of the VenSpec-H instrument on ESA's EnVision mission: highlighting the development of critical elements (FFCP and grating)**, J. Appl. Rem. Sens.: 19(1), 014523, doi.org/10.1117/1.JRS.19.014523

Abbreviations

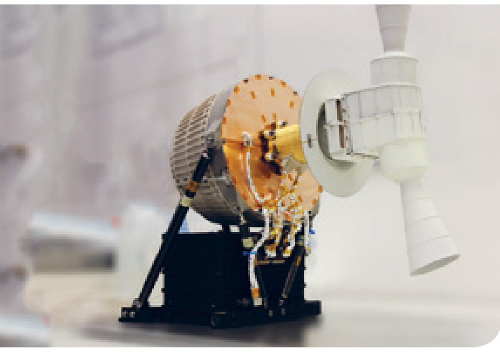
VenSpec-H	Venus Spectrometer with High resolution
VenSpec-M	Venus Spectrometer Multispectral imager
VenSpec-U	Venus Spectrometer Ultraviolet

Time-Line	From	To
Planning	Jul. 2021	2026
Construction	~2026	~2029
Measurement phase	mid-2033	~2039
Data evaluation	2034	-



EnVision will observe Venus from its inner core up to its upper atmosphere, to further reveal the planet's history, activity and climate. Image credit: ESA.

7.5 BepiColombo: Composition of Crust, Exosphere, Evolution, Formation and Evolution of Planet Mercury



The STROFIO instrument (part of SERENA experiment) on BepiColombo.

Institute
Space Res. & Planetology, Physics Inst., Univ. Bern, (UNIBE), Bern, Switzerland

In cooperation with
Inst. Fisica dello Spazio Interplanetari (IFSI), Rome, Italy (S. Orsini, A. Milillo); Swedish Space Research Inst. (SSRI), Kiruna, Sweden (S. Barabash, M. Wieser); Southwest Research Inst. (SWRI), San Antonio, TX, USA (S. Livi)

Principal Investigator(s)
S. Orsini (IFSI), S. Barabash (SSRI)

Swiss Principal Investigator(s)
P. Wurz (UNIBE)

Co-Investigator(s)
A. Vorburger, A. Galli, J. Hener (UNIBE)

Contribution
Development & construction of instrument(s): Within this project, there is participation in two instruments of the MPO BepiColombo mission. The SERENA instrument comprises several units, for which we provide substantial hardware for the STROFIO mass spectr. and the MIPA ion sensor.

Industrial hardware contract(s)
Empa, Rekolas, Sulzer Innotec, SWSTech AG

www.esa.int/Science_Exploration/Space_Science/BepiColombo

Purpose of Research

The European Space Agency (ESA) has defined the Cornerstone Mission, named BepiColombo, for the detailed exploration of the 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.

The launch of BepiColombo successfully took place on 20 October 2018 from the European Spaceport (Kourou, French Guiana). The spacecraft is currently on its way to Mercury with a scheduled arrival in December 2026. After orbital insertion, the nominal dataphase will start in March 2027 and will last for one year with a possible extension of an additional year.

The Univ. Bern is participating, within an international collaboration, in the BepiColombo mission on the Mercury Planetary Orbiter (MPO) spacecraft by contributing ion-optical units to two mass spectrometers: i) one mass spectrometer, STROFIO (Start from a Rotating Field Mass Spectrometer), is for the measurement of the neutral atmosphere with high sensitivity, and ii) one instrument, MIPA (Miniature ion Precipitation Analyser), is for the measurement of the ionised part of the atmosphere and the plasma environment.

Past Achievements and Status

Data analysis of the cruise phase data is ongoing, together with preparation of the science phase in the orbit of Mercury.

During the spacecraft's journey to Mercury, BepiColombo made two Venus flybys (on 15 Oct. 2020 and 11 Aug. 2021) and five Mercury flybys (2 Oct. 2021, 23 Jun. 2022, 20 Jun. 2023, 5 Sep. 2024, 9 Jan. 2025). These flybys offered unique opportunities to simultaneously characterise the plasma populations and the magnetic field properties of the solar wind in the vicinity of the innermost planet of the Solar System, at 0.4 AU, and its interaction with Mercury's magnetosphere. Data analysis of these encounters is ongoing. Orbit insertion is scheduled for December 2026.

Publications

Wurz P, Gamborino D, Vorburger A, Raines JM (2019) **Heavy ion composition of Mercury's magnetosphere**, J. Geophys. Res. 124: 10 pp, doi.org/10.1029/2018JA026319

Wurz P, Fatemi S, Galli A et al. (2022) **Particles and photons as drivers for particle release from the surfaces of the Moon and Mercury**, Sp. Sci. Rev. 218(10): doi.org/10.1007/s11214-022-00875-6

Wurz P, Jäggi N, Galli A et al. (2025) **The interplay of surface composition, mineralogy, and physical conditions that affect the surface release processes and particle environment of Mercury**, Planet. Sci. J. 6: 24, 40 pp, doi.org/10.3847/PSJ/ad95fa

Abbreviations

MIPA	Miniature Ion Precip. Analyser
MMO	Mercury Magnetospheric Orbiter
MPO	Mercury Planetary Orbiter Exp.
SERENA	Search Exopheric Refilling and Emitted Natural Abundances
STROFIO	Start from a Rotating Field Mass Spectrometer

Time-Line	From	To
Measurement phase	2027	2028
Data evaluation	2027	2030

7.6 BepiColombo MMO: Measurement of the Particle and Plasma Environment at Mercury

Purpose of Research

The European Space Agency (ESA) has defined the Cornerstone Mission, named BepiColombo, for the detailed exploration of the 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.

The launch of BepiColombo successfully took place on 20 October 2018 from the European Spaceport (Kourou, French Guiana). The spacecraft is currently on its way to Mercury with a scheduled arrival in December 2026. After orbital insertion, the nominal dataphase will start in March 2027 and will last for one year with a possible extension of an additional year.

The University of Bern (Bern, Switzerland) is participating, within an international collaboration, in the BepiColombo mission. Our contribution includes ion-optical elements to the Energetic Neutral Atom (ENA) imaging instrument of the Mercury Plasma Particle Experiment (MPPE) on the Mercury Magnetospheric Orbiter (MMO) spacecraft of the Japan Aerospace Exploration Agency (JAXA).

The ENA instrument will record images of the particle and plasma environment in the near-Mercury space. The panel on the right in the above figure shows the ENA instrument on the MMO satellite. The white semicircle shows the entrance system, protruding from the spacecraft surface on the bottom left. The panel on the left shows the flight model of the ENA instrument without heat shields.

Past Achievements and Status

During the spacecraft's journey to Mercury, BepiColombo made two Venus flybys (on 15 October 2020 and 11 August 2021) and several Mercury flybys (2 October 2021, 23 June 2022, 20 June 2023, 5 September 2024, 1 December 2024, 9 January 2025) before orbital insertion.

Detailed analysis of data collected during these encounters is currently being conducted.

Publications

Saito Y, Delcourt D, Hirahara M et al. (2021) **Pre-flight Calibration and Near-Earth Commissioning Results of the Mercury Plasma Particle Experiment (MPPE) onboard MMO (Mio)**, Sp. Sci. Rev. 217: 70, 91 pp, doi.org/10.1007/s11214-021-00839-2

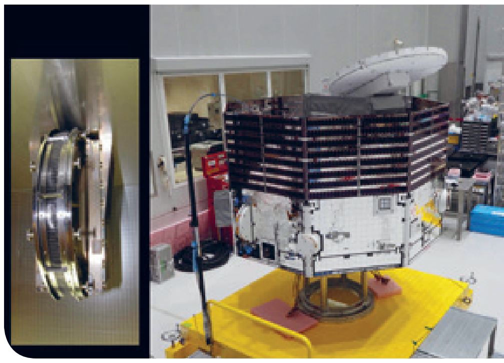
Wurz P, Gamborino D, Vorburger A, Raines JM (2019) **Heavy ion composition of Mercury's magnetosphere**, J. Geophys. Res. 124: 10 pp, doi.org/10.1029/2018JA026319

Wurz P, Fatemi S, Galli A et al. (2022) **Particles and photons as drivers for particle release from the surfaces of the Moon and Mercury**, Sp. Sci. Rev. 218(10): doi.org/10.1007/s11214-022-00875-6

Abbreviations

ENA	Energetic Neutral Atom
MMO	Mercury Magnetospheric Orbiter
MPPE	Mercury Plasma Particle Experiment

Time-Line	From	To
Measurement phase	2027	2028
Data evaluation	2027	2030



Main panel: The Mercury Magnetospheric Orbiter (MMO) spacecraft showing the ENA instrument. See body text for further details.

Institute
Space Res. & Planet., Physics Inst., Univ. Bern, (UNIBE), Bern, Switzerland

In cooperation with
Swedish Space Res. Inst., Kiruna, Sweden (S. Barabash, M. Wieser);
Japan Aerospace Exploration Agency (JAXA), Japan

Principal Investigator(s)
Y. Saito (JAXA, Japan)

Swiss Principal Investigator(s)
P. Wurz (UNIBE)

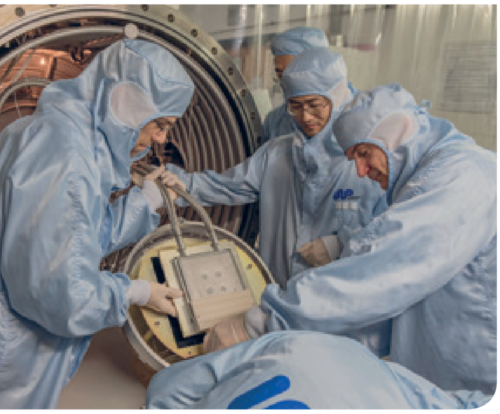
Co-Investigator(s)
A. Galli, A. Vorburger (UNIBE)

Contribution
Development & construction of instrument(s): Participation in the MPPE experiment within the ENA instruments for the BepiColombo mission. The MPPE experiment on the MMO spacecraft (Mio spacecraft) of BepiColombo, for which Bern provided substantial hardware for the ENA instrument.

Industrial hardware contract(s)
Rekolas; Sulzer Innotec, Switzerland

Website(s)
www.esa.int/Science_Exploration/Space_Science/BepiColombo

7.7 MINPA – Mars Ions and Neutral Particles Analyser



Integration of the MINPA flight instrument, for the Chinese Mars Global Remote Sensing Orbiter and Small Rover mission, into the MEFISTO calibration facility for calibration with ions and ENAs.

Institute
Physics Inst., Univ. Bern (UNIBE), Bern, Switzerland

In cooperation with
National Space Science Center, NSSC; Chinese National Space Science Centre, CAS China

Principal Investigator(s)
A. Zhang (NSSC)

Swiss Principal Investigator(s)
P. Wurz (UNIBE)

Co-Investigator(s)
A. Galli (UNIBE)

Contribution
Research based on existing instrument(s): Mars Ions and Neutral Particles Analyser (MINPA)

Website(s)
https://en.wikipedia.org/wiki/Tianwen-1

Purpose of Research

The Mars Global Remote Sensing Orbiter and Small Rover mission, also known as Tianwen-1 (formerly Huoxing-1), is a mission by China to send a spacecraft to Mars, which consists of an orbiter, a lander and a rover.

Tianwen-1 was launched on 23 July 2020 and went into Mars orbit on 21 February 2021. The lander was deployed on 14 May 2021. The scientific instruments on the orbiter are:

- Medium Resolution Camera (MRC) with a resolution of 100 m from a 400 km orbit.
- High Resolution Camera (HRC) with a resolution of 2 m from a 400 km orbit.
- Mars Magnetometer (MM).
- Mars Mineral Spectrometer (MMS), to determine mineral composition.
- Orbiter Sub-surface Radar (OSR).
- Mars Ions and Neutral Particles Analyser (MINPA).

The Univ. Bern (Bern, Switzerland) is participating in the MINPA instrument to study the interaction of the solar wind with the Mars atmosphere by measuring the ion and energetic neutral atom (ENA) environment at Mars.

Past Achievements and Status

MINPA combines, for the first time, the capability to record plasma ions as well as ENAs. For the plasma ions, MINPA performs full-sky observations resolved in energy, angle (elevation and azimuth) and species. For the registration of energetic neutral atoms, charge conversion technology developed by UNIBE is employed, with the ionised particles being analysed by the ion optical system of the ion measurement. MINPA was successfully built and calibrated.

First results of solar wind observations have been published, and analysis of the Martian magnetosphere is ongoing.

Publications

Wang L, Li L, Li W et al. (2024) **Characterizing and removing ultra-violet contamination in ion observations on board Tianwen-1**, MDPI Atmosphere 15(1): 19, 17 pp, doi.org/10.3390/atmos15010019

Wurz P (2000) **Detection of Energetic Neutral Particles**, in 'The Outer Heliosphere: Beyond the Planets', (eds. K Scherer, H Fichtner, and E Marsch), Copernicus Gesellschaft e.V., Katlenburg-Lindau, Germany, 251-288.

Zhang A-B, Kong L-G, Li W-Y et al. (2022) **Tianwen-1 MINPA observations in the solar wind**, Earth and Planetary Physics 6(1): 1-9, doi.org/10.26464/epp2022014

Abbreviations

ENA	Energetic Neutral Atom
MEFISTO	MEsskammer für Flugzeit-InStrumente u. Time-Of-Flight
MINPA	Mars Ions and Neutral Particles Analyser

Time-Line	From	To
Planning	2017	2018
Construction	2019	2019
Measurement phase	2021	ongoing
Data evaluation	2021	ongoing

7.8 Jupiter and Icy Moons Explorer (JUICE/ESA)

Purpose of Research

The European Space Agency selected the Jupiter and Icy Moons Explorer (JUICE) mission as an L-class mission to explore Jupiter and its icy moons (Europa, Ganymede, Callisto) in great detail, with particular emphasis on the moon Ganymede.

The Particle Environment Package (PEP) investigates all particle populations of neutrals, ions, and electrons in Jupiter's magnetosphere and its moons in the energy range from thermal energies to beyond MeV.

The Neutral and Ion Mass spectrometer (NIM) of PEP will measure the chemical composition of the neutral atmospheres of the icy moons and their thermal ion population. JUICE was launched on 14 April 2023 and will arrive in the Jupiter system in July 2031.

Past Achievements and Status

The JUICE mission is currently in the cruise phase to Jupiter. The JUICE mission adoption by ESA was in November 2014, and the industrial prime was selected in July 2015. The Particle Environment Package (PEP) is one of the 10 selected science experiments for the JUICE mission. The Swedish Institute for Space Physics (Sweden) is the PI institution, and the University of Bern (Switzerland) is the Co-PI institution for the PEP experiment. The spacecraft is now on its trajectory to Jupiter, with Earth and Venus flybys in 2024, 2025 and 2026.

The PEP Proto Flight Model (PFM) and the NIM PFM instrument are on the spacecraft, and the flight spare instrument is used for post-launch calibrations and for support of flight operations.

Publications

Vorburger A, Pfleger M, Lindkvist J, Holmström M, Lammer H, Lichtenegger HIM, Galli A, Rubin M, Barabash S, Wurz P (2019) **3D-modeling of Callisto's surface sputtered exosphere environment**, J. Geophys. Res. 124: 13 pp, doi.org/10.1029/2019JA026610

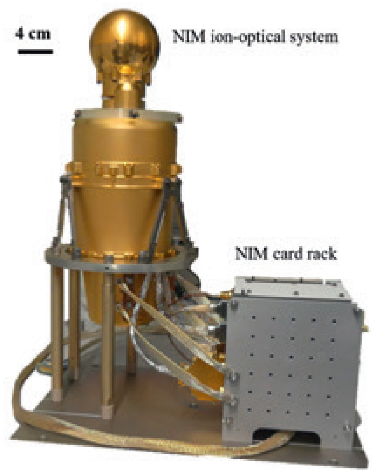
Vorburger A, Wurz P (2021) **Modeling of possible plume mechanisms on Europa**, J. Geophys. Res. 126: 20 pp, doi.org/10.1029/2021JA029690

Wurz P, Jäggi N, Galli A et al. (2025) **The interplay of surface composition, mineralogy, and physical conditions that affect the surface release processes and particle environment of Mercury**, Planet. Sci. J. 6: 24, 40 pp, doi.org/10.3847/PSJ/ad95fa

Abbreviations

JUICE	Jupiter and Icy Moons Explorer
NIM	Neutral and Ion Mass spectrometer
PEP	Particle Environment Package
PFM	Proto Flight Model

Time-Line	From	To
Planning	2012	2014
Construction	2014	2022
Measurement phase	Jul. 2031	2036
Data evaluation	Jul. 2031	2038



NIM instrument of the PEP experiment on JUICE: NIM sensor head (left, golden structure) with electronic box attached (on the right).

Institute
Space Res. & Planet., Physics Inst., Univ. Bern, (UNIBE), Bern, Switzerland

In cooperation with
Swedish Space Res. Inst., Kiruna, Sweden;
App. Phys., Lab., John Hopkins Univ., Laurel, USA;
Max-Planck-Inst. f. Sonnensystemforschung, Göttingen, Germany;
Finnish Met. Inst., Helsinki, Finland;
Univ. Wales Aberystwyth, Wales, UK

Principal Investigator(s)
S. Barabash (PI; IRF, Sweden)
P. Wurz (Co-PI, UNIBE)

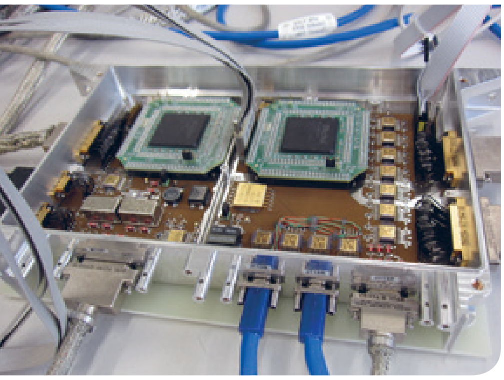
Swiss Principal Investigator(s)
P. Wurz (UNIBE)

Co-Investigator(s)
A. Galli, N. Thomas, M. Tulej, A. Vorburger (UNIBE)

Contribution
Development & construction of instrument(s): Neutral and Ion Mass spectrometer (NIM) for the Particle Environment Package of JUICE.

Website(s)
www.esa.int/Science_Exploration/Space_Science/Juice

7.9 GALA – Ganymede Laser Altimeter on JUICE



The Rangefinder Module (RFM) test-board.

Institute
Space Res. & Planetology Div., Univ. Bern, (UNIBE), Bern, Switzerland

In cooperation with
DLR Institute for Planetary Res. (DLR), Berlin-Adlershof, Germany;
Chiba Institute of Technology, Japan;
Instituto de Astrofisica de Andalucia (IAA), Granada, Spain

Principal Investigator(s)
H. Hussmann (DLR),

Swiss Principal Investigator(s)
N. Thomas (UNIBE)

Co-Investigator(s)
30 geophysicists from Europe

Contribution
Development & construction of instrument(s): UNIBE developed and built the GALA rangefinder module

Industrial hardware contract(s)
Thales-Alenia Space, Switzerland

Website(s)
www.space.unibe.ch/research/current_projects

www.dlr.de/de/forschung-und-transfer/projekte-und-missionen/juice/der-hoehenmesser-gala

Purpose of Research

GALA will measure the topography of the Jovian moon, Ganymede, from onboard ESA's Jupiter and Icy Moons Explorer (JUICE) mission. The University of Bern contributed the rangefinder electronics to the laser altimeter system.

This was a derivative of the BepiColombo Laser Altimeter (BELA) rangefinder, which was successfully implemented for the BepiColombo mission to Mercury. The rangefinder will mostly be constructed by 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 can be used to compute the following parameters:

- The altitude of the spacecraft above the surface.
- The topography of the surface (taking into account orbital 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 rangefinder module is a novel type of digital signal processing module for laser altimetry and has been adapted for the higher pulse repetition frequency (30 Hz) to be used for GALA. The signal from the detector is digitised prior to the pulse detection and pulse/time-of-flight analysis.

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 modified digital matched filtering can be applied.

Past Achievements and Status

The flight model of the rangefinder module (RFM) was delivered to DLR and integrated into the flight model of the GALA instrument. The instrument itself is now on the JUICE spacecraft and under test by ESA. The launch was on 14 April 2023, and near-Earth check out has indicated that the instrument is fully functional.

JUICE is scheduled to arrive at Jupiter in July 2031.

Publications

Hussmann H, Lingenauber K, · Kallenbach R, · Enya K, · Thomas N et al. (2019) **The Ganymede laser altimeter (GALA): key objectives, instrument design, and performance**, CEAS Space Journal, 11, 381.

Abbreviations

BELA	BepiColombo Laser Altimeter
GALA	Ganymede Laser Altimeter
JUICE	Jupiter and Icy Moons Explorer
RFM	Rangefinder Module

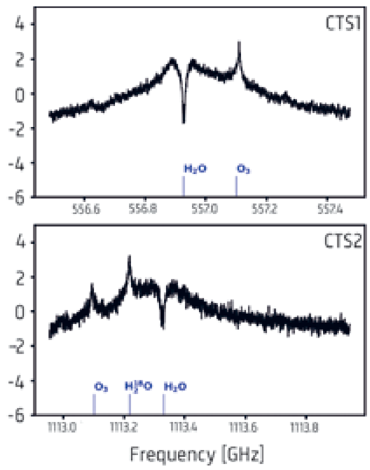
Time-Line	From	To
Planning	2017	2018
Construction	2018	2023
Measurement phase	2031	2034
Data evaluation	2031	2036

7.10 SWI – Submillimeter Wave Instrument on JUICE

Purpose of Research

The Jupiter Icy Moons Explorer (JUICE) is an L-class mission of the ESA Cosmic Vision 2015 – 2025 programme 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 Jupiter's atmosphere, as well as the exosphere and surface properties of its icy moons. SWI consists of two heterodyne receivers that are independently tunable between 530 – 625 GHz and 1080 – 1280 GHz. It includes a steerable off-axis telescope with a 29-cm aperture and different high resolution and broadband spectrometers.

The Institute of Applied Physics (IAP) at the University of Bern is responsible for the optical design of the instrument and the development of optical components as well as an onboard calibration target. In addition, IAP conducted radiometric performance tests of the SWI receiver unit, supports the instrument prime contractor in the radio frequency characterisation of the complete instrument, and participates in the evaluation of the in-flight data.



Observed limb emission spectra from the SWI instrument during the Earth flyby on 21 August 2024.

Past Achievements and Status

IAP delivered all Flight Model and Flight Spare optical hardware as well as the on-board calibration target to the instrument prime contractor, Max Planck Institute for Solar System Research (MPS), in 2020. In addition, IAP played an important role in the optical alignment of the instrument, provided an interferometric testbed for radiometric characterisation of the receivers, and supported the data analysis efforts related to the telescope near-field test campaign that took place at the ESA ESTEC centre (Noordwijk, Netherlands).

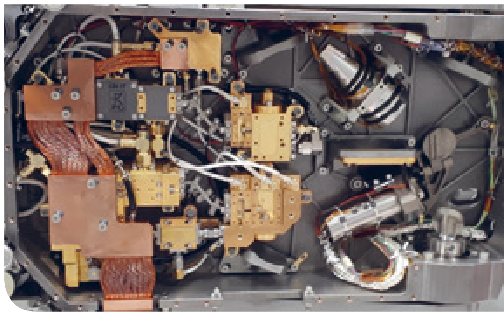
Juice was launched on 14 April 2023, and the Near Earth and Commissioning Phase was successfully concluded in July 2023. The Lunar-Earth Gravity Assist (LEGA) manoeuvre occurred in August 2024 and provided a unique opportunity to calibrate the instrument and perform scientific tests. IAP continues to support MPS in activities concerning the construction of the instrument ground reference model and evaluation of data obtained during the LEGA manoeuvre and the forthcoming Earth Gravity Assist manoeuvre in 2026.

Publications

Jarchow C et al. (2026) **Juice/SWI during the Lunar-Earth-Gravity-Assist. III. Observations of the Earth as Calibration Target**, EGUsphere [preprint], doi.org/10.5194/egusphere-2026-1096

Kotiranta M, Jacob K, Kim H, Hartogh P, Murk A (2018) **Optical design and analysis of the submillimeter-wave instrument on JUICE**, IEEE T-TST 8/6, doi.org/10.1109/TTHZ.2018.2866116

Time-Line	From	To
Planning	2010	2012
Construction	2013	2021
Measurement phase	2031	2035
Data evaluation	2023	>2035



The SWI receiver unit.

Institute
Inst. Applied Physics, Univ. Bern (UNIBE), Bern, Switzerland

In cooperation with
MPS, Germany;
CBK, Poland;
LERMA, France;
NICT, Japan;
AAC Omnisys, Sweden;
RPG, Germany

Principal Investigator(s)
P. Hartogh (MPS)

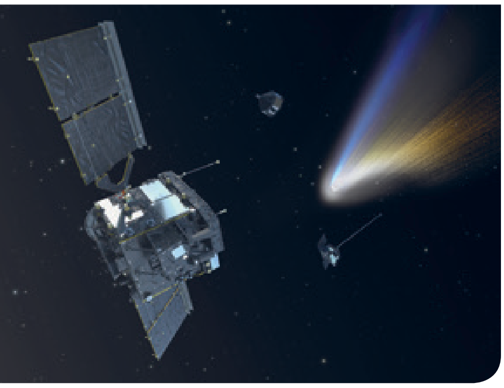
Swiss Principal Investigator(s)
A. Murk (Co-I, UNIBE)

Co-Investigator(s)
M. Kotiranta (UNIBE)
K. Jacob (UNIBE)

Contribution
Development & construction of instrument(s): Optics design, optical components, calibration unit, instrument testing

Industrial hardware contract(s)
Micos Engineering, Switzerland

7.11 MANiaC for ESA Comet Interceptor Mission



ESA Comet Interceptor spacecraft with probes deployed for encounter. Image credit: ESA.

Institute
Space Research and Planetary Sciences, Phys. Inst., Univ. Bern, (UNIBE), Bern, Switzerland

In cooperation with
European Space Agency (ESA);
IWF, Graz, Austria;
IAA, Granada, Spain;
IRAP, Toulouse, France;
DLR Inst. Planetary Res. Berlin, Germany

Principal/Swiss Investigator(s)
M. Rubin (UNIBE)

Co-Investigator(s)
P. Wurz (UNIBE), L. Lara (IAA), P. Garnier (IRAP), H. Lammer (IWF), J. Knollenberg (DLR), and others

Contribution
Development & construction of instrument(s): Comet Interceptor/MANiaC

Industrial hardware contract(s)
Creotech Instrs. SA, Piaseczno, Poland
P&P Software, Tägerwilen, Switzerland
SENER Aerospace & Defence, Barcelona, Spain

Website(s)
www.esa.int/Science_Exploration/Space_Science/Comet_Interceptor

https://cometinterceptor.unibe.ch

Purpose of Research

Comet Interceptor (CI) is a European Space Agency (ESA) mission with contribution from the Japan Aerospace Exploration Agency (JAXA). CI is scheduled to launch in late 2028 or early 2029, with the goal of flying by a yet-to-be-identified comet (Jones et al., 2024). First, the spacecraft will be parked at the Sun-Earth Lagrangian point L2. During this time, an Earth-based campaign will be dedicated to identifying a suitable target for the mission, ideally a Dynamically New Comet (DNC) or even an Interstellar Object (IO).

A key goal of CI is to fly by and study a comet that is more pristine than the periodic comets visited by spacecraft thus far. Ideally, the target comet will be entering the inner solar system for the first time. It is therefore expected to be less thermally processed and can thus help us understand the evolutionary processes that occur in comets that have passed by the sun multiple times.

A key instrument to address this science question is MANiaC, the Mass Analyzer for Neutrals in a Coma. It is composed of a time-of-flight mass spectrometer, a neutral density gauge, and an associated electronics box with software. MANiaC will measure the neutral gas densities along the flyby trajectory. These gases originate from the sublimation of ices in the comet. Based on these measurements, we will investigate whether highly volatile species, such as carbon monoxide, are more abundant compared to comets that have undergone more thermal processing. MANiaC measurements will also cover isotopes in water, which hold clues to the origin of Earth's water. Further investigations will yield organic molecules and possibly even the composition of impacting dust grains.

Past Achievements and Status

The Comet Interceptor mission was adopted by ESA in 2022 and is currently in the implementation phase. In the second half of 2023, MANiaC successfully passed the Critical Design Review (CDR), followed by assembly, integration, and testing (AIT) of the Engineering Model (EM). Currently, our work focuses on the Electrical and Functional Models (EFM) along with the associated boot and application software. In parallel, work on the Proto Flight Model (PFM) has started, with delivery planned for summer 2026.

In the meantime, planning exercises are being carried out to select target comets (Snodgrass et al., 2025) and to optimize flyby distances (De Keyser et al., 2025), both well in advance of the live mission, to prepare for the required decision-making process.

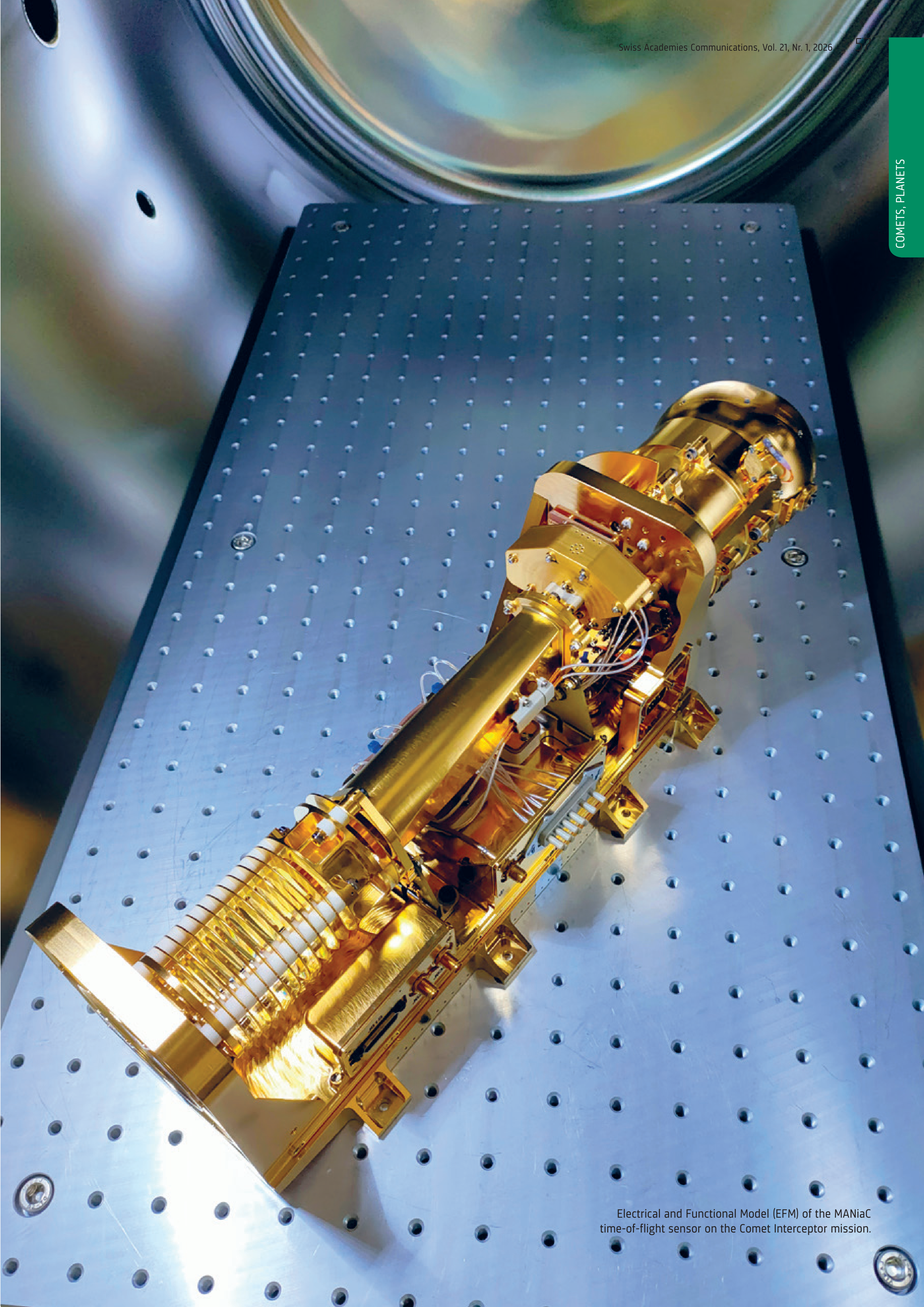
Publications

De Keyser J et al. (2025) **Optimal choice of closest approach distance for a comet flyby: Application to the Comet Interceptor mission**, Plan. Sp. Sci., 256: 106032, doi.org/10.1016/j.pss.2024.106032

Jones GH et al. (2024) **The Comet Interceptor mission**, Sp. Sci. Rev., 220: 9.

Snodgrass C et al. (2026) **Considerations on the process of target selection for the Comet Interceptor mission**, Icarus, 447: 116887.

Time-Line	From	To
Planning	2020	2022
Construction	2023	2026
Measurement phase	2029	2033
Data evaluation	2029	2036



Electrical and Functional Model (EFM) of the MANiaC time-of-flight sensor on the Comet Interceptor mission.

7.12 CoCa – Comet Camera on Comet Interceptor

The Comet Interceptor logo. Image credit: ESA.

Institute
Space Research and Planetology Division, Physics Inst., Univ. Bern, (UNIBE), Bern, Switzerland

In cooperation with
DLR Inst. Planetary Res., Berlin, Germany; Inst. de Astro. de Andalucia (IAA), Spain; Res. Centre Astron. & Earth Sci. Konkoly, Budapest, Hungary

Principal/Swiss Investigator(s)
N. Thomas (UNIBE)

Co-Investigator(s)
Numerous

Contribution
Development & construction of instrument(s): The University of Bern is developing and building the CoCa flight system in collaboration with our German, Spanish and Hungarian partners.

Industrial hardware contract(s)
Thales-Alenia Space Switzerland
WaveLab Engineering AG, Switzerland

Website(s)
www.esa.int/Science_Exploration/Space_Science/Comet_Interceptor

https://cometinterceptor.unibe.ch

Purpose of Research

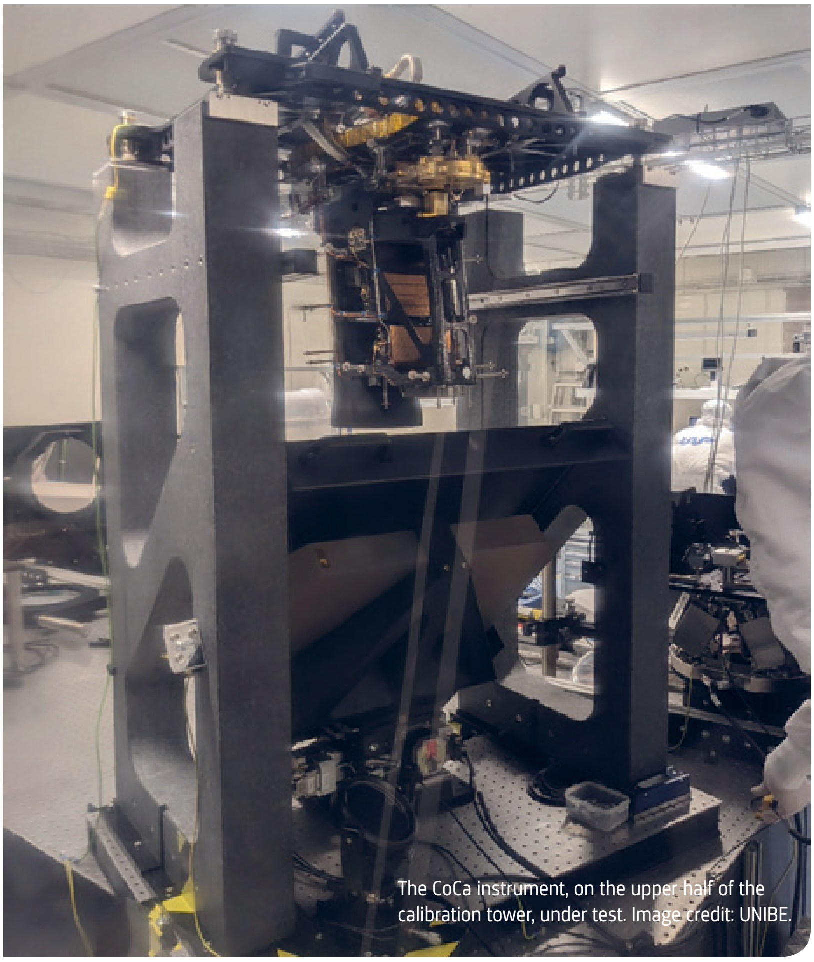
The Comet Camera (CoCa) is the main imaging system onboard the European Space Agency's new F-class mission, Comet Interceptor. The spacecraft will be launched as a passenger together with the Ariel mission and will fly to a holding position at a Lagrangian point.

Ground-based observers will identify a prospective target. It is expected that this target will be a dynamically new comet entering the Solar System or possibly an interstellar object. The spacecraft will then be directed to the target and will complete a high velocity fly-by. The scientific aim of CoCa will be to obtain the first images of a nucleus of a dynamically new comet.

Past Achievements and Status

The instrument has passed the Critical Design Review (CDR) and has now entered the build phase. The proto-flight model (PFM) is currently being integrated with an expected completion date of the PFM in the 2nd quarter of 2026. Delivery to the spacecraft is foreseen at the beginning of the 3rd quarter in 2026.

Time-Line	From	To
Planning	2020	2022
Construction	2022	2026
Measurement phase	2028	2034
Data evaluation	2031	2035



The CoCa instrument, on the upper half of the calibration tower, under test. Image credit: UNIBE.

7.13 M-SoSpIM – Solar Spectral Irradiance Monitor on M-MATISSE

Purpose of Research

M-MATISSE (Mars–Magnetosphere ATmosphere Ionosphere and Space-weather SciencE) is a candidate for the next ESA M-class mission. It is designed to study how the Martian Magnetosphere, Ionosphere, and Thermosphere (M-I-T) operate as a tightly coupled system that transports energy and matter from the solar wind down to the lower atmosphere and vice versa. Understanding this global coupling is fundamental to assessing Mars's past and present factors controlling habitability, especially keeping in mind potential human exploration of Mars in the near future.

M-MATISSE employs two identical spacecraft in different Martian orbits, to ensure simultaneous observations from different vantage points. The suite of instruments hosted on both spacecraft contains in-situ instruments (magnetometers, mass spectrometers and particle detectors) as well as remote sensing instruments (an aurora camera, a radio occultation experiment and a solar irradiance monitor).

PMOD/WRC leads a consortium responsible for the Mars Solar Spectral Irradiance Monitor (M-SoSpIM). This instrument is closely based on SoSpIM hosted on JAXA's Solar-C mission; however, it features an additional spectral channel sensitive to soft X-rays. With that, M-SoSpIM, measures solar flux at soft X-ray (0.1 to 7 nm), extreme ultraviolet (EUV, 17 – 22 nm), and Lyman-α (121.6 nm) wavelengths. These are key drivers of ionisation, heating, and atmospheric variability. M-SoSpIM will also enable measurements of the neutral lower atmosphere via measurements of solar irradiation during the beginning and end of solar occultations by the Martian disk. Based on the mission's attitude profile, approximately 3300 occultations from both spacecraft are expected to be usable.

M-MATISSE applies a selective, post-facto downlink strategy which ensures that the most scientifically valuable data are prioritised for downlink, and that the limited transmission capability from Mars to Earth is optimally used. M-SoSpIM will be heavily relied on in the process of prioritising the data, and the full data generated by M-SoSpIM will be employed for that purpose.

Past Achievements and Status

Phase A is expected to conclude in Q2/2026 with the Mission Selection Review (MSR). The selection of ESA's M7 mission will take place in early summer 2026.

Publications

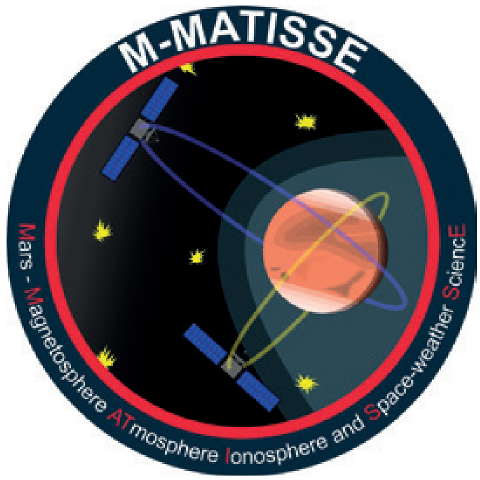
Sanchez-Cano B, Leblanc F (2024) **The M-MATISSE mission: Mars Magnetosphere ATmosphere Ionosphere and Space weather SciencE. An ESA Medium class (M7) candidate in Phase-A**, in Europlanet Science Congress 17: EPSC2024-545

Sanchez-Cano B, Leblanc F (2026) **M-MATISSE assessment study report**, ESA, ESA-SCI-DIR-RP-004

Abbreviations

M-SoSpIM Mars – Solar Spectral Irradiance Monitor

Time-Line	From	To
Planning	2022	2030
Construction	2030	2034
Measurement phase	2037	2040
Data evaluation	2037	2040



The M-Matisse mission logo. Image credit: ESA.

Institute
Phys. Met. Observatorium Davos/
World Radiation Center (PMOD/WRC),
Davos, Switzerland

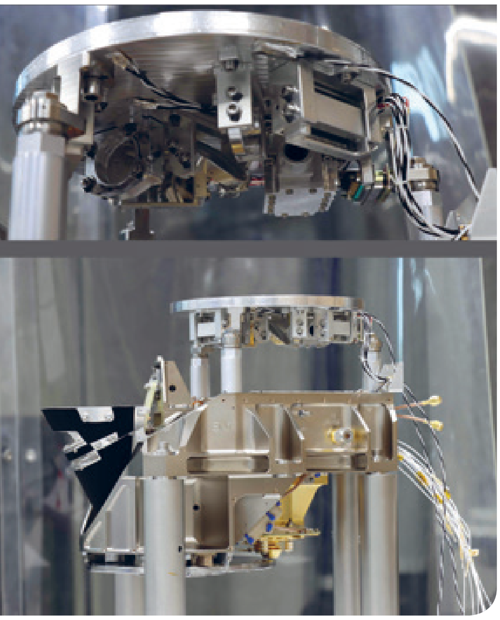
In cooperation with
CBK, Poland;
Admatis, Hungary;
ETH Zurich Space, Switzerland;
ESA

Principal Investigator
B. Sanchez-Cano (Univ. Leicester, England)

Swiss Principal Investigator
L. Harra (PMOD/WRC)

Co-Investigator(s)
K. Barczynski (PMOD/WRC)
Ed Thiemann (LASP, USA)
Konrad R. Skup (CBK)
Tomasz Mrozek (CBK)
Tamás Bárczy (Admatis)

7.14 Chemical Composition of Lunar Regolith with the LIA Instrument in the NASA Artemis Programme



Engineering qualification model of the CLPS-LIMS instrument for the CS-6 NASA CLPS mission. The top panel shows a view of the laser optical system. The bottom panel shows the entire instrument. The black structure on the left is the funnel for regolith reception, the golden structure is the actual mass spectrometer, and the sample carousel is at the bottom of the instrument.

Institute
Space Res. & Planetology, Physics Inst., Univ. Bern (UNIBE), Bern, Switzerland

In cooperation with
NASA

Principal /Swiss Investigator(s)
P. Wurz (UNIBE)

Co-Investigator(s)
A. Riedo (UNIBE), M. Tulej (UNIBE)

Contribution
Development & construction of instrument(s): Laser Ablation Ionisation Mass Spectrometer (LIMS)

Industrial hardware contract(s)
Spacetek Technology SA; Source Engineers; Thales Alenia Switzerland; Micos Eng. GmbH

Purpose of Research

We are building a laser-based mass spectrometer (LIMS) for the in-situ investigation of the chemical and mineralogical composition of lunar regolith grains. This development is for an application on a robotic mission within the Artemis Commercial Lunar Payload Services (CLPS) programme of NASA. The CLPS lander will be placed in the south polar region.

The LIMS system consists of a time-of-flight mass analyser (TOF-MS), a laser system (LSS) providing nano-second laser pulses focused to µm spots on the sample surface, electronics (ELU) to operate the LIMS system, and a sample handling system (SHS) for receiving and handling lunar regolith. The TOF-MS, LSS, and ELU are a further development of our established design of laboratory prototypes for planetary exploration. The SHS is specially designed for the CLPS lander to collect and process regolith from the lunar surface in the vicinity of the lander for grain-by-grain analysis.

Past Achievements and Status

For more than two decades, we have developed highly miniaturised Laser Ablation Ionisation Mass Spectrometry (LIMS) instruments for in-situ planetary research, which were originally intended for a lander on Mercury as part of the ESA BepiColombo mission. LIMS uses pulsed lasers of high intensity (MW/cm^2 to TW/cm^2) so that the material in the ablation plume is completely atomised and a large fraction of the atoms are ionised simultaneously.

We have continuously improved the LIMS instruments in preparation for future landed missions for versatile use on lunar, asteroid, Mars and other planetary surfaces. In 2022, our LIMS instrument was selected by NASA to be part of a CLPS mission in the Artemis lunar exploration programme. LIMS is assigned to be part of the CS-6 with a foreseen launch in mid-2029.

Publications

Keresztes Schmidt P, Hayoz S, … Wurz P (2025) **Sample handling concept for in-situ lunar regolith analysis by laser-based mass spectrometry**, IEEE Aerospace Conference Big Sky, MT, USA, 14 pp, doi.org/10.1109/AERO63441.2025.11068493

Wurz P, Tulej M, Riedo A, Grimaudo V, Lukmanov R, Thomas N (2021) **Investigation of the surface composition by laser ablation/ionisation mass spectrometry**, IEEE Aerospace Conference Big Sky, MT, USA, 50100, 15 pp, doi.org/10.1109/AERO50100.2021.9438486

Wurz P, Hayoz S, Piazza D, Bandy T, Blaukovitsch M, Keresztes Schmidt P, Mändli P, Plet BG, Riedo S, Studer S, Tulej M, Riedo A (2023) **In situ lunar regolith analysis by laser-based mass spectrometry**, IEEE Aerospace Conference Big Sky, MT, USA, 10 pp, doi.org/10.1109/AERO55745.2023.10115714

Abbreviations

CLPS	Commercial Lunar Payload Services
LIMS	Laser Ionisation Mass Spectrometer

Time-Line	From	To
Planning	2019	2021
Construction	2022	2028
Measurement phase	2029	2029
Data evaluation	2029	2030

7.15 Chemical Composition of Lunar Regolith with the DIMPLE Instrument in the NASA Artemis Programme

Purpose of Research

The DIMPLE (Dating an Irregular Mare Patch with a Lunar Explorer) instrument will determine the age and origin of the potentially young (33 ± 2 Ma) irregular mare patch, Ina, by using the Rb-Sr chronometer system. Ina's location is 18.66°N and 5.30°E).

DIMPLE is mounted on a robotic lander on a Commercial Lunar Payload Services (CLPS) platform. DIMPLE will image the geologic context of Ina, analyse rock samples collected by a rover, and determine their geological age, the chemical composition, and derive the local mineralogy. DIMPLE has been selected for flight as part of NASA's CLPS initiative of the Artemis programme of NASA.

Past Achievements and Status

DIMPLE, currently in Phase C/D, has four payload elements, which consist of the following:

i) The Chemistry, Organics, and Dating EXperiment (CODEX), which is comprised of a laser subsystem and a mass spectrometer (provided by the University of Bern, Switzerland).

ii) A sample handling system for gripping rocks from the lunar surface, creating smoothed rock faces, and presenting those smoothed faces first to a lander-mounted camera and then to CODEX.

iii) The Payload Control Unit that receives data from the CODEX instrument and operates the sample-handling system.

iv) A scooping rake to be mounted to a CLPS-provided rover, for collecting samples along traverses and carrying them to the lander.

DIMPLE will perform a full analysis of four rocks; one rock will be collected directly from the vicinity of the landing site within the reach of the sampling handling system, while three more rocks will be fetched by the rover from different locations with distances up to 1 km from the landing site. Rocks for analysis will be selected based on visual images.

Publications

Anderson FS et al. (2026) **The DIMPLE experiment to determine the age and origin of the Lunar Irregular Mare Patch Ina**, Planet. Sci. J., submitted.

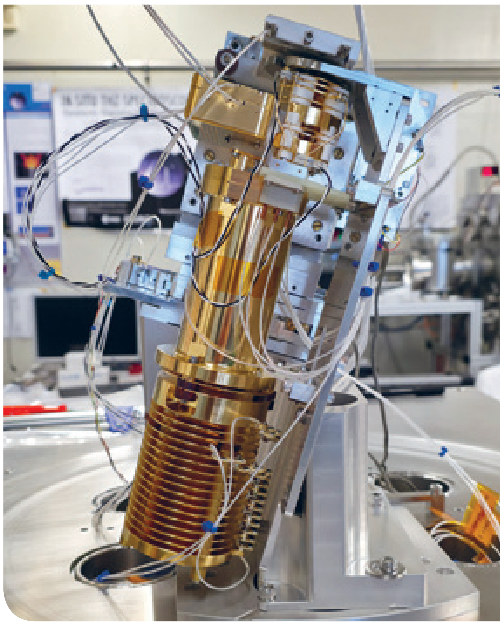
Wurz P Tulej M, Riedo A, Grimaudo V, Lukmanov R, Thomas N (2021) **Investigation of the surface composition by laser ablation/ionisation mass spectrometry**, IEEE Aerospace Conference Big Sky, USA, 50100, 15 pp, doi.org/10.1109/AERO50100.2021.9438486

Wurz P, Bandy T, Mandli P, Studer S, Havoz S, Blaukovitsch M (2023) **In situ lunar regolith analysis by laser-based mass spectrometry**, IEEE Aerospace Conference Big Sky, MT, USA, 10 pp, doi.org/10.1109/AERO55745.2023.10115714

Abbreviations

CLPS	Commercial Lunar Payload Services
CODEX	Chemistry, Organics, and Dating EXperiment
DIMPLE	Dating an Irregular Mare Patch with a Lunar Explorer

Time-Line	From	To
Planning	2019	2021
Construction	2023	2027
Measurement phase	2029	2029
Data evaluation	2029	2030



Engineering model of the CODEX mass spectrometer for the DIMPLE experiment of the NASA CLPS mission.

Institute
Space Res. & Planetology, Physics Inst., Univ. Bern (UNIBE), Bern, Switzerland

In cooperation with
NASA

Principal Investigator(s)
S. Anderson, Southwest Res. Inst. (SWRI), Boulder, USA

Swiss Principal Investigator(s)
P. Wurz (UNIBE)

Co-Investigator(s)
R. Fausch (UNIBE)

Contribution
Development & construction of instrument(s): Laser-Ablation Resonant Ionisation Mass Spectr.

Industrial hardware contract(s)
Spacetek Technology SA

Website(s)
www.nasa.gov/commercial-lunar-payload-services

8 Astrophysics

8.1 Gaia – Variability Processing and Analysis

An artistically informed representation of our Galaxy. See caption on next page for further details.

Institute
Dept. Astronomy, Univ. Geneva (UNIGE), Versoix, Switzerland

In cooperation with
23 Institutes, mostly in Europe (80 people)

Principal Investigator(s)
ESA

Swiss Principal Investigator(s)
L. Eyer (UNIGE)

Co-Investigator(s)
M. Audard, C. Chaudet, N. Chornay, B. Holl, G. Jevardat, D. Krefl, N. Mowlavi, K. Nienartowicz, L. Rimoldini (UNIGE, Sednai Sàrl)

Contribution
Research based on existing instruments: Gaia

Industrial contract to
Sednai Sàrl

Website(s)
www.esa.int/Science_Exploration/Space_Science/Gaia

Purpose of Research

The Gaia mission is a cornerstone mission of the European Space Agency (ESA). It performs a multi-epoch astrometric, photometric and spectrophotometric all-sky survey down to magnitude 20.7 of more than two billion celestial sources. These observed sources include stars, asteroids, quasars and galaxies. For the 100 million brightest sources, Gaia performs a spectroscopic survey as well. No other space agency has undertaken a comparable mission.

Within the Gaia Data Processing and Analysis Consortium, the variability analysis is coordinated by the University of Geneva and its Data Processing Center. This activity involves about 80 astronomers and computer scientists from 23 mostly European institutes.

Our goal is to detect, classify and characterise variable sources among the two billion objects observed by Gaia. For specific subgroups, we also derive some additional variability properties and astrophysical parameters. These results are published as part of the official ESA Gaia catalogues, made publicly available through successive Data Releases, enabling the broader astrophysics community to fully exploit Gaia data's scientific potential.

Past Achievements and Status

During the 2024 – 2025 period most of our effort was devoted to the preparation of the fourth Gaia data release (DR4). This release is currently scheduled for December 2026. In that release, we will present many record-breaking results. The Gaia consortium iteratively improves the processing and thus results between releases. Each cycle includes more data, improved calibrations and better algorithms. Outlier detection is also strengthened.

For the variability analysis each new release requires additional developments. The analysis becomes more complex as not only the volume of data increases, but also new data types are included. In DR4, for example, we will present some results where photometric variability is coupled with the astrometric (positional) time series. New methods are regularly introduced. Machine learning plays an essential role in the analysis, we pioneered some approaches. For Gaia DR4, we complement classical supervised machine-learning methods with a novel multi-modal variational autoencoder framework integrating Gaia light curves, spectra, and variability statistics into a unified latent space for unsupervised classification and anomaly detection.

There have also been developments on the computing side. The most compute-intensive part of our Java code has been adapted to run on GPUs as part of the pilot work-package of the EU Horizon Aero project. This dramatically improved the processing speed and enabled us to restructure the processing flow to compute essential metrics on all the processed sources, which had not been possible before. Algorithms have therefore been parallelised and the database infrastructure has been improved. The volume of data has continued to grow. The variability database now approaches half a petabyte. For DR5 we expect it to exceed one petabyte just for data products.

The Black hole task force that we co-created continued its work. In 2024 it announced a very significant discovery of a black hole with a mass of about 33 solar masses based on Gaia data. We also continued the citizen-science project GaiaVari, funded by ESA. It involves the public in the exploration of Gaia variability data and has been presented during ESA open-day events as a success story. We also lead and contribute to the ESA GaiaWeirdest effort. The goal of this project is to identify unusual sources in Gaia data. This work is related to machine-learning approaches for anomaly detection and to methods based on astrophysical knowledge. Finally, we presented the Gaia mission at several conferences, public and PhD school events and also our petabyte scale database-related efforts during general Postgres conferences for a wide audience.

In conclusion we have been developing a holistic approach to variability processing and analysis, with classical supervised machine-learning methods, a novel multi-modal variational auto-encoder framework, contributions of astrophysicist experts and the participation of citizen scientists.

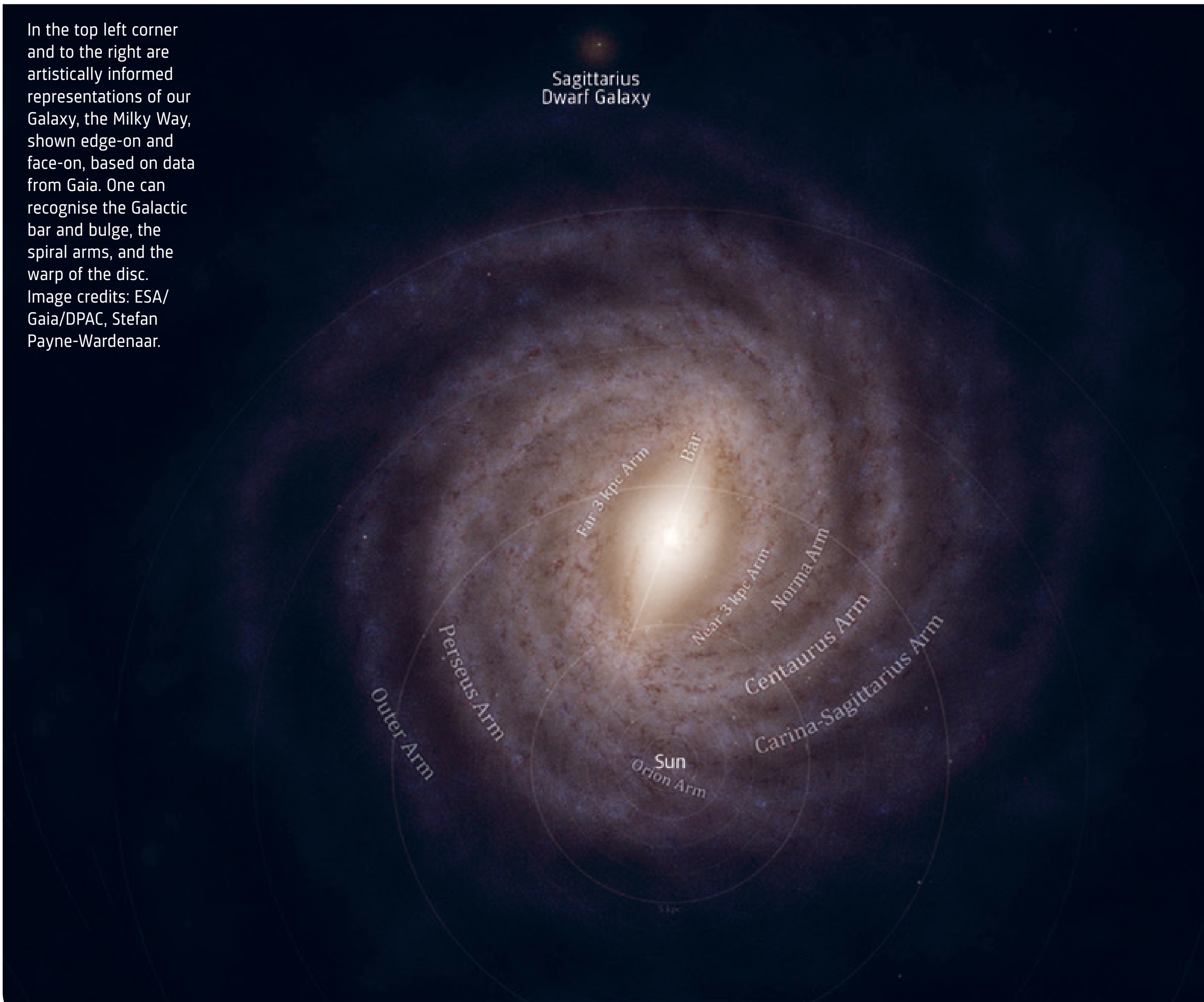
Publications

Eyer L (2024) **The variable sources in the Gaia archive**, Evry Schatzman PhD School: Stellar Physics with Gaia, Eds: C. Babusiaux, C. Reylé, 27-41.

Gaia Collaboration, Panuzzo P, Mazeh T, Arenou F et al. (2024) **Discovery of a dormant 33 solar-mass black hole in pre-release Gaia astrometry**, A&A 686: 2-24.

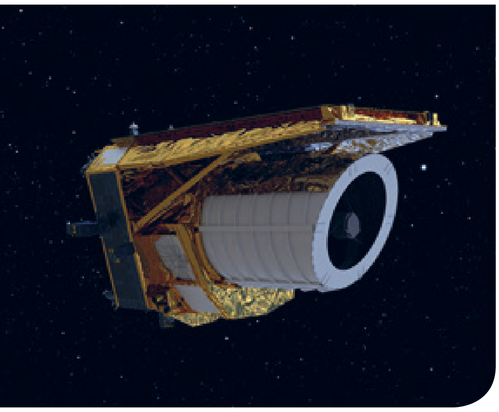
Huijse P, De Ridder J, Eyer L et al. (2025) **Learning novel representations of variable sources from multi-modal Gaia data via autoencoders**, A&A 701: 150-176.

Time-Line	From	To
Planning	2002	2030
Construction	cyclic dev.	up to 2031
Measurement phase	2014	2025
Data evaluation	cyclic	up to 2032



In the top left corner and to the right are artistically informed representations of our Galaxy, the Milky Way, shown edge-on and face-on, based on data from Gaia. One can recognise the Galactic bar and bulge, the spiral arms, and the warp of the disc. Image credits: ESA/Gaia/DPAC, Stefan Payne-Wardenaar.

8.2 The Swiss Contribution to Euclid



Artist's impression of Euclid. Image credit: ESA.

Institute
École Poly. Fédérale de Lausanne (EPFL)
Fachhochschule Nordwestschweiz (FHNW)
Univ. Geneva, (UNIGE); Univ. Zurich, (UZH)
Switzerland

In cooperation with
ESA and ~100 European institutes;
NASA;
>1000 astronomers and engineers worldwide

Principal Investigator(s)
Y. Mellier (deceased),
Inst. d'Astrophys. de Paris, Paris, France

Swiss Co-Investigator(s)
S. Paltani (UNIGE), S. Marcin (FHNW)

Contribution
Development & construction of instrument(s):
Development and construction of the Readout Shutter Unit of the VIS instr. Development of algorithms for photometric redshifts, and strong lensing. Development of infrastructure and processing software.

Industrial hardware contract(s)
APCO Technologies, Switzerland

Website(s)
www.esa.int/Science_Exploration/Space_

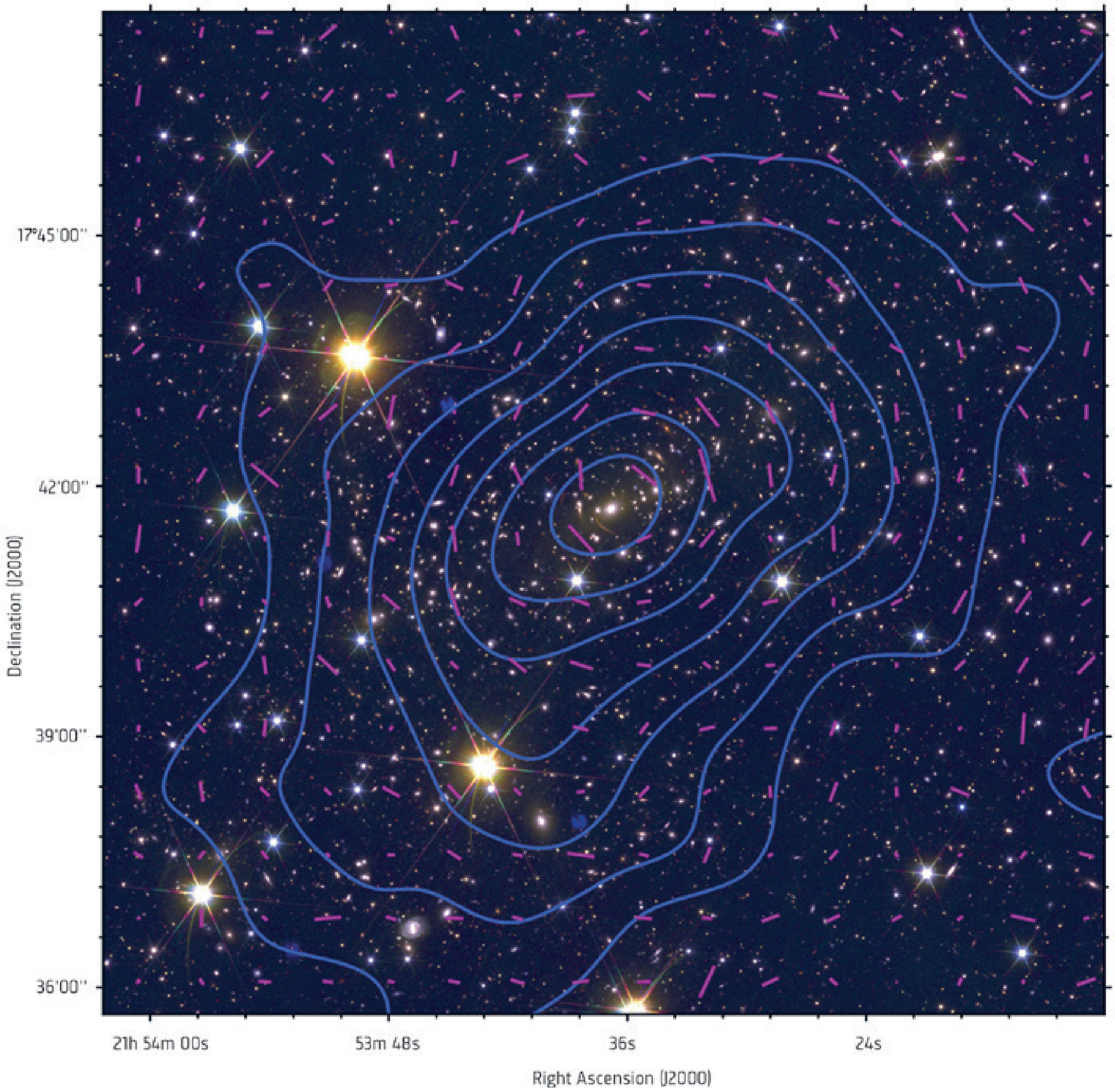
Purpose of Research

Euclid is the second Medium-Class mission of the ESA Cosmic Vision 2015 – 2025 programme and is 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 two main cosmological probes, and several secondary ones. The weak gravitational lensing is the study of the very tiny deformations in the images of distant galaxies due to the distribution of dark matter along the line of sight that acts as optical lenses. Baryonic acoustic oscillations is the study of the imprint of the gravitational collapse of the first structures in the spatial distribution of galaxies. Both probes are sensitive to the detailed energy content of the Universe, which consists of about 70 % dark energy and about 25 % dark matter, two components whose nature is largely unknown.

The Euclid payload consists of a 1.2 m Korsch telescope designed to provide a large field-of-view. The Euclid survey will cover 14,000 deg², i.e. a third of the sky, with its two instruments. The VISual imager (VIS) is a matrix of 6 x 6 CCDs providing a diffraction-limited spatial resolution (about 0.15") over a large field of 0.25 deg², equivalent to about 100 times the field-of-view of the Hubble or the James Webb space telescopes. The Near-Infrared Spectrometer Photometer instrument (NISP) is a matrix of 4 x 4 near-infrared detectors. NISP can be used as a photometer in three bands between 1 and 2 µm. Gratings can be placed in the optical beam in order to transform it into a slitless spectrometer.

Switzerland, under the lead of the University of Geneva (UNIGE), 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: EPFL, FHNW, UNIGE and UZH. On the science level, EPFL (strong lensing), UNIGE (theory) and UZH (cosmological simulations) are co-coordinating the respective Science Working Groups. On the software and algorithm level, EPFL coordinates the development of algorithms for the detection of strong gravitational lenses. FHNW contributes an important component of the data processing infrastructure called the Infrastructure Abstraction Layer (IAL), which integrates the different Euclid data centers into a uniform processing environment under a central orchestrator. UNIGE is in charge of the development of algorithms and software for the determination of photometric redshifts for the Euclid Pipeline, which is a central component of the weak-lensing science probe. UNIGE also hosts the Swiss Euclid Science Data Center and is in charge of the implementation of the algorithms for the determination of the photometric redshifts and for the detection of strong lenses. The Swiss Euclid Science Data Center also participates in the processing of the Euclid data as one of the ten distributed Euclid data centers. The global data processing effort is huge, with an expected need of about 20,000 cores and several tens of petabytes of storage. The Euclid data center in Geneva already hosts about 1200 cores and 1 petabyte.

UNIGE was responsible for the development of the Readout Shutter Unit (RSU), a very high-reliability mechanism for the VIS, whose goal is to block the optical beam during the readout of the CCDs. It is a very complex mechanism that needs to be operated at cold temperatures (~140 K); it must not export



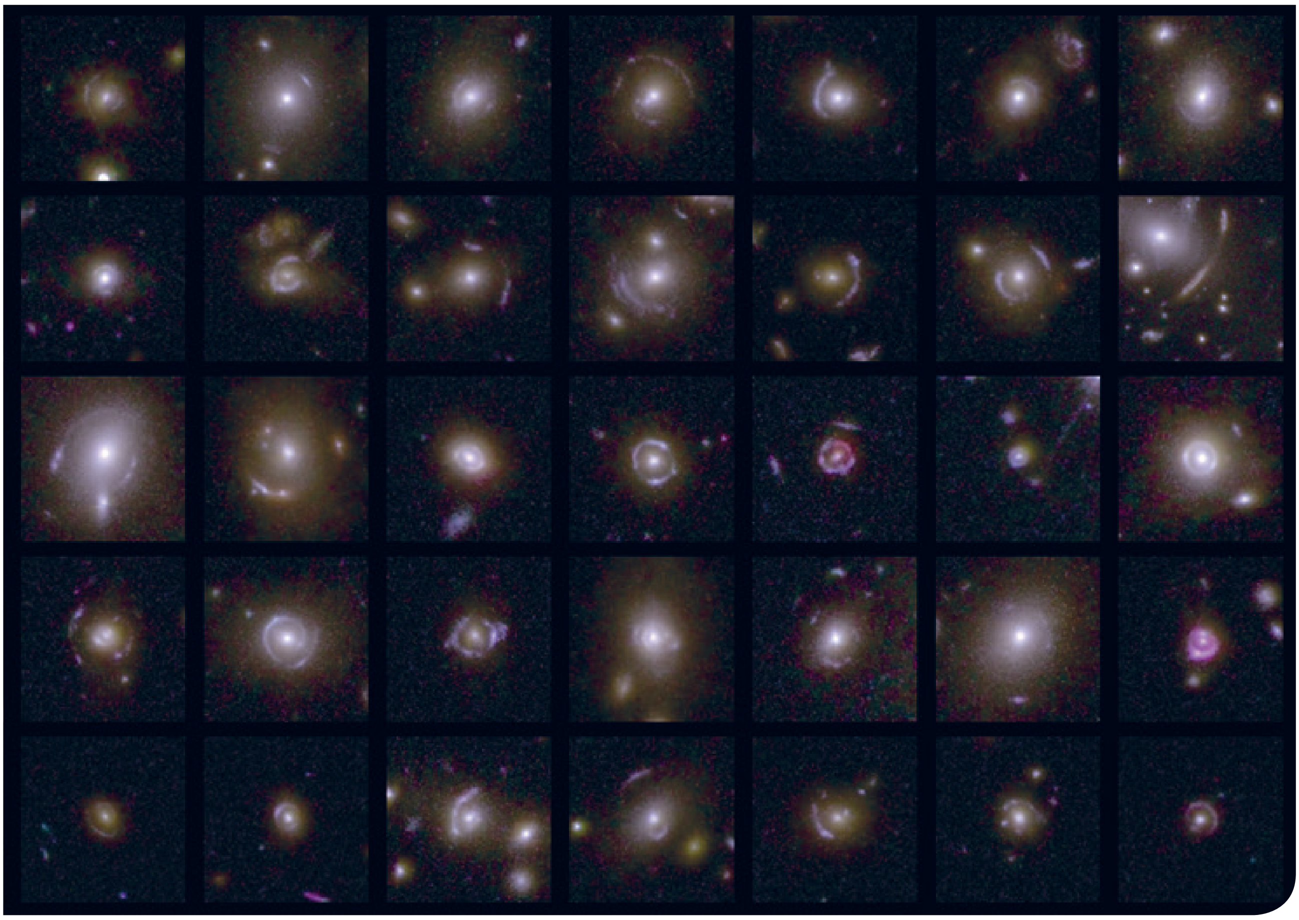
Euclid colour image of A2390 with the mass distribution (convergence) obtained from weak-lensing analysis shown as blue contours. The magenta whiskers show the estimated shear field for illustration purposes. From Schrabback et al. (2025), Euclid: Early Release Observations. Weak gravitational lensing analysis of Abell 2390, eprint arXiv:2507.07629.

any momentum, and has very stringent micro-vibration requirements. In addition, it should be able to open and close ~350,000 times. The RSU was initially designed by UNIGE. In Phase C/D, the responsibility was transferred to APCO, that finalised the design, manufactured the unit, and performed the qualification and testing.

Past Achievements and Status

Euclid was launched on 1 July 2023, from Cape Canaveral on a Falcon 9 rocket from SpaceX, and was successfully injected into a halo orbit around L2. Both the VIS and NISP instruments are working flawlessly, including the Swiss contribution, the VIS RSU, which plays a crucial role in obtaining high-quality images from the VIS instrument. The first engineering images from VIS were publicly released on 31 July 2023, demonstrating unprecedented image quality over such a large field-of-view of half a square degree, almost three times larger than the moon. Eu-

ASTROPHYSICS



A collage of images from Euclid containing examples of gravitational lenses. Each example typically comprises a bright centre with smears of stars in an arc or multiple arcs around it as a result of light travelling towards Euclid from distant galaxies being bent and distorted by normal and dark matter in the foreground. In some rare cases the smearing is in a complete ring, creating a so-called Einstein Ring. Image credit: ESA/Euclid/Euclid Consortium/NASA, image processing by M. Walmsley, M. Huertas-Company, J.-C. Cuillandre.

clid started its nominal science operations on 14 February 2024, and to date has already completed about a third of its planned survey of 14,000 deg². On 15 February, the Swiss Euclid Science Data Center was the first to receive and process the Euclid observations of the nominal survey. The first science images, the Euclid Early Release Observations, were released on 6 November 2023. The first public data release, the 'Quick Data Release 1' took place on 19 March 2025. It contained 63.1 deg² of wide-survey science data and approximately 26 million sources, and included VIS and NISP images, NISP spectroscopy, external ground-based data, catalogues, and masks. In addition to the production of the first Euclid science papers making use of the official pipeline, one of the goals of Q1 was to test the Euclid processing pipeline for the main data releases in realistic, albeit at a reduced scale, conditions.

Over the last two years, most of the effort has been made towards the first main data release, Data Release 1, which will contain about 2000 deg² of the wide survey, as well as parts of the deep survey.

The products were generated by the end of 2025 and are in the custody of the science team for scientific validation and science exploitation. The public Data Release 1 is scheduled for October 2026.

Publications

Euclid Collaboration, Mellier Y, Abdurro'uf, Acevedo Barroso JA et al. (2025) **Euclid: I. Overview of the Euclid mission**, A&A 697A: 1.

Euclid Collaboration, Aussel H, Tereno I, Schirmer M et al. (2025) **Euclid Quick Data Release (Q1) – Data release overview**, eprint arXiv:2503.15302

Euclid Collaboration, Tucci M, Paltani S, Hartley WG et al. (2025) **Euclid Quick Data Release (Q1). Photometric redshifts and physical properties of galaxies through the PHZ processing function**, eprint arXiv:2503.15306

Abbreviations

IAL	Infrastructure Abstraction Layer
NISP	Near-Infrared Spectrometer Photometer instrument
RSU	Read-out Shutter Unit
VIS	Visible Imager

Time-Line	From	To
Planning		2012
Construction	2012	2021 (HW)/ 2023 (SW)
Measurement phase	2023	2030
Data evaluation	2023	2032

8.3 PLATO Mission – Support for the Ground Observation Programme

Purpose of Research

The PLATO mission (PLAnetary Transits and Oscillations of stars) is the third medium-class mission in ESA's Cosmic Vision programme. Its objective is to detect and characterise (radii, mass, density, age) small-mass planets (Earth size) with the transit method, reaching out to the habitable zone around Sun-like stars, and investigate the seismic activity of stars, enabling the precise characterisation of the planet host star, including its age. In order to achieve these goals, the mission will perform continuous monitoring, at a very high photometric precision, of a very large number of bright solar-type stars and M-dwarfs (~250'000 stars, ~20'000 of them in a prime sample for the core science of the mission) and perform the required ground-based observations for the transiting candidates.

Past Achievements and Status

The PLATO spacecraft is fully assembled with its 26 cameras. Final testing of the spacecraft platform and payload module is being conducted as of the end of 2025. After launch (planned for Jan. 2027), PLATO will travel to the Lagrange point 2, where it will collect the photometric signals of stars in a fixed, unprecedented field-of-view of 2200 deg^2 to detect transits of small exoplanets, including Earth-like planets in the habitable zone of their host stars.

An integral and essential component of the mission lies in the complementary Ground-based Observations Programme (GOP) necessary to: i) establish the true planetary origin of the detected signal (vetting of false positives), and ii) accurately measure the mass of the transiting planets (goal is a 10% precision), to be then combined with the precise radii and system age derived from the PLATO data. An efficient and versatile operational organisation has been set up, coordinated by the GOP Office in Geneva, with a GOP Operational Center in Barcelona, and with interfaces with the other units of the PLATO consortium. The vetting part is articulated around three different types of observations: spectroscopy (radial velocity), photometry, and imaging, while the precise mass measurement for Earth-like candidates will be mainly performed with the European Southern Obs. (ESO) most precise radial-velocity instruments for the first PLATO field. The GOP successfully passed the Ground Segment Design and Implementation Reviews in 2024 and 2025. It now: i) includes increased functionalities in its processing modules; ii) performs additional tests to include more scenarios (false positives and planetary system types); iii) is consolidating its operational interface with the other Consortium units and, iv) is preparing for the submission of required telescope time proposals for the years to come.

At a Swiss level, the Univ. Bern (UNIBE) is also strongly involved in the mission. In the context of the GOP, it is responsible for monitoring of the advancement of GOP observations, making sure they progress according to plan. At a payload level, UNIBE was responsible for the development of the mounts of the PLATO Telescope Optical Units, with all required components delivered to the consortium in 2023.

Publications

Rauer H (2025) **The Plato mission**, Experimental Astronomy: 59, 26.

Abbreviations

GOP	Ground-based Observations Programme
PLATO	PLAnetary Transits and Oscillations of stars

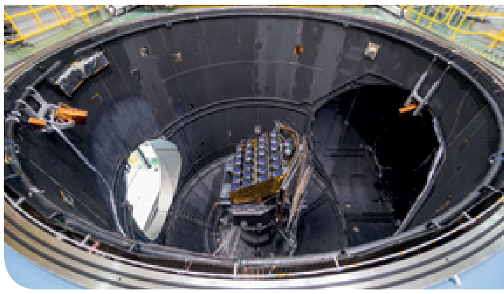


Photo taken looking down into a black-walled cylinder, at the bottom of which sits a large satellite with black panels and golden surfaces. On top of the spacecraft, we see the blue, shiny lenses of 26 large cameras. The cameras are mounted on a five-stepped platform and arranged in four rows of six cameras, plus a top row with two cameras. Image credit: ESA.

Institute
Department of Astronomy, Univ. Geneva (UNIGE), Versoix, Switzerland

In cooperation with
Plato Consortium

Principal Investigator(s)
H. Rauer, DLR Berlin, Berlin, Germany

Swiss Principal Investigator(s)
S. Udry, Univ. Geneva (UNIGE), Versoix, Switzerland

Contribution
Research based on existing instruments: Research based on ground-based telescopes, with a preponderant role of ESO facilites for the southern field.

Website(s)
www.esa.int/Science_Exploration/Space_Science/Plato

8.4 The Swiss Contribution to the X-Ray Imaging Spectroscopy Mission (XRISM)

XRISM mission logo. Image credit: JAXA.

Institute
Dept. Astronomy, Univ. Geneva (UNIGE)
Versoix, Switzerland

In cooperation with
Netherlands Institute for Space Research (SRON);
European Space Agency (ESA)

Principal Investigator(s)
Japan Aerospace Exploration Agency (JAXA)

Swiss Principal Investigator(s)
S. Paltani (UNIGE)

Contribution
Development & construction of instrument(s):
Manufacture of the filter-wheel mechanism and filter-wheel electronics.

Industrial Contracts to
Beyond Gravity
Syderal Swiss SA

Website(s)
https://www.astro.unige.ch/cdci/projects/xrism

https://www.xrism.jaxa.jp/en/

Purpose of Research

The X-Ray Imaging Spectroscopy Mission (XRISM) is a mission of the Japan Aerospace Exploration Agency (JAXA) launched in 2023 to recover the most ambitious scientific objectives of the Hitomi mission, which was successfully launched in 2016, but experienced a failure after six weeks in operation. Despite its extremely short life, Hitomi was incredibly successful, thanks to its new-generation Soft X-Ray Spectrometer (SXS) instrument.

XRISM is an essential mission for high-energy astrophysics, between the current generation of X-ray observatories and NewAthena, the future Large Mission of ESA's Cosmic Vision programme, dedicated to the study of the hot and energetic Universe. The main science goals of XRISM are the study of the dynamics of the hot gas in galaxy clusters and of the matter around super-massive black holes.

The University of Geneva (UNIGE; Switzerland) participated in the Hitomi mission together with the Dutch space research institute (SRON) by developing a filter-wheel for the SXS; a rebuild of the Swiss contribution to Hitomi has been prepared for the Resolve spectrometer on XRISM. Like the SXS, Resolve uses a cryogenic silicon detector working at 50 mK, aiming to provide outstanding energy resolution (about 5 eV) in the 0.3 – 10 keV energy range, while preserving some imaging capabilities and high throughput. The purpose of the filter wheel is to place different optical elements in the field-of-view, either: i) to reduce the X-ray count rate or the optical load on the detector, as well as to protect the detector from micro-meteorites, or ii) to insert a radioactive calibration source. It also supports and commands active X-ray calibration sources, which are provided by SRON, and assembled on top of the filter-wheel. The Resolve instrument is complemented with the Xtend instrument, a wide-field imager based on CCDs.

The filter-wheel consists of two separate units: the Filter-Wheel Electronics (FWE) and the Filter-Wheel Mechanism (FWM). For Hitomi, the control and power electronics module, the FWE, was designed by industry and assembled and qualified by UNIGE, while for XRISM the rebuild was assembled and qualified by the company, Syderal. The FWM was built and qualified by Beyond Gravity (formerly Ruag Space). The filter-wheel subsystem also includes modulated calibration X-ray sources (MXS) developed by SRON. The MXS and its associated high-voltage power supplies were integrated on the FWM by SRON.

Past Achievements and Status

XRISM was successfully launched on 7 September 2023, from Tanegashima Space Center in Japan with the rocket, H-IIA 202. The Performance Verification (PV) phase started on 8 February 2024. All instruments were nominal. However the gate valve, a door protecting the entrance of the dewar of Resolve, did not open. This anomaly unfortunately restricts the science case of XRISM, as low-energy X-ray photons are fully blocked by the door. Fortunately, the science cases relying on high-energy photons (mostly associated with atomic transitions of neutral and ionised iron) is essentially unaffected. There have been several attempts to open the door by shaking the spacecraft, which were unfortunately unsuccessful. The closed gate valve prevents the MXS active X-ray calibration sources from fulfilling their tasks. Therefore, the calibration of the Resolve instrument relies entirely on the radioactive source located in the middle of a filter in the filter-wheel. The radioactive source was implemented as a backup for the MXS, but turned out to be an essential element for the scientific operations of XRISM.

During this period, the XRISM Science Team concluded the scientific analysis of the Performance and Verification phase, and the first two open calls for observing time were completed. Already close to 100 publications using XRISM data have been published, including five in *Nature* and one in *Nature Astronomy*.

Publications

Tashiro M et al. (2020) **Status of x-ray imaging and spectroscopy mission (XRISM)**, Proc. SPIE 1444: id. 1144422.

XRISM Collaboration (2025) **The bulk motion of gas in the core of the Centaurus galaxy cluster**, Nature 638: 365.

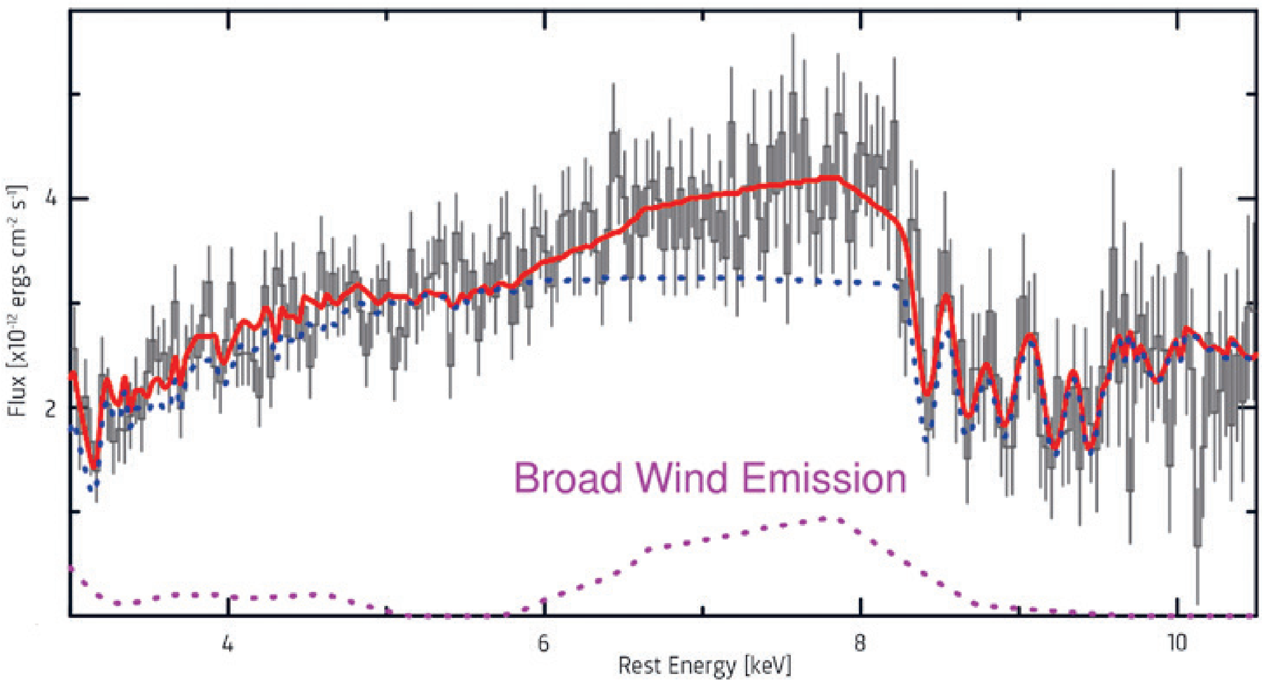
XRISM Collaboration (2025) **Structured ionized winds shooting out from a quasar at relativistic speeds**, Nature 641: 1132.

XRISM Collaboration (2025) **Stratified wind from a super-Eddington X-ray binary is slower than expected**, Nature 646: 57.

Abbreviations

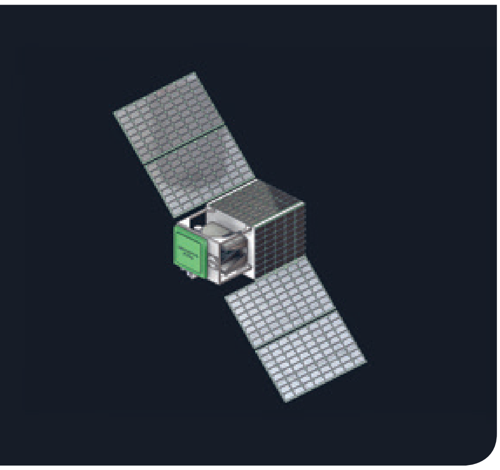
FWE	Filter-Wheel Electronics
FWM	Filter-Wheel Mechanism
JAXA	Japanese Aerospace Exploration Agency
MXS	Modulated X-ray Sources
SXS	Soft X-ray Spectrometer
XRISM	X-Ray Imaging Spectroscopy Mission

Time-Line	From	To
Planning	2017	2017
Construction	2018	2019
Measurement phase	2023	2028
Data evaluation	2023	2033



Spectrum of the quasar PDS 456 from the Resolve instrument showing five absorption features, which are the signatures of ejection of material at velocities between 10 and 30 % of the speed of light. These ejecta contain enough energy to influence the entire host galaxy (Adapted from XRISM Collaboration et al. 2025, arXiv:2505.09171).

8.5 POLAR-2



Exploded view of the POLAR-2 instrument.
Image credit: CMSA.

Institute
Dept. Nucl. Part. Phys. (DPNC), Univ. Geneva,
Geneva, Switzerland

Dept. Astronomy (DA), Univ. Geneva,
Geneva, Switzerland

In cooperation with
Max Planck Inst. Extraterr. Physics (MPE),
Germany;
Nuclear Research Institute of Poland (NCBJ),
Warsaw, Poland;
Inst. Astron. & Astrophys. (IAAT), Univ. Tübingen,
Tübingen, Germany;
Inst. High Energy Physics (IHEP),
Beijing, China

Principal/Swiss Investigator(s)
Xin Wu (DPNC)

Co-Investigator(s)
N. Produit (DA)

Industrial hardware contract(s)
Hybrid SA
Composite Design SARL

Website(s)
www.unige.ch/dpnc/fr/groups/xin-wu/experiences/polar-2

Purpose of Research

The POLAR-2 project is a follow-up of the successful POLAR project, which collected data for six months on the Tiangong-2 Spacelab. The aim of POLAR was to perform the most detailed polarisation measurements of Gamma-Ray Bursts (GRBs) in order to answer fundamental questions regarding their origin.

Results from POLAR, published in the Nature Astronomy journal, indicated an overall low polarisation as well as an unexpected complexity in the time evolution of the polarisation during a GRB. These results indicate that time-domain measurements with a significantly improved precision are required in the future. In addition, with the recent discovery of gravitational waves and their connection to GRBs, a new era in multi-messenger astrophysics has started. This major advance in the field together with the discoveries made by POLAR, warrant a high precision GRB polarimeter capable of providing both high precision polarisation measurements as well as detecting very weak GRBs.

An international collaboration, led by the DPNC group and consisting of leading members of the POLAR collaboration and new members from the Max Planck Institute for Extraterrestrial Physics (MPE), proposed the POLAR-2 instrument with the required capabilities based on recent advances in the field.

POLAR-2 is foreseen to answer several fundamental questions regarding the origin of GRBs by performing polarisation measurements for two years. Furthermore, as the most sensitive instrument in its energy range, POLAR-2 will be capable of detecting weak GRBs. It will therefore play an important role in multi-messenger astrophysics and will be capable of issuing alerts with position information for transient events to other instruments, thereby increasing the scientific potential of both POLAR-2 and other instruments.

Past Achievements and Status

The POLAR-2 instrument was selected in 2019 in the framework of the Call for Experiments onboard the China Space Station (CSS), issued by the UN Office for Outer Space Affairs (UNOOSA) and China's Manned Space Agency (CMSA), and is expected to be launched in 2028.

The Swiss contribution to the POLAR-2 payload development is supported by the Swiss Space Office through the ESA PRODEX programme. The project has completed its design and prototyping stage, and is now entering the production stage. A complete prototype of the Detector Module (DM) was produced and tested for its scientific performance at the European Synchrotron Radiation Facility (ESRF) in 2023. The prototype matched the design requirements. A module prototype has also successfully undergone shock and vibration tests, as well as thermal vacuum tests using facilities at the MPE. Several radiation campaigns were performed at the proton radiotherapy facility at the Institute of Nuclear Physics Polish Academy of Sciences in Krakow, Poland. The results showed that it is possible to maintain the scientific performance of POLAR-2 for up to 10 years in space. The Institute of Astronomy and Astrophysics (IAAT) of the University of Tübingen joined the POLAR-2 collaboration in June 2025 and will contribute to the Back-End Electronics (BEE) of the POLAR-2 payload. In February 2026, a 3x3 Engineering Qualification Model (EQM; see opposite Figure) was produced and successfully calibrated at ESRF.

Publications

Hulsman J et al. (2025) POLAR-2 – **Latest developments of the next generation GRB polarimeter**, PoS ICRC2025: v501, 687.

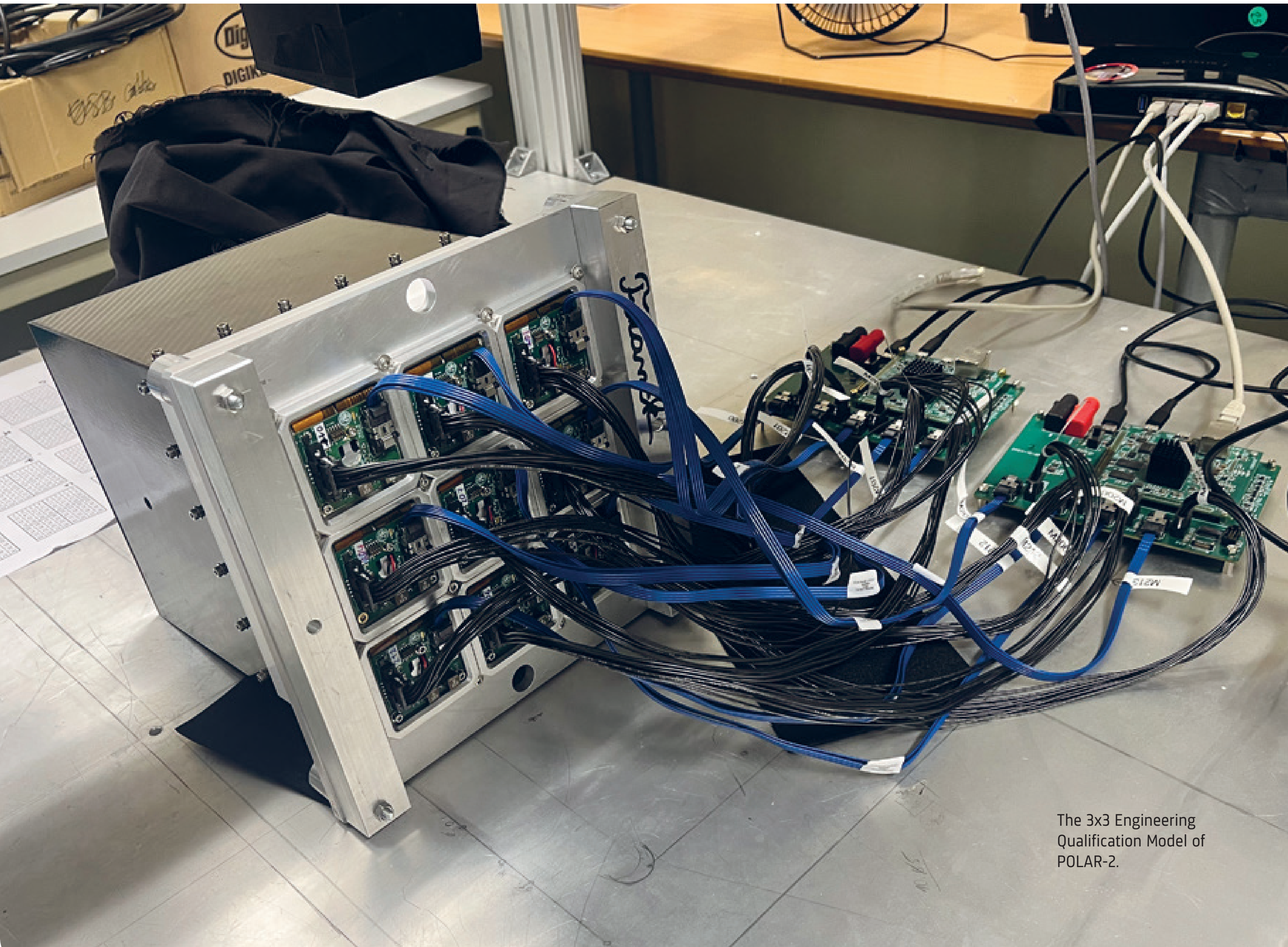
Kole M (2025) **Design and performance of a universal SiPM readout system for X- and gamma-ray missions**, Nucl. Instrum. Methods Phys. Res. A 1080: 170782.

Kole M (2025) **Response of the first POLAR-2 prototype to polarized beams**, JINST 19: P08002.

Abbreviations

ESRF European Synchrotron Radiation Facility
GRB Gamma-Ray Burst

Time-Line	From	To
Planning	2018	2019
Construction	2020	2027
Measurement phase	2028	>2030
Data evaluation	2028	>2030



The 3x3 Engineering Qualification Model of POLAR-2.

8.6 The Swiss Contribution to LISA

LISA Mission logo. Image credit: ESA.

Institute
ETH Zurich | Space
Zurich, Switzerland

In cooperation with
Inst. for Particle Physics and Astrophysics, ETH Zurich, Zurich, Switzerland; Inst. Geophysics, ETH Zurich, Zurich, Switzerland; Univ. Zurich (UZH), Zurich, Switzerland; LISA Distributed Data Proc. Center Univ., Trento, Italy; ESA; NASA

Principal Investigator(s)
ESA

Swiss Principal Investigator(s)
D. Giardini, M. Vallisneri, A. Renzini (all ETH Zurich)

Co-Investigator(s)
F. Kehl, L. Ferraioli, J. Robertsson (all ETH Zurich)

Contribution
Development & construction of the GRS FEE; Dev. of Software for Space Mission Data Analysis.

Industrial hardware contract(s)
Thales Alenia Space Switzerland

Website(s)
https://www.lisamission.org

Purpose of Research

The Laser Interferometer Space Antenna (LISA), a large-class mission led by ESA with NASA support, will be the first space-based gravitational wave observatory. By measuring ripples in space-time from sources across the entire Universe, LISA aims to revolutionise our understanding of populations of compact objects such as super-massive black holes, provide high-accuracy tests of general relativity, and potentially measure the evolution of the early Universe. Switzerland's participation in LISA is the largest of any scientific space mission to date and supported by two distinct yet complementary teams at ETH Zurich.

The mission's technical success relies on the Gravitational Reference Sensor (GRS), which houses the free-falling test masses that serve as the reference for gravitational wave detection. The Swiss hardware team is responsible for the GRS Front-end Electronics (FEE). This critical component provides the sensing and control electronics for the GRS Test-Mass to enable the required mission performances. The GRS FEE is based on amplitude-modulated capacitive sensing and audio-frequency actuation. It supports LISA science operations with small displacement sensing (up to 100 µm) and small actuation forces (~nN). Moreover, it implements a test mass acquisition/accelerometer mode with 'wall-to-wall' sensing (4 mm) and larger (~µN) forces. The sensing and actuation for the LISA GRS requires ultra stable performances in the low-frequency band from 1 Hz down to 100 µHz.

The highly sensitive data gathered by LISA is expected to contain a vast population of gravitational-wave signals of diverse nature: millions of overlapping faint compact binaries in our Galaxy, hundreds of massive black hole binaries merging, several extreme mass-ratio systems of compact objects inspiralling, to name a few. The international LISA ground segment is setting up the intricate data analysis suites required to turn LISA data into meaningful astrophysical measurements. As a part of this distributed international effort, the Gravitational Physics Research Group leads the implementation of the Swiss LISA Data Processing Center (DPC@CH). The DPC@CH team is designing and implementing deep global parameter estimation frameworks to extract maximum scientific information from complex data streams. This includes the development of comprehensive source catalogue techniques and the investigation of improved waveform functions for efficient data analysis.

Complementary to this, the team is developing early-alert pipelines for rapid identification and notification of significant events in low-latency to facilitate multi-messenger observations. A particular focus remains the exploration of deep learning applications alongside traditional methods to push the boundaries of modern data analysis.

LISA Poster for DPC@CH, 2026. Artist: Isabella Dente.

Past Achievements and Status

The Swiss contribution to LISA is built upon a foundation of long-standing expertise and steady growth within ETH Zurich and its international partners. The hardware development for the GRS FEE represents the culmination of Swiss engineering excellence in space instrumentation. The team, composed of participants from ETH Zurich and Thales Alenia Space Switzerland, has successfully designed and refined the sensing and actuation architectures required to meet LISA's stringent low-frequency stability requirements. An elegant breadboard is currently ongoing performance testing. The project is approaching the preliminary design review (PDR). The production of the engineering model is expected to be initiated after the PDR.

The data processing side is equally rooted in extensive know-how developed through continuous research. The software team has developed global analysis methods for galactic and massive black hole binaries that have already been successfully implemented in previous LISA mock-data challenges. These efforts have laid the foundation for new search and analysis techniques, including alternative deep-learning approaches for the separation of overlapping signals and non-stationary noise. Furthermore, the team has designed amortised trans-dimensional inference pipelines with normalising flows to perform signal search and parameter estimation.

Recent collaborations have also resulted in the design of novel clustering algorithms to produce accurate catalogues from the output of global analyses. These achievements ensure that the DPC@CH is prepared to lead the way in compiling the most informative catalogues from the wealth of data that LISA will provide.

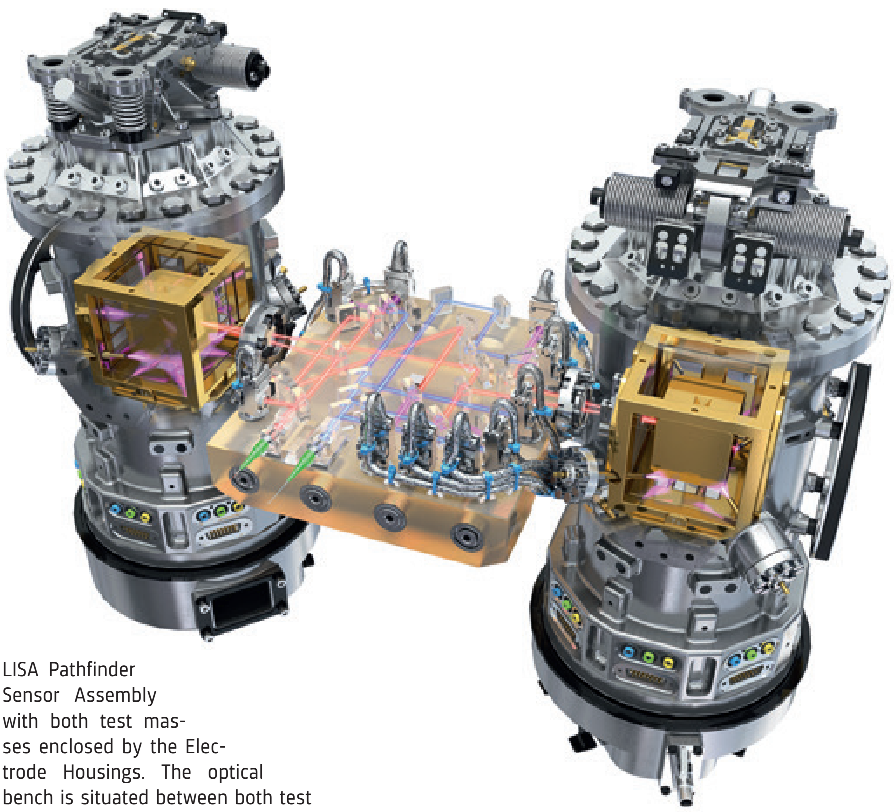
Publications

Armano M et al. (2024) **Nano-Newton electrostatic force actuators for femto-Newton-sensitive measurements: System performance test in the LISA Pathfinder mission**, Physical Rev. D 109: 102009.

Houba N, Ferraioli L, Giardini D (2024) **Detection and mitigation of glitches in LISA data: A machine learning approach**, Phys. Rev. D 109: 083027.

Houba N, Giarda G, Speri L (2025) **SlotFlow: Amortized trans-dimensional inference with slot-based normalizing flows**, arXiv: 2511.23228 – Preprint, November 28.

Strub SH, Ferraioli L, Schmelzbach C, Stähler SC, Giardini D (2024) **Global analysis of LISA data with Galactic binaries and massive black hole binaries**, Phys. Rev. D 110: 024005.



LISA Pathfinder Sensor Assembly with both test masses enclosed by the Electrode Housings. The optical bench is situated between both test masses. The LISA Pathfinder mission was successfully completed in 2017. Image credit: ESA.

Abbreviations

FEE	Front-End Electronics
GRS	Gravitational Reference Sensor
LISA	Laser Interferometer Space Antenna

Time-Line	From	To
Planning	2019	2025
Construction	2025	2035
Measurement phase	2035	2045
Data evaluation	2035	2045

8.7 NewAthena – Advanced Telescope for High Energy Astrophysics

Artist's impression of the NewAthena spacecraft. Image credit: IRAP, CNES, ACO, ESA.

Institute
Dept. Astronomy, Univ. Geneva (UNIGE)
Versoix, Switzerland

In cooperation with
European Space Agency (ESA);
Inst. Rech. en Astrophys. et Planét. (IRAP), Toulouse, France;
Max-Planck-Inst. Extraterr. Physik (MPE), Garching-bei-München, Germany

Principal Investigator(s)
K. Nandra (MPE), D. Barret (IRAP)

Swiss Principal Investigator(s)
S. Paltani (UNIGE)

Co-Investigator(s)
E. Bozzo, M. Audard, L. Genolet, C. Ferrigno, D. Eckert (UNIGE)

Contribution
Development & construction of instrument(s): Development of: i) X-IFU filter-wheel mechanism, control electronics and filters, ii) cryo-cables for X-IFU, iii) thick filter for soft X-ray suppression of the WFI filter-wheel. Development of data center activities for the WFI and X-IFU instrument science centers.

Website(s)
https://www.cosmos.esa.int/web/athena

Purpose of Research

NewAthena (Advanced Telescope for High Energy Astrophysics) is a large X-ray observatory mission selected by ESA for the so-called L2 slot of the Cosmic Vision Programme. Thanks to its two instruments, a large-field-of-view fast imager, the Wide FIeld Imager (WFI), and a cryogenic imaging calorimeter, the X-ray Integral Field Unit (X-IFU), NewAthena will provide tremendous improvements over the current generation of X-ray telescopes for high spatial and spectral resolution spectro-imaging and for survey grasp (effective area x field-of-view).

The WFI will be equipped with a 2x2 mosaic of large-area DEPFET (depleted p-channel field-effect transistor) active pixel sensor matrices covering a field-of-view of 40’ x 40’, together with a single smaller gateable DEPFET sensor matrix optimised for the high count-rate applications and achieving a time resolution of 80 µs. The X-IFU uses Transition Edge Sensors, operated at cryogenic (50 mK) temperatures, to perform imaging of the soft X-ray sky with ~ 4 eV resolution. This provides an improvement by a factor >50 over current imaging instruments.

UNIGE is leading the development of the X-IFU filter-wheel mechanism, together with the corresponding control electronics and all planned filters. The filters are needed to either reduce the load of soft X-ray photons from very bright X-ray sources, or limit the optical load due to UV photons from the bright counterparts of the X-ray sources to be observed. The filter-wheel will also host the radioactive sources needed for the calibration of the instrument. Beside controlling the filter-wheel mechanism, the filter-wheel electronics will also drive active X-ray sources, which can generate mono-energetic photons for the gain calibrations of the detector simultaneously during the scientific observation. This allows the X-IFU instrument to achieve an optimal calibration stability. The X-IFU filter-wheel development at UNIGE heavily relies on the heritage from the Swiss contribution to the JAXA ASTRO-H/Hitomi and XRISM missions. UNIGE is also responsible for the initial development of the cryo-cables to be used right at the core of the X-IFU instrument, within the cryostat.

UNIGE is also responsible for one of the filters that will be mounted on the WFI filter-wheel. This filter has the function of reducing the load on the detector from the softer X-ray photons of very bright X-ray sources, avoiding saturation and degradation of the instrument performances. The filter is being designed on the model of one of the X-IFU filters that has exactly the same function.

Concerning the mission ground segment and operations, UNIGE has a prominent central role in both the X-IFU and WFI Instrument Science Centers (ISCs). These centers will cover a number of key functions during the entire period of the mission development, operations, and post operations. These functions include the software development, the instrument health monitoring and calibrations, as well as the development of all data reduction/analysis software. UNIGE is responsible for the bulk of the science software production for the X-IFU ISC and the development of the data reduction pipelines of the WFI ISC. For the WFI ISC, UNIGE will also take care of the daily data processing mainly for quick-look analysis purposes and provides support for part of the science software development.

Past Achievements and Status

The Athena mission successfully completed a phase A study in 2019 and continued its development through Phase B1 between 2019 and 2022. In 2022, over-budget issues declared by ESA, forced the Agency in collaboration with the instrument consortia to partly re-design the mission to fit the available financial envelope. The re-design activities were carried out between 2022 and 2023. At the end of 2023, the reshaped mission, now called NewAthena, was declared feasible in terms of technical and programmatic constraints and entered a new phase A/B1 to be completed by the end of 2026. The adoption of the mission is now expected in mid-2027, finally allowing all NewAthena teams to engage in the construction of the instruments in view of the delivery of the flight models to ESA in 2031-2033 and to fulfil the conditions for the expected launch in 2038.

During 2024-2025, the team at UNIGE addressed the impact of the NewAthena re-design on the Swiss hardware components to be provided and re-designed, in collaboration with the Colleagues at the University of Palermo (Italy), the new filters which need to be hosted on the filter-wheel mechanism. In particular, the X-IFU filters became substantially more complex as their diameter was increased from 160 mm (Athena design, clean aperture) to 250 mm (NewAthena design, clean aperture).

In the remaining time until the NewAthena mission selection, the UNIGE team will procure new filter samples and re-perform dedicated vibrational tests. A new collaboration has started with the Swiss manufacturer, XRnanotech, for the production of new metallic meshes to be glued onto the X-IFU filters (see figure caption). The four contracts granted to Swiss industries to carry out a critical analysis of the X-IFU filter-wheel mechanism and control electronics that were concluded between 2022 and 2023, have now restarted to analyse the impact of the updated mission design and schedule. These activities will be completed by September 2026, in time to take these inputs into account in the preparation of the PRODEX proposal for phases B2/C/D in 2027.

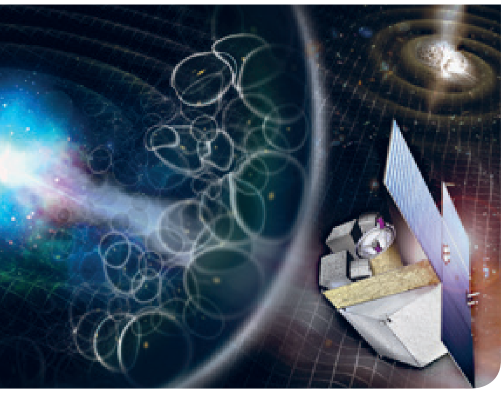
Abbreviations

NewAthena	Advanced Telescope for High-Energy Astrophysics
ISC	Instrument Science Centre
WFI	Wide-Field Imager
X-IFU	X-ray Integral FIeld Unit

Time-Line	From	To
Planning	2014	2027
Construction	2027	2037
Measurement phase	2038	2042
Data evaluation	2038	2042

One of the full-scale X-IFU optical blocking filters procured by the UNIGE team from LUXEL (USA) during the previous Athena phase A/B1. The photo shows the complex honeycomb structure of the metallic mesh glued on the filter to support the membrane. This filter was 160 mm in clean aperture. The re-designed filters for NewAthena have an increased diameter up to 250 mm (clean aperture).

8.8 THESEUS – The Transient High Energy Sky and Early Universe Surveyor



Artist's impression of the THESEUS spacecraft.
Image credit: THESEUS consortium.

Institute
Dept. Astronomy, Univ. Geneva (UNIGE)
Versoix, Switzerland

In cooperation with
INAF-OAS, Bologna, Italy

Principal Investigator(s)
L. Amati (INAF-OAS)

Swiss Principal Investigator(s)
S. Paltani (UNIGE)

Co-Investigator(s)
E. Bozzo, L. Genolet (UNIGE)

Contribution
Development & construction of instrument(s): Contribution to the IRT instrument, to the mission science ground segment, and to the mission project office.

Website(s)
https://theseus.astro-ge.ch

Purpose of Research

The Transient High Energy Sky and Early Universe Surveyor (THESEUS) is a space mission concept developed by a large international collaboration in response to the seventh call for M-class missions by the European Space Agency (ESA). THESEUS is designed to vastly increase the discovery space of high-energy transient phenomena over the entire cosmic history. Its driving science goals aim to find answers to multiple fundamental questions of modern cosmology and astrophysics, by exploiting the unique mission capability to: a) unveil the physical conditions of the Early Universe (the cosmic dawn and re-ionisation era) by detecting the Gamma-Ray Burst (GRB) population in the first billion years; b) perform an unprecedented deep monitoring of the soft X-ray transient Universe, thus providing a fundamental synergy with the next generation of gravitational wave and neutrino detectors (multi-messenger astrophysics), as well as the large electromagnetic (EM) facilities of the upcoming decades.

The most critical THESEUS targets, i.e. GRBs, are unique and powerful tools for cosmology, especially thanks to their huge luminosities, mostly emitted as X-rays and gamma-rays, their redshift (z) distribution (extending at least to z ~ 10, when the Universe was less than 500 million years old), and their association with the explosive death of massive stars. In particular, GRBs represent a unique tool to study the early Universe up to the re-ionisation era.

Besides high-redshift GRBs, THESEUS will serendipitously detect and localise, during regular observations, a large number of X-ray transients and variable sources, collecting prompt follow-up data in the IR. These observations will provide a wealth of unique science opportunities, by revealing the violent Universe as it occurs in real-time, exploiting the all-sky X-ray monitoring of extraordinary grasp and sensitivity carried out at high cadence. THESEUS will be able to locate and identify the electromagnetic counterparts to sources of gravitational radiation and neutrinos, which will be routinely detected by next generation facilities, such as aLIGO/aVirgo, LISA, the Einstein Telescope, Cosmic Explorer, and Km3NET. In addition, the provision of a high-cadence soft X-ray monitoring capability in the 2030s together with a 0.7 m infrared telescope in orbit will enable a strong synergy with transient phenomena observed with the large facilities that will be operating in the EM domain (e.g., ELT, SKA, CTA, ATHENA).

The foreseen payload of THESEUS includes the following instrumentation:

- The Soft X-ray Imager (SXI, 0.3 – 5 keV): a set of two lobster-eye telescope units, covering a total field-of-view (FOV) of ~1 sr with source location accuracy <1 – 2 arcmin.
- The InfraRed Telescope (IRT, 0.7 – 1.8 μm): a 0.7 m class IR telescope with 15 × 15 arcmin FOV, for fast response, with both imaging and spectroscopic capabilities.
- The X-Gamma Ray Imaging Spectrometer (XGIS, 2 keV – 20 MeV): a set of 2 coded-mask cameras using monolithic X-gamma ray detectors based on bars of silicon diodes coupled with a CsI crystal scintillator, granting up to 4 sr FOV, a source location accuracy of ~10 arcmin in 2 – 150 keV and an unprecedented broad energy band.

The Swiss THESEUS team, based at the Department of Astronomy of the University of Geneva, is part of the coordination team over-viewing all engineering and scientific activities around THESEUS. The University of Geneva contributes to the mission project office and hosts the mission website. The other responsibilities of the Swiss team cover the development of the cryogenic filter-wheel mechanism for the IRT and a leading role in the design of the mission science ground-segment.

Past Achievements and Status

THESEUS was originally selected as one of the three mission candidates for the 5th ESA call for medium-sized missions of the Cosmic Vision Programme. THESEUS underwent a successful phase A study between 2018 and 2021, but was finally not selected by the Agency in June 2021 as the M5 mission to be implemented. Activities in Switzerland included some prototyping and proof-of-concept development of the IRT filter-wheel, which were successfully completed in February 2022.

THESEUS was re-selected by ESA in 2022 as a candidate for the 7th call for medium-size missions, and it is undergoing a new phase A study, planned to be concluded by June 2026. If selected at the end of the new phase A study, THESEUS could be implemented and launched into a low equatorial orbit in 2037. Nominal scientific operations are planned for at least four years after launch and commissioning.

Time-Line	From	To
Planning	Jan. 2024	Dec. 2026
Construction	2027	2037
Measurement phase	2037	2041
Data evaluation	2037	2041

Publications

Amati L et al. (2021) **The THESEUS space mission: science goals, requirements and mission concept**, ExA 52: 183.

Stratta G et al. (2022) **Breakthrough Multi-Messenger Astrophysics with the THESEUS Space Mission**, Galaxies 10: 60.

Abbreviations

GRB	Gamma Ray Burst
IRT	InfraRed Telescope
SXI	Soft X-ray Imager
THESEUS	Transient High Energy Sky and Early Universe Surveyor
XGIS	X and Gamma Ray Imaging Spectrometer.

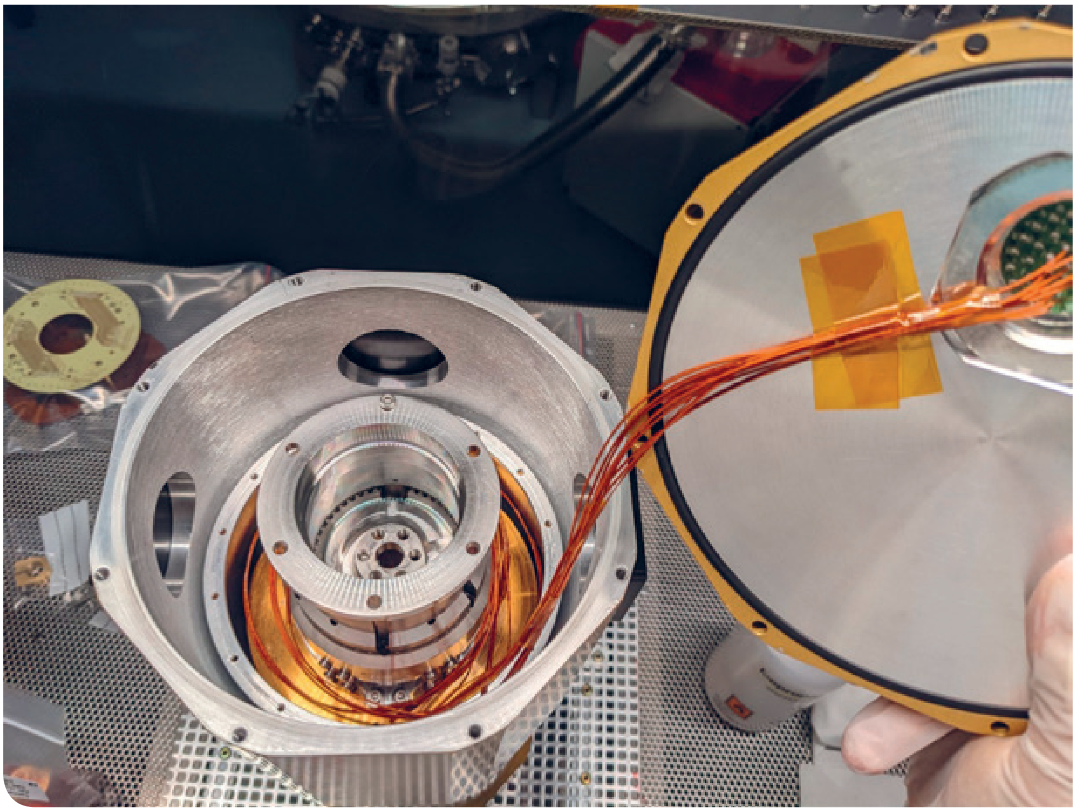
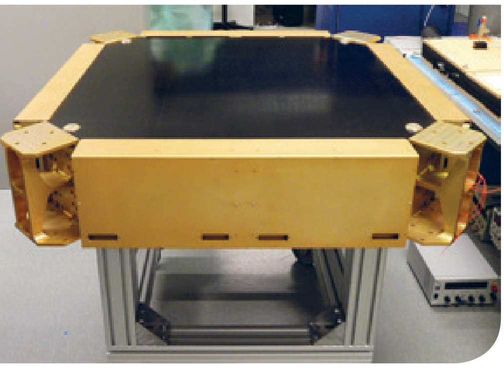


Photo of the IRT filter-wheel prototype realised as a proof of concept by the team at the University of Geneva (Switzerland).

8.9 DAMPE – DArk Matter Particle Explorer



The Silicon-Tungsten Tracker of DAMPE constructed at the University of Geneva

Institute
Dept. Nucl. & Part. Phys. (DPNC), Univ. Geneva, Geneva, Switzerland

In cooperation with
Istituto Nazionale di Fisica Nucleare (INFN), INFN Perugia; INFN Bari; INFN Lecce, Italy; Inst. High Energy Phys. (IHEP), Beijing, China; GSI, L'Aquila, Italy; PMO, Nanjing, China; Univ. Sci. Technol. China (USTC), Hefei, China; Inst. Modern Physics (IMP), Lanzhou, China

Principal Investigator(s)
J. Chang (PMO, China)

Swiss Principal Investigator(s)
X. Wu (DPNC)

Co-Investigator(s)
A. Tykhonov (DPNC), C. Perrina (EPFL, Switzerland)

Contribution
Research based on existing instruments: Astroparticle physics research using data collected by the DAMPE mission

Website(s)
https://dpnc.unige.ch/dampe

Purpose of Research

DAMPE (Dark Matter Particle Explorer) is a satellite mission of the Chinese Academy of Sciences (CAS) dedicated to high energy cosmic ray detection. Since its successful launch on 17 December 2015, a large amount of cosmic ray data has been collected and significant results published. With a relatively large acceptance, DAMPE is designed to detect electrons (and positrons) up to 20 TeV with unprecedented energy resolution to search for new features in the cosmic ray electron plus positron spectrum. It will also study cosmic ray nuclei up to 1 PeV with good precision, which will bring new input to the study of their still unknown origin and their propagation through the Galaxy.

DAMPE consists of a plastic scintillator strip detector (two layers) that serves as an anti-coincidence detector, followed by a silicon-tungsten tracker-converter (STK), then an imaging calorimeter of about 31 radiation lengths thickness, made up of 14 layers of bismuth germanium oxide (BGO) bars in a hodoscopic arrangement. Finally a layer of neutron detectors is situated at the bottom of the calorimeter. The STK, which greatly improves the tracking and photon detection capability of DAMPE, was proposed by the Geneva-DPNC (Dept. Nuclear & Particle Physics) group. An international collaboration led by DPNC, including INFN Perugia, INFN Bari, INFN Lecce (Italy) and IHEP Beijing (China), is responsible for the development, construction, qualification, on-ground calibration, and in-orbit calibration and monitoring of the STK.

The DPNC group played a leading role both in the hardware construction of the DAMPE payload, and is currently a major contributor to the processing and analysis of the scientific data.

Past Achievements and Status

The development and the construction of the STK was completed after three years of intensive effort. The final assembly was completed at the DPNC and delivered to China in April 2015 and integrated into the satellite in May 2015. The DAMPE satellite was successfully launched on 17 December 2015. All sub-systems of DAMPE are functioning well.

The STK is performing above expectation. In-orbit mechanical, thermal and electronic conditions have been very stable. More than 99.7 % of the STK 73728 readout channels are functioning well after more than 10 years in orbit. The DPNC group has major responsibilities for the ground science data operation, including periodic monitoring, calibration and alignment of the STK, as well as the development and the operation of the STK track reconstruction software.

In 2017, DAMPE published the most precisely measured CRE (cosmic ray electron plus positron) spectrum up to 4.6 TeV, and the detection of a break of the CRE spectral index at ~1 TeV, providing a new input to understand the origins of these particles. The DPNC group played a leading role in the electron analysis, and is currently extending the analysis to above 10 TeV with more than 10 years of data, using Machine Learning techniques. The DAMPE experiment is providing the most precise measurements of cosmic rays above 1 TeV to 1 PeV with direct detection. The proton flux up to 100 TeV and the helium flux up to 80 TeV (20 TeV/nucleon) have been published, both unveiling an intriguing spectral softening at about 10 TeV/nucleon. Recently, a universal spectral softening for primary cosmic rays was observed for the first time by DAMPE at a rigidity of ~ 15 TeV, indicating the possible presence of a nearby cosmic ray source. Currently the Geneva group is extending these measurements to the PeV range with more data and with Deep Learning algorithms that are more efficient and more precise compared to traditional algorithms.

In particular, the group has developed a Machine Learning algorithm to correct for energy saturations in the DAMPE BGO calorimeter for all nuclei: from protons and helium up to Fe nuclei. The group is also leading the flux measurements of heavier nuclei Li, Be, B, C, O and their ratios to probe the cosmic-ray diffusion mechanisms and propagation history in our galaxy.

Publications

DAMPE collaboration (2025) **Charge-dependent spectral softenings of primary cosmic-rays from proton to iron below the knee**, arxiv:2512.11425.

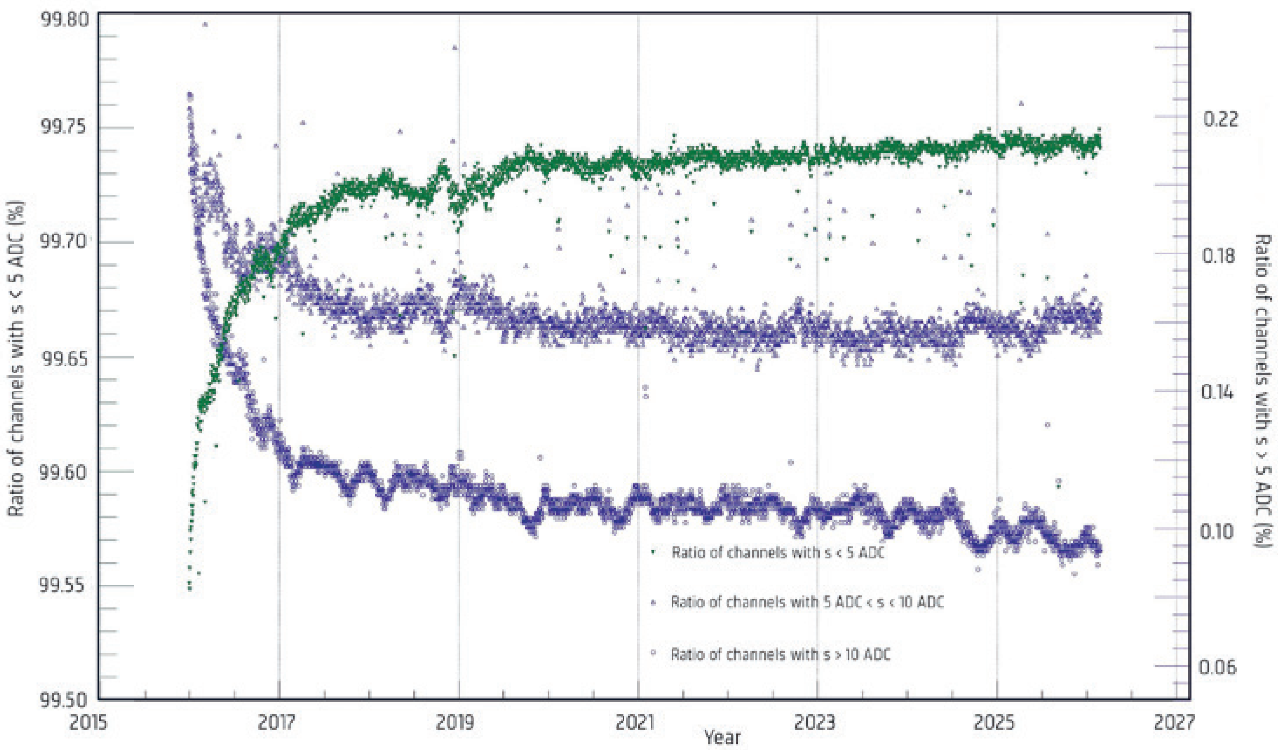
Putti-Garcia E et al. (2025) **Energy reconstruction of non-fiducial electron-positron events in the DAMPE experiment using convolutional neural networks**, JINST 20: P09033.

Serpolla A et al. (2026) **Machine-learning correction for the calorimeter saturation of cosmic-ray ions with the Dark Matter Particle Explorer: towards the PeV scale**, Nucl. Instrum. Methods Phys. Res. A 1085: pp. 171306.

Abbreviations

CRE	Cosmic ray electron plus positron
DAMPE	DArk Matter Particle Explorer
STK	Silicon-Tungsten Tracker

Time-Line	From	To
Planning	2012	2013
Construction	2013	2015
Measurement phase	2016	>2027
Data evaluation	2016	>2027



Fraction of good STK channels with noise below 5 ADC (analogue-to-digital counts; green), compared to those with noise between 5 and 10 (blue), and above 10 ADC (red). Data from Jan. 2016 to Feb. 2026.

8.10 The Swiss Contribution to eXTP

The cover page of the Science China volume where the last updated white papers on the science case of eXTP were published in 2025 with the collaboration of scientists at the Dept. Astronomy, Univ. Geneva. Image credit: Science China.

Institute
Dépt. Phys. Nucl. Corp. (DPNC), Univ. Geneva (UNIGE), Geneva, Switzerland
Dept. Astronomy (DA), Univ. Geneva (UNIGE), Versoix, Switzerland

In cooperation with
Inst. High Energy Phys. (IHEP), Beijing, China

Principal Investigator(s)
S-N. Zhang (IHEP)

Swiss Principal Investigator(s)
X. Wu (DPNC, UNIGE)

Co-Investigator(s)
S. Paltani (DA, UNIGE), E. Bozzo (DA, UNIGE)

Contribution
Research based on existing instruments: Definition of the re-designed mission science case via scientific simulations, contribution to the mission science ground segment.

Purpose of Research

The enhanced X-ray timing and Polarimetry mission (eXTP) is a science mission designed to study the state of matter under extreme conditions of density, gravity and magnetism. Primary targets include isolated and binary neutron stars, strong magnetic field systems such as magnetars, and stellar-mass and supermassive black holes. The mission carries a unique and unprecedented suite of state-of-the-art scientific instruments enabling the simultaneous spectral-timing polarimetry studies of cosmic sources in the 0.5 – 30 keV energy range. Key elements of the payload are:

- The Spectroscopic Focusing Array (SFA): a set of six X-ray optics for a total effective area of about 0.4 m^2 and 0.3 m^2 at 2 keV and 6 keV respectively, equipped with Silicon Drift Detectors offering <180 eV spectral resolution.
- The Polarimetry Focusing Array (PFA): a set of three X-ray telescopes, for a total effective area of 400 cm^2 at 2 keV, equipped with imaging gas pixel photoelectric polarimeters.

The eXTP mission has been under development since 2017 and is currently waiting to have a secured launch of opportunity in China. Following a redesign activity that took place from 2023 – 2025, the mission is no longer hosting payload elements provided by European member states, with the SFA and PFA being entirely developed in China. The European science community is, however, still supporting the Chinese Colleagues in redefining the mission science case. The Swiss eXTP team comprises scientists at the Particle Physics (DPNC) and Astronomy Departments, University of Geneva. Following the changes in the mission payload, the Astronomy Department was mainly involved in supporting the mission science case redesign in 2024 – 2025. Scientific simulations have been performed and included in the updated set of white papers that were published by the eXTP international collaboration in the journal, Science China, at the end of 2025. A possible contribution to the eXTP wide-field monitor by DPNC, and a possible role of the Department of Astronomy in the mission ground segment is under discussion, while plans for the launch of eXTP in the 2030 time-frame are being set-up.

Past Achievements and Status

The eXTP mission underwent a phase B1 study in China and Europe from 2020 – 2023. Following the drop of the European contributions to the mission payload in 2024 – 2024, the mission science case was revised and plans for a mission launch in the 2030 time-frame are now being discussed. The Department of Astronomy remains strongly involved in the definition of the mission science case that closely matches the scientific interest and know-how of the high energy group.

Publications

Zhang S-N et al. (2025) **The enhanced X-ray Timing and Polarimetry mission – eXTP for launch in 2030**, Science China Physics, Mechanics & Astronomy 68: 11, id.119502

Zhuo P et al. (2025) **Observatory science with eXTP**, Science China Physics, Mechanics & Astronomy 68: 11, id.119507

Abbreviations

eXTP The enhanced X-ray Timing and Polarimetry Mission

Time-Line	From	To
Planning	2017	2026
Construction	2027	2030
Measurement phase	2031	2036
Data evaluation	2031	2036

8.11 The LIFE Space Mission

Purpose of Research

The LIFE (Large Interferometer For Exoplanets) Space Mission aspires to become the world-leading mission to search for life beyond the Solar System and seeks to inspire humankind in the way we perceive ourselves and our home planet Earth. As a dedicated space-based interferometer, LIFE's scientific capabilities will outmatch those of any other existing or currently planned instrument or mission. In the current baseline description, LIFE is a formation-flying nulling interferometer consisting of four collector spacecraft with at least 3-m primary mirrors in a rectangular array and a central beam-combiner spacecraft. This significant collecting area provides the sensitivity required to resolve faint planetary signals from the glare of their host stars, enabling the mission to directly detect hundreds of exoplanets orbiting stars in the immediate galactic neighbourhood of our Sun (<30 parsec). It is expected that 30-50 of these exoplanets will have sizes and temperatures similar to Earth – a unique and unprecedented sample. LIFE will measure their intrinsic thermal emission and obtain spectral information in the IR wavelength range (~4-18 µm). LIFE is unique as all requirements are driven by its top science objectives, which is the identification of exoplanetary biospheres. These can be probed via the molecules they produce – so-called biosignature gases, eg O_2 and CH_4 on Earth – which accumulate in the exoplanetary atmospheres. Importantly, LIFE can search for biosignatures in Earth-twin exoplanets but can also find atmospheric biosignatures from biospheres that differ significantly from Earth's in their composition or stellar environment.

Past Achievements and Status

The Exoplanets & Habitability research group at ETH Zurich has been spearheading the development of LIFE. The first international LIFE-themed conference (Barcelona, Nov. 2025) was recently attended by ~250 researchers from >30 countries. Building on this global consensus, the project transitioned from community-building to rigorous engineering, resulting in the first set of mission requirements derived directly from the top-level science objectives. Required technology development needs were refined and, where possible, initiated (e.g., mid-infrared detectors, mid-infrared photonics). Several international partners have started LIFE-related R&D efforts (e.g., SRON, Australian National Univ., Univ. Michigan, Univ. Okayama) and preparatory studies at the sub-system level (e.g., collector spacecraft optics, passive cooling) have been completed. A state-of-the-art instrument simulation toolkit featuring the most relevant noise and optical perturbation terms has been established. Importantly, the Nulling Interferometry Cryogenic Experiment (NICE), a mid-infrared nulling testbed to increase the technological readiness of LIFE, achieved a major milestone.

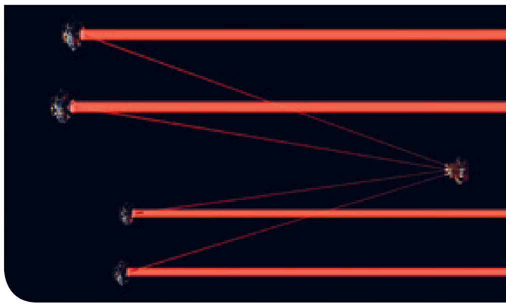
Near-term top priorities are the conclusion of a full end-to-end mission concept study, including a mission development plan, and the subsequent transition into the design phase. In addition to a deeper understanding of the overall mission architecture, these efforts will yield a consolidated understanding of the various systems and subsystems, how they integrate, and how the remaining technology development efforts flow into the overall mission development plan.

Publications

Dannert FA et al. (2025) Astron. J. 170: 3, id.193, 23 pp., doi.org/10.3847/1538-3881/add720

Glauser AM et al. (2024) Proc.SPIE 13095: id. 130951D, 21 pp, doi.org/10.1117/12.3019090

Quanz SP et al. (2022) A&A 664: A21, doi.org/10.1051/0004-6361/202140366



Rendering of the LIFE Space Mission constellation consisting of four collector spacecraft in a rectangular array configuration sending the incoming mid-infrared light to the beam combiner spacecraft. Image credit: LIFE Space Mission.

Institute
Exoplanets & Habitability Group,
Inst. Particle Physics & Astrophysics,
ETH Zurich,
Zurich, Switzerland

In cooperation with
ETH Zurich | Space;
Space Research Organization Netherlands (SRON), Netherlands;
NASA GSFC, USA;
Univ. Groningen, Netherlands;
The Australian National Univ. (ANU), Australia;
NCCR PlanetS;
Swiss Prodex Programme

Principal/Swiss Investigator(s)
S. P. Quanz (ETH Zurich)

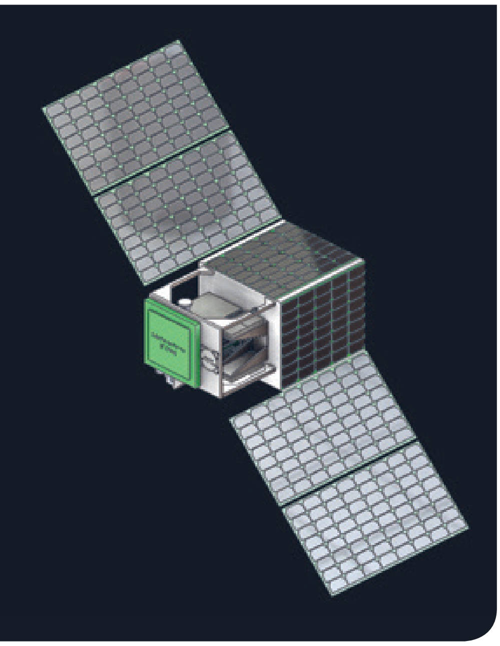
Co-Investigator(s)
A. Glauser (ETH Zurich)

Contribution
Development & construction of instrument(s): LIFE is in its mission definition phase.

Website(s)
https://www.life-space-mission.com

ASTROPHYSICS

8.12 PAN – Penetrating Particle Analyser



Conceptual CAD drawing of the LunPAN satellite from Areospacelab S.A.

Institute
Dépt. Phys. Nucl. Corp. (DPNC), Univ. Geneva, Geneva, Switzerland

In cooperation with
Czech Technical Univ. of Prague, Prague, Czech Republic;
CERN, Switzerland;
Politecnico di Milano, Milano, Italy;
Istituto di Matematica Applicata e Tecnologie Informatiche, Consiglio Nazionale delle Ricerche, Milano, Italy;
INFN, Perugia, Italy

Principal/Swiss Investigator(s)
Xin Wu (DPNC)

Industrial hardware contract(s)
Aerospacelab SA, Switzerland

Website(s)
https://www.pan-space.eu

Purpose of Research

PAN (Penetrating particle ANalyzer) is an innovative energetic particle detection technology based on a compact magnetic spectrometer to precisely measure and monitor the flux and composition of highly penetrating particles (> ~100 MeV/nucleon) in deep space, which will have broad applications. PAN will fill an observation gap of galactic cosmic rays (GCRs) in the 100 MeV/n – GeV/n range, helping to improve our understanding of the origin of GCRs and their propagation through the Galaxy and the Solar system. It will provide precise information of the spectrum, composition and timing of energetic particles originating from the Sun, which is essential for studying the physical process of solar activities, in particular those that produce intensive fluxes of energetic particles. The precise measurement of penetrating particles is also a unique contribution to space weather studies. As indicated by the name of this project, penetrating particles cannot be shielded effectively. PAN can monitor the flux and composition of these particles precisely and continuously, thus providing real-time radiation hazard warning against long-term radiation health risk for human space travellers.

LunPAN (Lunar Particle ANalyzer) is a lunar orbital mission designed to comprehensively map the particle spectra in the lunar radiation field. It aims to provide precise measurements of GCRs, Solar Energetic Particles (SEP), and albedo particles, including charged particles, neutrons, and gamma-rays, originating from the Moon's surface. This is achieved through two state-of-the-art instruments; Pix.PAN and NeuPix. Pix.PAN is a compact magnetic spectrometer designed for precise measurements of penetrating charged particles in the 100 MeV – 10 GeV range. Pix.PAN employs silicon pixel sensors optimised for energy resolution and particle identification. NeuPix is a hybrid active pixel sensor system capable of detecting neutrons, gamma-rays, and lower-energy charged particles between 10 MeV and 100 MeV.

Past Achievements and Status

PAN was funded by an EU H2020 FETOPEN grant to develop a demonstrator (Mini.PAN) in 2020 – 2023. The consortium consists of DPNC, INFN Perugia, the Czech Technical University in Prague and CERN. The demonstrator has been developed and its main functionalities validated with particle beams at accelerator labs. The H2020 project successfully passed the final review in February 2024.

A variant of PAN, called Pix.PAN, has been proposed as the Ultra Relativistic Particle Detector (URPD) of a mission concept to Jupiter's radiations belts, called COMPASS. It has been selected by NASA for pre-Phase A conceptual studies. These studies were completed in 2023, and the results published in a white paper. A separate white paper on the implementation of Pix.PAN has also been published.

The Pix.PAN proposal was submitted in July 2022 to ESA's Call for Reserve Pool of Science Activities for the Moon. It was selected in June 2023 and placed in the pool for the next launching opportunities. An Activity Requirements Document (ARD) has been prepared.

LunPAN is a lunar orbital mission concept based on Pix.PAN, and is designed to comprehensively map the particle spectra in the lunar radiation field. LunPAN was selected by ESA's call for 'Small Missions for Exploration – Destination the Moon' in 2024, and completed the pre-Phase A study in June 2026 that resulted in a successful Mission Definition Review (MDR). In February 2026, LunPAN was recommended by ESA as a payload for the MoonRAD satellite, a lunar SmallSat mission under study by ESA. The Phase A/B1 studies of MoonRAD/LunPAN are expected to be completed in 2026. The goal is to launch MoonRAD/LunPAN around 2030.

Publications

Hulsman J, Wu X, Azzarello P et al. (2023) **Relativistic particle measurement in Jupiter's magnetosphere with Pix.PAN**, Exp Astron. 56: 371–402.

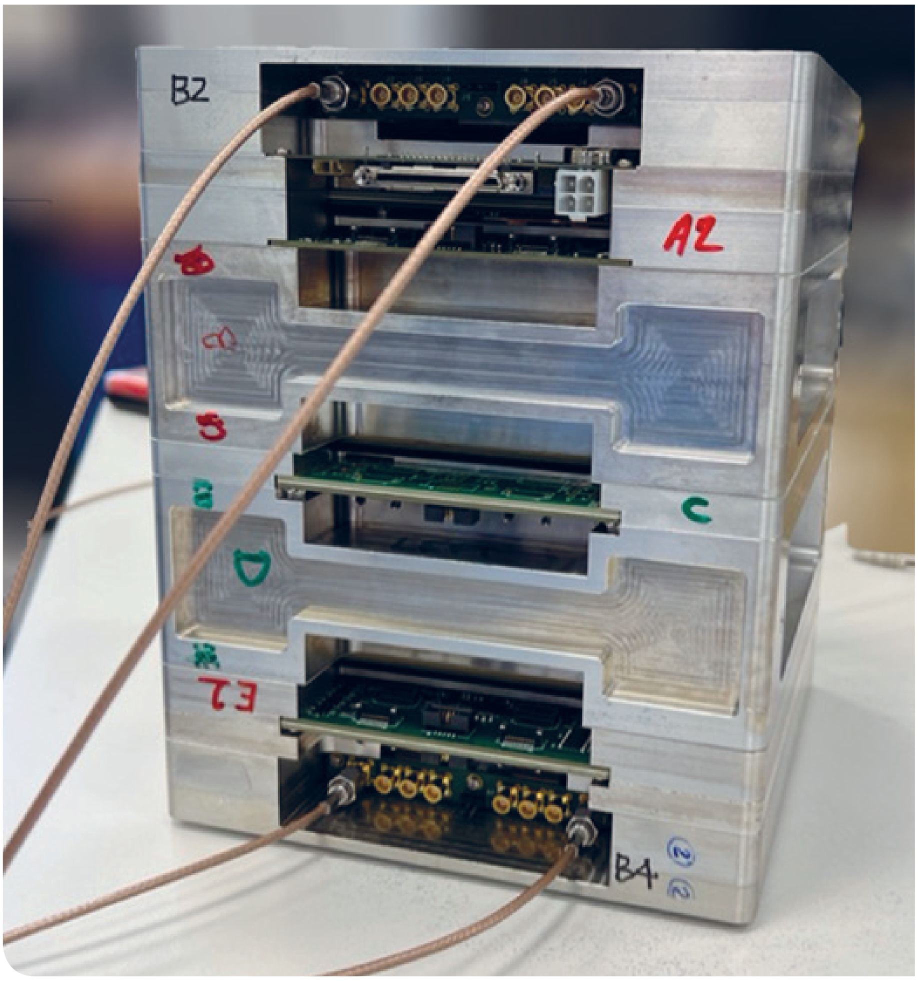
Hulsman J, Alessi E, Andreasi L, et al. (2025) **Comprehensive study of the Lunar energetic particle environment with LunPAN**, PoS ICRC2025, v501: 1301.

Wu X, Ambrosi G, Azzarello P, Bergmann B et al. (2019) **Penetrating particle Analyzer (PAN)**, Advances in Space Research 63: 2672-2682.

Abbreviations

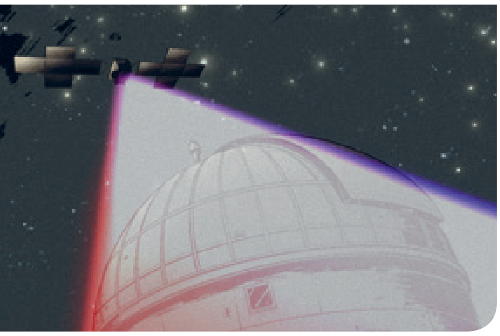
COMPASS	Comprehensive Observation of Magnetospheric Acceleration, Source, and Sinks
LunPAN	Lunar Particle ANalyzer
MoonRAD	Lunar Exploration Space Weather Monitoring SmallSat Mission
PAN	Penetrating Particle Analyser

Time-Line	From	To
Planning	2018	2026
Construction	2027	2030
Measurement phase	2031	>2033
Data evaluation	2031	>2033



The Mini.PAN demonstrator.

8.13 NuANCESTOR



Artist's impression of the light from NuANCESTOR illuminating a ground telescope equipped with an EPRV spectrograph. Image credit: MAGICSCIENCEPRO.COM.

Institute
Univ. Geneva (UNIGE), Geneva, Switzerland

In cooperation with
Centre Suisse d'Electronique et de Microtechnique (CSEM), Neuchatel, Switzerland; ETH Zurich (ETHZ), Zurich, Switzerland; Univ. Bern (UNIBE), Bern, Switzerland; Haute Ecole Spécialisée de Suisse Occidentale (HES-SO), Delémont, Switzerland

Principal/Swiss Investigator(s)
F. Pepe (UNIGE)

Co-Investigator(s)
C. Mordasini (UNIBE), S. Lecomte (CSEM), J. Moershell (HSO-SO), B. Soja (ETHZ)

Contribution
Development & construction of instrument(s): Feasibility study for the entire mission, including the spacecraft and the payload.

Website(s)
https://nuancestor.astro-ge.ch

Purpose of Research

The study of exoplanets, the search for Earth analogues and investigation of the nature of the Universe are the main subjects of high-fidelity astronomical spectroscopy. Since the discovery of the first exoplanet orbiting a solar-type star by Michel Mayor and Didier Queloz using the radial velocity technique, the field has been thriving, with new, often unexpected discoveries emerging one after the other. High-fidelity spectroscopy has become the main technique to detect planetary atmospheres and bio-signatures, to characterise host stars, to measure the expansion of the Universe, or even to test fundamental physics by measuring the possible variability of fundamental constants.

At present, there are several tens of high-resolution astronomical spectrographs scattered all around the world. Their scope ranges over various domains of astrophysics, from the search and characterisation of habitable exoplanets, through fundamental physics, e.g., the study of the variability of physical constants, to the direct measurement of the expansion rate of the Universe. These fundamental questions of astrophysics can all be addressed by high-fidelity spectroscopy provided that extreme accuracy is achieved.

The accuracy of the mentioned instruments, representing the state-of-the-art science and technology development, depends on the access to extremely precise and stable wavelength calibration sources. There are several available calibration sources (e.g., emission lamps, laser frequency combs, reference cavities) that can be used to calibrate an astronomical spectrograph. However, the calibration as it is currently performed is always local with the following consequences:

- Wavelength calibration of most of the astronomical spectrographs is 'precise'. While the wavelength calibration is sufficient in relative terms for some of the exoplanet studies, other investigations, such as the detection of Earth analogues, require long-term repeatability that can only be assured by 'accuracy', i.e., if the spectrograph is calibrated in absolute terms. Another example of a scientific measurement requiring accuracy, is a direct measurement of the expansion rate of the Universe.
- The vast majority of astronomical spectrographs lack a common wavelength reference. This signifies that the data taken by one spectrograph cannot be directly compared nor directly combined with data taken by another spectrograph. This impedes possibilities for performing long-term measurements simultaneously by several spectrographs in order to increase the measurement sensitivity, time sampling or time-span.

The usual scheme for spectrograph calibration requires that somewhere along the optical path from the telescope to the spectrograph, a light from the calibrator is injected to calibrate the latter. As a consequence, only a part of the optical path is used. Any error introduced in the path before the injection of the calibrator (atmosphere and telescope front-end) is not monitored, which may lead to additional unwanted effects in the scientific data that cannot be identified nor corrected for.

NuANCESTOR will address the above-mentioned issues with the wavelength calibration of astronomical spectrographs by using an optical frequency comb on-board a satellite equipped with an actively pointing telescope and precision orbitography. Its principal goals are:

- Provide an optical frequency anchor in the form of an absolute laser source operating at several wavelength bands (via a Laser Frequency Comb, LFC).
  - Astronomical spectrographs around the world will have access to a light source for cross-comparison of the local calibration source.
  - Astronomical spectrographs will become calibrated with the same reference frequency finally allowing comparison and merging of data from different instruments.
- Provide a means for calibrating the full telescope–spectrograph optical path, such that any errors introduced in the instrumentation chain are identified and corrected.

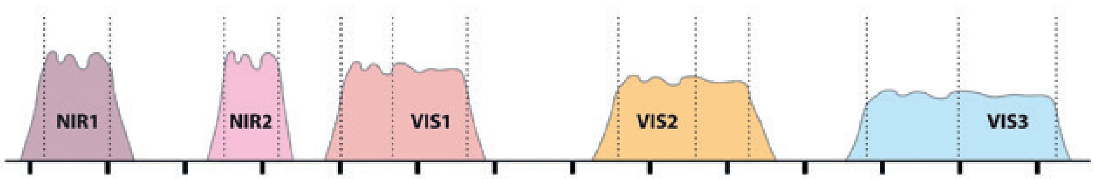
Past Achievements and Status

The project has been granted financial support from the Swiss Space Office for a phase 0 and phase A study, covering the period 2024 – 2027. During phase 0, that was concluded in early 2025, the consortium of Swiss Institutes participating in NuANCESTOR developed a set of requirement documents covering the scientific objectives of the mission, as well as all aspects related to the LFC, the telescope, the pointing system and the Global Navigation Satellite System (GNSS). These required documents have been used to issue an industrial Invitation To Tender (ITT) to cover the activities of phase A. This new phase kicked off in April 2025. It foresees the participation in the project of a consortium of industries coordinated by CSEM to transfer the set of requirements available so far into a suitable mission profile. The future construction of the mission is subject to the participation of additional international partners in order to cover the cost of the platform, payload, launch, and operations. The cooperation scheme is being investigated by the institutional consortium as part of the phase A activities.

Abbreviations

EPRV	Extreme Precision Radial Velocity
ITT	Invitation To Tenders
LFC	Laser Frequency Comb

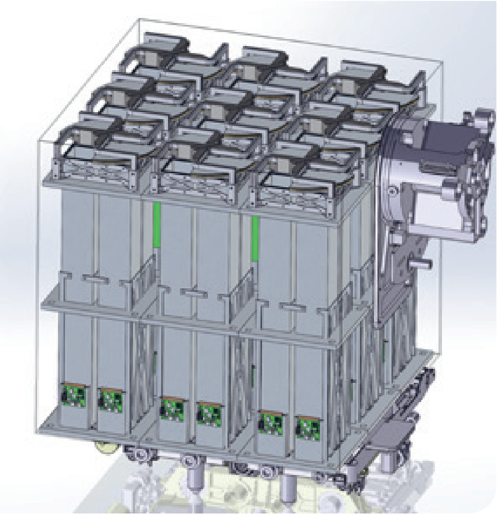
Time-Line	From	To
Planning	2024	2027
Construction	to be decided	tbd
Measurement phase	tbd	tbd
Data evaluation	tbd	tbd



The wavelength coverage planned for the LFC on-board NuANCESTOR. Image credit: CSEM.

ASTROPHYSICS

8.14 CXBe – The Cosmic X-Ray Background Explorer



CAD model of the CXBe instrument, consisting of 36 detector units (DUs). The payload has external dimensions of 500 × 500 × 500 mm³ (X × Y × Z) and a total mass of <140 kg, complying with the mechanical and mass constraints imposed by the China Space Station (CSS).

Institute
Dept. Astronomy, Univ. Geneva (UNIGE), Versoix, Switzerland

In cooperation with
Inst. High Energy Phys. (IHEP), Beijing, China; Particle Physics Department (DPNC), Univ. Geneva, Switzerland; Technology and Engineering Center for Space Utilization (CSU), Beijing, China

Principal/Swiss Investigator(s)
R. Walter (UNIGE)

Chinese Principal Investigator(s)
J.-Y. Liao (IHEP)

Co-Investigator(s)
N. Produit (UNIGE), H. Li (UNIGE)

Contribution
Development & construction of instruments: Preliminary definition, advanced prototype and calibration tests of the CXBe module.

Purpose of Research

The Cosmic X-ray Background Explorer (CXBe) is an X-ray instrument dedicated to measuring the spectrum of the Cosmic X-ray Background (CXB) with an unprecedented precision of ~1 % in the 10 – 100 keV energy range, representing an order-of-magnitude improvement over current measurements (15 – 20 %). This advance will enable significant refinement of CXB synthesis models and provide stronger constraints on the population of active galactic nuclei (AGN), including their obscuration properties, reflection components, average spectra, and ultimately the history of cosmic accretion in the Universe. In addition, the possible presence of a dipole anisotropy in the angular distribution of the CXB could provide an absolute reference to determine the local velocity of the Earth relative to the large-scale AGN distribution. CXBe will likely be the first instrument with sufficient sensitivity to probe this dipole.

The CXBe instrument consists of an array of 3 × 3 detector modules (DMs). Each module contains 2 × 2 detector units (DUs), forming a GAGG-based spectrometer read out by SiPM-based front-end electronics (FEE) derived from the POLAR-2 heritage. The spectrometers provides an effective area of ~300 cm² at 30 keV, corresponding to the peak of the CXB spectrum. Each DU is embedded within a sandwich collimator and equipped with a motor-driven rotating obturator operating across the field-of-view of the four DUs. This configuration enables differential flux measurements, allowing precise extraction of the CXB signal while suppressing various sources of contamination. Furthermore, the instrument will incorporate a dedicated calibration system designed to achieve precise knowledge of the detector's spectral response, particularly its absolute detection efficiency. Such accurate background rejection and calibration are essential to reach the targeted measurement precision.

Past Achievements and Status

The CXBe mission has been endorsed as a potential payload for the China Space Station (CSS) and is currently undergoing Phase B1 studies supported by the NASO funding scheme of the Swiss Space Office (SSO). Two key system requirements are being addressed: 1) the development of a long-lifetime rotating mechanism capable of stable multi-year operation, and 2) the achievement of quasi-absolute detector calibration at the ~1 % precision level. Building on these developments, the collaboration is progressing toward further funding suppose and formal mission adoption of the launch platform, followed by construction of the flight model, with a targeted launch timeframe of 2029 – 2030.

Publications

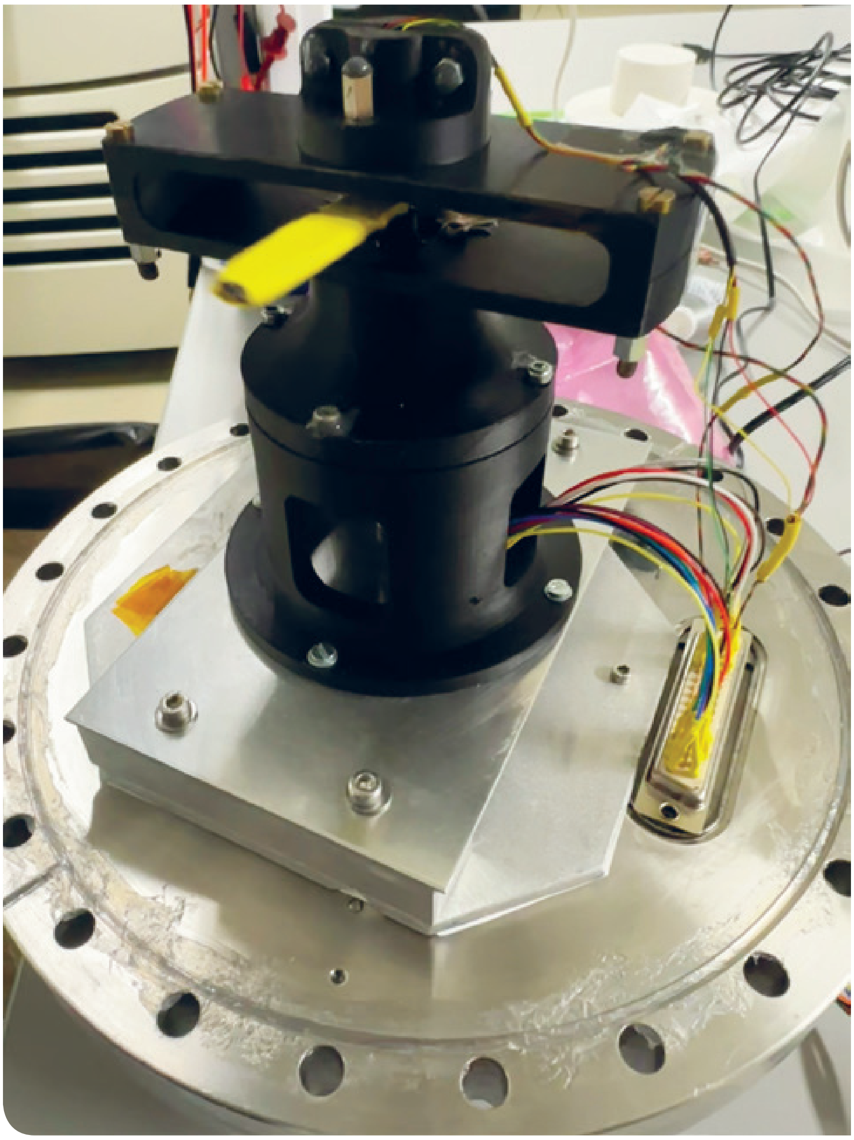
Li H, Walter R, Produit N, Hubert F (2023) **Measuring the cosmic X-ray background accurately**, Exp. Astronomy 56(1): 141–170, doi.org/10.1007/s10686-023-09896-7

Li H, Garcia B, Produit N, Walter R (2025) **Progress of the Cosmic X-ray Background explorer (CXBe) project**, 39th Int. Cosmic Ray Conf. 15-24, Geneva, 728, doi.org/10.22323/1.501.0728

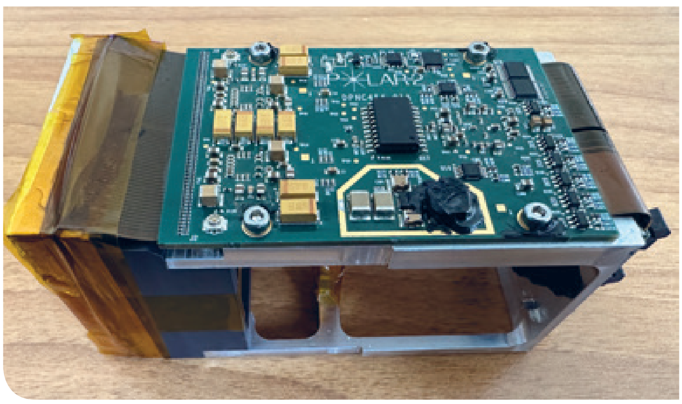
Abbreviations

CXBe Cosmic X-ray Background explorer

Time-Line	From	To
Planning	2021	2026
Construction	2027	2029
Measurement phase	2030	>2033
Data evaluation	2030	>2033

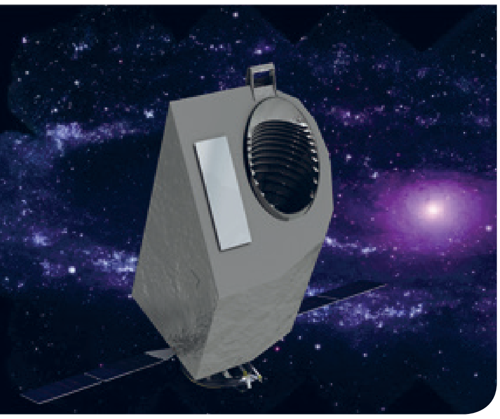


Prototype of the CXBe rotation system, qualified through extensive thermal-vacuum testing over a temperature range of –40 to 50°C at 7 × 10^{-7} mbar, and life-cycle tested to demonstrate a 20-year equivalent operational lifetime in space.



Prototype of the CXBe detector unit (DU), extensively tested through proton irradiation campaigns and X-ray calibration measurements at the European Organization for Nuclear Research (CERN) and the European Synchrotron Radiation Facility (ESRF).

8.15 UVEX – The Ultraviolet Explorer



Artist's impression of the current UVEX satellite design. Image credit: NASA.

Institute
Dept. Astronomy, Univ. Geneva (UNIGE)
Versoix, Switzerland

In cooperation with
Division of Physics, Math. & Astronomy,
Calthech, Pasadena, California, USA

Principal Investigator(s)
F. Harrison (Caltech)

Swiss Principal Investigator(s)
A. Verhamme (UNIGE)

Co-Investigator(s)
C. Ferrigno, L. Genolet, G Parma (UNIGE)

Contribution
Development and construction of the UVIM door mechanism, support to the definition of the mission science case, establishment of a European center of excellence for the mission.

Industrial hardware contract(s)
APCO Technologies, Switzerland

Website(s)
https://uvex.astro-ge.ch

Purpose of Research

UVEX was selected for implementation by NASA as part of their Medium-Class Explorer mission programme in February 2024. The UVEX selection was driven by the expected impact that such a mission will have in the field of time-domain and multi-messenger Astrophysics in the decades to come. Being at present the sole confirmed mission in the UV domain, UVEX will secure, via its unprecedented and unique capabilities, the coverage throughout a fundamental part of the electromagnetic spectrum, which extends from the near to the far UV. This nicely complements the coverage provided by the currently operating and incoming large scale facilities, such as the Atacama Large Millimeter-submillimeter Array (ALMA), the James Webb Space Telescope (JWST), the Nancy Grace Roman Space telescope, and Euclid. UVEX has three primary science objectives:

I. Exploring the low-mass, low-metallicity galaxy frontier.

II. Providing new views on the dynamic universe.

III. Leaving a broad legacy of modern, deep synoptic surveys, adding to the panchromatic richness of 21st century Astrophysics.

Exploring the low-mass galaxy frontier is at the forefront because low-mass galaxies dominate the local ($z<0.3$) population, and the processes taking place in their low-metallicity, actively star-forming environments are largely unexplored. Understanding them will shed new light on how processes like star formation and evolution work in low-metallicity, low-density galactic ecosystems, and will be crucial in interpreting data from ALMA and JWST at high redshifts. Yet, we know little about low-mass galaxy demographics, their stellar populations, and their evolution – all of which are dramatically different from those occurring in typical, well-studied galaxies like our Milky Way. UVEX will be transformative by adding essential deep far and near ultraviolet (FUV and NUV) imaging and spectroscopy.

UVEX will provide new views on the dynamic universe by discovering and diagnosing the early UV aftermaths of Gravitational Wave-discovered neutron star (NS) mergers. Also, through rapid spectroscopy, it will probe the evolutionary history of massive stars in the moments before their demise. Tapping into the creativity of the community, UVEX will be an unprecedented resource for deep, fast UV spectroscopic follow-up of Targets of Opportunity (ToOs).

UVEX will leave a broad legacy of modern, deep, synoptic all-sky surveys. It is time to replace the Galaxy Evolution Explorer (GALEX) Small Explorer data (flown in 2003 and decommissioned in 2013) with a modern survey that: i) is cadenced, covering the entire sky with 12 hr – 6 month intervals, ii) includes the Galactic Plane, iii) provides rapid transient alerts to the world-wide community for explosive events in the Universe, and iv) achieves depth and resolution, matching modern facilities in all other electromagnetic domains (see Figure opposite). UVEX is an explorer so it's unprecedented sensitivity will open a huge discovery space to UV transient and variable sources in the future.

The UVEX team at the University of Geneva (UNIGE) is responsible for the provision of the mechanism door, which opens and closes the field-of-view of the only instrument on-board UVEX, called UVIM. The mechanism is an operable door, which allows the scientific team to perform periodic calibrations of UVIM during the course of the nominal mission lifetime (2 years) and beyond (in case the mission operations are extended by NASA). The UNIGE team is also expanding the scientific objectives of the mission by performing simulations to optimise the surveying strategy in the UV domain and exploit UVEX data to search for sources responsible for the Cosmic Reionisation. Through the on-going survey design optimisation, UVEX data will be able:

- to quantify which fraction of the population of UV-bright galaxies at intermediate redshift ($z \sim 1$) are leaking ionising radiation.
- to identify leakers for follow-up spectroscopic observations with the UVEX spectrograph to determine their spectral energy distribution
- to characterise the properties of this sub-group of leaking galaxies with respect to the whole population.

Furthermore, the UNIGE team is responsible for establishing a center of excellence for UVEX in Switzerland, which will facilitate access to the mission data and capabilities for the European science community. This will be realised by locally acquiring a detailed knowledge of the data processing pipeline, organising training courses for scientists, promoting the mission exploitation and keeping a tight link with the leading instrument team at Caltech (USA).

Past Achievements and Status

The activities of the UNIGE team kicked off in 2025, supported by a dedicated PRODEX proposal. The design of the UVIM door mechanism is being carried out in collaboration with the Swiss industrial firm, APCO Technologies. The UNIGE and APCO teams are supporting the UVIM instrument Preliminary Design Review (PDR), expected to be concluded in April 2026. This will allow the mission to move from the current B1 phase into the next B2/C/D phases, when the construction of the engineering models will commence. The delivery of the UVIM door flight model is expected in 2028 – 2029, in time to support the launch campaign in 2030. On-going simulations have proved the suitability of the UNIGE team to exploit UVEX for Cosmological Reionization studies, and a report is being prepared for submission to the mission PI and inclusion in the survey strategy of the mission. Plans for the center of excellence have been laid down, allowing UNIGE to fulfil this task, well in time for the beginning of the science operations.

Publications

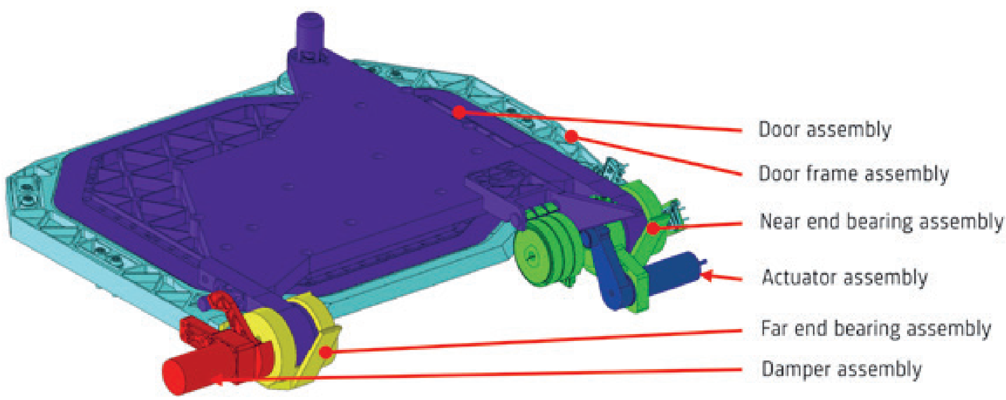
Grefenstette B et al. (2023) **Exploring the dynamic ultraviolet universe with UVEX**, AAS High Energy Astrophysics Division meeting #20, id. 103.40

Kulkarni SR (2023) **Science with the Ultraviolet Explorer (UVEX)**, eprint arXiv:2111.15608

Abbreviations

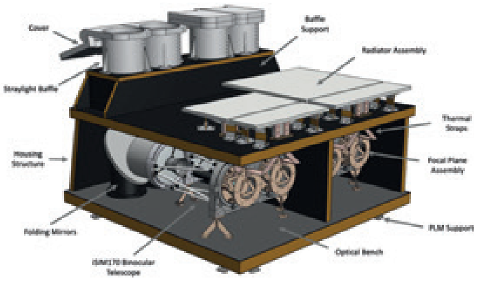
UVEX The Ultraviolet Explorer

Time-Line	From	To
Planning	2024	2026
Construction	2026	2030
Measurement phase	2031	2033
Data evaluation	2031	2033



Detailed design of the UVIM door being developed by UNIGE and APCO Technologies.

8.16 ARRAKIHS – Analysis of Resolved Remnants of Accreted Galaxies as a Key Instrument for Halo Surveys



Preliminary design of the ARRAKIHS payload.

Institute
Dept. Astrophysics, University of Zurich, Zurich, Switzerland

In cooperation with
Spain, Belgium, Sweden, UK, Austria, ESA, Switzerland: HSLU, FHNW, EPFL, ZHAW, KOEGL Space

Principal Investigator(s)
R. Guzman (IFCA)

Swiss Principal Investigator(s)
B. Moore (UZH)

Co-Investigator(s)
The ARRAKIHS team includes over 100 scientists and engineers from 7 ESA member states

Contribution
Development & construction of instrument(s): Switzerland is in charge of the design and production of the thermal and structural subsystem (V. Tamburello, UZH), the overall project payload management (S. Kögl, KOEGL Space), and the scientific coordinator (R. Bieri, UZH)

Website(s)
https://newathena.astro-ge.ch

Purpose of Research

In November 2022, ARRAKIHS (Analysis of Resolved Remnants of Accreted galaxies as a Key Instrument for Halo Surveys) was selected as ESA's second F-class mission, with a launch date target of 2030. Using a dual binocular telescope on a mini satellite in low Earth orbit, it will catalogue ultra-low surface brightness images of Milky Way-like galaxies. ARRAKIHS will annually capture 50 square degrees of the sky in four bands, aiming at 31 mag./arcsec^2 in visible and 30 mag./arcsec^2 in the near-infrared. It will specifically:

- Characterise the abundance and locations of satellite galaxies, down to MV < -6 for a complete sample of Milky Way-like galaxies beyond the Local Group.
- Provide robust statistics of the numbers and shapes of wide and thin stellar streams.
- Characterise the shape and extent of the ultra-faint intra-halo light.

These data will be used to test different theories for the nature of dark matter that dominates the mass component of galaxies.

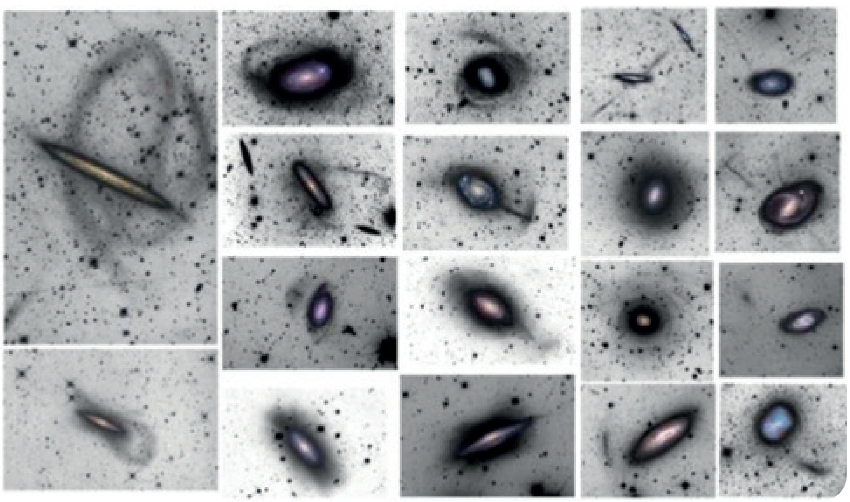
Past Achievements and Status

- Mission selection Nov. 2022.
- Mission Definition Review passed Sep. 2023.
- Phase A passed Mar. 2024.
- Phase B started Apr. 2024.
- Preliminary Design Review Q2 2026.

Abbreviations

ARRAKIHS Analysis of Resolved Remnants of Accreted galaxies as a Key Instrument for Halo Surveys

Time-Line	From	To
Planning	2023	2026
Construction	Jul. 2026	Jan. 2030
Measurement phase	2030	2033
Data evaluation	2030	open



Luminance filter images of nearby galaxies from the Stellar Tidal Stream Survey showing large, diffuse light structures in their outskirts (Image credit: David Martinez-Delgado, IAA).

9 Space Safety

9.1 SSA – International Space Situational Awareness

Purpose of Research

The proliferation of space debris, man-made non-functional objects of all sizes in near-Earth space and the increased probability of collisions and interference between man-made objects in space, raise concerns about the long-term sustainability of space activities, particularly in the low-Earth orbit (LEO) and geostationary orbit (GEO) environments. International organisations at different levels are examining measures to enhance the long-term sustainability of such activities, among them the UN Committee on the Peaceful Uses of Outer Space (UNCOPUOS) and the Inter-Agency Space Debris Coordination Committee (IADC).

Our modern societies increasingly depend on vital services provided by infrastructure in space. Among them are navigation services, critical data for weather forecast and climate models, Earth observation data used for agriculture, disaster management, monitoring of environmental pollution, etc., to name just a few. Protecting infrastructure in space is thus pivotal to protecting and furthering the success of important infrastructure on Earth.

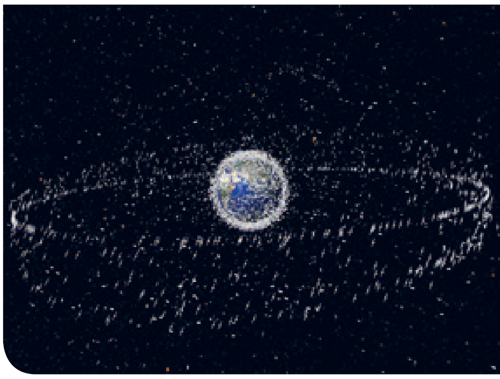
The central aim of Space Situational Awareness / Space Safety is to acquire information about natural and artificial objects in Earth orbits. The growing number of space debris results in an increasing threat to operational satellites and manned spaceflight. Research in this domain aims at a better understanding of the near Earth environment through extending the catalogues of known space objects toward smaller sizes, by acquiring statistical orbit information on small-size objects in support of statistical environment models, and by characterising 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.

Past Achievements and Status

This is an ongoing international collaboration between the Astronomical Institute of the University of Bern (AIUB; Switzerland), the Keldish Institute of Applied Mathematics (KIAM; Moscow), ESA, and the German Aerospace Center (DLR; Germany). Optical surveys performed by AIUB using its ZIMLAT and ZimSMART telescopes at the Zimmerwald Observatory (Switzerland) and the ESA telescope in Tenerife (Spain) on behalf of ESA, as well as the surveys performed by KIAM using the ISON telescopes, and the data from the AIUB/DLR SMARTnet sensor network, provide the data to maintain orbit catalogues of high-altitude space debris.

These catalogues 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 Safety programme.

An important source of space debris are fragments from on-orbit breakup events. During the past years, several severe fragmentations of upper stages have taken place in high-altitude orbits producing several thousand debris pieces of substantial size. The



Graphical representation of the space debris population of objects >10 cm as seen from 15 Earth radii (ESA).

Institute
Astronomical Inst., Univ. Bern (AIUB), Bern, Switzerland

In cooperation with
European Space Agency (ESA);
Keldish Inst. Applied Mathematics (KIAM), Moscow, Russia;
International Scientific Optical Observation Network (ISON);
DLR/German Space Operation Centre (GSOC), Oberpfaffenhofen, Germany

Principal Investigator(s)
T. Schildknecht (AIUB)

Co-Investigator(s)
I. Molotov (KIAM), H. Fiedler (DLR)

Contribution
Measurement, Compilation

Observatories
Zimmerwald, Switzerland
Sutherland, South Africa
Mount Kent, Australia
El Sauce, Chile
ESA, Tenerife
ISON telescopes

Website(s)
https://www.aiub.unibe.ch

SSA / Space Safety collaboration has made essential contributions to the identification and cataloguing of the debris clouds. As an example, the below figure shows the debris clouds from three of these events.

AIUB also hosts and operates the ESA/AIUB Space Safety Expert Centre, a service and coordination facility in support of space safety.

Publications

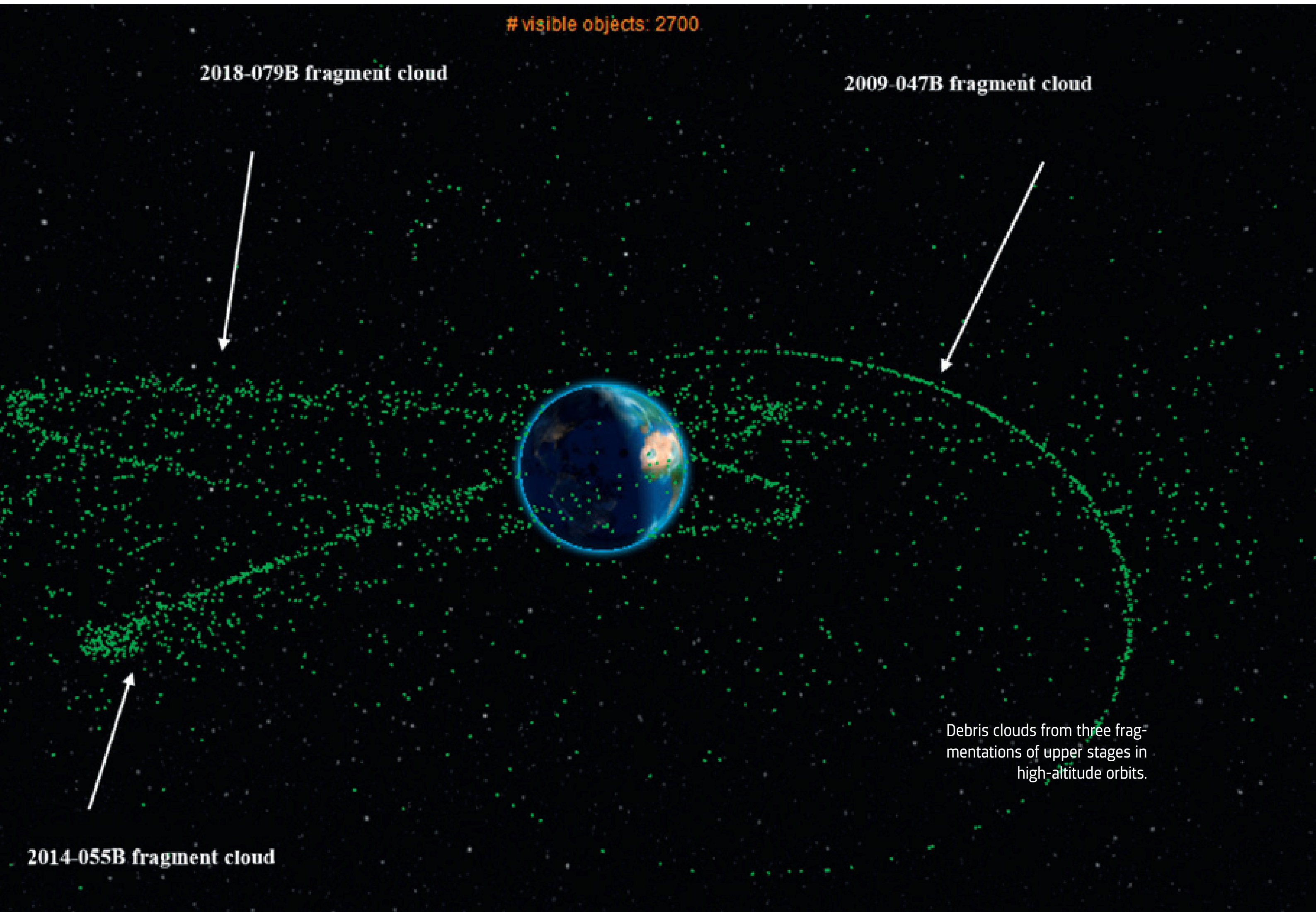
Schildknecht T et al. (2023) **Statistical analysis of space debris surveys in high-altitude orbital regions**, Proc. 24th AMOS conf., Maui, Hawaii.

Schildknecht T et al. (2023) **European Expert Centre for Space Safety providing services and support for space surveillance and traffic management**, Proc. 2nd ESA NEO and debris detection conference, Darmstadt, Germany.

Vananti A, Lu Y, Schildknecht T (2023) **Attitude estimation of H2A rocket body from light curve measurements**, Int. J. Astrophys. Space Sci. 11.

Abbreviations

AIUB	Astronomical Institute, Univ. Bern
IADC	Inter-Agency Space Debris Coordination Committee
ISON	International Scientific Optical Network
SMARTnet	SMall Aperture Robotic Telescope network
SSA	Space Situational Awareness
ZIMLAT	Zimmerwald Laser & Astrometry Telescope
ZimSMART	Zimmerwald SMall Aperture Robotic Telescope



Debris clouds from three fragmentations of upper stages in high-altitude orbits.

9.2 ESA Mission VIGIL / NASA JEDI

Purpose of Research

The Vigil Mission's primary objective is to station a satellite at the 5th Lagrange point (L5) to continuously monitor the Sun and the region between Earth and the Sun. It aims to enhance space weather predictions by providing real-time data, issuing event-based warnings for solar events, and improving forecasts for space weather impacts. Observing from L5 complements existing monitoring along the Sun-Earth line, enabling more accurate predictions and early warnings for potentially hazardous solar conditions.

The NASA instrument onboard Vigil was selected in May 2024 and will provide a constant view of the Sun from this perspective in extreme ultraviolet light. It will provide images on the solar disc where eruptions begin and in the middle corona where they are transported into the heliosphere.

PMOD/WRC is providing the front-end electronics (FEE) for the Joint EUV Coronal Diagnostic Investigation (JEDI) instrument.

Past Achievements and Status

The JEDI instrument is comprised of two telescopes, the Space Weather Operational Coronal Imager (SWOC) and the Enhanced Wide-angle Observations of the Corona (EWOC).

SWOC takes ~4 min cadence images of the full solar disk and extended corona out to 3.2x the nominal solar radius on the Earthward limb in three narrow passbands corresponding to temperatures ranging from the chromosphere to the flaring corona.

EWOC takes images of the full solar disk and extended corona in two passbands sensitive to chromospheric and coronal plasma out to 6x the nominal solar radius.

EWOC's game-changing field-of-view is enabled by a moveable occulter, proven by the Solar Orbiter Extreme Ultraviolet Imager, allowing interleaved, low-scattered light images of the extended corona and on-disk coronal structures to be made.

The preliminary design review of the instrument took place in December 2025 by NASA and was successfully passed.

Abbreviations

EWOC	Enhanced Wide-angle Observations of the Corona
EUV	Extreme UV
FEE	Front-End Electronics
JEDI	Joint EUV Coronal Diagnostic Investigation
SWOC	Space Weather Operational Coronal Imager

Time-Line	From	To
Planning	2023	2023
Construction	2024	2031
Measurement phase	open	open
Data evaluation	open	open

Artist's impression of the Vigil mission at the Lagrange L5 point in space. Image credit: ESA.

Institute
Physikalisch-Meteorologisches Observatorium Davos / World Radiation Centre (PMOD/WRC), Davos, Switzerland

In cooperation with
NASA, ESA, SWRI

Principal Investigator
D. Hassler (SWRI)

Swiss Principal Investigator
L. Harra (PMOD/WRC)

Co-Investigator(s)
A. Morandi (PMOD/WRC)

Contribution
Measurement

Industrial hardware/software contract(s) to
dlab GmbH, Switzerland

Website(s)
https://www.esa.int/Space_Safety/Vigil

10 Earth Observations and Remote Sensing

10.1 ARES – Airborne Research Facility of the Earth System

AIRBORNE RESEARCH OF THE EARTH SYSTEM

Institute
Remote Sensing Labs. (RSL)
Dept. Geography, Univ. Zurich,
Zurich, Switzerland

In cooperation with
ETH Zurich (ETHZ);
Institute for Mathematics, Univ. Zurich (UZH);
Inst. Atmos. Climate Science (IAC, ETHZ);
Inst. Agricultural Sciences (IAS, ETHZ);
Inst. Geodesy & Photogramm. (IGP, ETHZ);
Empa; EAWAG; EPFL ENAC; Univ. Fribourg (UniFr); Inst. des Dynam. de la Surface Terrestre, Univ. Lausanne (UniL)

Principal/Swiss Investigator(s)
M. E. Schaepman (RSL)

Co-Investigator(s)
A. Hueni (RSL), R. Furrer (UZH)
S. Seneviratne (IAC. ETHZ), N. Buchmann (IAS, ETHZ)
K. Schindler (IGP, ETHZ), D. Brunner (Empa)
D. Odermatt (EAWAG), M. Hoelzle (UniFr)
R. Veron (EPFL ENAC), G. Mariethoz (UniL)

Contribution
Research based on existing instrument(s):
ARES is an airborne research facility to predominantly address research questions within the Earth System Sciences

Industrial hardware contract(s)
Zürcher Hochschule für Angewandte Wissenschaften (ZHAW) for the improvement of the flight hardware and software in collaboration with UZH

Website(s)
https://ares-observatory.ch

Purpose of Research

The Airborne Research Facility of the Earth System (ARES) is an airborne research facility to mainly address research questions within the Earth System Sciences.

The main components of ARES are:
- An aircraft, leased or contracted during flight periods.
- An instrument package consisting of an imaging spectrometer (IS), a multispectral LiDAR, and a high-performance photogrammetric camera (hpPC).
- A flight management, instrument control and navigational system giving attitude and positional information allowing an automated georectification of data products.

The goal of this project is to run, improve and extend the ARES infrastructure, including purchase/development of hardware and software, integration of the components, airworthiness certifications, acceptance tests and establishment of payload specific processing and archiving facilities.

Past Achievements and Status

The AVIRIS-4 imaging spectrometer was integrated with flight hardware and software by ZHAW. AVIRIS-4 was flown operationally from early 2024 onwards. The option to combine AVIRIS-4 with a full waveform LIDAR was added in early summer 2025. Updates and further information can be found on the ARES web page: https://ares-observatory.ch. An overview of imagery acquired by AVIRIS-4 and its predecessors APEX and AVIRIS-NG can be found on the ARES data portal: https://ares-observatory-portal.ch. Parties interested in acquiring data with ARES sensors are kindly asked to contact the ARES team.

Time-Line	From	To
Planning	2017	2018
Construction	2018	2024
Measurement phase	2024	ongoing
Data evaluation	2024	ongoing

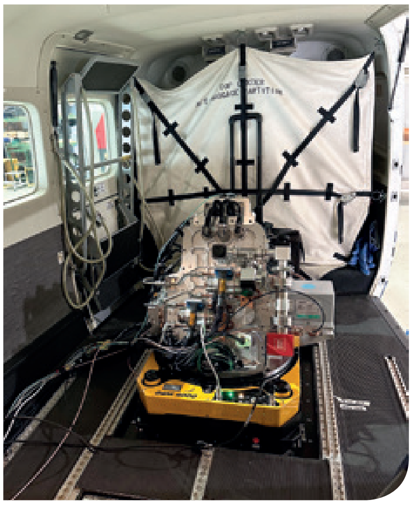
Publications

Hueni A, Geier S, Vögtli M, et al. (2025) **The AVIRIS-4 Airborne Imaging Spectrometer**, IEEE Geosci. Rem. Sens. Lett., 1–1, doi.org/10.1109/LGRS.2025.3572349

Meier S, Vögtli M, Hueni A, et al. (2026) **Quantifying CH_4 point source emissions with airborne remote sensing: first results from AVIRIS-4**, Atmos. Meas. Tech., 19(1), 333–358, doi.org/10.5194/amt-19-333-2026

Abbreviations

APEX	Airborne Prism Experiment
ARES	Airborne Research Facility of the Earth System
AVIRIS-4	Airborne Visible / Infrared Imaging Spectrometer 4



AVIRIS-4 instrument built into a Cessna Caravan operated by Swiss Flight Services.

10.2 Arctic Weather Satellite

Purpose of Research

The Arctic Weather Satellite (AWS) is a prototype mission for the first meteorological constellation (EPS-Sterna) that will be used for operational weather forecasting. This constellation will consist of six SmallSats built by OHB Sweden on three orbital planes. Each satellite carries a single instrument: the microwave cross-track radiometer, which is built by AAC Omnisys. The radiometer operates in the 54, 89, 183 and 325 GHz bands, which are used to retrieve temperature and water vapour profiles as well as liquid water content and precipitation.

AWS was launched in August 2024, and following a successful commissioning phase its data has been assimilated by weather services such as ECMWF. It also provides the first ever measurements at 325 GHz from orbit.

Past Achievements and Status

The Institute of Applied Physics (IAP; Univ. Bern, Switzerland) developed a custom absorber for the calibration targets, built and delivered all of them and consulted in the radiometric tests and near-field antenna measurements.

Furthermore, the IAP optimised the quasi-optics of the radiometer and simulated the antenna patterns for all bands and several scan angles using physical optics and method of moment simulations, which included the complete structure of the radiometer.

IAP also supported AAC Omnisys during the ground RF testing campaign prior to launch, and EUMETSAT in the analysis of the comissioning data after the launch.

Publications

Albers R (2024) **Optical design and calibration of the Arctic Weather Satellite**, Dissertation at Inst. Applied Physics, Univ. Bern, doi.org/10.48549/5697

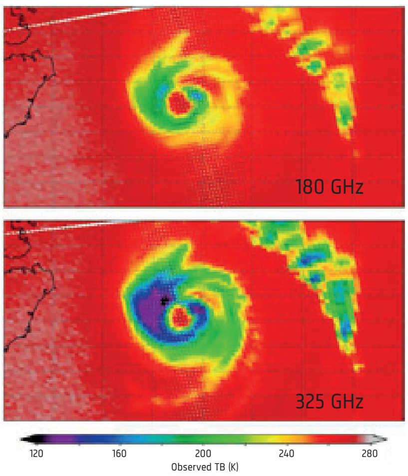
Albers R, Plüss T, Eggimann L, Murk A (2024) **Development of the onboard calibration target for the Arctic Weather Satellite**, IEEE Trans. Geoscience and Remote Sensing 62: 1-8, Art no. 5301908, doi.org/10.1109/TGRS.2024.3436517

Eriksson P et al. (2025) **The Arctic Weather Satellite radiometer**, Atmos. Meas. Tech. 18: 4709–4729, doi.org/10.5194/amt-18-4709-2025

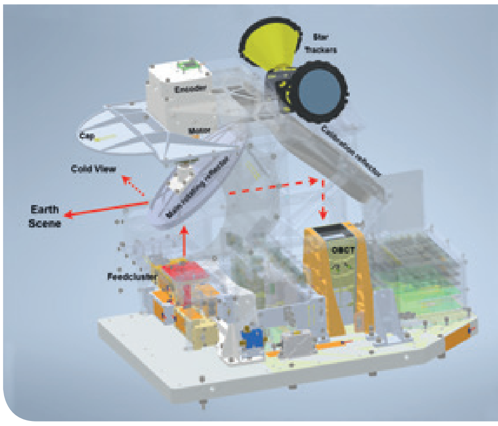
Abbreviations

AWS Arctic Weather Satellite
OBCT Onboard Calibration Target
OGCT On-ground Calibration Target

Time-Line	From	To
Planning	2020	2022
Construction	2022	2023
Measurement phase	2024	2029
Data evaluation	2024	2029



Observed brightness temperatures from the AWS channels at 180 GHz (top) and 325 GHz (bottom) of Typhoon Yinxing on 9 November 2024. Image credit: ECMWF.



CAD model of AWS instrument. Image credit: Eriksson et al. (2025).

Institute
Inst. Applied Phys. (IAP), Univ. Bern (UNIBE), Bern, Switzerland

In cooperation with
AAC Omnisys, Sweden

Swiss Principal Investigator(s)
A. Murk (UNIBE)

Co-Investigator(s)
R. Albers (UNIBE)

Contribution
Development & construction of instrument(s): Development of on-board and on-ground calibration equipment and simulation of instrument performance.

Industrial hardware contract(s)
AAC Omnisys, Sweden

Website(s)
www.esa.int/Applications/Observing_the_Earth/Meteorological_missions/Arctic_Weather_Satellite

10.3 SPECCHIO – Spectral Information System

Institute
Remote Sensing Labs. (RSL)
Dept. Geography, Univ. Zurich
Zurich., Switzerland

In cooperation with
Geoscience Australia (GA)

Principal/Swiss Investigator(s)
A. Hueni (RSL)

Co-Investigator(s)
M. Thankappan (GA)

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

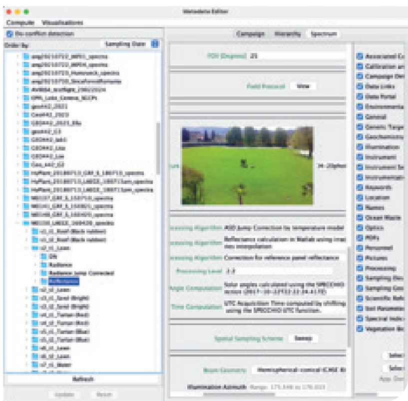
Website(s)
https://www.specchio.ch

Purpose of Research

Spectroscopy and in particular imaging spectroscopy have seen a sharp increase in available instruments and methods over the past five years. Consequently, there remains a need for the organised storage of spectral field data and associated metadata that underpin imaging systems by providing independent measurements for model development and calibration/validation (CAL/VAL). 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 use of a spectral information system not only ensures the long-term storage of data but supports scientists in data analysis activities, essentially leading to improved repeatability of results, superior reprocessing capabilities, and the promotion of best practice.

Past Achievements and Status

SPECCHIO remains under active development. SPECCHIO is installed in some 40 research institutions worldwide and is used in research and teaching activities at the Remote Sensing Laboratories, University of Zurich. SPECCHIO has been updated to support the storage of uncertainty budgets in the structure of uncertainty tree diagrams. SPECCHIO is used operationally to carry out CAL/VAL for airborne imaging spectrometer campaigns with the APEX, AVIRIS-NG and AVIRIS-4 instruments in support of ESA satellite end-to-end simulations and general scientific studies in the Earth-System domain. The Australian instance of SPECCHIO is hosted by Geoscience Australia within the framework of Digital Earth Australia. SPECCHIO is today the most advanced spectral information system within the domain of Earth observing remote sensing. SPECCHIO is also open source and is available as a virtual machine image, which allows anyone to run the full system on their personal laptop, thus supporting its full functionality under field conditions. For further information please visit: www.specchio.ch.



SPECCHIO Metadata Editor GUI showing metadata of spectral ground control points collected during an APEX imaging spectrometer airborne mission over the Laegern mountain range in Switzerland.

Publications

Hueni A, Chisholm L, Ong C, Malthus T, Wyatt M, Trim SA, Schaepman M E, Thankappan M (2020) **The SPECCHIO Spectral Information System**, IEEE J. Selected Topics in Appl. Earth Obs. Remote Sensing 13: 5789-5799.

Hueni A, Mason K, Trim S (2023) **Uncertainty support in the spectral information system SPECCHIO**, IEEE J. Selected Topics in Applied Earth Observations and Remote Sensing 16: 2668-2680.

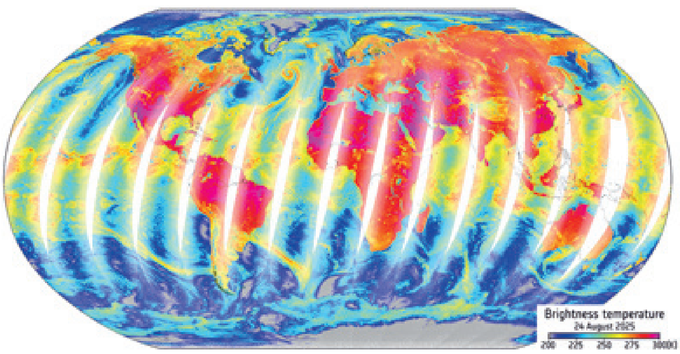
Abbreviations

APEX	Airborne Prism Experiment
AVIRIS-NG	Airborne Visible / IR Imaging Spectrometer – Next Generation
CAL/VAL	Calibration/Validation
SPECCHIO	Spectral Information System

10.4 Calibration Targets for MetOp-SG Instruments MWS and ICI

Purpose of Research

The Microwave Sounder (MWS) and Ice Cloud Imager (ICI) are two instruments for the second generation of Meteorological Operational Satellites (MetOp-SG). MWS includes microwave radiometers between 23 GHz and 230 GHz to measure atmospheric temperature and humidity profiles, while the ICI radiometers will cover frequencies between 175 GHz and 670 GHz to characterise ice clouds. A key component of the MWS and ICI instruments are their onboard blackbody targets, which are required for their accurate radiometric calibration. The Institute for Applied Physics (IAP), University Bern, is responsible for the electromagnetic design and the experimental verification of the onboard calibration targets for MWS and ICI. The IAP also contributed to the development of the on-ground calibration system for ICI, which will be used to verify the radiometric performance prior to launch by providing scenes with either a cryogenic or variable brightness temperature. It includes two temperature-controlled wedged cavities for accurate calibration in a thermal-vacuum chamber, as well as a simpler liquid nitrogen target for system checks at ambient pressure. IAP have optimised their geometry, to match the ICI antenna pattern, verified the RF performance by measurements, and simulated the variation of the coupling efficiencies with the scan angle by using physical optics antenna simulations.



Global map of the brightness temperature measured with the MWS 89 GHz channel. Image credit: EUMETSAT.

Past Achievements and Status

The first MWS instrument was launched with the MetOp-SG-A1 satellite in August 2025. The instrument is operating nominally and the data is currently supporting the EUMETSAT Calibration/ Validation phase. The first ICI instrument is scheduled for launch with the MetOp-SG-B1 satellite in autumn 2026.

Publications

Döring D et al. (2021) European Conf. on Spacecraft Structures, Materials and Environmental Testing.

Murk A. (2022) 32nd IEEE Int. Symp. Space THz Technology, (ISSTT 2022).

Schröder A et al. (2017) IEEE Trans. THz Sci. Technol. 7: 677-685, doi.org/10.1109/TTHZ.2017.2757442

Abbreviations

ICI Ice Cloud Imager
MWS Microwave Sounder
OBCT Onboard Calibration Target
OGCT On-ground Calibration Target

Time-Line	From	To
Planning	2013	2015
Construction	2016	2018
Measurement phase	2018	2023
Data evaluation	2025	open

The MWS instrument with OBCT installed on the MetOp-SG-A1 satellite before launch.
Image credit: Airbus.

Institute
Inst. Applied Phys. (IAP), Univ. Bern (UNIBE), Bern, Switzerland

In cooperation with
TK Instruments, UK;
Airbus Space and Defence, UK and Spain;
IABG, Germany

Swiss Principal Investigator(s)
A. Murk (UNIBE)

Co-Investigator(s)
M. Kotiranta (UNIBE)

Contribution
Development & construction of instrument(s):
Development of onboard and on-ground calibration equipment

Industrial hardware contract(s)
TK Instruments, UK
IABG, Germany

10.5 Traceable Uncertainty Propagation for the CHIME Level-2 Processor

Artistic rendering of the CHIME satellite. Image credit: ESA.

Institute
Remote Sensing Labs. (RSL)
Dept. Geography, Univ. Zurich
Zurich., Switzerland

In cooperation with
ESA CHIME team;
Earth Obs. Center, DLR Oberpf., Germany;
National Physical Lab. (NPL), UK;
Image Processing Lab. (IPL),
Univ. Valencia, Spain;
GFZ, Potsdam, Germany

Principal Investigator(s)
R. de los Reyes, (DLR)

Swiss Principal Investigator(s)
A. Hueni (RSL)

Co-Investigator(s)
P. de Vis (NPL)
J. Verrelst (IPL)
K. Segl (GFZ)

Contribution
Development of software for:
Propagation of radiometric and auxiliary input uncertainties through the CHIME atmospheric correction code and high priority product algorithms.

Website(s)
https://sentiwiki.copernicus.eu/web/chime

Purpose of Research

The European Space Agency's (ESA) Copernicus Hyperspectral Imaging Mission for the Environment (CHIME) mission is an upcoming satellite constellation composed of two identical satellites, each equipped with an imaging spectrometer as its primary payload. CHIME is one of ESA's six Copernicus Sentinel Expansion missions, developed on behalf of the European Union (EU). The spectrometers will acquire imagery across more than 200 spectral bands, covering a wavelength range from 400 – 2500 nm (visible to shortwave infrared). The system will provide a ground resolution of 30 m per pixel and cover a swath width of ~130 km.

The mission goal of CHIME is to provide routine global hyperspectral observations, achieving a revisit time of 11 days at the equator when both satellites are operational. The resulting products will support a wide range of applications, including sustainable agriculture, biodiversity management, soil property characteristics, raw material exploration, food security, among others. The CHIME satellites are designed for a nominal operational lifetime of approximately seven years, with the possibility of extending the mission up to 12 years.

The CHIME Level 2 (L2) consortium is responsible for developing the atmospheric correction processing chain for the mission's imaging spectrometers. This implies processing the Top-Of-Atmopshere (TOA) radiance measurements acquired at-sensor into Bottom-Of-Atmosphere (BOA) reflectance, as well as water-leaving surface reflectance products. In addition, the mission requirements mandate the provision of a propagated uncertainty estimation throughout the entire processing chain, culminating in the BOA reflectance products to ensure fully informed usage. The uncertainties shall further be propagated to all the defined high priority derived products, such as leaf chlorophyll content or kaolinite distribution maps.

Past Achievements and Status

In a first phase, a prototype L2 processor was developed along with the uncertainty propagation embedded in the atmospheric correction workflow by using the CoMet toolbox. CoMet supports the propagation of uncertainties using a Monte Carlo approach, implemented in a Python package (punpy). This implementation delivers propagated uncertainties and their correlations for L2 products such as water vapour or aerosol optical thickness maps as well as the land surface and water-leaving surface reflectance. The next phase is to focus on propagating uncertainties to the higher level products (such as leaf chlorophyll or mineral maps) and to work on alternative approaches to a faster and hence operational estimation of uncertainties, based on the initial Monte Carlo approach as a benchmark.

Publications

Zimmermann AM et al. (2025) **Uncertainty assessment and propagation for the CHIME L2A processor**, ESA LPS 2025, Vienna.

Abbreviations

CHIME	Copernicus Hyperspectral Imaging Mission for the Environ.

Time-Line	From	To
Planning	2023	2024
Construction	2024	2028
Measurement phase	2028	2029
Data evaluation	open	open

10.6 ECO – Earth Climate Observatory

Purpose of Research

The Earth's climate system is governed by the small imbalance between incoming solar radiation (ISR) at the top of the atmosphere (ToA) and both the reflected solar radiation (RSR) and outgoing longwave radiation (OLR). Current observations indicate an energy imbalance of approximately 1 Wm^{-2}, implying that the Earth system is presently gaining energy. This excess energy constitutes the fundamental driver of ongoing climate change.

Compared to the pre-industrial period, the increase of Greenhouse Gasses (GHG), primarily CO_2, reduces the OLR; this represents a positive radiative forcing leading to a warming. As a result of the GHG radiative forcing, the Earth Energy Imbalance (EEI) becomes positive and the Earth's temperature rises. This positive GHG radiative forcing is partially compensated by a negative radiative forcing of aerosols, partially decreasing the energy absorbed in the Earth system. To understand the radiative forcing and climate feedbacks, it is necessary to separate the Total Outgoing Radiation (TOR) spectrally into the Reflected Solar radiation (RSR) and OLR. This allows clear-sky to be separated from cloudy scenes, and to map them at relatively high spatial resolution, on the seasonal or sub-seasonal time-scale.

ECO will determine the annual EEI, i.e., the difference of the ISR and TOR at the ToA, which is the key parameter for future climate change projection (see opposite figure). In addition, ECO will provide absolutely calibrated maps of the surface net radiation, RSR, OLR, and EEI at the ToA. This is illustrated in the below figure by the four shells around Earth from left to right.

Illustration of the ECO mission objectives (for details see the text). The vertical bars indicate the average temperature anomaly for a single year compared to the average temperature over the entire period from 1850 to 2020. Image credit: ESA.

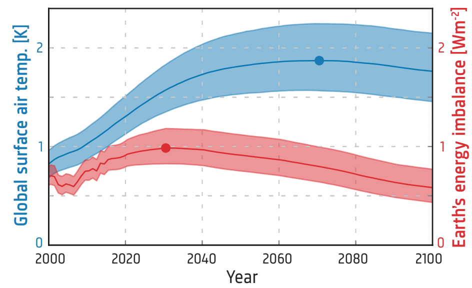
Past Achievements and Status

The Earth Climate Observatory (ECO) mission concept was selected in 2024 by the European Space Agency as one of the four candidate Earth Explorer 12 (EE12) missions. Currently, it is in Phase 0. In July 2026, a User Consultation Meeting (UCM) will be held where two out of the four EE12 candidate missions will be selected to continue to the Phase A study. MH acknowledges support by the Karbacher Funds.

Publications

Dewitte S, Mauritsen T, Meyssignac B et al. (2025) **The Earth Climate Observatory space mission concept for the monitoring of the Earth Energy Imbalance**, IOP Conf. Ser.: Earth Environ. Sci. 1522 012019: doi.org/10.1088/1755-1315/1522/1/012019

Mauritsen T, Tsushima Y, Meyssignac B et al. (2025) **Earth's energy imbalance more than doubled in recent decades**, AGU Advances 6: doi.org/10.1029/2024AV001636



Climate model global mean temperature and energy imbalance under a strong mitigation scenario meeting the 2° target (SSP1-2.6). Uncertainty ranges indicate the 90 % confidence interval of the spread. The dots mark the peak year on each time-series (from Mauritsen et al., 2025).

Institute
Physikalisch-Meteorologisches Observatorium Davos / World Radiation Centre (PMOD/WRC), Davos, Switzerland

In cooperation with
Royal Obs. Belgium (ROB), Belgium;
Stockholm University (ST-UNI), Sweden;
Lab. d'études en Géophysique et Océanographie Spatiales (LEGOS), Toulouse, France;
ESA

Principal Investigators
S. Dewitte (ROB), T. Mauritsen (ST-UNI),
B. Meyssignac (LEGOS)

Swiss Principal Investigator
M. Haberreiter (PMOD/WRC)

Co-Investigator(s)
N. Clerbaux (RMIB, Belgium); R. Hollmann (DLR, Germany); J. Marotzke (MPI for Met., Germany); J. Riedi (Lille Univ., France); A. Riihelä (FMI, Finland); J. Russell (Imperial College London, UK); T. Trent (Univ. Leicester, UK); M. Wendisch (Leipzig Univ., Germany)

Industrial hardware/software contract(s) to
OHB (Bremen, Germany);
Thales Alenia Space (Toulouse, France)

Website(s)
www.astro.oma.be/en/the-earth-climate-observatory-new-space-mission-concept-for-monitoring-the-earth-energy-imbalance

10.7 FDR4AVHRR – Advanced Very High Resolution Radiometer Fundamental Data Record

Receiving antenna at UNIBERN operated by the Remote Sensing Research Group, Institute of Geography, since August 2000. The received and archived data are the backbone of the European AVHRR Master Data-Set re-processed in the frame of the FDR4AVHRR project.

Institute
Inst. Geography, Univ. Bern (UNIBE), Bern, Switzerland

In cooperation with
ESA
Swedish Met. Hydrological Inst. (SMHI), Sweden
National Physical Lab. (NPL), UK

Principal/Swiss Investigator(s)
Stefan Wunderle (UNIBE)

Co-Investigator(s)
Christoph Neuhaus (UNIBE)
M. Raspaud (SMHI)
J. Mittaz (NPL)

Contribution
Harmonisation and re-processing of a Fundamental Data Record.

Website(s)
www.geography.unibe.ch/research/remote_sensing_group/index_eng.html

Purpose of Research

Data from the Advanced Very High Resolution Radiometer (AVHRR) onboard NOAA satellites, and since 2006 on the EUMETSAT MetOp satellites, is the only source of long time-series data based on an almost unchanged sensor over the last 40 years with daily availability and a 1.1 km spatial resolution. This unique data-set: i) has a high scientific study value, ii) is independent of ground-based measurements, climate change induced shifts of Essential Climate Variables (ECV), and iv) fulfills the requirements of the World Meteorological Organisation for a sufficiently long period (> 30 years) to analyse environmental changes.

In the first phase of the FDR4AVHRR project, which is an activity in the frame of ESA's Heritage Space Programme, we developed new modules and procedures to be added to the open-source software, pyGAC. These modules focus on improved geocoding including orthorectification (M. Raspaud, J. Nilsson; SMHI) and the retrieval of uncertainty. The uncertainty module was developed by colleagues at NPL (J. Mittaz, N. Yaghnam).

Based on these improvements more than 500,000 1 km-AVHRR data-sets (Europe, Africa, South America) were reprocessed into level 1c NetCDF (C. Neuhaus, UNIBE). In a final step, metafiles and quicklooks are generated to be included in a data container (EO-SIP). The full data-set is accessible via the ESA dissemination service (https://earth.esa.int/eogateway/catalog/avhrr-level-1b-1c-local-area-coverage-imagery).

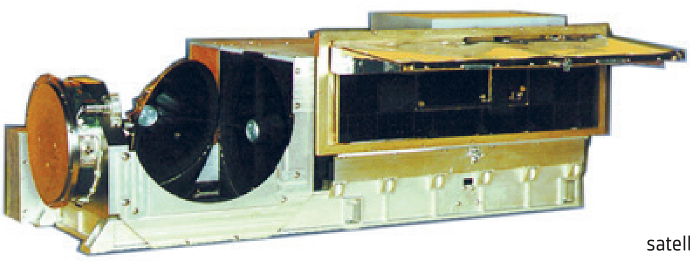
Based on the successful first phase of the FDR4AVHRR project, a continuation began in February 2026 with the objective of further improvement of the software and to include more 1 km AVHRR data covering other regions of the world. Finally, a fundamental data record with more than 1 million AVHRR data-sets will be available via the ESA dissemination service.

Past Achievements and Status

PyGAC is a software package to read, calibrate and navigate AVHRR data. It has been installed with the new 'georeferencer' and 'uncertainty' modules on the UNIBE UBELIX cluster to process 500,000 data-sets. The first Network Attached Storage (NAS) with ~350,000 data sets has been shipped to ESA to integrate the AVHRR level 1c data into ESA's dissemination system and to make the unique data-set publicly available. The second phase of the project ends in June 2027 and will result in an updated version of PyGAC and an improved coverage of the globe with 1 km AVHRR data.

Publications

Wunderle S et al. (2025) **FDR4AVHRR – generation of a consolidated fundamental data record based on > 40 years of AVHRR-LAC data (Europe, Africa and South America)**, ESA Living Planet Symp., C.02.02 Heritage Missions and Long Time Data Series; 0.96/0.97



AVHRR sensor onboard the NOAA and Metop satellites (1979 – 2026).

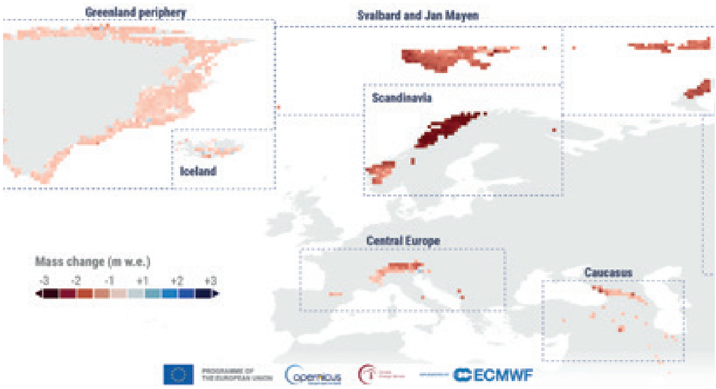
10.8 C3S – Copernicus Climate Change Service

Purpose of Research

The Copernicus Climate Change Service (C3S), implemented by the European Centre for Medium-Range Weather Forecasts (ECMWF) on behalf of the EU, develops and delivers authoritative, quality-assured information about the past, current and future states of the climate in Europe and worldwide. C3S responds to user requirements defined by the Global Climate Observing System (GCOS) for the observation of atmospheric, ocean and terrestrial Essential Climate Variables (ECVs). The cryosphere in the terrestrial domain includes several components that are highly sensitive to climate change. The related Cryosphere Service of C3S provides products and services for three components that are intensely studied by remote sensing: snow cover, glaciers and ice sheets. Their global extent and changes can be derived by well-established algorithms and retrieval schemes, allowing to follow their state and evolution through time on a global scale. Related products for the three components are made freely available in the C3S Climate Data Store (CDS) to facilitate applications and services for the benefit of society.

Past Achievements and Status

The University of Zurich together with the World Glacier Monitoring Service (WGMS) is responsible for the glacier component of the C3S Cryosphere Service and provides three products: glacier area, elevation and mass change. Whereas the former two are derived by remote sensing, mass changes require density information that is provided by field measurements on selected glaciers via a global network of observers reporting to WGMS. We combine this information to determine the annual variability of glacier mass changes on a global scale. The glacier area product is derived for selected mountainous regions in the world, contributing to a global dataset of glacier outlines provided to the community as the Randolph Glacier Inventory (RGI). Its latest version (RGI 7.0) strongly benefited from the contributions of the Cryosphere Service. Apart from the products, the service also contributes to high-level information such as the 'European State of the Climate' report (https://climate.copernicus.eu/esotc/2024), providing the latest numbers of glacier mass changes on a global and European scale, which are also provided as a gridded product.

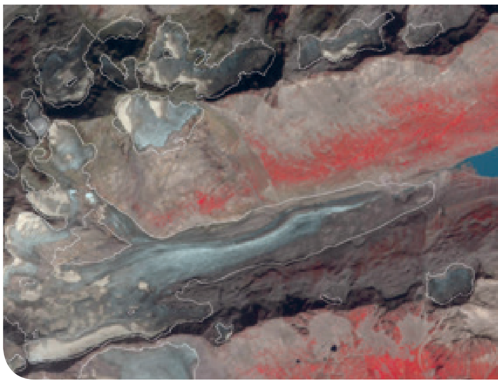


Glacier mass change in Europe for the 2023/24 hydrological year, modified from the C3S report (https://climate.copernicus.eu/esotc/2024/graphics-gallery/snow-glaciers). Data: WGMS, Credit: WGMS/C3S/ECMWF.

Publications

Dussaillant I et al. (2025) **Annual mass change of the world's glaciers from 1976 to 2024 by temporal downscaling of satellite data with in situ observations**, Earth Sys. Sci. Data 17(5): 1977–2006.

GlaMBIE Team (2025) **Community estimate of global glacier mass changes from 2000 to 2023**, Nature 639(8054): 382–388.



False-colour infrared image of the 4 km long Oberaar Glacier in Switzerland as seen with Sentinel-2 on 24 August 2022. In this extreme year, all winter snow and large amounts of ice melted away, causing a very negative mass balance. Glacier outlines (white) have been created within C3S using a Sentinel-2 image acquired on 29 August 2015. Image source: Copernicus Sentinel data 2022.

Institute
World Glacier Monitoring Service (WGMS), Dept. Geography, Univ. Zurich (UZH), Zurich, Switzerland

In cooperation with
Partners of the C3S Cryosphere Service

Principal Investigator(s)
ENVEO Environmental Earth Observation IT GmbH (Enveo), Innsbruck, Austria

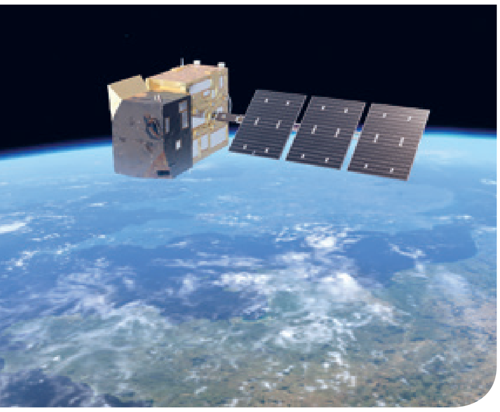
Swiss Principal Investigator(s)
M. Zemp (WGMS), F. Paul (UZH), J. Bannwart (WGMS)

Co-Investigator(s)
T. Nagler, J. Wuite, G. Schwaizer (Enveo); S.B. Simonsen, N. Havelund (DTU); A. Shepherd, T. Slater (NU); K.P. Luojus, M. Kosmale (FMI)

Contribution
Research based on existing instrument(s): Sentinel-2, Landsat, Terra ASTER, ICESat

Website(s)
https://cds.climate.copernicus.eu

10.9 Copernicus Greenhouse Gas Emissions Monitoring System



Copernicus CO_2 Monitoring (CO2M) Mission. Image credit: ESA.

Institute
Empa, Switzerland

In cooperation with
SMARTCARB:
ETHZ, MPI-BGC

CoCO2:
AGH, BSC, SNRS, CICERO, DWD, DLR, ENPC, Empa, ECMWF, FC.ID, FMI, CMCC, FORTH, ICOS, ILAB, JRC, CEA, Uni Lund, MPI-BGC, Mercator Ocean, MeteoFrance, TNO, Cyprus Institute, Uni Edinburgh, VU, WUR;

CORSO:
ECMWF, BSC, MeteoFrance, AGH, CEA, ILAB, TNO, Univ. Heidelberg, Univ. Lund, Univ. Toulouse III, CNRS, WUR, Empa, ETHZ, Univ. Bristol, Univ. Edinburgh, Univ. Groningen

Principal Investigator(s)
SMARTCARB: Dominik Brunner (Empa); CoCO2 and CORSO: Richard Engelen (ECMWF)

Swiss Principal Investigator(s)
Dominik Brunner (SMARTCARB, CoCO2); Gerrit Kuhlmann (CORSO)

Website(s)
www.empa.ch/web/s503//modelling-remote-sensing

Purpose of Research

The Copernicus Earth Observation programme is the European Union's flagship initiative that uses satellite and ground-based measurements to provide continuous, high-quality information on Earth's environment and climate. To combat climate change, the Paris Agreement seeks to limit global warming to well below 2°C above pre-industrial levels by reducing anthropogenic greenhouse gas emissions. Its Enhanced Transparency Framework requires all signatory states to report their emissions annually and to submit Nationally Determined Contributions (NDCs) that outline their mitigation commitments. At present, progress is assessed mainly through emission inventories derived from socioeconomic and environmental statistics. The approach is labour-intensive and lacks independent verification.

To complement these inventories with measurement-based evidence, the Copernicus Programme is developing a dedicated system for monitoring and verification support (MVS) of anthropogenic CO_2 and CH_4 emissions using both in-situ and satellite observations. These data will be integrated into the Copernicus Atmosphere Monitoring Service (CAMS), implemented by ECMWF, to deliver robust information on anthropogenic emissions from countries, cities, power plants, and industrial facilities. In addition, the system will provide accurate data about the uptake and release of CO_2 by the biosphere and oceans.

A core component of service will be a new constellation of CO_2 monitoring (CO2M) satellites, which will be launched from 2027 onwards, to provide global CO_2 and CH_4 measurements at high spatial resolution with global coverage every three days. These satellites, developed under the Copernicus Expansion programme, will provide the first spaceborne measurements explicitly optimised to detect and quantify anthropogenic CO_2 emissions from facility to a national scale. Each satellite will carry instruments capable of measuring atmospheric CO_2 and CH_4 concentrations, enabling global observations at high spatial resolution, essential for verifying emission inventories and supporting climate-policy implementation.

Past Achievements and Status

Over the past decade, several international research projects have laid the foundation for the European MVS system by developing the instrument design, retrieval algorithms and inversion frameworks required for its operational capability. These efforts have collectively defined the scientific and technical requirements for accurately quantifying anthropogenic greenhouse gas emissions at scales ranging from local to national.

The SMARTCARB study played a key role in defining the mission requirements for the CO2M constellation. The study generated synthetic satellite images from high-resolution model simulations to help define the precision requirements for greenhouse gas measurements. Furthermore, the study demonstrated the essential nature of additional NO_2 satellite observations for detecting anthropogenic emissions, as well as the significant benefits of a third satellite in enhancing the accuracy of emission measurements.

Several international projects, such as the CoCO2 and CORSO projects, have focused on developing the prototype system for monitoring anthropogenic CO_2 and CH_4 emissions as a CAMS service. These projects have developed algorithms and methods for quantifying anthropogenic emissions, including community frameworks for estimating emissions from hotspots and countries.

The full emissions monitoring and verification support system is expected to reach pre-operational status in 2027, with the CO2M satellites providing critical observations from 2028 onwards. Once operational, the system will provide countries with independent, measurement-based information on anthropogenic CO_2 and CH_4 emissions, supporting them in reporting and verifying their inventories under the The United Nations Framework Convention on Climate Change (UNFCCC) as part of the Paris Agreement.

Publications

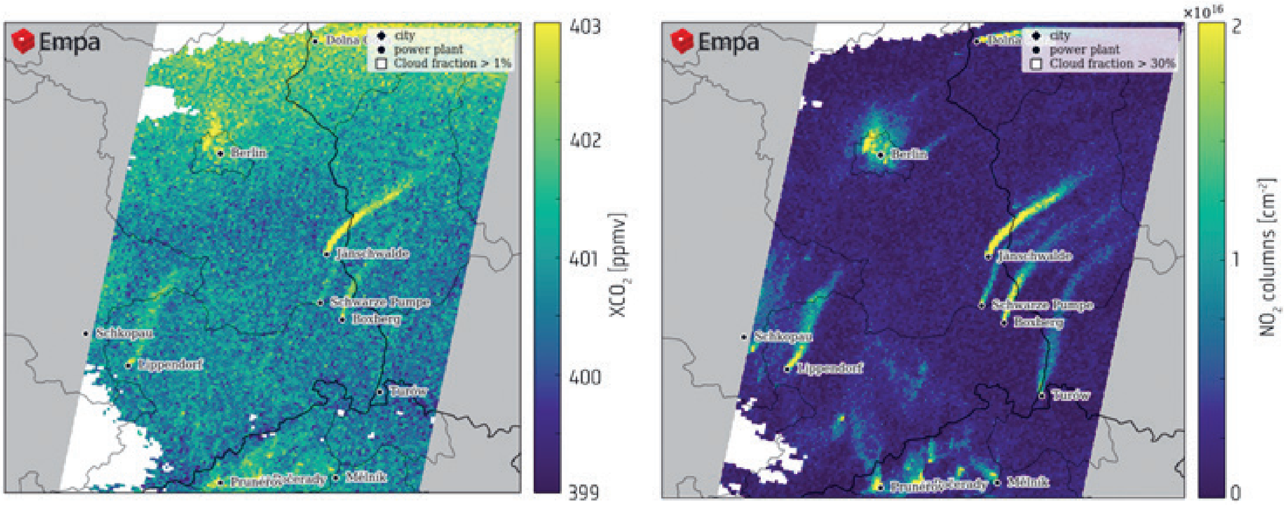
Janssens-Maenhout G et al. (2021) **Toward an operational anthropogenic CO_2 emissions monitoring and verification support capacity**, doi.org/10.1175/BAMS-D-19-0017.1

Kuhlmann G et al. (2019) **Detectability of CO_2 emission plumes of cities and power plants with the Copernicus Anthropogenic CO_2 Monitoring (CO2M) mission**, doi.org/10.5194/amt-12-6695-2019

Santaren D et al. (2025) **Benchmarking data-driven inversion methods for the estimation of local CO_2 emissions from synthetic satellite images of XCO_2 and NO_2**, doi.org/10.5194/amt-18-211-2025

Abbreviations

CAMS	Copernicus Atmosphere Monitoring Service
CoCO2	Prototype system for a Copernicus CO_2 service
CORSO	CO2MVS Research on Supplementary Observations
CO2M	Carbon Dioxide Monitoring constellation
SMARTCARB	Satellite Meas. of Auxiliary Reactive Trace gases for fossil fuel CARBon dioxide emission estim.



CO2M, CO_2 and NO_2 satellite images generated from high resolution simulations conducted by Empa. The images show CO_2 and NO_2 emission plumes originating from several larger power plants and from the city of Berlin. Clouds are shown in white. Image credit: Empa.

EARTH OBS. AND REMOTE SENSING

10.10 Radiation Closure Experiments for EarthCARE Validation

The EarthCARE mission logo. Image credit: EarthCARE.

Institute
Phys. Met. Observatorium Davos/ World Radiation Center (PMOD/WRC)

Principal/Swiss Investigator(s)
S. Kazadzis (PMOD/WRC)

Co-Investigator(s)
A. Hueni, Univ. Zurich (UZH),
K. Papachristopolou (PMOD/WRC)

Website(s)
https://earth.esa.int/eogateway/missions/earthcare

Purpose of Research

Radiation Closure Experiments for EarthCARE Validation (RACE-ECV) is a project supported by the Swiss State Secretariat for Education, Research and Innovation (SBFI) and the EarthCARE Validation Team/ESA/EVID 44. The project aims to advance EarthCARE validation through high precision solar radiation and aerosol measurements, by organising two focused experimental field campaigns (2025 and 2026).

The basic objective of RACE-ECV is to understand the interactions between aerosols, clouds, and radiation. RACE ECV Research focuses on:

- Satellite Validation: Comparing EarthCARE aerosol & cloud optical thickness products with ground-based observations.
- Radiation Closure Experiments: Using precise solar radiation measurements to evaluate radiative transfer models.

Past Achievements and Status

In May 2024, the EarthCARE satellite mission was successfully launched, marking a major milestone in Earth observation.

The RACE-ECV project organised an experimental campaign in April – May 2025 in the wider area of Thessaloniki, Greece. Measurements were carried out at three coordinated sites (urban, semi-urban and rural) selected to capture different aerosol and cloud regimes while remaining close to the EarthCARE ground track. Major goals of the campaign included:

- The direct validation of aerosol optical depth EarthCare products based on sun photometric and Lidar ground-based measurements.
- Radiation closure studies using both EarthCARE and ground-based atmospheric inputs towards simulating 1D and 3D solar radiation at the surface and at the top-of-the-atmosphere.

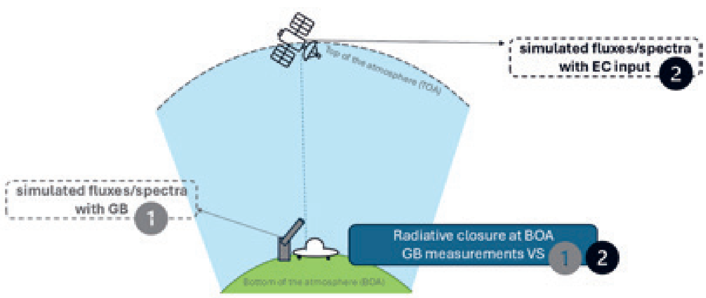
A second experimental measurement campaign is foreseen for spring – summer 2026.

Publications

Marinou E. (2025) **Validation of EarthCARE Aerosol, Cloud, and Synergistic Products within ACROSS Activities**, EarthCARE Science and Validation Workshop, Tokyo, Japan.doi.org/10.5194/egusphere-egu25-18737

Papachristopoulou K et al. (2025) **Use of state-of-the-art spectral solar radiation and aerosol measurements for EarthCARE validation**, ESA Living Planet Symp., Vienna, Austria.

Papachristopoulou K et al. (2025) **Validation of EarthCARE products based on radiative closure experiments using State-of-the-Art spectral solar and aerosol measurements**, EarthCARE Sci. & Validation Workshop, Tokyo, Japan.



Radiative closure: Overview of the radiative closure experiment strategy using ground based and Earth Care atmospheric data.

10.11 Swiss National Forest Inventory (NFI)

Purpose of Research

Affordable, up-to-date, and regularly provided information on the current state of forest ecosystems is being increasingly demanded by both research and stakeholders. This demand is driven by the recognition of forests as multifunctional ecosystems and their exposure to climate change, as well as economic and societal pressures. The Swiss National Forest Inventory (NFI) systematically monitors the condition, structure, and development of Switzerland's forests, delivering continuous, precise data on numerous forest characteristics obtained through terrestrial surveys.

Cutting edge remote sensing technologies and data sets with high spatial and temporal resolution in combination with methodological advances in machine learning and fast data processing have opened a new era of reliable, reproducible, and wall-to-wall forest products. In the Swiss NFI, these products serve as a valuable information source complementing the terrestrial survey-based estimates by providing spatially explicit information. One of these is the data series, 'Forest type NFI', which offers systematic, nationwide information about forest composition (broadleaf and coniferous). The data set is particularly valuable for a variety of applications in the forestry sector and beyond and supports forest services and governments for sustainable, multifunctional and climate adapted forest management.

Past Achievements and Status

A series of Forest Type NFI datasets covering Switzerland have been produced, and are currently available for the years 2023 and 2018. The two datasets provide the probability (0 – 100 %) of the broadleaf class at the pixel level. While pixel values with low probabilities correspond to the coniferous class, pixel values with high probabilities correspond to the broadleaf class.

The classification approach is based on machine learning, i.e. Random Forest (RF), that combines predictors derived from multi-temporal Sentinel-1 and Sentinel-2 data with the SwissAlti3D terrain model. In addition to the original Sentinel-2 spectral bands, a bundle of vegetation indices were used in the final models. The classification models were tested, trained and validated using up to 400,000 labels representing the two broadleaf and conifers classes, derived from aerial image delineations from swisstopo's (Federal Office of Topography) SwissImage. Furthermore, an independent validation based on NFI plot data was performed and showed that the data-set is highly precise.

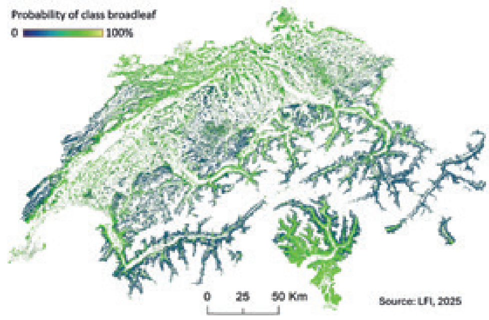
Both data sets are openly accessible or made available via the swisstopo geodata portal (see URLs at end) and are widely employed in numerous transdisciplinary projects in Switzerland and internationally (eg, in European forest initiatives). Updating the 'Forest Type NFI' dataset has become an iterative procedure that directly engages stakeholders (forest practitioners) in its validation, distribution and correct application. This approach strengthens the interaction between applied remote sensing research and practitioners.

Publications

Waser LT et al. (2021) **Mapping dominant leaf type based on combined Sentinel-1/-2 data – Challenges for mountainous countries**, ISPRS J. Photogramm. Rem. Sens. 180: 209-226, doi.org/10.1016/j.isprsjprs.2021.08.017

Abbreviations

NFI National Forest Inventory



The Forest Type NFI map of Switzerland serves as a basis to distinguish broadleaf from coniferous forests. The probability of the broadleaf class is given at a 10 m spatial resolution. Image credit: LFI.

Institute
Swiss Federal Institute for Forest, Snow and Landscape Resarch WSL, Birmensdorf, Switzerland

In cooperation with
Federal Office of the Environment

Principal/Swiss Investigator(s)
Lars Waser (WSL)

Co-Investigator(s)
C. Ginzler, A. Psomas, M. Rüetschi, N. Rehush (all WSL)

Contribution
Research based on existing instrument(s): Remote sensing applications using National Forest Inventory data.

Website(s)
www.envidat.ch/#/metadata/forest-type-nfi

www.geo.admin.ch/en/dataset-13012025

10.12 Genes from Space – Leveraging Earth Observation for Genetic Diversity Monitoring

Purpose of Research

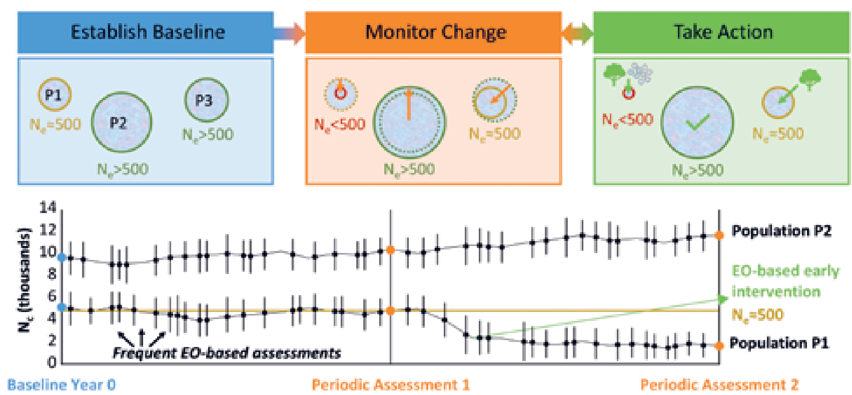
By providing images of the globe that are measured frequently across several optical domains, public Earth Observation (EO) data from satellites have high potential to facilitate and advance biodiversity monitoring. However, there is currently a consensus that EO cannot contribute to monitoring genetic diversity. Within the ISSI working group 'Genes from Space', we challenge this consensus by developing an operational tool and workflow demonstrating how EO can help to develop, monitor, and report on the headline and complementary indicators of genetic diversity adopted at the 15th Conf. of the Parties to the Conv. on Biol. Diversity (CBD, COP15). These indicators are part of the Global Biodiversity Framework (GBF) for monitoring and conservation. The tool allows non-EO experts to access EO products that can be used to assess habitats (suitable for populations) for change monitoring, or as a first estimate of these population-based indicators in the absence of other information. The tool walks users through key decisions that require their expert knowledge such as species density and range, and habitat types and supports access to documented observations. This approach thus puts EO products in the hands of users to complement knowledge existing through traditional in-situ methods such as DNA sampling, species ecology and life history, or local expert knowledge. The inclusion of such scalable data to support monitoring is essential to achieve the ambitious targets of the GBF, wherein the monitoring and conservation of genetic diversity -- which provides the potential for species to adapt to global change -- is one of the top priorities.

Past Achievements and Status

The tool has been developed within an expert team including the main developers and testers of the GBF's genetic diversity indicators and has been tested by more than 100 collaborators in research and conservation organisations across the globe in online workshops. The tool is currently under further development and testing to allow operational use by any country worldwide in regard to the next reporting period of the Parties in 2029.

Publications

Schuman MC, Röösli C et al. (2024) **Leveraging earth observation to monitor genetic diversity from space,** doi.org/10.32942/X2RS58



EO can help monitor and conserve the genetic diversity of natural populations. Examples are shown for three imaginary populations of the same species, P1, P2, and P3. P1 drops below the critical threshold of Ne > 500, P2 stays above, and P3 completely disappears. Frequent EO-based assessments can interpolate between periodic in-situ assessments and could support timely intervention.

Institute
Remote Sensing Labs. (RSL)
Dept. Geography, Univ. Zurich (UZH)
Zurich, Switzerland

In cooperation with
15 Scientists from around the world

Principal/Swiss Investigator(s)
C. Röösli (UZH)
M. C. Schuman (UZH)

Contribution
Development of software for:
Biodiversity monitoring.

Website(s)
https://www.genesfromspace.org

10.13 Living Switzerland

Purpose of Research

Living Switzerland represents a strategic evolution of the Swiss Data Cube (SDC), moving beyond first-generation Earth Observation infrastructure that primarily captures environmental states and impacts towards a fully integrated system embedded in the Driver-Pressure-State-Impact-Response (DPSIR) framework. While the SDC excels at delivering Analysis Ready Data and tracking landscape changes over time, it stops short of systematically connecting observations to the causal chain that explains why landscapes are changing and what can be done about it.

Living Switzerland bridges this gap by building on the Living Earth framework: a fully implemented FAO Land Cover Classification System optimised for Earth Observation (EO) data that uses structured land-cover taxonomies underpinned by DPSIR to deliver standardised, globally comparable landscape information. Rather than only answering 'What is happening?', Living Switzerland connects satellite-derived observations to the pressures (land-use change, climate stress, urbanisation) and drivers (economic, demographic, and policy forces) that cause environmental change, while also supporting the design of meaningful policy responses.

By applying the Living Earth classification approach to the SDC's multi-decadal satellite archive spanning 1984 to the present, Living Switzerland can generate consistent, scalable land-cover and landscape dynamics products at a national scale, enabling robust trend detection across decades. Critically, the system is designed not just to document past and current landscape conditions, but to provide a rigorous, evidence-based foundation to inform planning for the future — including biodiversity targets, land-use policy, and climate adaptation strategies.

Aligned with FAIR principles and fully interoperable with Open Data Cube infrastructure, Living Switzerland thus transforms national EO capacity from a sophisticated data archive into a national environmental intelligence system — one that speaks the language of policy, bridges science and governance, and delivers unique capacity to capture consistent information on the states and dynamics of past and present landscapes in service of a more sustainable future.

Past Achievements and Status

Living Switzerland is currently under development and initial results will be presented in September 2026 during the EARSeL Symposium in Athens.

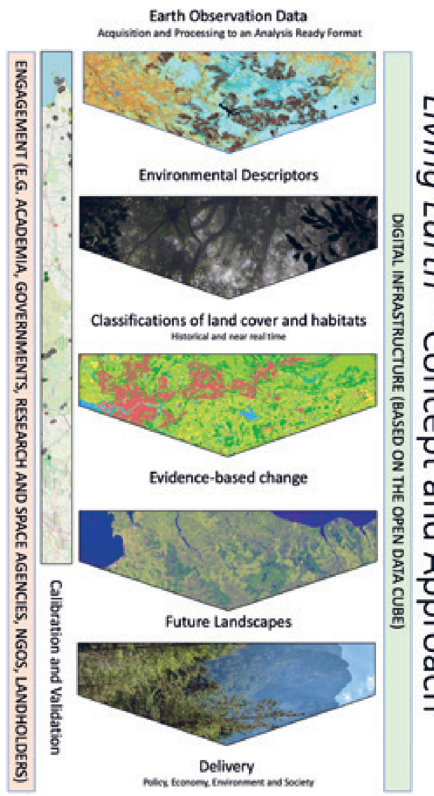
Publications

Kussul N et al. (2026) **Digital twins for land use change**, in: Zgurovsky M, Pankratova N (eds) System Analysis and Data Mining, Studies in Systems, Decision and Control, Vol. 609, Springer, Cham. doi.org/10.1007/978-3-031-97529-5_22

Owers CJ et al. (2021) **Living Earth: Implementing national standardised land cover classification systems for Earth Observation in support of sustainable development**, Big Earth Data 5(3): 368-390, doi.org/10.1080/20964471.2021.1948179

Abbreviations

EO	Earth Observation
FAO	Food and Agriculture Organisation
SDC	Swiss Data Cube



The Living Earth concept to support the development and implementation of Living Switzerland (source: doi.org/10.1080/20964471.2021.1948179).

Institute
Inst. Envrionmental Sciences,
University of Geneva (UNIGE), Switzerland

Principal/Swiss Investigator(s)
G. Giuliani (UNIGE)

Contribution
Living Switzerland builds upon the Swiss Data Cube and many national data resources (e.g. swisstopo, FSO, …) providing a service to capture consistent and scalable information on the states and dynamics of past and present landscapes that can inform planning for the future.

Website(s)
https://livingearth.ch

11 Space Geodesy

11.1 COST-G – Combination Service for Time-Variable Gravity Fields

COST-G
Combination Service for Time-variable Gravity Fields

Institute
Astronomical Inst., Univ. Bern (AIUB),
Bern, Switzerland

In cooperation with
COST-G Consortium

Principal/Swiss Investigator(s)
A. Jäggi (AIUB)

Co-Investigator(s)
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Website(s)
https://cost-g.org

Purpose of Research

Ultra-precise inter-satellite ranging, as performed from 2002 to 2017 by the Gravity Recovery And Climate Experiment (GRACE) mission, has been established as the state-of-the-art technique to globally observe mass variations in the Earth system from space. Such measurements have continued since March 2018 with the follow-on mission, GRACE-FO. An increasing number of institutions are processing the GRACE/GRACE-FO Level-1B instrument data to derive mass variations on a monthly basis.

Although each new release of monthly gravity fields represents a significant improvement with respect to earlier releases, the solutions of different institutions usually differ considerably in terms of their signal-to-noise ratio. In the frame of the European Gravity Service for Improved Emergency Management (EGSIEM) initiative (2015 – 2017), which received funding from the European Commission, a prototype of a scientific combination service was set up to demonstrate that improved solutions may be derived by combining individual solutions which are based on different approaches but also on commonly agreed processing standards.

Since July 2019, the Combination Service of Time-Variable Gravity Fields (COST-G) continues the activities of the scientific combination prototype service of the EGSIEM initiative to realise a long-awaited standardisation of gravity-derived mass transport products under the umbrella of the International Association of Geodesy (IAG). In the frame of the Global Gravity-based Groundwater Product (G3P) initiative, which again was funded by the European Commission, the COST-G combination was extended to the monthly gravity fields derived from GRACE-FO data, and the weighting scheme has been adapted to better accommodate the continuously advancing analysis techniques of the individual COST-G Analysis Centers (ACs).

Past Achievements and Status

COST-G was formally established at the 2019 General Assembly of the International Union of Geodesy and Geophysics (IUGG) as a new Product Center of IAG's International Gravity Field Service (IGFS) for time-variable gravity fields. COST-G is providing consolidated monthly global gravity models with improved quality, robustness, and reliability of either reprocessed time-series of the GRACE mission, where the COST-G analysis centers agreed upon consistent processing standards, or operationally produced solutions based on GRACE-FO low-low satellite-to-satellite tracking (ll-SST), where the analysis centers are free to apply their most recent analysis techniques and tools. In addition, COST-G makes use of existing and publicly available solutions or normal equations of Partner Analysis Centers, who are directly linked to the GRACE and GRACE-FO project.

The combined products are provided in terms of spherical harmonic coefficients and derived global grids or time-series of surface mass variations in specific areas. COST-G is providing a first release of combined GRACE monthly gravity fields covering the entire GRACE time period between April 2002 and June 2017, and since November 2020 also operational combinations of GRACE-FO, which are made available with a latency of 3 months.

After extensive quality control, COST-G has been extended by Chinese ACs using GRACE data, and a COST-G GRACE RL02 combination was released in June 2025, now also including the monthly gravity field solutions of the Innovation Academy for Precision Measurement Science and Technology, Chinese Academy of Sciences (APM-SYSU), the HuaZhong Univ. Sci. Technol. (HUST), the Southern Univ. Sci. Technol., Dept. Earth and Space Science (SUSTech), the Tongji Univ., College of Surveying and Geo-informatics, as well as the Leibniz Univ. Hannover (LUH; Germany), which had already been contributing to the operational GRACE-FO combination. With high-quality contributions from 11 ACs, COST-G has now a larger basis than the International GNSS Service (IGS), archetype of all IAG services.

HUST (since Sep. 2024) and Tongji (since 06/2025, after a reprocessing due to attenuated mass trends in polar regions in their original release, detected by the COST-G quality control) meanwhile also provide monthly solutions to the operational GRACE-FO combination. This extension of the data basis, and the update with the reprocessed release RL06.3 gravity fields of the analysis centers of the GRACE-FO Science Data System (SDS), led to a recombination and publication of a new release COST-G GRACE-FO RL02.1 of the GRACE-FO combinations in June 2025, generated with a consistent weighting scheme like COST-G GRACE RL02.

The COST-G quality control and the operational combination of the GRACE-FO and Swarm gravity fields and the quarterly update of the Fitted Signal Model (FSM) for operational orbit determination of Low Earth Orbiters (LEOs) has been performed without relevant interruptions since the start of the COST-G service in 2019.

Since April 2026, the Copernicus Climate Change Service (C3S) is providing a Terrestrial Water Storage Anomaly (TWSA) dataset based on the monthly COST-G RL02 GRACE/GRACE-FO Level-2 products. The TWSA represent the deviations from the long-term average of water stored on or below the Earth's surface in the form of soil moisture, groundwater, surface water, snow and ice.

In view of ESA's Next Generation Gravity Mission (NGGM, to be launched in 2032), which together with NASA-DLR's GRACE-C (to be launched in 2028) will form the Mass-change And Geoscience International Constellation (MAGIC), the combination of monthly gravity fields on the normal equation level is currently reconsidered, taking also Satellite Laser Ranging (SLR) for the very low degree gravity field coefficients into account.

Publications

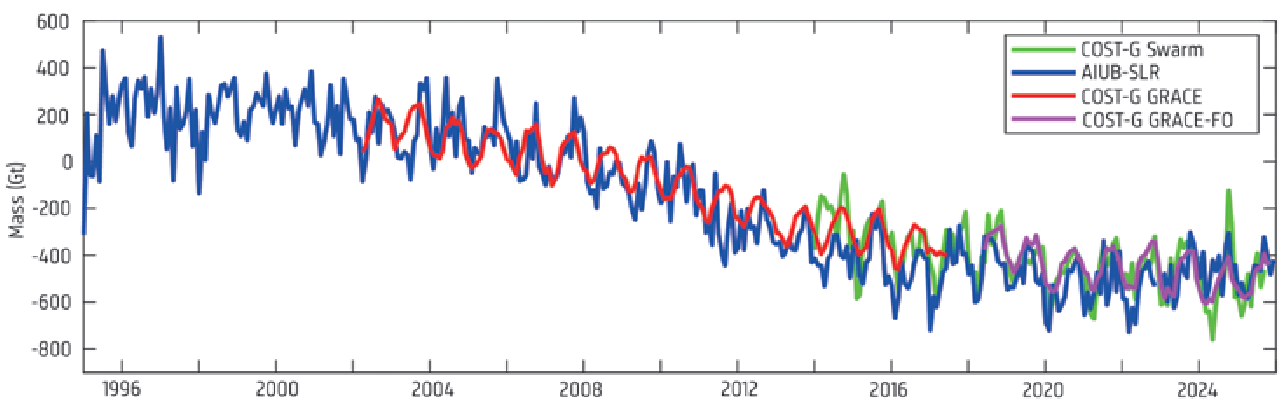
Jäggi A et al. (2020) **International Combination Service for Time-variable Gravity Fields (COST-G) – Start of Operational Phase and Future Perspectives**, Int. Assoc. Geodesy Symposia Series, 152: 57-65, doi.org/10.1007/1345_2020_109

Meyer U et al. (2024) **Combined monthly GRACE-FO gravity fields for a Global Gravity-based Groundwater Product**, Geophys. J. Int., 236(1): 456-469, doi.org/10.1093/gji/ggad437

Meyer U et al. (2025) **International Combination Service for Time-variable Gravity Fields (COST-G) Monthly GRACE/GRACE-FO RL02 Series**, V. 2.1. GFZ Data Services, doi.org/10.5880/COST-G.ICGEM_02_L2

Abbreviations

COST-G	Combination Service for Time-Variable Gravity Fields
EGSIEM	European Gravity Service for Improved Emergency Management
GRACE	Gravity Recovery And Climate Experiment
GRACE-FO	GRACE Follow-On
G3P	Global Gravity-Based Groundwater Product



Mass change in Greenland, derived by different satellite gravimetric observation techniques (due to the limited resolution of SLR truncated at degree 10).

11.2 Copernicus Precise Orbit Determination Service

Institute
Astronomical Inst., Univ. Bern (AIUB), Bern, Switzerland

In cooperation with
ESA's CPOD Quality Working Group

Principal Investigator(s)
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Swiss Principal Investigator(s)
A. Jäggi (AIUB)

Co-Investigator(s)
D. Arnold (AIUB)

Website(s)
https://www.copernicus.eu

Purpose of Research

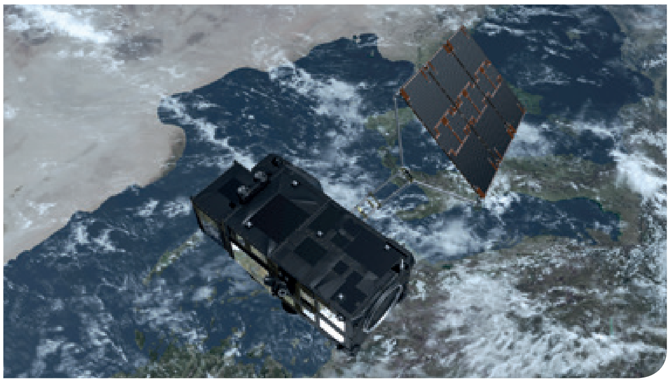
Copernicus is the European Programme for the establishment of a European capacity for Earth Observation. Based on satellite and in-situ observations, the Copernicus services deliver near-real-time data on a global level to improve the understanding of our planet and to sustainably manage our environment. The core of the Copernicus programme consists of Earth observation satellites. The so-called Sentinel satellites are developed for the specific needs of the Copernicus programme. Sentinel-1 provides all-weather, day and night radar imagery for land and ocean services.

Four satellites have so far been launched: Sentinel-1A (3 April 2014), Sentinel-1B (25 April 2016), Sentinel-1C (5 December 2024) and Sentinel-1D (4 November 2025). Sentinel-1B started to suffer from power issues at the end of 2021 and was deactivated in August 2022. Sentinel-1A/C/D are in Sun-synchronous near-polar orbits at an altitude of about 700 km. Sentinel-1B was placed into a decaying orbit in April 2024 and, by February 2026, had reached an altitude of about 570 km. The official, non-time-critical Sentinel-1 orbit solutions are expected to fulfill an accuracy requirement of 5 cm 3D RMS.

Sentinel-2 provides high-resolution optical imagery for land services. The three satellites, Sentinel-2A, Sentinel-2B and Sentinel-2C, were launched on 22 June 2015, 7 March 2017, and 21 January 2025, respectively. Sentinel-2A was replaced by Sentinel-2C from January 2025 on. The Sentinel-2 satellites are in Sun-synchronous near-polar orbits at an altitude of about 790 km. No stringent accuracy requirement has to be fulfilled for the Sentinel-2 orbit solutions.

Sentinel-3 provides high-accuracy optical, radar and altimetry data for marine and land services. The twin satellites, Sentinel-3A and Sentinel-3B, were launched on 16 February 2016 and on 25 April 2018, respectively. They are in Sun-synchronous near-polar orbits at about 800 km altitude. The official, non-time-critical Sentinel-3 orbit solutions need to fulfill an accuracy requirement of 2 cm in the radial component.

Sentinel-6 is the world's next radar altimetry reference mission, set to extend the legacy of sea-surface height measurements until at least 2030. Sentinel-6A (Michael Freilich) was launched on 21 November 2020, and Sentinel-6B on 17 November 2025. The two satellites orbit Earth in 66° inclined orbits at about 1300 km altitude. The mission requirement for the radial orbit accuracy is 1.5 cm.



Artist's impression of the Sentinel-3 satellite. Image credit: ESA/ATG medialab.

For the precise orbit determination, the early Sentinel satellites, i.e., Sentinel-1A/B, Sentinel-2A/B and Sentinel-3A/B are equipped with dual-frequency GPS receivers. Sentinel-6A was the first Sentinel satellite to carry a PODRIX multi-GNSS receiver, which can make use of both GPS and Galileo signals to perform the mission-critical precise orbit determination. The same multi-GNSS receiver is also on board the Sentinel-1C/D, Sentinel-2C, and Sentinel-6B units.

As part of ESA's Copernicus Precise Orbit Determination (CPOD) Service, the CPOD Quality Working Group (QWG) regularly delivers independent orbit solutions for all active Sentinel satellites generated with different state-of-the-art software packages and based on different reduced-dynamic orbit determination techniques. These alternative orbit solutions are used to check the quality and to improve the official, non-time-critical orbit solutions of the CPOD Service.

Past Achievements and Status

Orbit solutions delivered by the members of the CPOD QWG are used for the validation of the non-time-critical orbit solutions on a regular basis. Every four months a so-called Regular Service Review (RSR) is performed. Orbit solutions from a selected time interval within the RSR period are compared to each other, to a combined solution and, in the case of Sentinel-3 and Sentinel-6, to Satellite Laser Ranging (SLR). The Astronomical Institute of the University of Bern (AIUB) contributes two solutions, a reduced-dynamic solution without explicit modelling of non-gravitational forces and a more dynamic solution relying on a more detailed force model. The RSR analyses confirm that the quality of the delivered AIUB solutions is among the best of all solutions contributing to the CPOD QWG. For the more dynamic Sentinel orbit solutions of AIUB, the latest COST-G Fitted Signal Models (operationally computed at the AIUB in the frame of the Combination Service of Time-Variable Gravity Fields, COST-G) are always used. This has been shown to significantly improve the orbital accuracy.

Since 18 July 2023, the CPOD uses the COST-G Fitted Signal Models for gravity field modelling in all their operational chains.

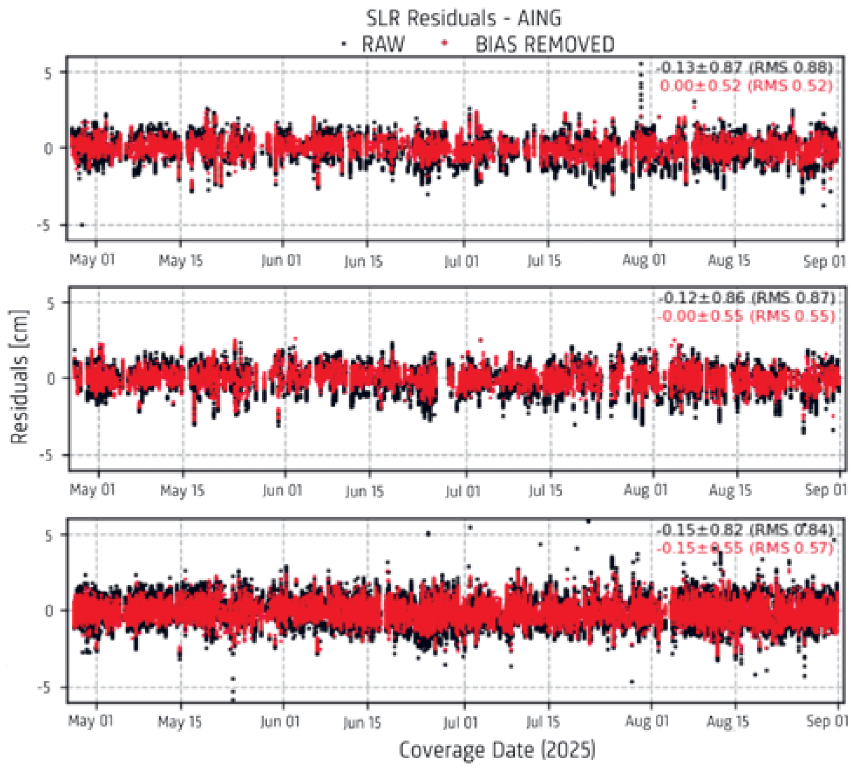
Publications

Fernandez J et al. (2024) **The Copernicus POD Service**, Adv. Space Res., 74(6): 2614-2648, doi.org/10.1016/j.asr.2024.02.056

Peter H, Meyer U, Lasser M, Jäggi A (2022) **COST-G gravity field models for precise orbit determination of Low Earth Orbiting Satellites**, Adv. Space Res., 69(12): 4155-4168, doi.org/10.1007/s00190-022-01678-x

Abbreviations

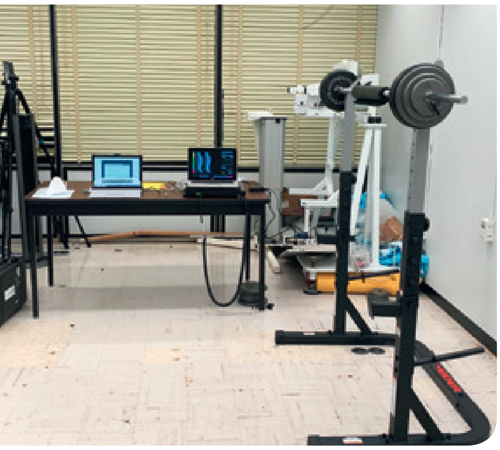
COST-G	Combination Service for Time-variable Gravity Fields
CPOD	Copernicus Precise Orbit Determination
CPOD QWG	CPOD Quality Working Group
GNSS	Global Navigation Satellite System
SLR	Satellite Laser Ranging



SLR residuals of the dynamic orbit solutions (AING) computed at AIUB (Astronomical Institute, University of Bern) for the satellites Sentinel-3A, Sentinel-3B, and Sentinel-6A from Regular Service Review 35 (black: original residuals; red: after bias removal).

12 Life Science

12.1 Low Back Pain of Astronauts: Holistic Approach to Determine Origin and Medical Implications



Measurement setup, Houston, USA, 2022.

Institute
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In cooperation with
Inst. Medical Eng., Space Biology Group, Lucerne Univ. Applied Sciences and Arts (HSLU), Hergiswil, Switzerland

King's College London, Centre of Human & Applied Physiological Sciences (CHAPS), UK

Swiss Principal Investigator(s)
J. Swanenburg (UZH), M. Egli (HSLU)

Co-Investigator(s)
D. A. Green (ESA), F. Ille (HSLU), R. Sutter (Balgrist)

Contribution
Research based on existing instruments: This project will investigate the microgravity-induced changes in the human spine.

Website(s)
www.space.uzh.ch/en/research/space-life-science/spinal-health.html

www.balgrist.ch/forschung/forschergruppen/chiropraktische-medizin/jaap-swanenburg-phd

Purpose of Research

Astronauts exposed to microgravity often report lower back pain that can significantly affect their ability to work. Total unloading of the spine, which happens in microgravity, also leads to de-conditioning of the paraspinal muscles and a change in spine movement kinematics. It has been shown that the lumbar curvature flattens by 11% after returning from an extended mission on the Int. Space Station (ISS). Only a few studies have investigated the thoracic portion of the spine. An assessment of the whole spine is needed for a complete and detailed picture of spinal curvature changes under various loading conditions. Unfortunately, ISS studies, parabolic flight studies, and bedrest studies have only been conducted among small subject groups. In summary, accurate and detailed measurement of the lumbar and thoracic spine with sufficient statistical power is required. This study aims to investigate lumbar and thoracic curvature and extensor muscle activity under changing gravity conditions.

Low back pain often relates to degenerated intervertebral discs (IVD). It is assumed that microgravity facilitates the degenerative processes of IVDs that then lead to a higher risk of astronauts developing an IVD herniation after their return from space. Furthermore, it is well known that microgravity induces swelling of the lumbar IVDs, which could also contribute to low back pain. To understand the microgravity-induced changes on a cellular level in IVDs, the science team will perform ground reference experiments on cultured bovine IVDs in a simulated microgravity environment. The data gathered by these experiments, in combination with the results from the astronaut studies, mentioned earlier, will provide a more holistic view of the low back pain problem astronauts are facing.

Past Achievements and Status

PI: Acceptance of Long Duration ISS Mission (Pre/Post) Study: Low back pain of astronauts: Holistic approach to determine the origin and medical implications (2020-2024).

PI: European Space Agency (ESA) access to 76th ESA partial gravity Parabolic Flight Campaign, December 2021: The effect of partial gravity on spinal stiffness.

PI: Access to 74th ESA partial gravity Parabolic Flight Campaign, December 2020: The effect of partial gravity on spinal stiffness.

PI: Access to 71st ESA Parabolic Flight Campaign, June 2019: The effect of changing gravity on spinal stiffness.

Publications

Meinke A, Baez AL, Wiesmann N, Ullrich O, Green DA, Egli M, Swanenburg J. (2025) **Adaptation of thoracic and lumbar curvature and spinal muscle activity under changing gravity**, Front Physiol. 16: 1549249.

Swanenburg J, Easthope CA, Meinke A, Langenfeld A, Green DA, Schweinhardt P. (2023) **Lunar and Mars gravity induce similar changes in spinal motor control as microgravity**, Front Physiol. 14: 1196929.

Abbreviations

IVD Intervertebral Discs
RPM Random positioning machine

Time-Line	From	To
Planning	2019	2020
Construction	2021	2023
Measurement phase	2022	2026
Data evaluation	2023	2026

12.2 OoDrop Experiment

Purpose of Research

Exposure to microgravity triggers numerous physiological adaptations in humans and animals. To date, the underlying molecular mechanisms are not well understood and several pathways have been proposed. Among other candidates, specific ion channels are hypothesised to be gravity-dependent, but until now it has not been possible to conclusively demonstrate gravity-dependency of specific proteins.

Past Achievements and Status

We developed a miniaturised two-electrode voltage clamp (TEVC), which allowed electrophysiological experiments on *Xenopus laevis* oocytes (frog eggs) using the GraviTower Bremen Prototype (GTB-Pro). The GTB-Pro, located at the Center of Applied Space Technology and Microgravity (ZARM; Bremen, Germany) is capable of flying experiments on a vertical parabolic trajectory, providing microgravity for a few seconds. As an interesting first candidate, we examined if the non-selective mechano-sensitive ion channel PIEZO1 is gravity-dependent. Oocytes were micro-injected with mRNA coding for PIEZO1, six days before the experiments. The results showed no difference between PIEZO1-overexpressing and control oocytes under acute microgravity conditions.

Publications

Wuest SL, Cerretti G, Polzer J et al. (2025) **Recordings on PIEZO1-overexpressing oocytes in microgravity**, Microgravity Sci. Technol. 37: 3, doi.org/10.1007/s12217-024-10155-3

Time-Line	From	To
Planning	May 2020	Dec. 2020
Construction	Jan. 2021	May 2023
Measurement phase	Jun. 2023	Sep. 2023
Data evaluation	Nov. 2023	Mar. 2024

The OoDrop project logo.

Institute
Lucerne Univ. Appl. Sci. & Arts (HSLU)
Horw, Switzerland

In cooperation with
Univ. Zurich, Faculty of Medicine, Inst. Anatomy & Zurich Kidney Center, Zürich, Switzerland

Principal/Swiss Investigator(s)
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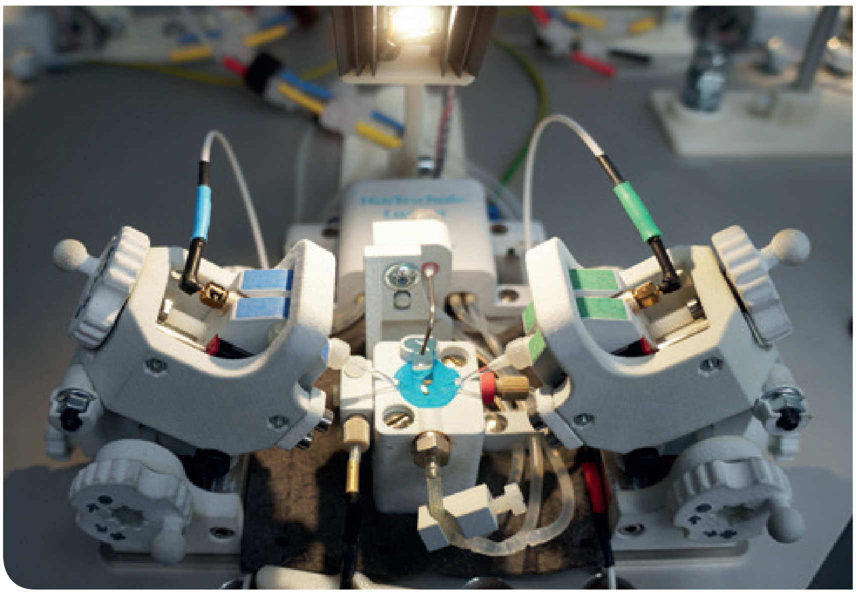
Co-Investigator(s)
G. Cerretti, J. Polzer, S. Gerig, C. Zumbühl, C. Jost, L. Rüfenacht, R. Eberli, B. Bösch, J. Traversari, M. Horn, D. Invernot Pérez, C. Giger, K. F. Rattenbacher-Kiser, F. Ille, G. Székely, S. S. Lienkamp, P. Torabi, M. Egli

Contribution
Development & construction of instrument(s): Miniaturisation of a two-electrode voltage clamp (TEVC) for *Xenopus laevis* oocytes.

Website(s)
https://www.hslu.ch/imt

QR-Code to view a short campaign video.



Close-up view of the OoDrop experiment hardware. *Xenopus laevis* oocytes were placed in the central bath and subsequently impaled with two glass capillaries for electrophysiological recordings under microgravity conditions.

12.3 Yeast Bioreactor Experiment

NATIONAL CENTER FOR BIOMEDICAL RESEARCH IN SPACE

Institute
Inst. Medical Eng., Space Biology Group, School Eng. & Architecture, Lucerne Univ. Appl. Sci. & Arts (HSLU) Hergiswil, Switzerland

In cooperation with
Vrije Univ. Brussel, Lab. Structural Biology, Dept. Bioeng. Sci., Brussels, Belgium

Ghent Univ., Lab. Protein Biochem. Biomol. Eng., Ghent, Belgium

KU Leuven & VIB, Dept. Molec. Microbiol., Lab. Molecular Cell Biology, Leuven, Belgium

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Swiss Principal Investigator(s)
M. Egli (HSLU)

Co-Investigator(s)
B. Rattenbacher (HSLU)
P. Van Dijck (KU Leuven & VIB)
B. Devreese (Univ. Gent)

Website(s)
www.hslu.ch/de-ch/technik-architektur/ueber-uns/organisation/kompetenzzentren-und-forschungsgruppen/technik/bioscience-and-medical-engineering/weltraumbiologie

Purpose of Research

The project focuses on microgravity's effect on the physiology of the yeast strain Saccharomyces cerevisiae. Previous studies conducted in a simulated microgravity environment have shown a significant gene change. Furthermore, S. cerevisiae grows in clusters under microgravity, which is not the case when cultivated on the ground.

In the proposed experiment, S. cerevisiae will be used to investigate the effect of microgravity on yeast growth and induced stress responses by applying heat and osmotic shock.

An integrative-experimental approach will be used to assess the effect of microgravity. Therefore, various -omics technologies will be used to analyse the samples, i.e., fluxomics, transcriptomics, proteomics and genomics, and specific cell analysis methods. A network biology model for S. cerevisiae will be set up to process the -omics data.

This will lead to insight into how gravity influences global regulation of energy metabolism, (stress) signalling transduction pathways, transcriptional regulatory networks, gene regulatory networks, protein-protein interaction networks, and metabolic networks.

Yeast cultivation will be performed in a custom-made space bioreactor that allows continuous cultivation. This hardware will monitor and control growth parameters such as temperature and flow rate and monitor pH, oxygen, and carbon dioxide levels, which are necessary to achieve steady-state and stable growth. The samples will be automatically withdrawn, treated (shock), filtrated, and fixed.

Past Achievements and Status

The project's status is a delta B phase where scientific requirements for the hardware development are being established.

Publications

Granata T et al. (2021) **Methods for oxygenation of continuous cultures of brewer's yeast, saccharomyces cerevisiae**, Fermentation 7: 282, doi.org/10.3390/fermentation7040282

Granata T et al. (2022) **Micro-bioreactors in Space: Case study of a yeast (saccharomyces cerevisiae) bioreactor with a non-invasive monitoring method**, Front. Space Technol. 2: 773814, doi.org/10.3389/frspt.2021.773814

Granata T et al. (2024) **Microbial factories and exploiting synergies of bioreactor technologies to produce bioproducts**, Fermentation 10(3): 135, doi.org/10.3390/fermentation10030135

Time-Line	From	To
Planning	2013	2014
Construction	2015	2027
Measurement phase	2028	2028
Data evaluation	2028	2029

The yeast bioreactor.

12.4 EReCC – Electrophysiological Recordings During Centrifugation in Chondrocytes

Purpose of Research

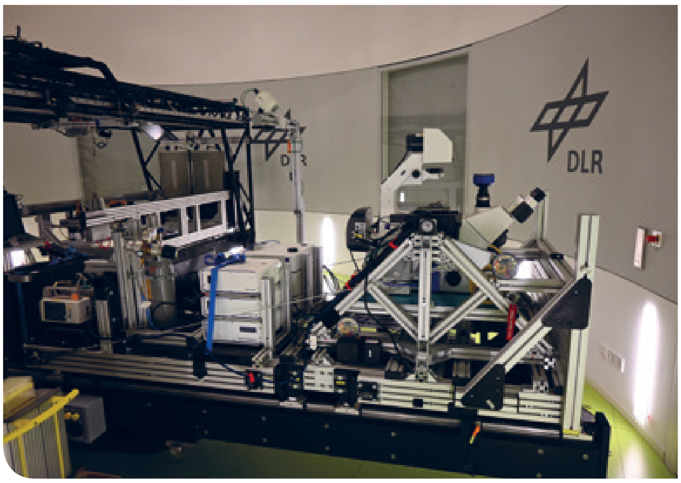
Articular cartilage lines the articulating bones in joints and allows almost effortless movement. Adequate daily mechanical loading is critically important for cartilage maintenance and prevention of a pathological breakdown developing into osteoarthritis. Irreversible cartilage breakdown has been reported in simulated microgravity as well as in astronauts after space journeys. Therefore, understanding the underlying mechanisms of mechano-sensation of cartilage is of central importance: not only for preserving good health of astronauts during long-term space missions but also for patients suffering from irreversible cartilage degeneration.

In articular cartilage, only one cell type is found, the chondrocytes, which are responsible for the synthesis and maintenance of the matrix. These cells have shown to respond greatly to their mechanical environment. To date, however, the underlying mechano-transduction pathways are not fully understood. Experiments suggest that mechano-sensitive ion channels could play a central role in the early events of mechano-sensation. However, the response of chondrocytes to altered gravitational load is currently not understood.

Past Achievements and Status

To better understand the influence of gravitational loads, and its potential link to intracellular calcium signalling, we recorded cytosolic free calcium and the membrane potential in primary bovine chondrocytes exposed to elevated gravity on a centrifuge. In a first campaign, a modified plate reader was mounted on the human short-arm centrifuge at the German Aerospace Center in Cologne, Germany. The plate reader allowed high-throughput recordings of various cell populations. In a second campaign, an adapted high-end microscope, called ‘Hyperscope’, was used for recordings with single cell resolution but lower throughput. The two methods are complementary to each other in terms of resolution and sample throughput. The data analysis is currently ongoing.

Time-Line	From	To
Planning	Sep. 2023	Nov. 2023
Construction	Dec. 2023	May 2025
Measurement phase	Jun. 2025	Mar. 2026
Data evaluation	Jul. 2025	present



The ‘Hyperscope’: an adapted fluorescent microscope, mounted on the human short-arm centrifuge at the German Aerospace Center (DLR) in Cologne, Germany.

Institute
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Horw, Switzerland

In cooperation with
Univ. Zurich, Dept. Molecular Life Sciences, Electrophysiology Facility, Zürich, Switzerland

Univ. Bern, Medical Faculty, Dept. BioMedical Res. (DBMR), Bone & Joint Program, Bern, Switzerland

German Aerospace Center (DLR), Applied Aerospace Biology, Cologne, Germany

Principal/Swiss Investigator(s)
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Co-Investigator(s)
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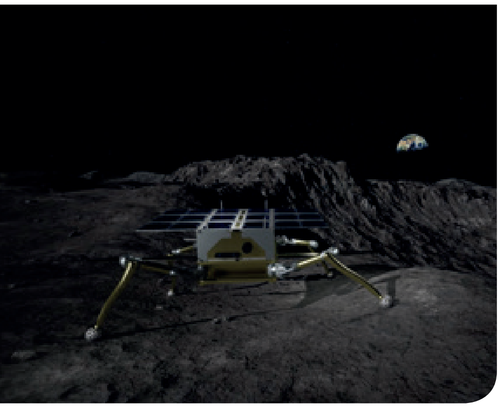
Contribution
Research based on existing instrument(s): Cytosolic free calcium meas. in bovine articular cartilage cells during elevated gravity conditions.

QR-Code to view a short campaign video.

13 Technologies

13.1 LunarLeaper



Artistic rendering of LunarLeaper operating on the surface of the Moon.

Institute
ETH Zurich | Space + Institute of Geophysics (Dept. Earth and Planetary Sciences) and Inst. Robotics & Intelligent Systems (Dept. Mechanical and Process Engineering), ETH Zurich, Zurich, Switzerlad

In cooperation with
Fachhochschule OST, Buchs and Rapperswil, Switzerland;
University of Bern (UNIBE), Bern, Switzerland

and international partners:
Royal Observatory Belgium (ROB), Belgium
Univ. Oslo (UiO), Norway
DLR, Germany

Principal/Swiss Investigator(s)
A. Mittelholz (ETH Zurich)

Co-Investigator(s)
+30 International co-investigators

Contribution
Research based on existing instruments: Legged robot as robotic exploration platform

Industrial hardware contract(s)
Beyond Gravity; Maxon; Switzerland

Website(s)
https://www.lunarleaper.space

Purpose of Research

The LunarLeaper project aims to advance autonomous robotic exploration of challenging lunar terrains that are inaccessible to conventional rovers, such as regions around lunar pits that may serve as entry points to subsurface lava tubes. These environments are difficult to access due to steep slopes, loose regolith, and irregular terrain, which severely limit the mobility of traditional wheeled rovers. LunarLeaper addresses this challenge by developing a legged robotic platform capable of flexible and precise locomotion, enabling traversal of obstacles that conventional systems cannot overcome.

Exploring lunar pits and potential lava tube systems can provide new insights into lunar volcanic history, crustal structure, and the stratigraphy of subsurface regolith layers. Such environments may preserve records of past volcanic activity and ancient surface conditions that are not accessible through orbital observations or traditional surface missions. In addition, subsurface lava tubes have the potential to serve as future habitats for lunar explorers due to the natural protection they provide from radiation, micrometeorites, and extreme temperature variations. LunarLeaper is envisioned to carry compact geophysical instruments to investigate the subsurface structure and physical properties of the regolith and underlying rock, helping to constrain local geology and lunar interior processes.

A key objective of the project is to optimise legged mobility in low-gravity environments using simulations calibrated to lunar gravity (1/6 g) and regolith properties derived from Apollo and modern lunar data. This includes investigating energy-efficient traversing and adaptive mobility strategies across heterogeneous terrain. LunarLeaper also integrates advanced sensing and autonomy for operations in partially mapped or unknown environments, including terrain mapping, hazard detection, and autonomous navigation, with the goal of reducing operational risk while increasing mission productivity.

Overall, LunarLeaper seeks to enable in-situ exploration of scientifically valuable lunar subsurface environments while advancing robotic mobility technologies for future missions to the Moon and other low-gravity planetary bodies.

Past Achievements and Status

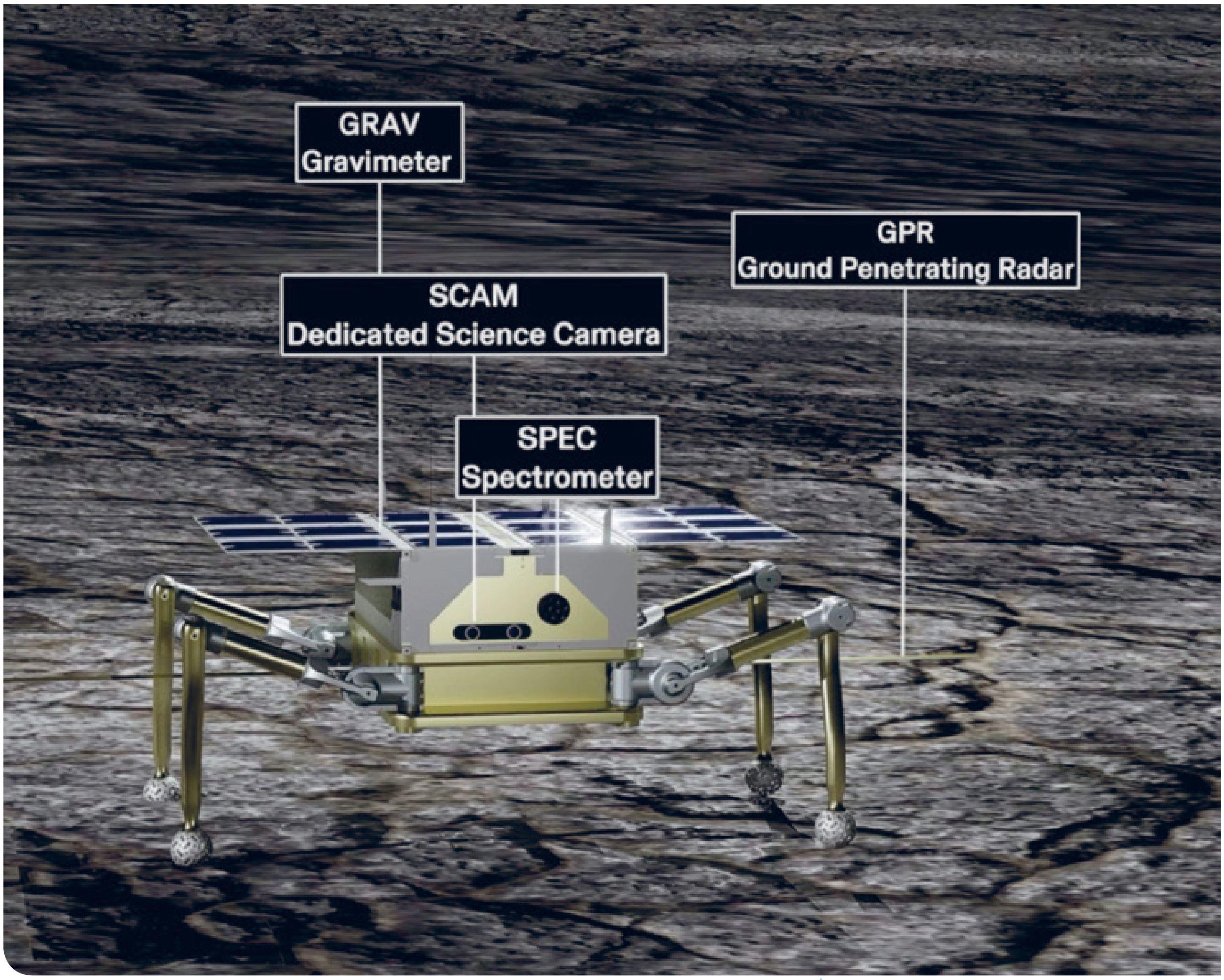
LunarLeaper has successfully completed initial design studies and simulation work, and testing in ESA's LUNA analogue facility has validated legged locomotion in the lunar environment/terrain.

Publications

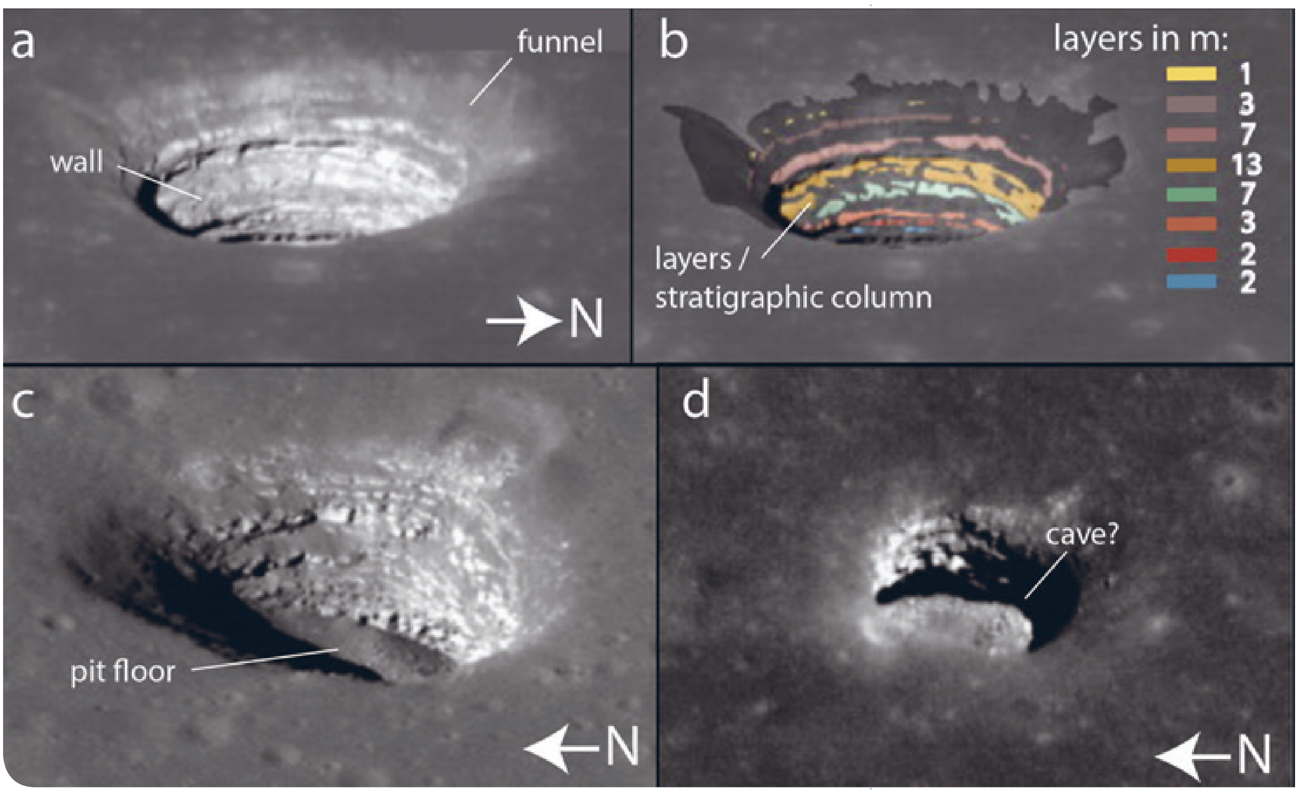
Church Joseph et al. (2025) **LunarLeaper: From simulation to hardware for lunar legged locomotion**, IAC 2025 Congress Proc. Int. Astronautical Federation.

Kolvenbach H et al. (2025) **LunarLeaper—A mission concept to explore the lunar subsurface with a small-scale legged robot**, Acta Astronautica 240: 63-75, doi.org/10.1016/j.actaastro.2025.11.039

Time-Line	From	To
Planning	2023	2029
Construction	2026	2028
Measurement phase	2029	2029
Data evaluation	2029	2030



LunarLeaper equipped with scientific payload.



Oblique orbital images taken of exposed pit walls of (panel a+b) Mare Tranquillitatis Pit, (c) Mare Ingenii Pit and (d) Marius Hills pit; key morphological characteristics of pits are highlighted. Panel (b) shows mapping of individual layers and their approximate thickness in meters. Modified from Robinson et al. (2012).

14 Swiss Space Industries Group (SSIG)

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Beyond Gravity Schweiz AG,
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Carbomill AG, www.carbomill.ch

Cassio-P SA, www.cassio-p.com

Clearspace SA, www.clearspace.today

Clemessy (Switzerland) AG,
www.clemessy.ch

CSEM, www.csem.ch

dlab GmbH, www.dlab.ch

Fly High Engineering AG,
www.fly-high-engineering.ch

Franke Industrie AG, www.industech.ch

Scientific, Industrial and Economic Importance of the Institutional Space Sector

The world space industry is a strategically important growth sector of high value-creating potential and great economic importance. While the commercial sector is reshaping with an increasing interest for a Low Earth Orbit constellation, security and space exploration, with private initiatives creating increasing impact, the truly scientific endeavours are still firmly in the hands of large institutions such as the European Space Agency (ESA).

For Europe to compete globally and to secure a leading position in space science, the available resources must be efficiently deployed and activities pooled. These tasks are handled by ESA.

ESA 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 about seven billion Euros. Switzerland contributes around 170 million Francs annually. As a result, funds flow into research, and enable Swiss scientists to participate in significant ESA missions, while industry carries out the implementation of the hardware, from design to production and testing, for the research sector or directly through contracts awarded by ESA.

European and Swiss Collaboration

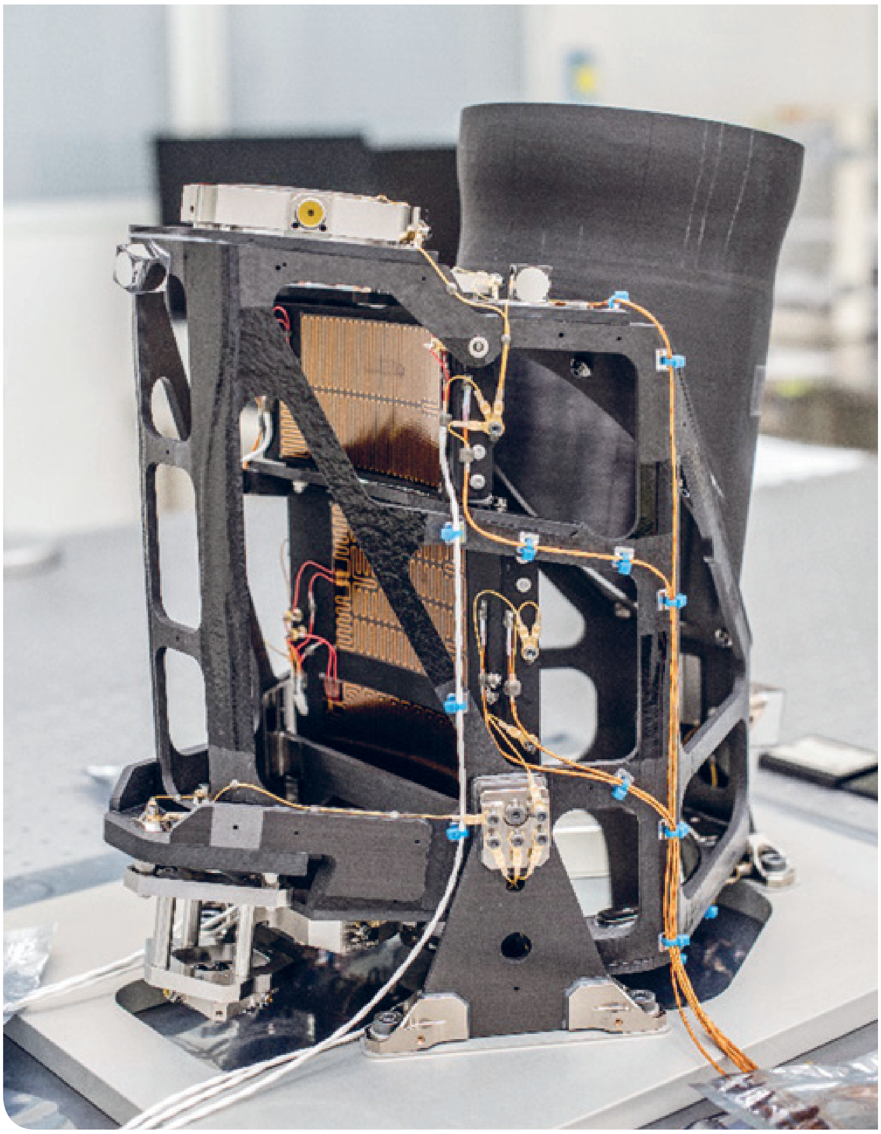
The European collaboration between ESA, EC and EUSPA (European Union Agency for the Space Programme) is going to be fundamental to the success of the EU Space Programme. EUSPA's core mission is to implement the EU Space Programme and to provide reliable, safe and secure space-related services, maximising their socio-economic benefits for European society and business. The Swiss space industry will have ESA and EUSPA as essential partners and clients in future projects.

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. For instance, the Ariane and Vega launchers, Galileo, the Sentinel satellites for Copernicus, Europe's Global Monitoring for Environment and Security system, the Earth Explorers or LISA and Comet Interceptor are just some examples of important space programmes in which Swiss manufacturers have played and will play a major role. There is hardly a current European mission, which does not incorporate Swiss technology. None of this would be possible without Switzerland's early commitment to ESA, right from day one.

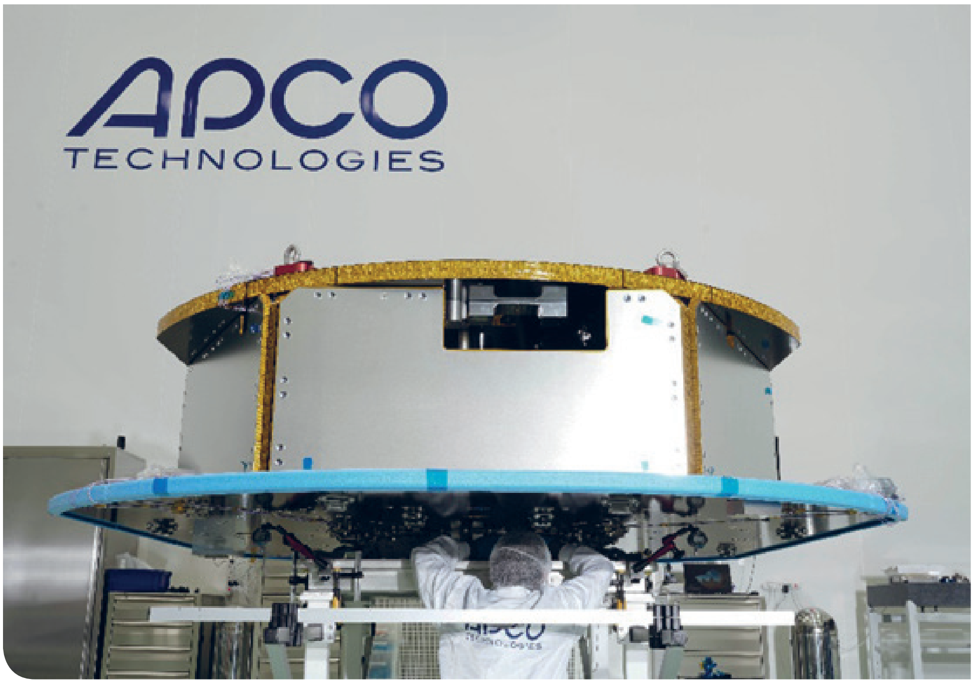
ESA's ambitious programmes enable Swiss space companies to acquire the expertise that underpins its excellent reputation and promising position in the global growth market for space technology. Strengthening and further expanding this position has to be the goal in the coming years. This means not only overcoming technological and economic challenges but also dealing with difficult political issues. The leading players – science, politics, industry and military – have to work seamlessly together.

Engagements within the Space Industry

Swissmem unites the Swiss electrical and mechanical engineering industries and associated technology-ori-



The Comet Interceptor Telescope. Image credit: Thales Alenia Space, Switzerland.



A satellite structure. Image credit: APCO Technologies.

General Atomics Synopta GmbH, www.ga-synopta.ch

Geo Data Solutions, www.geodatasolutions.ch

Gritec AG, www.gritec.ch

Huber+Suhner AG, www.hubersuhner.com

icotec AG, www.icotec-medical.com

Klepsydra Technologies AG, www.klepsydra.com

nanoTRONIC AG, www.nanotronic.ch

PWB AG, www.pwb.ch

RUAG AG, www.ruag.ch

Safran Timing Technologies SA, www.safran-navigation-timing.com

SAPHYRION Sagl, www.saphyrion.ch

Sauter, Bachmann AG, www.sauterbachmann.ch

Schurter AG, www.schurter.ch

Sirin Orbital Systems AG, www.sirin-os.com

Solenix Engineering Schweiz GmbH, www.solenix.ch

SpacePharma SA, www.space4p.com

SpacePNT Sarl, www.spacepnt.com

Spacetec Technology AG, www.spacetec.ch

Stellar Alpina AG, www.stellar-alpina.ch

SWISSto12 SA, www.swissto12.ch

Thales Alenia Space Schweiz AG, www.thalesgroup.com

ViaSat Antenna Systems SA, www.viasat.com

ented sectors. The space industry is an important division among them.

International competitiveness is not guaranteed despite having ESA membership. The ability to compete internationally is not a matter of course, it must be worked on. Having a location that is able to compete is the basis of success. Swissmem is committed to Swiss companies and the qualities of Switzerland as a centre of industry and research. Continuous groundwork 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 organisations, representatives of employees and the public. Apart from this, Swissmem offers companies numerous practice-oriented services, which help them to maintain their ability to compete and to successfully meet new challenges.

The Specialists: SSIG, Swiss Space Industries Group

SSIG (Swiss Space Industries Group) is organised as a technology group within Swissmem. SSIG includes companies that are significantly involved in the wide-ranging, competitive Swiss space technology environment. These manufacturers and engineering companies play a prominent role in the broadly faceted, competitive Swiss space industry, and develop solutions for all areas of space business, including: satellite prime, structures for launchers, satellite structures, space transporters, ground support equipment, components for propulsion engines, electronics and optics products and scientific instruments. Our companies participate in various ESA projects and earn themselves a merited high place in the fiercely competitive international 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.

In addition, new satellite-based military applications are becoming increasingly important for independent operations. SSIG therefore also follow s developments relevant to the Swiss Armed Forces and supports joint developments with the aim of building satellites, where possible, entirely in Switzerland.

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 1100 employees in Switzerland in the Space sector, but thousands of other professionals are also indirectly connected. Many 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 these companies, 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 diverse store of expertise. This includes a wide range of knowledge from mission definition to specialist in the fields of electronics, optics, precision mechanics, aero and thermodynamics, tribology, information technology, material science and additive manufacturing. This broad spectrum of expert knowledge enables the companies to provide innovative solutions to the complex challenges arising in the space sector.

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