INTERNATIONAL
SPACE
SCIENCE
INSTITUTE

Annual Report 2024

Cover Page

The puzzle is composed of six images (from the upper left to the lower right):

1. James Webb Space Telescope (artist's impression) reveals Cosmic Cliffs, Glittering Landscape of Star Birth (Image Credit: NASA, ESA, CSA, STScI and ATG medialab)

2. This artist's impression shows exocomets orbiting the star Beta Pictoris (Image Credit: ESO/L. Calçada)

3. Illustration of exoplanets (Image Credit: Foreground: Courtesy of Lena Noack, FU Berlin. Background: Except from the Hubble Ultra Deep Field view (NASA, ESA, S. Beckwith (STScI), the HUDF Team))

4. Black hole visualisation (Image Credit: NASA's Goddard Space Flight Center/Jeremy Schnittman)

5. Space Weather (Image Credit: Courtesy of Joe Grebowsky, NASA Goddard Flight Space Center)

6. This image shows the polarised view of the black hole in M87 (Image Credit: EHT Collaboration)

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The International Space Science Institute (ISSI) is an Institute of Advanced Studies where scientists from all over the world meet in a multi- and interdisciplinary setting to reach out for new scientific horizons. The main function is to contribute to the achievement of a deeper understanding of the results from different space missions, ground based observations and laboratory experiments, and adding value to those results through multidisciplinary research. The programme of ISSI covers a widespread spectrum of disciplines from the physics of the solar system and planetary sciences to astrophysics and cosmology, and from Earth sciences to astrobiology.

From the Chair of the Board of Trustees

While writing this foreword, I learned of the sudden and untimely death of Prof. Maurizio Falanga, who was not only a director of ISSI and the secretary of the Board of Trustees (BoT), but also a trusted colleague and good friend. ISSI, though a professional environment, is small enough to foster a family-like, atmosphere rendering such a loss profoundly tragic.

Writing this foreword has suddenly become far more challenging. The remarkable successes of ISSI in 2024, which I had intended to highlight, now seem to carry a more relative weight. They are overshadowed by the brutal realisation that everything can come to an abrupt, unexpected end.

Having taken some time to reflect, I am more convinced than ever that the growing number of visitors to ISSI and the expanding opportunities for scientific exchange are truly the result of a dedicated team effort – one in which Maurizio played an absolutely central role. He would have wanted the work not only to continue, but to develop and flourish, ensuring that the collective impact of the effort is felt for many years to come.

The BoT adopts the strategy and oversees the activities organised by ISSI. Starting in 2023, the BoT, together with the Directorate, has begun a review of ISSI's strategy, with a focus on improving the way the Institute can fulfil its mission while maintaining the quality that is ISSI's hallmark. Taking advantage of the opportunity to expand its premises in the same building, the BoT approved in 2024 an updated strategy which includes, among other things, the addition of a new type of workshop, the Breakthrough Workshop, to ISSI's portfolio on an annual basis. A first 'experimental' Workshop on “The chronology of the very early universe according to JWST: The first billion years” was held in March 2024 and led to the submission of a paper summarising the Workshop within three months. The next Breakthrough Workshop, entitled “Life beyond Earth: The missing link”, will be held in June 2025. It is already fully booked.

In 2024 the BoT said farewell to Prof. Georges Meynet of the University of Geneva, who completed his second term and to whom we would like to express our gratitude for his commitment to ISSI over these years. To replace him, the BoT elected Prof. Ravit Helled of the University of Zurich, who started her term on 1 January 2025. Finally, ISSI would not be ISSI without its staff: small in number but extremely dedicated, they are the ones who make it all happen. Their commitment and dedication are deeply appreciated.

Of course, we cannot forget the generous support of our funders, in particular the European Space Agency (ESA) and the Swiss Federal Government. Their commitment to supporting ISSI over the years in providing this global and neutral forum for scientists to discuss science is exemplary, especially these days, and may inspire others to consider joining them.

W Benz

Willy Benz
Chair of the ISSI Board of Trustees
University of Bern
March 2024

From the Directors

Traditionally, this Editorial has been a meaningful opportunity to connect with our stakeholders and our communities, to share the progress made during the previous year, to celebrate ISSI successes, and to thank our outstanding staff for their commitment and dedication.

Traditionally, this Editorial has been signed by the four Directors, as we all shared the pride of belonging to this unique institution.

Not this time.

On March 6 2025 we lost our friend and colleague Prof. Dr Maurizio Falanga, who passed away suddenly and unexpectedly. In addition to being a prominent scientist, Maurizio was the ISSI Administrative Director, the only Director to be employed full time and to be always available and present at ISSI. To the staff he was a constant and reassuring presence; to our visitors a perennial welcoming smile. His absence is deeply felt and the sense of loss is huge.

We had originally planned a suite of initiatives, to be sprinkled across the year, to celebrate the amazing 30-year anniversary of ISSI. This plan will now take a different flavour, and a more sombre approach. Especially sad, this loss comes at the time where ISSI had all the reasons to rejoice and a bright future ahead: 30 years of scientific successes, high interest from the communities we serve, a full portfolio of interesting scientific activities.

Here are some of the highlights from 2024:
• A new Strategic Plan: The Board of Trustees approved in November the five-year Strategic Plan for ISSI. Deeply rooted in the plan is the understanding that the ISSI recipe has worked very well for thirty years and should be continued. We saw this especially when the COVID pandemic was over, and scientists could not wait to meet again in person in such a welcoming environment. We also added a few new initiatives, such as the Breakthrough Workshops, with the first one in the series successfully executed in 2024. The Strategic Plan also included a modest increase in the ISSI physical footprint. With the return of in-person meetings and the enthusiasm of the science community to be physically present at ISSI, we felt that the organisation could do with a little more breathing space. ISSI had effectively lost a few offices with the renovation of the J. Geiss Auditorium, so when the opportunity was presented to rent a new, beautiful, wing on the fourth floor, we felt that this was an opportunity not to be missed. The Board of Trustees agreed with our proposal, and we rented the new space. Throughout 2024, the fourth floor has been fully operational. It now hosts two Directors, five Discipline Scientists, soon two ISSI Fellows, and offers new and augmented modern meeting space. We are delighted to report that at the end of 2024, the Board of Trustees decided to keep this space permanently.
• Science is the main pillar of the ISSI Strategic Plan. We always place emphasis on choosing and highlighting compelling and emerging science topics. In 2024 we hosted a wide variety of successful Workshops, Working Groups, Fora and 58 International Teams (61 Team meetings) in the four disciplines that ISSI covers. ISSI welcomed 976 international scientists in person in 2024, 612 of them from ESA Member States and ESA. 432 visited ISSI for the first time. Also in 2024, we held the first Breakthrough Workshop. This was a new format for ISSI. Each Breakthrough Workshops focus on a very specific question that is ripe for discussion, because of new observational data or theoretical or modelling developments. For this very first Breakthrough Workshop the chosen topic was "The chronology of the very early universe according to JWST: the first billion years". The Breakthrough Workshop was successful, and from 2024 our intention is to plan one Breakthrough Workshop every year. See here https://workshops.issibern.ch/first-billion-years/ for additional details on this Breakthrough Workshop.
• The Discipline Scientists: Also included in the ISSI Strategic Plan was the desire to provide additional ISSI support to some science areas where the scientific demand is growing. In 2024 we hired four Discipline Scientists, in exoplanet and planetary science, climate science and upper atmosphere.
• Enhanced science communications: With an eye to the evolving community needs, it was recognised that ISSI's overall scientific communication could do with a refresh, starting with the website. The new website was unveiled in May 2024, and has received wide praise from our customer base. This was a real team effort but two people must be recognised here: Andrea Fischer, who led the development and implementation phase, and

From the Directors

Willi Wäfler, who provided the IT and technical support, and now is responsible for the website maintenance and modifications. The new website is faster, easy to navigate and aesthetically attractive.
Finally, we also recognised that one of the services we offer to the ISSI community is to highlight the important science that is done at ISSI by the communities we serve. In January 2024 our team welcomed an expert Communication Specialist, Fabio Crameri, to help us with scientific communications, to the science community and to the public, in partnership with the association Pro ISSI. Fabio brought to ISSI communication expertise and a creative approach; for example, the series of ISSIcasts, short videos featuring scientists visiting ISSI, was started in 2024. A list of the 2024 ISSIcasts can be found here: https://www.issibern.ch/outreach/issicast/.

In all these activities, Maurizio Falanga was instrumental in both the ideation and implementation.

Also in 2024, we hosted the 2024 Johannes Geiss Fellow, Prof. Michael Meyer (Univ. Michigan). ISSI is very grateful for his visits and his presence. During 2024 ISSI also invited a large number of individual visitors, who greatly contributed to the lively scientific life of the organisation.

Finally, we want to take this opportunity to express our gratitude to the ISSI Science Committee, whose commitment and hard work allow ISSI to maintain the level of excellence in the science programme that our stakeholders have come to expect.

On the staff side, in 2024 we welcomed Planetary Discipline Scientist Rosita Kokotanekova, Earth Sciences Discipline Scientist Marta Marcos, and Senior Scientist Martin G. Mlynczak and we renewed our connection with Heliophysics Discipline Scientist Rumi Nakamura. The collaboration with Senior Scientist Alvaro Giménez and Planetary Discipline Scientist Geraint Jones came to an end in 2024, and ISSI is very grateful for their contributions. In 2024 we also bid farewell to Silvia Wenger and Jennifer Fankhauser, long time pillars of the institute, and to ISSI Fellow Christian Malacaria. We also recognised that, in order to serve the community at the level of professionality and responsiveness that is expected of ISSI, we needed to augment the secretarial staff, and we did that, recruiting two wonderful additions to the secretariat team: Cosima-Lea Baier and Xeila Monteagudo. Also in 2024, we were delighted to announce that Dominique Fuchs assumed the role of Executive Assistant to the Executive Director.

In conclusion, none of this could happen without the amazingly dedicated and welcoming ISSI staff, the strong support of our Board of Trustees, and the financial support of our funding agencies. None of this could have happened without the commitment and dedication of Maurizio Falanga, who we will miss dearly. As we together chart ISSI's bright future, the best tribute to his memory will be to continue carrying out his dream of an institution that is fulfilling a unique role in the world, enabling important science and uniting humanity under one, large sky.

Antonella Nota | Thierry Dudok de Wit | Michael Rast

In Memoriam Maurizio Falanga

Prof. Dr Maurizio Falanga (1969–2025)

"I gang emol ufe„ – Remembering Maurizio Falanga with a Smile

Some people leave a mark on an institution not just through their work but through their warmth, their presence, and the way they make everyone feel at home. Maurizio was one of those people. His passing leaves a space at ISSI that can never truly be filled, but rather than mourn, we celebrate the joy, humour, and humanity he brought into our lives.

The Morning Rounds

Every morning, like clockwork, Maurizio would make his rounds, stepping into each office, sharing a quick chat, a joke, or a simple "How are you today?". It was never just small talk—it was his way of staying connected, of making sure ISSI wasn't just a workplace but a little close family. Then, with his signature phrase, "I go up then"—or in German „I gang emol ufe"—he would head up to his office on the fourth floor, leaving behind a little warmth in every room he passed through.

Now, in a way that feels both poignant and fitting, he has taken his final trip up. And while he may no longer physically walk these halls, his presence lingers in the stories we share, the traditions he started, and the echoes of laughter that still seem to hum in the air.

The Heart of ISSI

If ISSI had a front door in the form of a person, it was Maurizio. Our scientific visitors, whether first-timers or regulars, were greeted with his signature smile, open arms, and the kind of warmth that made them feel instantly at ease. He was more than a host; he was the person who embodied the essence of our institute—welcoming and neutral—best, the friendly face most ISSI visitors knew, and the person who made sure everyone, regardless of their stature in the scientific world, felt valued.

A Scientist and a Builder

Maurizio joined ISSI in June 2009 as a full-time Science Program Manager, and quickly became a cornerstone of the scientific operations. He poured his energy into co-organising countless workshops and co-editing numerous volumes of the 'Space Science Series of ISSI', including the first books published by ISSI Beijing.

His leadership and dedication became even more visible in 2013, when he took on the role of founding Executive Director of ISSI-BJ, helping shape and expand ISSI's reach in Asia. In 2021 he took over the full-time position as ISSI Director in Bern, while also becoming a Professor at the University of Bern. Through all of this, he remained deeply involved in the scientific heartbeat of the institute—connecting scientists, building collaborations, and curating spaces where ideas could flourish.

In Memoriam Maurizio Falanga

A Leader Who Travelled and Listened

As Director, Maurizio had a leadership style that wasn't just about policies or big decisions—it was about people. He led by listening, by taking the time to check in, by valuing conversation as much as conclusions. His door (and his mind) was always open, and his ability to turn a casual chat into an impactful discussion was legendary. Having spent much of his research career traveling across institutions and collaborations around the world, Maurizio knew firsthand the challenges and joys of working far from home. These experiences broadened his mind and deepened his perspective—both scientifically and personally. He carried with him a global outlook, an openness to different ways of thinking, and an effortless ability to connect across cultures. This gave him a deep appreciation for the scientists who passed through ISSI's doors, and he made it his mission to ensure they felt not just welcomed, but understood.

A Life in High-Energy Astrophysics

Maurizio's scientific background was in high-energy astrophysics, and he was widely recognised as an expert in accreting systems—particularly black holes and X-ray pulsars. His contributions spanned the theory of accretion, growth, and merger of black holes across the mass spectrum, from stellar-mass to supermassive. His review volume "The Physics of Accretion onto Black Holes" remains a valuable contribution to the field, bringing together physical models and observations from galactic binaries to quasars. He also had a deep interest in exotic phenomena such as pulsars, especially millisecond X-ray pulsars in binary systems, and in recent years had turned his attention to the intriguing domain of exoplanets around pulsars.

As a dedicated researcher, he authored or co-authored over 300 scientific papers and worked with observers and theoreticians from around the world. He made key contributions to X-ray astronomy, particularly through his work with missions like BeppoSAX and INTEGRAL. But even in the midst of such a productive scientific career, Maurizio always found time to nurture community—whether through editing books, mentoring young scientists, or simply sharing a coffee between sessions.

Jazz, Conversations, and the Fourth Floor

Music and conversation were his rhythms, and just like a good jazz piece (he would, for example, recommend João Gilberto – https://www.youtube.com/watch?v=UJJK-DzqVpvE), his presence was smooth, lively, and impossible to ignore. Jazz was a passion of his, and much like the great improvisers he admired, he knew how to navigate any situation with charm, humour, and a natural ability to make people feel comfortable.
The halls of ISSI may be quieter without his footsteps and his morning check-ins, but the melody of his impact plays on.

A Legacy That Lives On

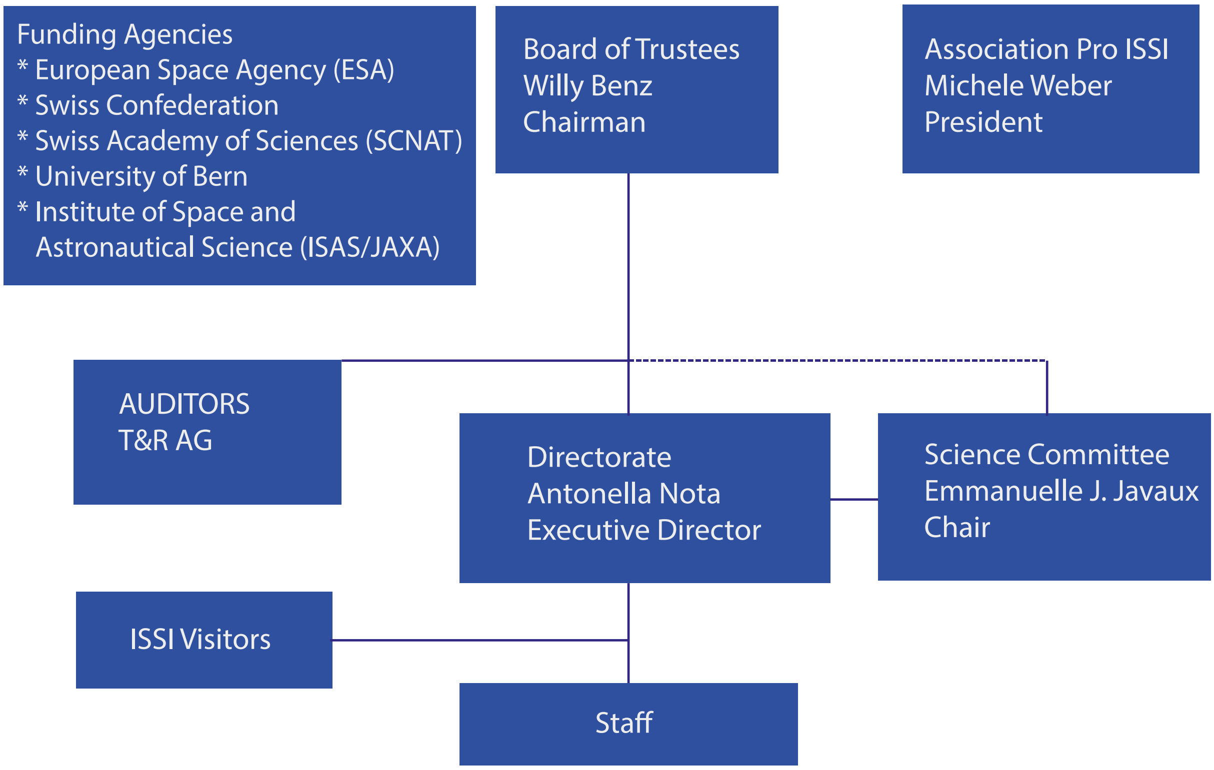
It's hard to sum up what Maurizio meant to ISSI in a single article, but fortunately, we don't have to. The space science community has come together to share their own stories, memories, and heartfelt messages about him. From touching anecdotes to humorous recollections, you can read these tributes here: https://www.issibern.ch/memorial-maurizio-falanga/.

Through these stories, through the people he touched, and through the laughter he left behind, Maurizio remains very much a part of ISSI. He may have gone up, but he will never be gone.

Grazie, Maurizio, for everything.

Obituary written by Fabio Crameri

About the International Space Science Institute



The International Space Science Institute (ISSI) is a nonprofit organisation set up in Bern in 1995 as a foundation under Swiss law with an endowment by Contraves Space AG, later renamed Oerlikon Space AG and now part of RUAG. Three statutory bodies govern ISSI: the Board of Trustees, the Directorate, and the Science Committee. A fourth important body, the Association Pro ISSI, promotes the idea of ISSI, especially within Switzerland.

The European Space Agency (ESA), the Swiss Confederation, and the Swiss Academy of Sciences (SCNAT) provide the financial resources for ISSI's operation. The University of Bern contributes through a grant to a Director and in-kind facilities. The Institute of Space and Astronautical Science (ISAS/JAXA) is supporting ISSI with an annual financial contribution. ISSI received tax-exempt status from the Canton of Bern in May 1995.

ISSI's **Board of Trustees** oversees the work accomplished at the Institute, exerts financial control, and appoints the Directors and members of the Science Committee. It consists of representatives of the Founder, and of the funding Institutions. In addition, the Board of Trustees may nominate up to five personalities representing the national and international scientific community, space industry and space politics for a term of three years. The Board of Trustees is presided over by Willy Benz.

The **Science Committee**, chaired by Emmanuelle J. Javaux, is made up of internationally renowned scientists active in the fields covered by ISSI. The Science Committee advises and supports the Directorate in the establishment of the scientific agenda, providing a proper equilibrium among the activities, and reviews and grades the Team proposals in response to the annual call. Science Committee members serve a three-year term (with a possible extension of one year).

The **Directorate** is in charge of the scientific, operational, and administrative management of the Institute. It interacts with the Funding Agencies, the Swiss authorities, the Board of Trustees, the Science Committee and the Association Pro ISSI. The Directorate consists of Antonella Nota (Executive Director), Maurizio Falanga (University of Bern), Thierry Dudok de Wit and Michael Rast.

The **Association Pro ISSI** promotes the idea of ISSI by organising public lectures, when internationally known scientists introduce their results. Summaries of these talks are published in the journal SPATIUM. The Board of the Association Pro ISSI is presided over by Michele Weber.

The overview shows the status at the end of the 29th business year on 31 December 2024.

Scientific Activities in 2024: The 29th Year

The Programme and its Elements

ISSI's mode of operation is generally fivefold: multi- and interdisciplinary Workshops, Working Groups, International Teams, Forums, and Visiting Scientists. 976 international scientists participated in ISSI's scientific activities in person in 2024, 612 of them from ESA Member States and ESA. 432 visited ISSI for the first time.

A **Forum** is an informal and free-ranging debate consisting of some 25 high-level participants who discuss open questions of a scientific nature or science policy matters. A Forum does not necessarily lead to formal recommendations or decisions. Five Forums were held during the reported period.

Breakthrough Workshops are designed to address key questions in science, bringing together the main experts in the field. They are invited to spend a week discussing the topic in question and to produce, within three months, a high-visibility, high-impact, open-access, peer-reviewed paper setting out the community consensus on the topic, and identifying areas of disagreement.

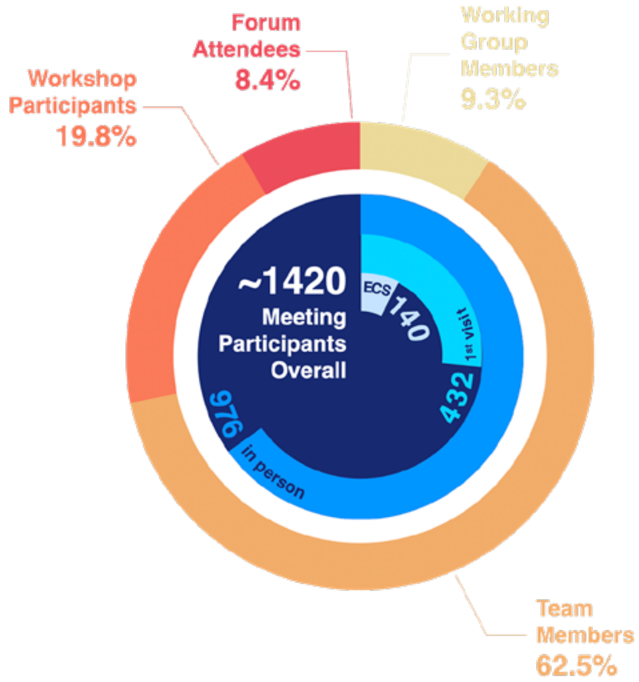
Workshops consist of up to 50 invited scientists exchanging their views on a scientific theme, typically over one week. Workshops always lead to a volume of the Space Science Series of ISSI and in parallel as issues of Space Science Reviews or Surveys in Geophysics. In 2024 five Workshops were organised, summaries of which can be found on the following pages.

International Teams consist of about 15 external scientists, addressing a specific scientific topic in a self-organised fashion. The results of these activities are customarily reported in scientific journals.

Working Groups have a smaller number of members and meet as often as necessary to achieve the assigned objective. Three new Working Groups started their projects in 2024. The results of the Working Groups are in general published as titles of ISSI Scientific Report Series or in the scientific literature.

Visiting Scientists spend between one week and two months at ISSI to work on a research project of their own, or to collaborate with ISSI's staff and/or with research institutes in Switzerland.

The **Johannes Geiss Fellowship (JGF)** is established to attract to ISSI – for limited duration visits – international scientists of stature, who can make demonstrable contributions to the ISSI mission and increase ISSI's stature by their presence and by doing so will honour Johannes



Geiss for his founding of ISSI and his contributions to ISSI, and for his many contributions to a broad range of space science disciplines.

The **Early Career Scientist (ECS)** Programme is designed to bring PhD students and postdocs into contact with their research community. These scientists are invited by the conveners of the different activities to complement the membership.

How to use ISSI Tools

As a general rule, any member of the community can submit a proposal for any of the ISSI tools. Once an activity is approved, the financial support for invited scientists covers the local accommodation expenses and a per diem while in Bern.

International Teams: A call for proposals is released every year in mid-January for a deadline in mid-March. These proposals are evaluated by the ISSI Science Committee and approved by the Directorate. Over the past years the number of accepted Teams is about 30 per year.

Workshops, Working Groups, and Forums: The scientific community may suggest at any time Workshops, Working Groups, and Forums. Proposal templates can be found at www.issibern.ch. Interested applicants should always liaise with an ISSI staff member when preparing a proposal. The ISSI Science Committee will evaluate these suggestions and the ISSI Directorate will make the final decision.

Forums are informal and free-ranging debates among some twenty-five high-level participants on open questions of a scientific nature or science policy matters.

Humanity's Cosmic Footprint and Large-Scale Space Ethics

8–10 January 2024

The primary objective of this Forum was to practically delve into the relationship that connects present-day decisions and actions with their impact at large scales – our cosmic footprint, and investigate practical conclusions towards a responsible and accountable handling of humanity's cosmic footprint.

To embrace this task, an international cohort of 21 academics was convened, including scientists, philosophers, and space law specialists. In addition, key stakeholders actively participated in the event, including the former Acting Director of the United Nations Office for Outer Space Affairs (UNOOSA), the Executive Director of the Committee on Space Research (COSPAR), the COSPAR Chair of the Planetary Protection Panel, METI.org Executive Director, the founder of the GENESIS project, the ethics officers from The Spring Institute for Forests on the Moon, and a member of the new CNES Ethics Panel. The pivotal roles of these individuals in the ecosystem facilitated a discussion that was both practically grounded and informed. The wide range of ages (24–84), cultural backgrounds, geographical origins, gender diversity, and ethical viewpoints amongst the participants provided a comprehensive array of insights and contrasting perspectives and opinions within the established framework, allowing a rich and dialectic conversation.

It is noteworthy that the conversation contributed to the formalisation by the organisers of an open letter project, to humankind, to the nations of Earth, and to the agents of the new space age. The structure of the group and its contrasting perspectives gave significant value to the letter. It should be noted that while attending the conference didn't necessarily mean an endorsement of the project outcome and letter itself, the invited participants were selected on the basis of their knowledge and expertise for an open dialogue on the topic.

The letter is advocates for the initiation of a global ethical conversation about humanity's acceptable cosmic footprint. A shared scientific representation being an absolute necessity for an informed conversation to happen, it first calls for the creation of a registry of humanity's cosmic footprint. It then acknowledges the ongoing efforts within the UN framework, proposes utilising existing platforms for these discussions, and highlights the necessity of establishing a new, dedicated body. This new entity will complement existing structures by providing the flexibility needed to navigate the rapid developments of the current space era. Additionally, the forum recognised the importance of periodically publishing a list of empirical questions, pivotal to the evaluation of critical ethical considerations regarding our impact on the large scale.

Agreeing upon the importance of timely action and acknowledging the pace of global governance processes, Forum participants who actively endorsed the project then delved into the drafting of the practical registry and entity projects. It was agreed in that group to proceed with their creation without delay.

Outcomes

• Open Letter: www.cosmicfootprint.org/openletter.html
The open letter is currently gaining momentum, with today a census of 66 co-endorsers, academics (80%) and significant stakeholders (20%). Amongst them are a number of professors and emeritus from the space ecosystem, Astronaut Claude Nicollier, central figures of the field of space ethics, such as Ian Crawford and Antonny Milligan, and key stakeholders regarding the effort towards understanding of our presence in space, such as Dr Jonathan McDowell. The presence of professors and doctors from a wide range of space-related disciplines, as well as the variety of geographical origins, outlines the significance of the work initiated at ISSI.

• Cosmic Footprint Foundation:
www.cosmicfootprint.org/
The Foundation seeks to engage with the global governance of space activities to ensure responsible actions in the cosmos. This will be achieved by maintaining a global conversation on the ethics of our cosmic footprint, particularly regarding today's decisions that may have significant cosmic consequences. The Foundation aims to complement existing global governance mechanisms for space activities by providing additional agility and a scientifically established perspective on the cosmic footprint issue.

Adrien Normier

Coastal Blue Carbon from Space

14–17 May 2024

Coastal Blue Carbon describes the carbon stored in vegetated coastal and marine ecosystems, mostly by seagrass, mangroves, and salt marshes. When protected or restored, these ecosystems sequester and store large quantities of carbon in both their living biomass (leaves, roots, etc.) and the underlying soil, where it can be stored for centuries to millennia. They are hence an essential piece of the solution to global climate change. On the other hand, when degraded or destroyed, these ecosystems emit the carbon they have stored into the atmosphere, leading oceans to become sources of greenhouse gases.
Space data has the potential to provide key information for a global and sustained monitoring of Coastal Blue Carbon ecosystems. The objective of the Forum was to bring together Coastal Blue Carbon experts from different fields (remote sensing, in-situ, modelling), relevant stakeholders (e.g. governments, investors, NGOs, communities,…) and international initiatives (e.g., the Blue Carbon Initiative, the Global Carbon Projects, the IPCC,..) to discuss the state of the art, challenges and opportunities regarding the use of satellite observation to advance key Blue Carbon priority topics including:

• Coastal Blue Carbon Observing System: status, gaps, opportunities
• Impact of external drivers (climate change, aquaculture, pollution, coastal development) on Coastal Blue Carbon Coastal Blue Carbon ecosystem preservation and restauration as a nature-based solution for climate change mitigation
• The economic value of Coastal Blue Carbon tools/products/indicators to support policy needs related to Coastal Blue Carbon

Coastal Blue Carbon ecosystems provide highly valuable services to humankind, including outstanding carbon sequestration and storage, which leads them to play a key role in global climate change mitigation. However, their health is under enormous threat as a result of human activities and climate change impacts.

The Coastal Blue Carbon from Space Forum successfully took place from May 14th to May 17th, 2024, at the ISSI premises in Bern, Switzerland. Organised jointly by ESA and NASA with the support of ISSI, it gathered 24 participants from 14 different countries across six continents (North America, Central America, Africa, Australia, Europe, Asia), with diverse and complementary expertise in the realm of blue carbon, including remote sensing and in-situ observations experts, blue carbon ecosystems and climate change ecologists, marine biologists, and representatives of international organisations and NGOs (IPCC, UNESCO, Wetland Internationals, Conservation International, the Nature Conservancy, GRID-ARENDAL).

Participants were asked to brainstorm on how Earth Observation (EO) data can best be used to support policy and user needs, in particular the ambition cycle of the Global Stocktake of the Paris Climate Agreement, and contribute to carbon credits and voluntary carbon markets, and the role of Monitoring, Reporting and Verification (MRV) strategies. The use of EO data to enhance the monitoring and prediction of external driver effects on ecosystem health and their carbon stocks/sequestration potentials was also discussed, together with EO capability to quantify the impact of blue carbon ecosystem conservation and restoration on their climate change mitigation capabilities. Moreover, the status of EO capabilities to map blue carbon ecosystem extent, carbon stock and change was discussed together with the main gaps and upcoming opportunities for improvement.

The Forum, organised around plenary and breakout sessions, triggered three days of engaging, insightful, and thought-provoking discussions. A Forum summary is in preparation together with a perspective paper on the role for improved Earth Observations to boost blue carbon ambition. This paper will identify the main gaps and opportunities related to the use of space-borne data to support Coastal Blue Carbon science and policy needs. This will include a roadmap towards filling the identified research gaps, benefiting the international carbon scientific community at large.

Michael Rast

Forums

International Cooperation in Space to Advance Science

4–6 June 2024

The second and final session of this Forum was held on 4–6 June 2024. A group of active scientists with diverse backgrounds and with extensive experience in space science gathered at ISSI to discuss international cooperation in space science. The goal of this Forum was to help scientists interested in establishing space missions in cooperation among different agencies and funding bodies, and to better inform them of some of the challenges related to international cooperation. Ultimately, the goal was to develop a common understanding that could lead to broader, more effective cooperation. The second part of the Forum took place June 2024 and the goal was to complete the discussion and finalise the publication.

Elements of a successful international cooperation were discussed: ownership and governance of missions, possible approaches to cooperation, and costs and benefits of cooperation. Participants described the approach to space science missions in different institutional contexts, which highlighted some interesting differences: top-down vs bottom-up approach to decision making, how a mission comes to be proposed and then accepted, who owns the mission vs. who manages it, funding allocations, or collaboration with PIs. Common elements were identified, like external and internal reviews, that cooperation should not just be out of necessity, but also as an opportunity for 'bigger and better science', and that trust is fundamental, together with clear communication and clear interfaces. Among the topics discussed, the importance of starting cooperation as early as possible, and carefully evaluating partnership.

The publication describes the key elements of any cooperation: trust (at all levels, not just at the top), respect, clear interfaces, shared science goals, diversity, advantages for all partners, transparency, communication, and persistence. It was felt that cooperation plays a role not just during the mission implementation but afterwards as well, in sharing and even jointly analysing the data to maximise the scientific return for all partners involved.

Cooperation adds to the mission cost and usually entails an increased overhead for the bigger partners but one of the conclusions of the meeting, and therefore of the publication, is that International cooperation is fundamental to advancing space science and humanity as a whole, and the intention of this publication is to make it easier for the scientists involved to make cooperation most effective. The publication is in its final form and will be submitted to the professional refereed literature in 2025.

Alvaro Giménez, Fabio Favata, and Antonella Nota

Measurement disparities in the Scientific Parameter Space of Earth Observation Sensors at the Example of Imaging Spectrometers

11–13 June 2024

With growing interest in ready-to-use hyperspectral imaging Earth Observation (EO) data at the global scale, an intensified global cooperation in the field of EO is needed. With numerous VSWIR imaging spectroscopy missions launched to orbit (e.g. PRISMA, DESIS, EnMap and EMIT) and CHIME (ESA), and SBG (NASA) due to be launched in the late 2020s/early 2030s, space-based imaging spectroscopy data will be available at unprecedented spatial and temporal scales. This data availability will be beneficial to a wide range of applications (e.g. agriculture and soil, biodiversity, food security, raw materials, water quality and environmental degradation). However, the use of multiple spectroscopy satellites is prone to disparities in the way geobiophysical measurements are derived from the recorded data, hampering their uptake by users.

Disparities as defined here in the context of EO describe spectro-radiometric differences between a variety of sensors measuring the same target on Earth's surface. These disparities describe the differences which arise from the different ways that imaging spectroscopy satellite operators are handling the spectro-radiometric information from the sensors in the processing chain between at-sensor radiance down to bottom-of-atmosphere (BOA) reflectance. They are not necessarily standardised between different spacecraft operators, space agencies and communities of practice and arise from two main sources: 1) the hardware used to measure incoming solar radiance reflected from Earth's surface and 2) from processing the measured data to get from Top Of Atmosphere (TOA) radiance to Bottom Of Atmosphere (BOA) reflectance. Different types of hardware are used to convert the photons to digital numbers (Level 0 (L0)) and the pre-launch laboratory and/or in-flight calibration to get calibrated radiances ($Wm^{-2}nm^{-1}sr^{-1}$) (Level 1 (L1)). Also, different data processing algorithms applied to transform the TOA radiances to BOA reflectances (e.g. ATCOR, PACO and ISOFIT) cause disparities between the different sensor measurements of the same target.

To tackle these disparities and unlock the potential of unprecedented spatio-temporal space-based imaging spectroscopy observation densities, ISSI organised a Forum on understanding disparities between space-based VNIR/SWIR imaging spectroscopy sensors in mid-June 2024.

The main objective of this Forum was to establish a common strategy for handling scientific space-based sensor artefacts and understand the reasons for disparity between sensors as a source of further impacts on the scientific data products. Considering the current 'zero-term' policy, the Forum sought to outline the key requirements, concept and recommendations for a reference to which operators of scientific space-based imaging spectroscopy missions can adhere.

While some space agencies have started to initiate a quantitative analysis of these uncertainty terms, this is still often outside the scope of satellite mission projects. Therefore, an assessment driven by reasonable assumptions on which of these terms contribute more to the uncertainty budget will be relevant to drive further investigations with a view to gaining confidence in error assumptions of higher-level scientific data products.

The key outcome, to get a better understanding and a better handle on measurement disparities, is in a commonly accepted and metrologically sound methodology of uncertainty estimation. It is accompanied by a rigorous propagation to compute a traceable uncertainty budget associated to the BOA reflectance (L2) and a thorough sensitivity analysis of the different parameters contributing to the different processing algorithms along the processing chain (L1 – L2). The recommendations resulting from this Forum are building on work done in the CEOS, and QA4EO projects.

Michael Rast

Using Earth Observation Systems to Improve Climate Adaptation Policy and Action

25–28 June 2024

The Intergovernmental Panel on Climate Change (IPCC) defines adaptation as *the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities*. With global warming surpassing 1 degree Celsius, adapting to current and future climate changes has become a primary concern for policymakers at all levels. Despite notable progress, the IPCC highlights gaps in adaptation efforts, which are projected to grow at current rates of implementation.

At the Conference of the Parties (COP28), a framework for a Global Goal on Adaptation (GGA) was endorsed, with monitoring, evaluation and learning forming one of four core targets. The text states that *by 2030 all Parties have designed, established and operationalised a system for monitoring, evaluation and learning for their national adaptation efforts and have built the required institutional capacity to fully implement the system. The GGA also decided to launch a two-year work programme on indicators for measuring progress achieved towards the targets.*

Satellite Earth Observations revolutionised systemic observations and have played a pivotal role in understanding climate changes to date, yet their potential to support adaptation monitoring and development is only beginning to be explored.

The main objective of this Forum was to discuss current methods and capabilities of Earth Observations to support adaptation planning and monitoring. Specifically, the Forum aimed to collect in a peer-reviewed article the status of research and development (R&D) for using EO to support climate change adaptation and to develop a list of Earth Observation metrics of Essential Climate Variables (ECVs) that can help to support the ongoing discussions around the Global Goal on Adaptation.

Therefore the participants were selected to represent a collection of research communities, focusing on climate change and adaptation for health, extremes, and agriculture in the international policy context.
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In this Forum, international organisations such as the United Nations' World Adaptation Science Programme hosted by UNEP, Nairobi (WASP, www.wasp-adaptation.org), NASA and ESA joined and representatives of other organisations joined efforts to meet the following objectives:

• Discuss current methods and capabilities of EO to support adaptation planning, implementation and monitoring.
• Explore knowledge gaps that require filling to further enhance EO adaptation research and development necessary to inform adaptation policy and practice.
• Agree on a list of EO metrics of essential climate variables that can support the GGA's workplan.

The ongoing work below by other stakeholders was considered and to a large degree incorporated into the Forum's programme to maximise the science-to-policy relevance of the resulting forum outputs.

• The EU's adaptation mission projects Climate-Adapt, which covers EU-funded projects past and present, focusing on research and developing innovative approaches and options for climate adaptation and associated guidance, tools, data, and case studies to help regional and local authorities deliver the EU Mission on Adaption to Climate Change.

• The newly established Copernicus Health Hub, which brings together all the Copernicus environmental data and products pertinent to health, partly based on space data, including that related to physical health, mental health and well-being,

• The GCOS adaptation task team (GCOS_GATT), which addresses the call for collective actions focusing on different aspects of adaptation, as formulated in the 2022 GCOS Implementation Plan.

• The European Climate Change Adaptation, ECCA2023, led by the Joint Programme Initiative, which provides further insights into the uptake of EO for climate adaptation.

The Forum also focussed on adaptation aspects related to Health and Extreme Events and knowledge gaps that require filling to further enhance Earth Observation adaptation R&D.

Michael Rast

Breakthrough Workshops are designed to address key questions in science, gathering the main experts on the topic. They are invited them to discuss, deliberate and produce one high-visibility, high-impact, open-access peer-reviewed paper providing the community consensus on the topic in question, to be submitted within three months from the completion of the Workshop. Breakthrough Workshops have a format that includes an abundance of moderated discussions and collaborative paper writing.

The Chronology of the Very Early Universe According to JWST: The First Billion Years

11–15 March 2024

The James Webb Space Telescope (JWST) is one of the most ambitious scientific experiments of the 21st century. By far the largest and most sophisticated observatory ever sent into space and over 100 times more powerful in terms of sensitivity and resolution than its predecessors, JWST is poised to revolutionise our understanding of galaxies in the Universe, both near and far.

For the first Breakthrough Workskop, we brought together researchers with highly specific expertise from different subdisciplines related to cosmology. At the time, the first year of JWST data had been digested by the astronomical community and the second year of data had just started to arrive, notably spectroscopy.

Our goal was to answer some specific questions:

• How extreme were the stars in the first generation of galaxies and where did they form?

Early spectra of very high-redshift galaxies with JWST have indicated highly ionised low-metallicity gas – conditions at least as extreme as can be found as in the most extreme galaxies today, that require extreme ionising sources (stars). At yet still higher redshift, the first stars should have been zero-metallicity “Population III”. These stars may be findable by JWST if gravitationally lensed, or caught in their supernova deaths.

• When did the first proto-globular clusters form?

• In what ways are the first galaxies unique?

Since the first generations of stars and galaxies form out of primordial gas, their metallicities are expected to be significantly lower than at later cosmic times. Indeed, the first spectroscopic observations of z>6 galaxies confirm metallicities that are subsolar, but perhaps not as low as expected. Additionally, the excitation and ionisation properties of galaxies at z~6-9 appear to be consistent with galaxies at z~2. The question is: how different are galaxies during the reionisation epoch from their descendants at the peak of cosmic star formation, ~2 billion years later? How does star formation proceed in rapidly assembling galaxies? At what redshift are the scaling relationships for galaxies in place?

At lower redshift, star-forming galaxies show tight correlations between the mass in stars and these quantities: oxygen abundance, the star formation rate, and the mass of the supermassive central black hole — which suggests that star formation may be a tightly regulated process. Similarly, at lower redshifts, galaxies dominated by old stars show tight relationships among size, luminosity, and mass. How quickly do galaxies become orderly? How quickly are regulatory processes established, to bring order to the chaos? And what does this tell us about feedback processes?

• Are AGN important in the first billion years?

Most models find that the ionisation budget of the early universe was dominated by galaxies, with black hole accretion a distant second place. It may therefore be safe to assume that black hole accretion is not important in the first billion years. On the other hand, the discovery of billion solar mass black holes powering z=7 quasars indicates that black holes can accrete extremely rapidly and efficiently. How important is black hole accretion to the story of the first billion years?

• Are JWST discoveries challenging the current cosmological framework?

Perhaps the most surprising early discovery of JWST was a large number of luminous, and apparently very massive, galaxies in the first few JWST datasets. The implied number and mass density of some of these galaxies are so high that they cannot be explained by our standard galaxy formation models, that is galaxies forming inside dark matter halos with a relatively low star formation efficiency. In fact, some galaxies appear to be so massive so early on that they cannot be explained even if all the baryons in dark matter halos were turned into stars. One extreme possibility would be that our cosmology would need to be changed. Alternatively, other possible astrophysical explanations for these galaxies need to be examined and tested.

We invited PIs of large and medium cosmology JWST Cycle 1 programs and a few other experts, including theorists. We encouraged in-person participation. The format included ample discussion time, and time to draft the final product. We achieved close to 50% representation by women and non-binary scientists. We included a large number of Early Career Scientists. Our goal was to provide an environment fostering free and respectful exchange of ideas, to collectively advance the scientific knowledge on this topic and reach, if possible, a community consensus opinion on the topic. The product was one high-visibility refereed paper, co-authored by all participants, which was submitted to Nature Astronomy within three months after completion of the Workshop and posted on arXiv: The First Billion Years, According to JWST: https://arxiv.org/pdf/2405.21054

Antonella Nota

Physical Links Between Weather and Climate in Space and the Lower Atmosphere

22–26 January 2024

Workshops are selected by the Directorate in consultation with the Science Committee. Proposals or suggestions for Workshops may originate from the external community. The programme and speakers are defined by a group of experts serving as conveners. The Workshops can be attended by up to 50 invited scientists. Workshops always lead to a volume of the Space Sciences Series of ISSI (SSSI) published by Springer and in parallel as a Topical Collection in Space Science Reviews or an issue of Surveys in Geophysics.

Building on the successful Forum "Physical Links Between Weather in Space and Weather in the Lower Atmosphere" in November 2022, a workshop on "Physical Links Between Weather and Climate in Space and the Lower Atmosphere" was held on January 22–26 2024, at ISSI in Bern. This Workshop involved space, Earth observation and meteorology experts in discussion of the links between weather and climate in space and in the lower atmosphere.

Earth's predominantly neutral atmosphere interfaces with the "sea of plasmas" surrounding it via its ionosphere and the upper and middle atmosphere, providing an interface layer through which a broad diversity of energy transfer processes takes place in this comingled plasma-neutral domain. Developing an integrative understanding of global geospace energy and momentum transfer processes acting within and across this layer is a major scientific challenge with important societal implications.

This workshop targeted a deeper understanding of the solar and terrestrial interactions through energy and momentum transfer processes between the ionosphere and the upper and middle atmosphere, thus possibly enabling the detection of signatures by natural and anthropogenic hazards. The results of this analysis should be based on the existing worldwide capability in the related fields and should support the conceptual design of a future space-borne and ground based observing capability.

A previous ISSI Forum addressing this subject had noted good progress in the scientific field and showed results demonstrating the value of studying space weather forcing from above and atmospheric weather forcing from below. The Forum's recommendation to continue and extend the scientific framework by addressing a wider range of scientific sub-disciplines and involving a larger number of scientists, thus attaining a broader perspective was implemented through this Workshop.

Central to the Workshop was the establishment of a framework within which all related observations can be combined for assimilation and visualisation (including data from ground-and space based systems). This would necessitate an interoperable 'working' environment with homogeneity in data formats etc. and the improvement of the discoverability and interoperability of ground- and space-based data. As a result the concept development of an Ionosphere-Thermosphere-Mesosphere Observatory could be enabled, using existing and planned missions as focal points, towards an "International Solar-Terrestrial Physics Programme-Next".

The Workshop's main aims were to:
• Provide a scientifically unified view in the area of space and atmospheric weather and climate, in light of the plans of the involved disciplines
• Act as focus for discussion of the scientific interests of these communities, including the European ground-based community and data archiving activities
• Assess potential synergies and provide inputs and recommendations as relevant
• Receive inputs from the scientific community that cutting across Space and other Agency Programmes encourage inter-agency activities to improve communication

The outcome of the Workshop is being summarised in peer-reviewed papers to be published as individual papers in Surveys in Geophysics and subsequently as a volume in the Space Sciences Series of ISSI. This book will describe the state of the art of our current understanding of the physical processes within and across this area, identify the main observational gaps both in space and on the ground, and the gaps in scientific understanding and modelling capabilities in this still underexplored region. Further, the book will address observational infrastructure and ground segment topics, enabling data sharing and combination. All papers are intended to have open access status.

The original peer-reviewed paper summarising the findings of the Forum preceding this Workshop is planned to become the introductory overview to set the scene for the different peer-reviewed contributions to this Workshop in the planned Special Issue.

Michael Rast

The Geoscience of Exoplanets: Going Beyond Habitability

8–12 April 2024

"Where is everybody?" Enrico Fermi is said to have asked Emil Konopinski, Edward Teller, and Herbert York on their way to lunch at the Los Alamos National Laboratory sometime in the summer of 1950. The question expressed what became known as Fermi's Paradox: in a universe of trillions of planets, where are the life-bearing, inhabited planets? Nearly 75 years later, the question still puzzles scientists and the interested public, although it has recently been argued, based on Bayesian statistics and observational data, that our planet may instead be rare and that the vast majority of formally habitable planets in the galaxy may lack important elements to make them truly habitable and inhabited.

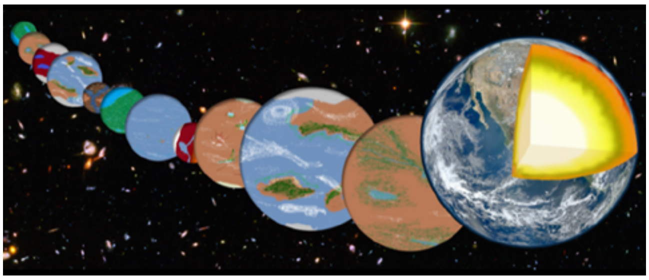


Illustration of exoplanets (Image Credit: Foreground: Courtesy of Lena Noack, FU Berlin. Background: Except from the Hubble Ultra Deep Field view (NASA, ESA, S. Beckwith (STScI), the HUDF Team))

Nearly 6000 exoplanets have been detected, with another nearly 6000 candidates awaiting confirmation. Among these are a growing number of planets of approximately Earth size and mass. A significant number of these orbit their host stars in the habitable zone and may support extraterrestrial life. Although the concept of the habitable zone is useful for an initial assessment of the likelihood of finding extraterrestrial life, it is probably too general for sophisticated and costly follow-up observations. Considerations of more specific planetary physical properties include the balance between land and (deep) ocean surfaces, the availability of water versus nutrients from riverine sources such as phosphorus and nitrogen, and the potential for the accumulation of free oxygen in the atmosphere to support more advanced life forms.
About fifty scientists from around the world gathered at ISSI to discuss the requirements for life to emerge and evolve beyond the basic requirement of water availability. Instead, the participants asked what can be learned from Earth (and other terrestrial planets and moons) about the requirements for the growth of a substantial biosphere that can be detected by modern remote sensing instruments. Having identified these requirements, participants asked what it would take to remotely detect these planets and conclude that life is likely to exist. To this end, the participants discussed how "truly habitable" might be defined.

It was agreed that the discussion of how exoplanets "work" should go far beyond simple models of their interior and environment based on their radius, mass, and orbital distance from the host star. Rather, the discussion should include many more aspects of the geosciences such as the tectonic modes (viz. plate vs single plate tectonics), interior, atmosphere and magnetic field evolution, as well as star-planet interactions, from the formation process to the later evolution of the planet. Since many host stars are low-mass stars, tidal interactions were found to be worth considering.

For the geosciences, rocky exoplanets were recognised as important objects of comparison, if only to assess how unusual or common Earth is and to motivate considerations of Earth's properties in ways that would probably never have been raised without the comparison.

The Workshop covered a wide range of topics, bringing together exoplanet observers and modellers, astrophysicists, planetary scientists, astrobiologists and Earth scientists to learn about Earth-sized rocky planets in general and discuss the chances of finding extraterrestrial life and strategies for how best to detect it. This was the first Workshop of its kind for ISSI. It was particularly timely given the wealth of data already available and to be expected from JWST and upcoming missions such as PLATO, ARIEL, ROMAN and eventually, HWO and LIFE.

The Workshop was convened by Tilman Spohn (DLR Berlin, Germany), Brice-Olivier Demory (University of Bern, Switzerland), Joao Duarte (University of Lisbon, Portugal), Alvaro Giménez (CAB Madrid, Spain and ISSI), Rumi Nakamura (Space Research Institute, Graz, Austria and ISSI), and Lena Noack (Freie Universität Berlin, Germany).

Tilman Spohn

Electron Kinetic Physics: The Next Frontier in Space and Astrophysical Plasmas

22–26 April 2024

Workshop Participants

Electron astrophysics has become a very active field of research, focusing on electron kinetic scales, i.e. characteristic plasma scales that are typically much smaller than the global scales of space and astrophysical plasmas. Physical processes in this regime play a key role in mediating energy transport, conducting heat, and dissipating turbulence. Typical phenomena that are governed by such processes are collisionless shocks, magnetic reconnection events and the dissipative range of turbulence. Several space missions in the inner heliosphere, such as MMS and Solar Orbiter, nowadays allow these processes to be studied in much greater detail thanks to their in-situ observing capabilities. Outside the heliosphere, the same processes are important but unfortunately can only be studied indirectly by remote sensing. This difference and the great variety of manifestations of kinetic processes have so far been major obstacles to their better understanding.

This Workshop provided a unique opportunity for plasma physicists from different communities (astrophysical plasmas, heliospheric plasmas, laser plasmas) to discuss and compare the similarities and differences in the properties of these processes. The meeting was structured around three transdisciplinary themes (including an excursion to the Swiss Plasma Centre at the EPFL):

1) What is the nature of waves and fluctuations at electron-scales in astrophysical plasmas? This includes electron-scale plasma waves and instabilities in astrophysical systems, and the nature and properties of electron-scale plasma turbulence.

2) How are electrons heated and accelerated in astrophysical plasmas? This includes electron-scale dissipation processes, electron-scale physics of collisionless shock waves, and electron physics of magnetic reconnection.

3) What processes govern the heat conduction of electrons in astrophysical plasmas? This includes electron heat conduction of collisionless plasmas, and effective heating models/functions and large-scale implications of electron heat conduction.

While the Workshop revealed a striking similarity in the processes over a wide range of spatial scales, it also highlighted the strong need for a common framework for inferring kinetic plasma properties from remote sensing observations as a key to their understanding. First, we noted the diversity of regions in which these processes operate, from planetary atmospheres and magnetospheres, through the solar wind, the solar corona, the local interstellar medium, compact objects, supernova remnants, active galactic nuclei and gamma-ray bursts, to galaxy clusters. Several open questions were raised, such as the impact of electron-scale processes on large-scale structures, and the partitioning and transport of energy, with the subtle distinction between heating and acceleration. We also considered aspects such as electron transport in highly entangled fields, with particle trapping and cross-field diffusion.

These different questions will be addressed in a series of eight papers, all of which are being co-authored by members of the different communities.

The Workshop was attended by 43 scientists, including 11 early career scientists. Its conveners are: D. Verscharen (UCL, UK), A. Simionescu (SRON, NL), O. Pezzi (Institute for Plasma Science and Technology, National Research Council, IT), J. Stawarz (Imperial College / Northumbria University, UK), K. Klein (University of Arizona, USA), Denise Perrone (I. Space Agency, IT), R. Nakamura (IWF/OEAW, Graz & ISSI, CH), and T. Dudok de Wit (ISSI, CH & University of Orléans, F).

Thierry Dudok de Wit

Accretion Disks: The First 50 Years

17–21 June 2024

The Workshop focused on reviewing the remarkable progress in our understanding of accretion process – the fundamental mechanism powering the brightest X-ray sources in the Universe – since the seminal work of Shakura & Sunyaev (1973). Over the past five decades, an entire scientific community has emerged around the studies of the accretion physics in white dwarfs, neutron stars, stellar-mass and supermassive black holes. Yet, nowadays research continues to reference and compare new findings to this foundational paper.

The meeting was characterised by a strong sense of shared purpose among participants, many of whom expressed how their entire careers have been profoundly shaped by efforts to unravel the complexities of accretion first outlined in the Shakura & Sunyaev model. Throughout the Workshop, various research groups presented a comprehensive overview of the current state of knowledge, including observational data, theoretical advances, and numerical simulations.

Discussions covered different types of compact objects, aiming to highlight both common characteristics and distinct features of accretion across these systems. Novel approaches and breakthroughs in theoretical and simulation frontiers were integrated with the latest observational discoveries.

One of the key aspects of the Workshop was exploring the links between different accreting sources. These discussions provided valuable insights into underlying mechanisms and potential unifying principles governing accretion processes, helping bridge the gap between observations and simulations.

The conference was split into larger blocks, each lasting approximately half a day. These included observational signatures of white dwarfs, neutron stars, stellar-mass black holes and active galactic nuclei, followed by sub-Eddington and super-Eddington accretion and disk outflows.

These topics reflect the primary directions of recent scientific advances in accretion disk research. Each block concluded with a 30-minute discussion session, examining the applicability of the basic models in light of new data obtained through cutting-edge technologies.

These included high-angular-resolution radio and infrared polarimetry and imaging (Event Horizon Telescope and GRAVITY results), X-ray polarimetry (IXPE results), advanced technologies for fast multiwavelength timing (ULTRACAM, HIPERCAM, SIRAF), spectroscopy (ALMA, HST/STIS, VLT/X-shooter, GTC/OSIRIS) and polarimetry (VLT/FORS2, DIPol) instruments, as well as the new discoveries made using high-sensitivity, large effective area space X-ray spectrometers (NICER, XMM-Newton, Chandra, INTERGRAL).

On the simulations side, significant advances were highlighted, particularly in models that successfully reproduce some of the global behaviours observed in accretion systems.

Key questions centred on the essential ingredients required to put the simulations into realistic environment (such as particle content, general relativity effects).
The presence of both observers and theoreticians in the room enabled extended dialogues, often continuing informally after the scheduled sessions.

The Workshop brought together senior scientists (both in-person and online), including the authors of the original 1973 paper and a number of other researchers from that pioneering era, alongside with the present-day leading scientists (such as PIs of proposed space missions and group leaders) and the younger generation of researchers, including students and postdocs.

This diverse mixture of participants created a unique atmosphere in which past understanding and ideas were linked to the modern data and simulations. This environment fostered a deeper understanding of the topic and facilitated knowledge transfer.

As an outcome of these discussions, the Workshop participants will produce a volume in the Space Science Series of ISSI comprising ten in-depth chapters, each providing a detailed description on a specific aspect of accretion disks. This publication is intended to serve as a fundamental reference for future research(ers), capturing both the progress made over the past five decades and the challenges that remain in this field.

Alexandra Veledina

Exocomets: Bridging our Understanding of Minor Bodies in Solar and Exoplanetary Systems

22–26 July 2024

Exocomets are defined as evaporating small bodies in orbit around other stars. Like Solar System comets, they provide information on the material which went on to form planets, or, in the case of young star systems, will become planets in the future.

One Workshop had previously been dedicated to the study of these bodies, at the Lorentz Centre, Leiden, in 2019. That highly successful meeting brought together experts from both the Solar System and exoplanet and debris disc communities to share ideas and exchange knowledge (Strøm+ 2020). The case was made that there was a strong impetus for a second Workshop to further encourage collaborations among those working in fields relevant to exocomets, and to author a book to summarise the current state of this relatively young research area.

The attendees at the Workshop were researchers from both the above communities, representing a wide range of career stages, nationalities, and scientific backgrounds. Eleven invited plenary talks were given on fundamental topics, including: Detection techniques, Solar System Comets, Diversity of Small Bodies, Comet-Stellar Wind Interactions, Planetary Debris Disks, and the Beta Pictoris system. These talks allowed those working in complementary research areas to learn what is known about small bodies in other contexts. A fundamental difference between the study of Solar System comets and minor bodies in exoplanetary systems is the great wealth of information we have on many Solar System objects, down to microscopic scales, compared to the very limited information that is available on exocomets.

The meeting activities including a considerable degree of discussion, including numerous walk-on talks. There was much discussion of the Beta Pictoris system, as it is the best-studied of the stars believed to host exocomets; the understanding of the various detections of evaporating bodies in that system was discussed extensively. Also debated were topics such as what techniques are the most expedient at determining exocomet composition given what is known about Solar System comets. An assessment of how the physical processes affecting gas and dust vary in other stellar systems was also the subject of debate, including the combinations of various parameters including stellar wind contexts, stellar luminosity, spectral type, and gravitational conditions. These and other discussions were inputs into the sessions held during the week to put together draft book chapters.

The Workshop had 43 participants, 40% being female and 60% male. Participants were mostly professional scientists, but eight students also attended the meeting. The participants were based in 14 countries: United Kingdom (14), USA (6), France (4), Sweden (4), Netherlands (3), Spain (2), New Zealand (2), Germany (2), Switzerland (1), Bulgaria (1), Japan (1), Taiwan (1), Slovakia (1), and Chile (1).

There was active participation by early- to mid-career researchers, which was strongly encouraged by the conveners. Several of the proceedings' chapters are led by those early-/mid-career scientists.

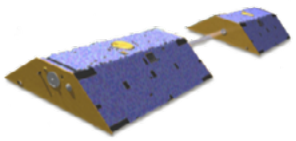
The results of the Workshop will be published as open access peer-reviewed papers in Space Science Reviews, and also published by Springer as a book in the Space Science Series of ISSI. It is hoped that this second exocomet Workshop will spur the organisation of future meetings on this growing research field.

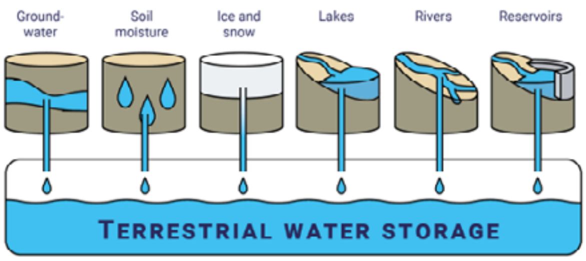
The Workshop was organised by Maria Drozdovskaya (PMOD/WRC, CH), Geraint Jones (ISSI & UCL Mullard Space Science Laboratory, UK, now at the European Space Agency), Matthew Knight (U.S. Naval Academy, USA), Rosita Kokotanekova (Bulgarian Academy of Sciences, BG, now also at ISSI), Isabel Rebollido (Centro de Astrobiología INTA-CSIC, ES, now at the European Space Agency), and Paul Strøm (University of Warwick, UK).

Geraint Jones

Working Groups

Global Terrestrial Water Storage Product: Error Assessment and Improvements





Terrestrial water storage is observed by GRACE and GRACE-FO and comprise the water storage in the groundwater, soil moisture, surface water bodies, and snow and ice. (Image Credit: Künsting/GFZ)

The GRACE (2002–2017) and GRACE-FO (since 2018) satellite missions measure spatial and temporal variations in the Earth's gravity field. Over the continents, water mass redistributions are the dominant source of these gravity variations. Unlike all other remote sensing techniques, GRACE/GRACE-FO can observe the whole water column, called terrestrial water storage (TWS), including groundwater. Thus, with its global coverage and over 20 years of monthly data, the TWS data set is invaluable for geosciences, particularly hydrology.

The last years have brought considerable improvements in the GRACE/GRACE-FO gravity field processing that lead to Level-2 gravity field products and their so-called formal error characterisation (Jäggi et al., 2020 and ISSI International Team COST-G). Meanwhile, the subsequent derivation of unconstrained and filtered TWS global grids (Level-3 products) as provided via the GravIS portal (Gravity Information Service, gravis.gfz-potsdam.de) has undergone only minor updates. Parallel to these unconstrained and filtered TWS grids, JPL (Jet Propulsion Laboratory) provide a constrained TWS product known as Mascons (Wiese et al., 2016). At the same time, many applications in the geosciences and climate sciences need uncertainty estimations for drawing reliable conclusions from the TWS data set.

This Working Group aims at improving of the TWS processing by bringing together scientists working with different Level-3 processing strategies. Its uncertainty estimation will be improved by recent developments in the statistical modelling necessary for Level-2 processing.

Working Groups are set up by the ISSI Directorate for specific tasks, often also of a technical nature. The results of the Working Groups' activities are published as volumes of the ISSI Scientific Report Series (SR) or in the scientific literature.

Further, the uncertainty estimation will expand to take temporal correlation into account.

Improvements in TWS processing and its uncertainty estimations will benefit the applications of the data sets such as gravity-based ground water products, estimation of solid Earth deformations, or regional studies.
The objectives are improving the TWS processing and its uncertainties together with a thorough validation of the new data sets in the aforementioned applications, including a comparison to Mascon solutions.

The kick-off meeting of the Working Group took place on June 28 and 29, 2024. During this meeting the state of the art of GRACE/GRACE-FO data processing was presented by the responsible members and current and first validation approaches were critically discussed.

The members of the Working Group combine the expertise of the relevant data processing levels of GRACE/GRACE-FO data with experts in TWS data validation:
Eva Boergens, Section Earth System Modelling, GFZ Helmholtz Centre for Geosciences, Germany, Responsible PI, Ulrich Meyer, Astronomical Institute, University Bern, Switzerland, Co-PI, Kristel Chanard, Institut de physique du globe de Paris, Université de Paris-Cité, France, Christoph Dahle, Section Global Geomonitoring and Gravity Field, GFZ Helmholtz Centre for Geosciences, Germany, Thorben Döhne, Institute for Planetary Geodesy, TUD Dresden University of Technology, Germany, Felix Landerer, Jet Propulsion Laboratory, California Institute of Technology, Pasadena,California, USA, Andreas Güntner, Section Hydrology, GFZ Helmholtz Centre for Geosciences, Germany, Roland Hohensinn, International Space Science Institute, Switzerland, Martin Horwath, Institute for Planetary Geodesy, TUD Dresden University of Technology, Germany, Adrian Jäggi, Astronomical Institute, University Bern, Switzerland, Anna Kłos, Faculty of Civil Engineering and Geodesy, Military University of Technology, Warsaw, Poland, Torsten Mayer-Guerr, Technical University Graz, Austria, Ingo Sasgen, Alfred-Wegener-Institute, Helmholtz Centre for Polar and Marine Research, Germany, Davis Wiese, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, USA, and Vivek Yadav, Indian Institute of Science, Bangalore, India.

Eva Boergens

Auroral Research Coordination: Towards Internationalised Citizen Science (ARCTICS)

This spectacular picture was taken by Emma Bruus in Helsinki (Finland) on 11 May 2024, as the Gannon/Mother's Day Storm was nearing its peak (Image Credit: Emma Bruus).

The ARCTICS Working Group aims at coordinating the citizen science efforts in space physics and aeronomy at international level. It gathers together experts in auroral processes, ionospheric dynamics, and substorm physics, as well as citizen scientists from various parts of the world.

In 2024 ARCTICS held two meetings at ISSI (15–19 January and 3–7 June), in which a few external collaborators joined remotely. Additionally, eight online meetings were organised with rotating schedules between Europe, North America, and Oceania to accommodate members and collaborators across time zones. Over the past year, our working group has identified topics for up to 18 possible papers, of which three were published and one is accepted, while others are currently in progress. A review paper on citizen science in atmosphere and space physics, to which multiple ARCTICS members contributed, was also submitted in October 2024. Furthermore, the Working Group conceptualised, produced and released a set of two open-access documents: the ARCTICS Aurora Field Guide and the Handbook for Citizen Science, widely distributed across the aurora chasing communities. A grant to print copies of the Field Guide and distribute them to citizen scientists in view of a campaign was awarded to Katie Herlingshaw (UNIS, Norway) by the Hurtigruten Foundation. Finally, ARCTICS's ongoing efforts and results were presented at several international conferences (AGU Fall Meeting, European Space Weather Week, EISCAT Symposium/Optical Meeting).

The ARCTICS core members are: Maxime Grandin (Finnish Meteorological Institute, Finland; lead), Bea Gallardo-Lacourt (NASA-GSFC/Catholic University of America, USA; co-lead), Noora Partamies (University Centre in Svalbard, Norway), Toshi Nishimura (Boston University, USA), Emma Bruus (Citizen Scientist, Finland), Eric Donovan (University of Calgary, Canada), Mathieu Barthelemy (Université Grenoble Alpes, France), Neethal Thomas (University of Oulu, Finland), David Knudsen (University of Calgary, Canada), Katie Herlingshaw (University Centre in Svalbard, Norway), Donna Lach (Citizen Scientist, Canada), Eero Karvinen (Citizen Scientist, Finland), Vincent Ledvina (University of Alaska Fairbanks, USA; early-career researcher), Rowan Dayton-Oxland (University of Southampton, UK; early-career researcher), and Lena Mielke (University Centre in Svalbard, Norway; early-career researcher)

In addition to the above core members, over 20 external collaborators (academics and citizen scientists from Australia, Belgium, Canada, England, Finland, Japan, the Netherlands, New Zealand, Scotland, Svalbard, Sweden, and the USA) have been contributing to the efforts of the Working Group.

Maxime Grandin and Bea Gallardo-Lacourt

Working Groups

Disentangling Pulse Profiles of (Accreting) Neutron Stars

X-ray pulse profiles of neutron stars (NSs) are one of the most promising observables to assist with constraining the geometry and physics of the observed emission and, ultimately, the NSs equation of state. This holds whether emission escapes along a kilometres-long dipole-shaped accretion column wall, or as photons pierce through the upper structure of the column to contribute as a pencil-beam pattern, or even as a blackbody hotspot at the base of the stellar surface and contained within a thermal mound structure.

However, to thoroughly understand the vastness of different observed behaviours from a variety of pulsating objects, we first need to collect the current state of the art of our accreting NS pulse profile knowledge from an observational and modelling perspective, with appropriate attention also given to other pulsating systems.

Our group has been working constantly towards the creation of an extensive review on pulse profiles from highly magnetised accreting pulsars. This will be the most updated and comprehensive review on this class of objects and will lay the foundations to future characterisation and classification of these systems. Since our meeting, we keep weekly virtual meeting to refine and finalise our project within an enlarged collaboration.

As such, our work will prepare the ground for the next step, which is also the main topic of our second meeting, that is, modelling of X-ray pulse profiles observed from magnetised neutron stars. Thanks to this effort, researchers will be able to infer physical information from the observed source by modelling the X-ray pulse profile shape.

Our efforts will provide the wider research and observation community with tools to make pulse profile analyses for astrophysical inference more common and more easily achievable.

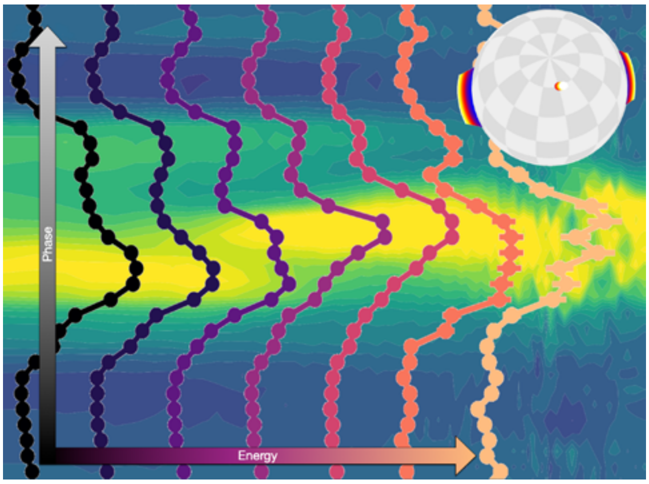
The Working Group is convened by Christian Malacaria (ISSI/INAF-OAR), Katja Pottschmidtt (UMBC & NASA GSFC), and Joern Wilms (ECAP/FAU). The first meeting was held on 10–14 June 2024, while the second meeting is scheduled for March 10–14, 2025.

Works acknowledging our WG:
– Energy-resolved pulse profile changes in V 0332+53: Indications of wings in the cyclotron absorption line profile, A. D'Aì et al. 2025, A&A (in press)

– Work on pulse-to-pulse variations in Vela X-1, P. Kretschmar et al. (in progress)

– Double-hump spectrum observed at low accretion rate in MAXI J0655, Malacaria et al. (in progress)

Christian Malacaria



Colour-coded phase-energy map of the accreting X-ray pulsar Hercules X-1 with energy-resolved pulse profiles superimposed. On the top right, a neutron star emitting X-ray flux with sky projection with two antipodal accretion columns, the hidden one observed as lateral emitting structures due to light bending effects. Credit Header Image: P. Kretschmar based on Ferrigno et al. (2023) and Falkner (2018, PhD thesis)

Further Working Groups met in 2024

Their purposes are described in previous Annual Reports

Global Assessment of Limnological, Estuarine and Neritic Ecosystems (GALENE)
Session at ISSI: 7–9 February 2024

Towards a Universal Tracers Portal in Astrobiology
Session at ISSI: 25–27 March 2024

The Variability of the Airglow for the Detection of Atmospheric Dynamics
Session at ISSI: 1–5 July 2024

Solar Forcings for CMIP 7
Session at ISSI: 22–26 July 2024

International Teams

International Teams consist of about 8–15 external scientists, addressing a specific scientific topic in a self-organised fashion, under the responsibility of a leader in a series of two to three one-week meetings over a period of 18 to 24 months. The results of these activities are customarily reported in scientific journals. The selection of International Teams results from an annual call issued in January and from the subsequent review and prioritisation done by the Science Committee.

Listed are Teams that had a meeting at ISSI in the period of the 29th business year. A rationale is given only for the Teams selected in 2023 and 2024; for the others see the previous Annual Reports.

Teams selected in 2020

Understanding Satellite, Aircraft, Balloon, and Ground-Based Composition Trends: Using Dynamical Coordinates for Consistent Analysis of UTLS Composition
Team Leader: Luis Millan, NASA Jet Propulsion Laboratory, Pasadena, USA
Session: April 30 – May 3, 2024

Multi-Sensor Observations of Antarctic Sea Ice and its Snow Cover
Team Leaders: Petra Heil, Australian Antarctic Division & AAPP Australia, and Rachel Tilling, University of Maryland, USA
Session: June 24–28, 2024

Teams selected in 2021

Geomagnetic Activity and Solar Cycle Dependence of Electromagnetic Ion Cyclotron (EMIC) Wave Activity and Wave Parameter in the Earth's Magnetosphere
Team Leaders: Remya Bhanu and Alexa J. Halford, NASA Goddard Space Flight Center, USA
Session: March 4–8, 2024

Thermophysical Characterization of Ice-Rich Areas on the Surface of Specific Planetary Bodies: Conditions for the Formation of a Transient Exosphere
Team Leader: Michelangelo Formisano, INAF, Rome, Italy
Session: March 19–21, 2024

Toward A 3-D Observation of the Ocean Color: Benefit of Lidar Technique (ISSI – ISSI Beijing Team)
Team Leaders: Cédric Jamet, Université du Littoral-Côte d'Opale, France and Davide Dionisi, CNR, Italy
Session: April 2 –5, 2024

Understanding Interhemispheric Asymmetry in MIT Coupling
Team Leader: Hyomin Kim, New Jersey Institute of Technology, USA
Session: October 7–11, 2024

Unraveling Surges: A Joint Perspective from Numerical Models, Observations, and Machine Learning
Team Leader: Daniel Nobrega-Siverio, Instituto de Astrofísica de Canarias (IAC), Spain
Session: February 12–15, 2024

Magnetotail Dipolarizations: Archimedes Force or Ideal Collapse?
Team Leader: Evgeny Panov, Austrian Academy of Sciences, Graz, Austria
Session: September 23–27, 2024

Ice Beyond Earth: Laboratory Investigations of Planetary Ices
Team Leader: Ganna Portyankina, University of Colorado in Boulder, USA
Session: August 12–16, 2024

Teams selected in 2022

Impacts of Climate Change on the Middle and Upper Atmosphere and Atmospheric Drag of Space Objects
Team Leaders: Juan A. Añel, Universidade de Vigo, Spain and Ingrid Cnossen, British Antarctic Survey, United Kingdom
Session: April 22–26, 2024

Observe Local Think Global: What Solar Observations can teach us about Multiphase Plasmas across Astrophysical Scales
Team Leaders: Patrick Antolin, Northumbria University, United Kingdom and Clara Froment, CNRS, Univ. Orléans, France
Session: May 13–17, 2024

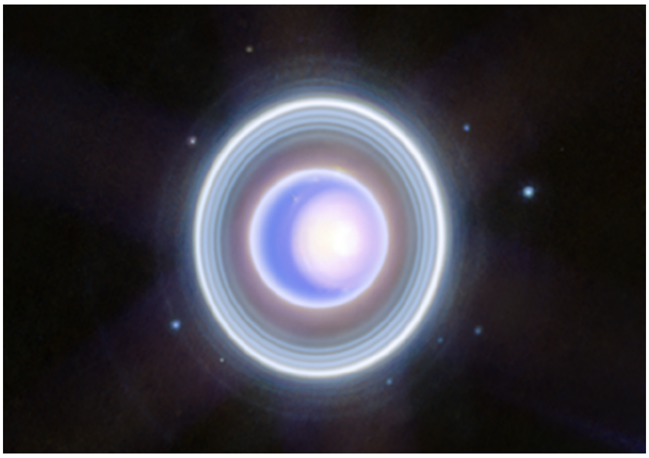


Image of Uranus from NIRCam (Near-Infrared Camera) on the NASA/ESA/CSA James Webb Space Telescope shows the planet and its rings in new clarity (Image Credit: NASA, ESA, CSA, STScI)

Magnetohydrodynamic Surface Waves at Earth's Magnetosphere (and Beyond)
Team Leaders: Martin Archer, Imperial College London, United Kingdom and Katariina Nykyri, Embry-Riddle Aeronautical University, USA
Session: September 2–6, 2024

Understanding the Activity of Comets Through 67P's Dynamics
Team Leader: Nicolas Attree, Technische Universität Braunschweig, Germany
Session: June 10–14, 2024

Future Missions to Uranus and Neptune: Prospects for Non-Planetary Science
Team Leaders: Daniel D'Orazio, Niels Bohr International Academy, Denmark and Prasenjit Saha, Univ. of Zurich, Switzerland
Session: December 2–6, 2024

Wide-Ranging Characterization of Explosive Volcanism on Mercury: Origin, Properties, and Modifications of Pyroclastic Deposits
Team Leader: Anna Galiano, INAF-IAPS Institute for Space Astrophysics and Planetology, Italy
Session: May 6–8, 2024

CSES and Swarm Investigation of the Generation Mechanisms of Low Latitude Pi2 Waves
Team Leaders: Essam Ghamry, National Research Institute of Astronomy and Geophysics, Arab Republic of Egypt and Zeren Zhima, National Institute of Natural Hazards, MEMC, China
Session: October 7–11, 2024

A Framework for Improving All-Weather Visible and Near-Infrared Satellite Data Assimilation
Team Leaders: Benjamin Johnson, UCAR/JCSDA, USA and Angela Benedetti, ECMWF, United Kingdom
Session: October 29–31, 2024

Cross-Scale Energy Transfer in Space Plasmas
Team Leaders: Rungployphan Kieokaew, Recherche en Astrophysique et Planétologie (IRAP), France and Yan Yang, University of Delaware, USA
Session: October 21–25, 2024

Transformation of Planetary Systems by Environmental Perturbations
Team Leader: J. M. Diederik Kruijssen, Heidelberg University, Germany
Sessions: September 30 – October 4 and December 9–13, 2024

Improving the Description of Exosphere Surface Interface
Team Leaders: François Leblanc, CNRS/IPSL, France and Menelaos Sarantos, NASA Goddard Space Flight Center, USA
Session: February 5–9, 2024

First Light at Cosmic Dawn: Exploiting the James Webb Space Telescope Revolution
Team Leaders: Pascal Oesch, University of Geneva, Switzerland and Michael Maseda, Univ. of Wisconsin-Madison, USA
Session: February 19–23, 2024

The Cosmic Baryon Cycle from Space
Team Leader: Céline Péroux, ESO, Germany
Session: February 26 – March 1, 2024

Multi-Wavelength Studies of the Culmination of Structure Formation in the Universe
Team Leader: Gabriel Pratt, CEA Saclay, Service d'Astrophysique, France
Session: May 27–31, 2024

Seismicity on Venus: Prediction & Detection
Team Leader: Iris van Zelst, German Aerospace Center, Germany
Session: January 23–27, 2023

Magnetohydrostatic Modeling of the Solar Atmosphere with New Datasets (ISSI–ISSI Beijing Team)
Team Leaders: Xiaoshuai Zhu, Chinese Academy of Sciences, China and Iulia Chifu, University of Göttingen, Germany
Session: August 26–30, 2024

Teams selected in 2023

Quantitative Comparisons of Solar Surface Flux Transport Model

Team Leader: Graham Barnes (team leader) NorthWest Research Associates, USA
Session: March 4–8, 2024
Scientific Rationale: To model the global magnetic field of the Sun's corona and the solar wind in the heliosphere, it is necessary to start with at least the radial component of the magnetic field over the entire photospheric surface of the Sun. Because only the Earth-facing side of the Sun is observed routinely, it is common to approximate changes to the field during the interval between observations using evolving models such as the commonly used Surface Flux Transport (SFT) model. A recent study comparing the predictions from two SFT models showed that even though the models were attempting to represent the same physical processes on the Sun, the results were at times substantially different, raising the question of their accuracy and viability for common applications such as solar-wind predictions and other, related space weather forecasting efforts. The Team brings together multiple SFT models and modellers, as well as experts in validation techniques, to understand why some models are more successful than others, using a combination of techniques newly applied to the predictions from global maps as well as new observations. The result will be improved global maps which will enhance solar and heliospheric modelling efforts with implications for space weather forecasting. Additionally, a better understanding of the processes that determine the surface magnetic flux distribution could also shed light on the solar dynamo, as well as improving modelling of other stars.

Coastal Sea Level Rise: Observations and Causes

Team Leader: Anny Cazenave, LEGOS, Toulouse, France
Session: March 25–28, 2024
Scientific Rationale: For 30 years, space-based radar altimetry has been routinely measuring changes in sea level at global and regional scales. But so far, this technique designed for the open ocean has not provided reliable sea level data within 15 km of the coast, mostly due to land contamination within the radar echo in the vicinity of the coast. This problem can now be solved by a new specific reprocessing of past altimetry missions. This gives access to valid sea level data in the 0-15 km band from the coast and as a result to novel information on sea level change in the world coastal zones. This work performed in the context of the ESA Climate Change Initiative 'Coastal Sea Level' project now provides sea level time series and associated trends over 2002-2020 at 756 coastal sites worldwide. At several sites, the rate of sea level rise at the coast deviates from offshore. The scientists intend to investigate the causes of such behaviour and identify the small-scale coastal processes and forcings (e.g., shelf currents, trends in waves, wind forcing, river runoff in estuaries and deltas, natural climate modes, changes in bathymetry and shoreline, etc.) able to explain why coastal sea level rise may differ from offshore. For that purpose, the scientists use a variety of satellite-based and in situ measurements as well as outputs from high-resolution coastal ocean and wave models.

The Mesosphere and Lower Thermosphere at Low Latitudes (MLT-LoLa): Its Day-To-Day Variability and its Contributions to Thermospheric/Ionospheric Weather (ISSI–ISSI Beijing Team)

Team Leaders: Jorge L. Chau, Leibniz Institute of Atmospheric Physics, Germany and Huixin Liu, Kyushu University, Japan
Session: February 19–23, 2024
Scientific Rationale: The project explores the boundary between Earth's atmosphere and near-Earth space, i.e., the mesosphere and lower thermosphere (MLT) region, with a special emphasis on low-latitudes (MLT-LoLa). The MLT in general has not been well studied given the challenges faced by observing techniques (too high for balloons and too low for satellites to make in situ measurements) and the complex dynamical and chemical processes of the region (e.g., co-existence of plasma and neutrals, large temperature gradients, wind shears). An urgent issue is its day-to-day variability, and its connection to thermospheric and ionospheric (TI) weather. The knowledge of its variability is highly limited, and a systematic picture across different atmosphere layers and an array of major thermosphere/ionosphere parameters (e.g., plasma density and drift, thermosphere density, ion and neutral concentrations, wind, and temperature) is yet to be achieved. However, the past several years have seen a rapid expansion of datasets probing the MLT (e.g., ICON, Swarm, multistatic meteor radars) as well as unprecedented modelling capability which captures realistic lower-atmosphere forcing (e.g., WACCM-X, GAIA). In this proposed effort, a team of experts on middle atmosphere dynamics and chemistry, thermosphere dynamics, ionosphere electrodynamics, and plasma instabilities, is brought together. By combining ground-to-space whole atmosphere models with ground- and satellite-based observations and statistical inverse problems approaches, this team aims to develop an in-depth understanding of the day-to-day variability (e.g., dynamics, temperatures, composition of both the plasma and neutral atmosphere) by addressing the following questions: (1) How can day-to-day variability of the MLT and TI at low lati-

tudes be systematically quantified? (2) What is the role of troposphere and stratosphere processes in the observed MLT-LoLa day-to-day variability? (3) What is the role of MLT-LoLa processes in the day-to-day variability of the TI (including plasma instabilities)? Answering these questions will provide a significant step forward towards a systematic understanding of the vertical connection between atmospheric layers from ground to space.

Models and Observations of the Middle Corona

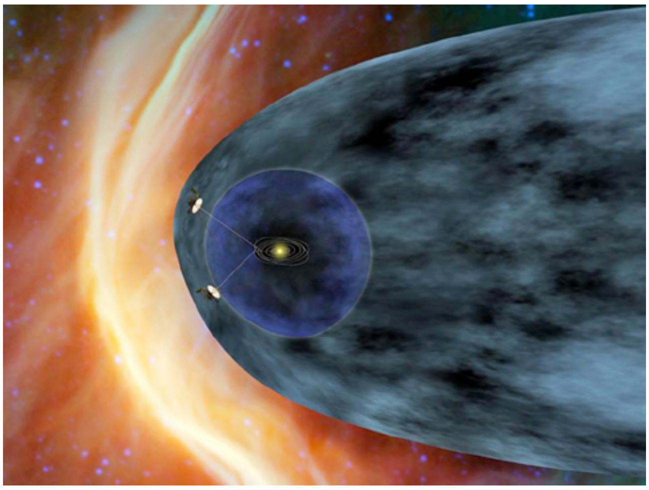
Team Leaders: Giulio Del Zanna, University of Cambridge, Cambridge, UK and Matthew West, Southwest Research Institute, Boulder, USA
Session: April 29 – May 3, 2024
Scientific Rationale: The region between the mainly magnetically closed inner corona and the mostly radial outer corona– the middle corona – is largely unexplored in long-term data-sets, despite the fact that important, but unknown, physical processes and transitions, which accelerate the solar wind and affect the inner corona, are acting there. Studies have relied on sporadic off-point campaigns from space-based instrumentation and ground-based eclipse observations.
Several space-based missions aim to soon fill this observational gap. However, obtaining information on the plasma state (such as densities, temperatures, velocities, magnetic field, and chemical abundances) is a non-trivial task.
The Team gathers a range of leading experts to assess/compare forward modelling techniques and benchmark them against observations to obtain such information. Emphasis is on 1) 3-D codes for the calculation of spectral line intensities taking into account resonant photo-excitation and Doppler dimming effects; 2) 3-D codes for the calculation of the Stokes profiles including the magnetic field, estimated from global MHD simulations.

Active Galactic Nuclei in Next Generation Surveys

Team Leader: Sotiria Fotopoulou, University of Bristol, UK
Session: November 4–8, 2024
Scientific Rationale: Supermassive black holes are believed to be a fundamental ingredient of galaxy evolution. Most massive galaxies are thought to self-regulate the formation of new stars through the powerful winds from the vicinity of the supermassive black hole. Euclid, the new optical and near-infrared space telescope of the European Space Agency, delivered the first 'quick-look' data release (Q1) in March 2025. The identification of actively accreting supermassive black holes (Active Galactic Nuclei, AGN) and their extremely luminous counterparts, quasars, is paramount for the success of the mission as they are a nuisance for the Cosmology and a fundament component of the Legacy Science. This Team used Euclid, and other ground based and space based data to identify, characterise, and create the first catalog of AGN and Quasars from Q1, submitting seven papers to accompany the Q1 data release. The methods developed from this project will pave the ground for efficient processing of future data releases.

Shocks, Waves, Turbulence, and Suprathermal Electrons in the Very Local Interstellar Medium

Team Leaders: Frederico Fraternale, University of Alabama, USA and Stella Ocker, Cornell University, USA
Session: May 21–24, 2024
Scientific Rationale: The interaction between the solar wind (SW) and the local interstellar medium (LISM) determines the heliosphere’s structure and global properties. Observational data and models indicate that the very local interstellar medium (VLISM) – the portion of LISM affected by the presence of the heliosphere – is highly dynamic. The region of space in front of the heliopause (HP) occupied by the VLISM is also known as the outer heliosheath (OHS).
The VLISM is partially ionised, multi-species, and collisional with respect to Coulomb collisions on scales larger than a few AU. Charge-exchange processes are fundamental in the OHS where they slow down the interstellar atoms and produce secondary ions that are quickly decelerated, creating a region of compressed plasma, draped interstellar magnetic fields (ISMF), and hydrogen and helium walls. Charge exchange and elastic collisions couple neutrals and ions, thereby setting the fundamental spatial and temporal scales of this system. The solar cycle sets a large-scale periodicity in the system, whereas a compressible turbulence cascade exists down to kinetic scales. The Voyagers (V1, V2) have been sampling the VLISM plasma since their crossing of the HP (2012/121 AU, 2018/119 AU for V1 and V2, respectively). In situ Voyager data continue to prompt new theoretical studies and lay out critical challenges for modelling and simulations.
This project addresses critical open questions about the physics of shocks, turbulence, the properties of electrons and associated plasma oscillations and radio emissions in the VLISM. The Voyagers have observed all these interrelated phenomena, but the relationship between their underlying physical mechanisms and the global structure of the heliosphere remains poorly understood.
The Team investigates the origin, properties, and evolution of shocks, turbulence, kinetic instabilities, particle distribution functions, plasma oscillations, and radio emission in the OHS by means of theoretical models, numerical simulations, and new analysis of Voyager/PWS/MAG data.



This artist's concept shows NASA's two Voyager spacecraft exploring a turbulent region of space known as the heliosheath, the outer shell of the bubble of charged particles around our Sun. (Image Credit: NASA/JPL-Caltech)

Collisionless Shock as a Self-Regulatory System
Team Leader: Michael Gedalin, Ben-Gurion University, Israel
Sessions: January 8–12, and August 5–9, 2024
Scientific Rationale: Collisionless shocks (CS) are one of most fundamental phenomena in plasmas. The heliosphere is a natural laboratory for in situ studies of these shocks but their Mach numbers are well below the Mach numbers of supernova remnant (SNR) shocks. With the increase of the Mach number the shock transition undergoes a sequence of structural changes. Understanding this sequence and the dependence of the structure on the global shock parameters is the key to bridging direct heliospheric studies and indirect studies of SNR shocks. So far such studies have focused on specific microscopic processes producing various features.
The Team suggests that a CS is a self-regulatory system, in which the mass, momentum, and energy fluxes should be stable. The shock structure is the one which ensures this stability for given upstream parameters. Within this approach, the focus is shifted from reason to purpose: more than one microscopic process may lead to the same type of CS structure, which is determined solely by the requirement of stable fluxes. The Team consists of specialists in heliospheric shock observations, numerical simulations, astrophysical shocks, and theory, in order to advance this novel paradigm. The specific topics are: a) transition from a monotonic profile to the overshoot-undershoot structure, b) transition from a plane overshoot-undershoot structure to a rippled structure, c) whether reformation or a completely turbulent state come beyond rippling.

Constraining Trade-Cumuli Feedback by Means of Process Understanding
Team Leaders: Geet George, TU Delft, Germany and Hauke Schulz, University of Washington, USA
Session: *May 5–9, 2025*
Scientific Rationale: Climate models widely disagree on how tropical low-level clouds will respond to climate warming, causing large uncertainty in climate sensitivity estimates. The underlying reason for the models' disagreement is a poor understanding of processes of shallow convection, in particular on scales that remain unresolved in current climate simulations. The proposed International Team aims to understand the mesoscale processes that couple trade-cumuli to circulations in order to constrain their feedback, with a focus on the spatial patterning of these clouds — a largely ignored feedback component. The team will use novel field measurements of clouds and circulation, satellite observations, and large-eddy simulations to identify these processes. The ultimate goal is to improve climate sensitivity estimates by using this process-understanding to constrain the wide range of cloud feedback provided by climate models. The expected outcomes of the study are several articles describing mesoscale processes and a joint reference dataset providing regional mesoscale quantities for the modelling community to validate their simulations. With the help of this dataset the team will disentangle the trade-cumulus feedback into its individual components, and provide a basis for future investigations.

Exploiting Intracluster Light for Cosmology and Galaxy Evolution with Next Generation Facilities
Team Leader: Nina Hatch, University of Nottingham, UK
Session: *March 10–14, 2025*
Scientific Rationale: Within the next five years, the space-based Euclid and Roman missions and the ground-based Rubin Observatory will be operational, and Euclid and Rubin will both be producing data within a year. The combination of wide field of view and sensitivity afforded by these surveys will greatly expand the area for which deep imaging is available (from a thousand square degrees to half of the sky). This step-change in data will enable a revolution in our understanding of the low surface brightness (LSB) Universe. We plan a series of meetings focused on using these new facilities to study one class of LSB structure — intracluster light (ICL) from galaxy clusters. Our diverse group of investigators from six countries, including both observers and theorists, will map out the best path forward to exploit data from these new missions to advance our understanding of ICL.
While the existence of the ICL has been known for over 75 years (Zwicky 1957), it is only with new facilities such

as Euclid, Rubin and Roman, and improvements in the capabilities of computational methods, that it is now possible to solve the key challenges in the measurement and interpretation of the ICL. Our team's investigations of the ICL are driven by two scientific questions.

Science question 1: What physical processes dominate ICL production over cosmic time? Science question 2: How well does the ICL trace dark matter?

The Extremely Low Surface Brightness Universe: Calling for Synergy between the ESA Euclid and ARRAKIHS Space Missions

Team Leaders: Kate Isaak and René Laureijs, European Space Agency, the Netherlands

Session: May 6–8, 2024

Scientific Rationale: The Euclid Legacy Science and the ARRAKIHS missions are two key initiatives within ESA to explore the nearby extragalactic Universe to an unprecedented low level of surface brightness (SB). This new window into the local Universe will provide the crucial observations to test the nature of dark matter from a different, but complementary, approach to Euclid's primary scientific focus on the distant Universe. The Euclid Legacy Science project will initiate the systematic exploration of the extremely low SB Universe over a very large area using the Euclid Wide Survey. ARRAKIHS will push forward this initiative by obtaining deeper observations for a representative sample of nearby galaxies. Although the orbital conditions, instruments, and observational strategies of the two space missions are very different, both face similar technical challenges to achieve the exceptionally low SB values required.

The project aims together with experts in the extreme low SB research field from the two mission Consortia in order to: (i) develop the best techniques of image processing to reach the lowest possible SB in both missions; (ii) simulate accurate mock images from Euclid and ARRAKIHS to test these techniques and assess systematics; and (iii) use the mock images to evaluate the discriminating power between dark matter model predictions as a function of the limiting SB in both missions. The resulting data reduction pipeline and mock image simulator will be used by both missions and shared by the two scientific communities.

Perspectives on Stratospheric Aerosol Observation

Team Leaders: Corinna Kloss, Forschungszentrum Jülich GmbH, Jülich, Germany and CNRS, Orléans, France and Mahesh Kovilakam, ADNET Systems Inc /NASA Langley Research Center, Hampton, USA

Session: September 18–20, 2024

Scientific Rationale: Stratospheric aerosols have a direct impact on Earth's climate through their albedo and their impact on ozone. Thus, they must be accounted for in all chemistry climate models. One source for such aerosol information, used by the modelling community, is the Global Space-based Stratospheric Aerosol Climatology (GloSSAC, Thomason et al., 2018; Kovilakam et al., 2020). GloSSAC's primary product is a continuous record (currently from 1979-2022) of zonally and monthly averaged global stratospheric aerosol extinction coefficients at 525 and 1020 nm. Clearly, a continuation of the GloSSAC record with the current or improved coverage is highly desirable. However, two key instruments currently providing GloSSAC input data (Optical Spectrograph and Infrared Imaging System, OSIRIS, and Cloud-Aerosol Lidar with Orthogonal Polarization, CALIOP) are near the end of their life, leaving only the Stratospheric Aerosol and Gas Experiment (SAGE III/ISS) solar occultation observations, which will not provide the current coverage and temporal resolution. In addition, the in situ instruments, which have been used in the past for validation of the space-borne measurements, are being replaced with new improved instruments, but still need to be tied to the legacy records. Plus, the rather simple picture of stratospheric aerosol dominated by sulphate is being challenged by recent pyrocumulonimbus (pyroCb) events, by the discovery of nitrates in the lower stratosphere above the Asian monsoon, and by the incursion of organics into the lower stratosphere.

To address these issues the project is divided into four tasks: 1) To review the GloSSAC climatology. Does it capture current understanding of stratospheric aerosol? Could the parameter space be improved? 2) To explore options for GloSSAC continuation and possible data record additions (i.e. what other instruments could be included?). 3) To review challenges and limitations for comparisons between in situ aerosol observations and 4) To identify key variables that represent the stratospheric aerosol layer, key existing gaps and to develop strategies to fill them.

Meteors and Phenomena at the Boundary between Earth's Atmosphere and Outer Space

Team Leaders: Alexander Kozlovsky, Sodankylä Geophysical Observatory of the University of Oulu, Finland and Renata Lukianova, Institute of Seismology, Kazakhstan

Sessions: January 29 – February 2 and November 18–22, 2024

Scientific Rationale: The project focuses on the mesosphere – low thermosphere (MLT) region comprising the height range of about 80-100 km, which is the least explored region of Earth's atmosphere. The air in the MLT is too rarefied for aircraft and balloons, but it is too dense for flying space objects, both the artificial and those which cause meteor phenomena. Using data from meteor radars and conjugate satellites' data, we expect to obtain new knowledge on the following issues:

- Formation and decay of meteor trails, taking into consideration the atmospheric conditions and physical properties of meteoroids.
- Properties of meteoroids in different meteor streams and sporadic sources.
- Generation and propagation of atmospheric gravity waves into the ionosphere and their transformation to magnetospheric MHD waves.
- Atmosphere-ionosphere-magnetosphere coupling through the ionospheric dynamo mechanism due to the motion of air mass.

Understanding the Release of Hard X-Rays, Type III Radio Bursts and In-Situ Electrons in Solar Flares (ISSI–ISSI Beijing Team)

Team Leaders: Gang Li, University of Alabama in Huntsville, USA and Linghua Wang, Peking University, Beijing, China

Session: April 29 – May 3, 2024

Scientific Rationale: The Team examines how electrons are accelerated in impulsive SEP events and how they subsequently propagate in the solar wind. Solar electron events are common phenomena observed in interplanetary space. In-situ electrons from <1 keV to >300 keV are often observed in these events with an occurrence rate near the Earth of 190 events per year during solar maximum and ~10 per year during solar minimum. A majority of these events is related to small flares with no accompanying coronal mass ejections (CMEs), suggesting that the underlying acceleration process is confined both spatially and temporally. Once accelerated at the flare site, electrons propagate out along open magnetic fields and excite type III radio bursts. Observations of these in-situ electrons (time intensity profiles and particle spectra) and type III radio bursts can put strong constraints on the underlying acceleration process at the flares. They also help to understand the configuration of the interplanetary magnetic field, and in particular, how it differs from the nominal Parker field.

Since 2020, after which solar activity picked up noticeably, many HXRs, type III radio bursts, and in-situ electron events have been identified by two recently launched spacecraft: Parker Solar Probe (PSP) and Solar Orbiter (SolO). In many instances, the distances between the s/c and the Sun were much closer than 1 au. This means the uncertainty in the arrival time of electrons, which is affected by pitch angle scattering during electron propagation, is much reduced comparing to previous observations made at 1au, by, e.g. Wind and ACE missions.

Such an observational advantage implies that the above-mentioned constraint on electron acceleration at flares will be further strengthened, thus greatly advancing our understanding of solar flares. The much reduced uncertainty will also imply that we will get a better understanding of the IMF configuration.

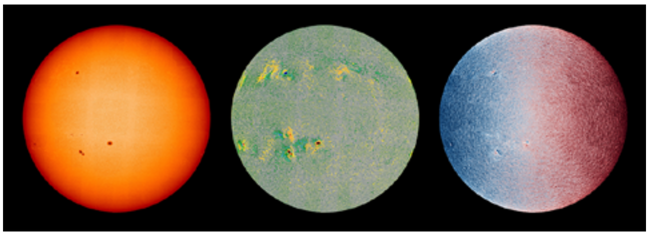
We plan to perform a comprehensive investigation of impulsive solar electron events from PSP and SolO observations. Observations of HXRs, type III radio bursts and in-situ electrons will be combined together to understand the energy dependence of the release time of energetic electrons in solar flares, and the configuration of IMF. A major portion of the proposed study will be on data analysis of PSP and SolO data. This will be further assisted by numerical simulations addressing the pitch angle scattering of energetic electrons in the solar wind. To achieve the goal, a group of experts in solar physics and heliosphysics, including theorists, modellers, and observers is being formed.

Understanding the Mars Space Environment through Multi-Spacecraft Measurements (ISSI–ISSI Beijing Team)

Team Leaders: Wenya Li, National Space Science Center Beijing, China and André Galli, University of Bern, Switzerland

Session: November 20–23, 2023

Scientific Rationale: Currently, the concurrent operation of MEX, MAVEN, and TW-1 provides a unique opportunity to explore the Mars space environment with three-point simultaneous observations, especially with one spacecraft as a real-time solar wind monitor. When combined, the instruments on board the three orbiters fulfil all the main observational elements required to study the planet's magnetosphere, atmosphere, and plasma environment. December 2019 marked the beginning of the 25th solar cycle, during which the sunspot numbers have quickly increased and exceeded theoretical predictions for this solar cycle. The sunspot numbers in January 2023 were already close to the maximum level of the past 24th solar cycle; solar activity could be extremely strong through the rising phase up to the expected peak year of 2025 (McIntosh et al., 2020). At Mars, the much more frequent solar storms bring more chances to investigate the variations of the Mars space environment, to quantify the intense escape processes and to estimate the associated atmospheric loss over time. Here, we propose to combine the three orbiters in Mars orbit for a comprehensive investigation of the Mars space environment. This project will also lay the groundwork for two dual-spacecraft missions, including the Escape and Plasma Acceleration and Dynamics Explorers (ESCAPADE) mission from NASA and the Mars Magnetosphere ATmosphere Ionosphere and Surface SciencE (M-MATISSE) mission from ESA.



The three views of the Sun's surface shown are based on measurements taken on 22 March 2023 by the Solar Orbiter mission. From left to right, you see the Sun in visible light, a magnetic map of the Sun, and a map of the line-of-sight speed and direction of movement of material at the Sun's visible surface.
(Image Credit: ESA & NASA/Solar Orbiter/PHI Team)

Investigation of the Lithosphere Atmosphere Ionosphere Coupling (LAIC) Mechanism before the Natural Hazards (ISSI–ISSI Beijing Team)

Team Leaders: Dedalo Marchetti, Jilin University, China and Essam Ghamry, National Research Institute of Astronomy and Geophysics (NRIAG), Egypt
Session: September 11–15, 2023
Scientific Rationale: This Team aims to identify the mechanisms of the lithosphere atmosphere and ionosphere coupling. In particular, the Team members aim to investigate which are the mechanisms of coupling as a function of the geographical context (land or sea), the rupture style from focal mechanisms (reverse, strike-slip or normal faults), depth and magnitude of the incoming event. Furthermore, the earthquake source will be approximated by a rupture surface. Preliminary investigations show that considering the segment that the seismic event has broken, the atmospheric pre-earthquake investigations can be better interpreted by discriminating anomalies not related to the incoming earthquake from the ones possibly related to it. The Team expects to constrain better the characteristics of the anomalies in the lithosphere, atmosphere, and ionosphere more likely related to pre-earthquake and pre-eruption phenomena in the light of the physical-chemical relationships of a specific LAIC model and atmospheric chemistry as well as ionospheric plasma physics.

Development of Galaxy Zoo: JWST

Team Leader: Karen Masters, Haverford College, USA
Session: April 15–19, 2024
Scientific Rationale: The Galaxy Zoo science team is an International Team project with the goal of collecting, processing and making available to the community Galaxy Zoo style classifications for public, multi-filter JWST NIRCam imaging of resolved galaxies. The scientists have several specific science cases, but more importantly will enable the creation of a homogeneous quantitative visual morphology catalogue of wide benefit to the extragalactic community making use of JWST imaging for years to come.

REASSESS - gRound and spacE-bAsed analySis of Strong sEp eventS and Study of their terrestrial effects

Team Leader: Alexander Mishev, University of Oulu, Finland
Session: March 18–22, 2024
Scientific Rationale: A specific class of strong solar energetic particle (SEP) events are the ground-level enhancements (GLEs) in which solar ions are accelerated to sufficiently high energies to induce nucleonic cascades in the Earth’s atmosphere, whose secondaries can be registered by ground-based detectors, e.g., neutron monitors (NMs). Significant progress in the study of SEPs has been achieved in recent years, using space-borne instruments in the range up to hundreds of MeV. On the other hand, NMs respond to ions with energy over ~300 MeV/n. Therefore, a gap exists between the response of most spacecraft instruments and NMs. Moreover, there are systematic differences between the results of GLE analyses performed with low-energy space-borne instruments and those derived from NMs, particularly in the high-energy range of the SEP spectra. It is known that SEP fluxes can cause terrestrial and space weather effects. For reliable quantification of those effects, precise knowledge of SEP spectra is necessary. Within the scope of the project, the Team brings together SEP measurements from NMs and the fleet of space-borne instruments, which will be cross-calibrated to fill in the long-standing gap between NM and space-borne measurements. As a result, the scientists will produce verified and cross-calibrated spectra during strong SEP events which will provide the solar/space/solar-terrestrial physics and space weather communities with a necessary basis to deepen the current knowledge on the acceleration and transport of SEPs and to quantify the related space weather and terrestrial effects.

Novel Insights Into Bursts, Bombs, and Brightenings in the Solar Atmosphere from Solar Orbiter

Team Leaders: Chris J. Nelson, European Space Agency, the Netherlands, and Lakshmi Pradeep Chitta, Max Planck Institute for Solar System Research, Germany
Session: March 18–22, 2024
Scientific Rationale: How the Sun’s corona is heated to million-Kelvin temperatures remains an open problem. One of the most promising theories proposed to explain coronal heating is the ubiquitous occurrence of small-

scale magnetic reconnection events in the upper atmosphere, known as 'nanoflares'. In the nanoflare model, constant buffeting of the photosphere inputs stress into the coronal magnetic field making it highly non-potential. At some point, the magnetic field becomes too stressed, after which it restructures to a lower energy state through a process known as magnetic reconnection, releasing (some of) the non-potential energy to heat the local plasma. Potential signatures of this process have been over a range of spatial and temporal scales; however, if it is to be important in widespread coronal heating, then small-scale magnetic reconnection signatures must be detectable at wavelengths sampling million-degree temperatures with a high frequency. One of Solar Orbiter's key early results was the discovery of ubiquitous quiet-Sun transient EUV brightenings on previously undetectable spatial scales, seemingly with temperatures around 1 MK. These potential magnetic reconnection related features have excited the solar physics community, with numerous follow-up studies being conducted. We now know that many EUV brightenings form around 1-5 Mm above the solar photosphere and that potentially 70% overlie photospheric magnetic bipoles. Despite this progress, many important questions remain before we can assess the role of these events in coronal heating. This Team contains experts in the field and aims to improve our understanding of EUV brightenings and will answer three overarching questions, namely: (A) What is the connectivity between the Solar Orbiter EUV brightenings and previously reported bursts?; (B) What is the magnetic connectivity of EUV brightenings?; and (C) can we reconcile the signatures of EUV brightenings with numerical simulations?

Tomographic Inversion of Synthetic White-Light Images: Advancing Our Understanding of CMEs in 3D

Team Leaders: Erika Palmerio, Predictive Science Inc., USA and David Barnes, Rutherford Appleton Laboratory, UK
Session: October 7–11, 2024
Scientific Rationale: One of the greatest challenges in coronal mass ejection (CME) forecasts is that most input parameters for prediction models – usually derived from remote-sensing imagery – are only loosely constrained and, thus, are associated with large uncertainties that are difficult to quantify. One prominent example is the mass, with crucial implications for the interplanetary propagation of a CME. This project explores a technique based on white-light imagery of the solar corona and/or heliosphere that has drawn little attention to date owing to its inherent complexity, i.e. tomography. The success of tomographic inversion is greatly improved with the number of observing viewpoints, hence making the technique hard to apply and validate using the small number of space-based assets that have been available thus far.
To overcome the limitations arising from an insufficient number of observers, the Team applies tomography techniques on modelled CMEs and, hence, on synthetic white-light images that emulate existing coronagraph and heliospheric imager data. The members will derive CME input parameters (such as density, speed, size, mass) for different configurations of the observers and determine the optimal arrangement of spacecraft for an adequate recovery of the full 3D CME structure. They will compare tomography results with forward modelling (i.e., the most common remote-sensing analysis tool currently in use) and use the inputs derived with both techniques for CME propagation models. It is expected that the results of the project will not only enhance the planning and development of future heliospheric missions but also serve as a benchmark for current CME propagation models and forecasting tools.

Unveiling Energy Conversion and Dissipation in Non-Equilibrium Space Plasmas

Team Leaders: Oreste Pezzi, University of Calabria, Italy and Paul Cassak, West Virginia University, USA
Session: June 3–7, 2024
Scientific Rationale: The Team aims to investigate how space plasmas convert and dissipate energy, focusing on systems that are not in local thermodynamic equilibrium (LTE). In collisional fluids and plasmas, such processes are well understood: large-scale energy in the form of kinetic and/or magnetic energy is transferred to small scales, where viscosity and/or resistivity cause the irreversible conversion of energy into internal (thermal) energy. Collisions in such systems restrict the fluid or plasma to remain close to LTE. However, collisional processes in numerous space plasmas are weak, so the intuitive understanding derived from neutral fluids does not work in such systems. Weakly collisional and collisionless plasmas stray far from LTE, and the conversion and dissipation of energy are completely different than in LTE. In particular, degrees of freedom unavailable to collisional plasmas arise in non-LTE systems, and there is a growing appreciation that these degrees of freedom play a crucial role in energy conversion and dissipation in non-LTE systems.
Two complementary theoretical approaches to describe energy conversion in weakly collisional or collisionless plasmas have been developed – the so-called velocity-space cascade approach and an approach associated with entropy. These two approaches must be fundamentally interrelated. The implications of understanding these processes are broad, with applications to nearly all the Space Sciences research like Astrophysics, Funda-

mental Physics in Space, Magnetospheric and Space Plasma Physics, Planetary Sciences, Solar and Heliospheric Physics, and Solar-Terrestrial Sciences.

Bridging the Gap: From Terrestrial to Icy Moons Cryospheres

Team Leaders: Ana-Catalina Plesa, DLR, Germany and Julia Kowalski, RWTH Aachen University, Germany
Session: February 19–23, 2024
Scientific Rationale: Ice is omnipresent in our Solar System, on Earth, on planetary bodies, and on moons in the outer Solar System. In the past, terrestrial and extraterrestrial cryosphere science mostly developed as independent research fields whereas synergies may shed light on both fields. This Team brings together scientists working on terrestrial and extra-terrestrial cryospheres.
The goal is to make knowledge hidden in the vast amounts of existing data from different research groups accessible by consolidating it into a comprehensive meta-data enriched compilation of ice properties. This extends to relevant physical regimes on both Earth and icy moons including data from field campaign measurements, laboratory experiments, and planetary missions.
Information on thermal, physical, and chemical ice properties will be used to derive parametrisations (interpolations to express the dependence of properties on e.g., temperature, pressure or depth, and chemical composition). These can be easily implemented as initial and boundary conditions or sub-scale material parameters in numerical models, thereby significantly enhancing the data's simulation readiness. The database, the accompanying parametrisations, and potential simulation results will be made publicly available. This approach will provide the unique opportunity to transfer and extrapolate the information from Earth to the outer Solar System bodies.

"Genes from Space" – Leveraging Earth Observation Technologies to Monitor Essential Genetic Diversity

Team Leaders: Meredith C. Schuman and Claudia Röösli, University of Zurich, Switzerland
Session: February 12–16, 2024
Scientific Rationale: Earth's biodiversity is declining into a sixth mass extinction. International monitoring efforts attempt to quantify this decline and facilitate accountability measures for mitigation. Genetic diversity within and among populations is essential for species persistence. While targets and indicators for genetic diversity are captured in the Kunming-Montreal Global Biodiversity Framework, assessing genetic diversity across many species at national and regional scales remains challenging. Parties to the Convention on Biological Diversity (CBD) need accessible tools for reliable and efficient monitoring at relevant scales.
Sampling effort is especially limited for genetic diversity indicators and related Essential Biodiversity Variables (EBVs), which support assessments of species' potential to adapt to global change and are important for preventing extinctions and designing effective conservation measures. Recently adopted indicators for genetic diversity focus on the targeted and effective use of genetic sequence data supported by proxies of sequence diversity which can be more rapidly and frequently monitored, and may be more directly translated into policy. Now is the time to incorporate important aspects of genetic diversity which can be obtained more easily using Earth Observation (EO).
The Team brings together experts on EO for biodiversity including satellite and aerial observation, integration of EO into EBV workflows, linking EO data to genetic variation, genetic EBV development, genetic diversity assessment, and linking genetic diversity to policy. The Team estimates the impact of timely EO integration into genetic diversity monitoring on the protection of genetic diversity and the services it provides, and disseminate this information to the scientific community, policymakers, and the public.

Evolution of Turbulence in the Expanding Solar Wind

Team Leaders: Luca Sorriso-Valvo, KTH – Royal Institute of Technology, Stockholm, Sweden and Lina Hadid, Laboratoire de Physique des Plasmas, Palaiseau, France
Session: February 12–16, 2024
Scientific Rationale: The launches of Parker Solar Probe, Solar Orbiter, and BepiColombo offer unique opportunities for investigating the evolution and dynamics of the expanding solar wind.
This Team performs coordinated studies using multi-point in-situ and remote observations from these and other spacecraft, which will allow the most accurate measurements of the radial evolution of solar wind turbulence energy budget to be obtained and overcome the broad uncertainty in the more standard single-spacecraft statistical estimates. Data analysis, models and numerical simulations will be used to obtain such estimates and to subsequently address unresolved questions:
How do turbulence properties and plasma heating precisely evolve with the heliocentric distance?
How does the solar wind expansion affect these properties?
Can solar-wind models be improved using multi-spacecraft observations?
This Team will tackle such questions to maximise the science return of the available spacecraft configurations in the inner heliosphere.

Jupiter's Non-Auroral Ionosphere

Team Leader: Tom Stallard, Northumbria University, UK
Session: February 26 – March 1, 2024
Scientific Rationale: Planetary upper atmospheres, which contain both a charged ionosphere and neutral thermosphere, represent an important transition region between the dense meteorological atmosphere below and the near-vacuum space environment above. They mediate the exchange of particles, energy, and momentum between these two distinct environments and, at Earth, host satellites. The study of planetary upper atmospheres, in general, therefore helps us to understand atmospheric evolution and planetary habitability as well as to adapt and protect the technologies that society has become entirely dependent upon, such as satellite communications and positioning.
Recent measurements of Jupiter's equatorial regions have revealed surprising complexity in the ionosphere and thermosphere, suggesting a wide range of energy inputs and ionisation processes. While Jupiter's upper atmosphere shares many commonalities with Earth, there are notable contrasts. Jupiter's upper atmosphere is much hotter than predicted based on our understanding of the energetics of Earth's upper atmosphere. This behaviour was mirrored at the other giant planets, yet the origin of the stark differences between terrestrial and giant planet ionospheres remains unresolved. This Team will draw together a combination of various current datasets of observations from Earth and ongoing Juno measurements around Jupiter, comparing and contrasting the ionosphere with the surrounding magnetospheric environment. It will also investigate the development of ionosphere-magnetosphere coupled models that reveal the drivers of these ionospheric variations.

Understanding the Physical Processes that Control the Magnetotail Structure and Dynamics within Unmagnetized and Hybrid Magnetospheres

Team Leader: Katerina Stergiopoulou, University of Leicester, UK
Session: September 2–6, 2024
Scientific Rationale: Mars and Venus are the only unmagnetised planets in the solar system. Thus, instead of an intrinsic magnetosphere as a result of an internal dipole field, an induced magnetosphere forms around these planets. Significant progress has been made in understanding the physics in these plasma environments, but most of the studies targeting the two planets only examine them individually. The Team addresses the following overarching science question and three sub-questions:
1. What are the physical processes that drive the magnetotail structure and dynamics within unmagnetised and hybrid magnetospheres?
How do the structure and dynamics of the near Venusian and Martian magnetotail regions differ; what processes drive the observed structure and variability; how do the near magnetotail regions facilitate the flow of energy back towards the nightsides of the planets and away from them downstream?
What are the structure and dynamics of the far Venusian and Martian magnetotail regions?
How do the Venusian and Martian magnetotail regions respond to solar driving, and what processes control these responses?

A Multi-Mission Approach to Close the Gaps in Understanding of the Structure and Variability in the Mars Upper Atmosphere

Team Leader: Ed Thieman, University of Colorado at Boulder, USA
Session: January 29 – February 2, 2024
Scientific Rationale: The Mars's upper atmosphere is important for understanding the planet's climate evolution as well as serving as a laboratory for understanding processes in planetary atmospheres throughout the Universe. Over the past five years, the ESA Trace Gas Orbiter (TGO) and NASA Mars Atmosphere and Volatile EvolutioN (MAVEN) orbiter made contemporaneous measurements of the Mars upper atmosphere. When taken together, these missions can provide the most complete understanding of the Mars upper atmosphere ever realised. This study will be the first concerted attempt to combine the MAVEN and TGO observations and interpreting them on a global scale. The two goals are:
• To understand the structure and variability in the Mars's upper atmosphere at a global-scale revealed in the MAVEN and TGO composite data
• To compile the most comprehensive observational record of the neutral density and composition of the Mars's upper atmosphere using MAVEN and TGO
These goals will be achieved by:
• Comparing contemporaneous/simultaneous solar occultations measured by MAVEN/EUVM and TGO
• Comparing composition and minor species measurements from MAVEN/NGIMS and TGO from the homopause to the exobase
• Generating a composite dataset of atmospheric density and composition from the mesopause to the exobase
• Analysing the composite dataset's variations with latitude, local time and solar activity with the aid of general circulation models.

The Thermal and Petrological History of Mercury's Heterogeneous Mantle

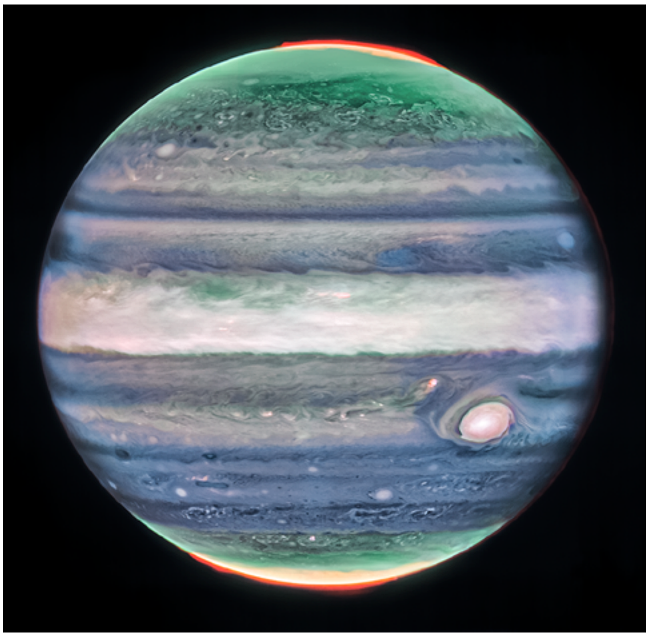
Team Leaders: Nicola Tosi, DLR, Berlin, Germany and Olivier Namur, KU Leuven, Belgium
Session: January 22–26, 2024
Scientific Rationale: With its high bulk density, large liquid core, active magnetic field and heterogeneous surface, Mercury is an endmember planet in the Solar System with unique and still unexplained characteristics. The NASA mission MESSENGER, which orbited Mercury from 2011 until 2015, revolutionised our understanding of the innermost planet. Yet it left a number of key questions unanswered, including how to disclose the link between the planet's volcanic surface, the evolution of the deep interior and its present-day structure. The ESA-JAXA mission BepiColombo launched in 2018 will orbit Mercury from late 2025 with the main scientific objectives of understanding "the internal structure and physical characteristics and the surface composition and evolution" of Mercury.
Thermal models of Mercury's evolution have been successful at explaining important global constraints such as the net amount of radial contraction, thickness of the crust, and history of magnetic field generation. Critically, all such state-of-the-art models do this whilst assuming a homogeneous mantle composition. However, spectral measurements from the MESSENGER spacecraft provide abundant evidence of compositional heterogeneity in Mercury's igneous surface and crust. These data, when combined with melting experiments at conditions of Mercury's interior, indicate that the mantle is significantly more structured than geophysical models currently consider, possibly preserving traces of its formation from a crystallising magma ocean.
In this project, the Team intends to develop petrological and geodynamic models linking Mercury's surface and deep interior. By combining experiments, thermodynamic and geophysical modelling, the Team will develop a new paradigm for Mercury's interior evolution, the first that is faithful to each of the geophysical, petrological, and geochemical constraints we have for the planet. This new paradigm will be central to interpreting the wealth of data that will come from the BepiColombo mission.

Tracking Plasma Flows in the Sun's Photosphere and Chromosphere: A Review & Community Guide

Team Leaders: Benoit Tremblay, National Solar Observatory, and Maria D. Kazachenko, University of Colorado, Boulder, USA
Session: May 13–17, 2024
Scientific Rationale: How is magnetic energy transported across the photosphere and the chromosphere? This energy heats the chromosphere and corona, and controls variety of atmospheric phenomena (e.g., fibrils, spicules, jets, surges, flux ropes). The rate of magnetic energy input, or Poynting flux, depends on both magnetic fields and plasma velocities (flows). While derivation of magnetic fields from spectropolarimetric inversions has been heavily studied, much less effort has been devoted to methods of inferring flows. Therefore, the development and validation of observation-based flow reconstruction techniques is critical for understanding the input of magnetic energy into solar atmosphere and its role in driving a variety of solar phenomena.
Our multidisciplinary International Team brings together experts on various flow inversion techniques, including observations, theory, simulations, computer vision and deep learning. The objective will be to develop, validate and improve flow-tracking methods for a wide range of use cases in solar physics, including simulations with known ground truths and observations. This effort will intensify interactions between the observational and theoretical communities to provide new insights into our understanding of flows, and the nature of magnetic energy input into the solar atmosphere. The Team will also prepare an open-source community toolkit applicable for existing and future datasets.

3-D Chemical Kinetics Model Benchmark for Hot Jupiter Atmospheres

Team Leader: Shang-Min Tsai, The University of Oxford, UK
Session: March 4–8, 2024
Scientific Rationale: Exoplanets offer an unprecedented opportunity to put our understanding of the Solar System in context. Hot Jupiters (short-period gas giants) are the first discovered and most studied class of exoplanets. They are expected to be tidally-locked (with the same side always facing the host star) and exhibit remarkable thermal and chemical variations across the permanent dayside and nightside. Space telescopes such as HST and Spitzer have provided powerful spectroscopic data to probe their atmospheric compositions. With recent JWST discoveries that revolutionise our ability to study exoplanet atmospheres in detail, it is timely to establish a consistent modelling framework to interpret the observational data. However, exoplanet models are generally not up to date for this task. Detailed chemical kinetics models that treat a large number of chemical species and reactions remain primarily in 1-D, precluding the chemical distribution regulated by global transport, whereas sophisticated 3-D general circulation models (GCMs) tend not to include chemistry properly because of limited computing power. Standardised protocols for Jovian planets like those for Earth climate models are lacking as well. In this project, we are motivated to bridge this gap



This image of Jupiter from the James Webb Space Telescope's NIRCam (Near-Infrared Camera) shows stunning details of the majestic planet in infrared light. (Image Credit: NASA, ESA, CSA, STScI, Ricardo Hueso (UPV), Imke de Pater (UC Berkeley), Thierry Fouchet (Observatory of Paris), Leigh Fletcher (University of Leicester), Michael H. Wong (UC Berkeley), Joseph DePasquale (STScI)

by testing simplified chemical schemes that are computationally feasible to couple to a 3-D GCM. The Team brings together expertise in both chemical kinetics and GCMs to consolidate the optimal strategy. The Team will format a 3-D GCM chemistry benchmark scheme for hot Jupiters for the first time. The model intercomparison is a crucial step before comparing to the spectra observations by HST, Spitzer, JWST, and the upcoming ARIEL. The Team aims to standardise the protocol of model validation where we optimise the trade-off between accuracy and efficiency. The benchmark will improve communication within the community as well as advance the ability to unravel the upcoming data from space telescopes.

Coastal Resilience Using Satellites: CRESTE
Team Leader: Emma Imen Turki, Normandy University, France
Session: April 2–5, 2024
Scientific Rationale: Within the context of global climate change and increasing human pressure, coasts and estuaries are more vulnerable to environmental hazards and are currently facing an intensification of natural hazards including erosion, floods, saltwater intrusion, subsidence, and tsunamis. These hazards have become more serious in the last decade owing to the over-expansion of urbanisation and infrastructure that these areas are facing, together with the climate change effects such as sea level rise and the increase in storminess. While sea level change controls the position of the coastline on the long term (decades to centuries), climate change also affects seasonal fluctuations and changes in storm frequency and patterns.
The combined effects of such internal (geometry, sediment) and external (climate, energy, presence of anthropogenic activities) drivers have often degraded coastal areas and the associated ecosystems. To correctly evaluate the resilience of a coastal system it is important to know its trajectory or evolution at different timescales in response to external and internal drivers. The evaluation of coastal resilience also requires the integration of several scales, in time and space, to cover the overall dynamics of the system. CRESTE aims to investigate the resilience of coastal systems from the use of Earth-science satellites operated by European and international space agencies. The work will highlight the relevance of different satellites, separately, validated by in-situ measurements, compiled between them and finally combined with numerical models.

International Teams approved in 2024

Teams selected in 2024

The following listed Teams have been selected for implementation from the proposals received in response to the 2024 Call for International Teams:

Satellite-Based Evaluation of Stratospheric Transport in Chemistry-Climate Models
Team Leader: Marta Ábalos Álvarez (Universidad Complutense de Madrid, Spain)
Session: December 9–13, 2024
Scientific Rationale: Observed ozone trends in the mid-latitude lower stratosphere remain contradictory with results from climate model simulations; this is likely due to shortcomings in the representation of tracer transport and variability. But the exact nature of these limitations and the relative role of different mechanisms remain unclear, which hampers our ability to interpret observational changes. Moreover, while models project consistent changes in stratospheric transport in response to external forcings, trends derived from observations are inconclusive in some regions.
Large climate variability and the imperfect representation of transport processes in models are believed to be responsible for the lack of consistency in observed and modelled trends, but these uncertainties remain to be quantified. Because long-term trends are hard to constrain from observations of many trace gases, the models' ability to simulate transport is best assessed looking at the natural year-to-year variability. New datasets of satellite observations offer a unique opportunity for model evaluation.
Since 2010 there has not been a thorough evaluation of stratospheric transport in chemistry-climate models, even though several new generations of models have been produced. An updated evaluation based on high-quality satellite data will help identify the most important biases to address in order to improve projections and attribution capabilities in future model generations, and assess the progress made over the last 15 years. The timing of the work is optimal to inform the 2026 WMO/UNEP Scientific Assessment of Ozone Depletion.

How does the emerging cosmic web shape the galactic baryon cycle?
Team Leaders: Yannick Michael Bahé, EPFL, Switzerland, and Allison Noble, Arizona State University, USA
Session: *no meetings in 2024*
Scientific Rationale: Galaxies are shaped by the cosmic web of large-scale structure around them. The physics of this interaction remains poorly understood, but profound changes in gas flows to and from galaxies – their baryon cycle – are thought to play a key role. Star formation began to be suppressed in the densest parts of the cosmic web at redshifts between one and two, identifying this epoch as the critical one for gaining new insight. A systematic exploration of galaxies and the early cosmic web around them is therefore needed, and requires the combination of data from new space missions (especially Euclid and JWST) and ground-based facilities (ALMA, MOONS, LSST). The Team will realise this ambitious goal, bringing together astronomers with a highly complementary range of expertise and skills from the traditionally disconnected research areas of the cosmic web and the galactic baryon cycle. They will map gas properties in galaxies over a wide range of environments and will provide the first insight into environmental imprints on the baryon cycle from the cosmic web. This collaboration will therefore make a huge leap towards understanding how galaxies co-evolve with the Universe around them.

Active Region Evolution Under the Spotlight, with Unprecedented Coordinated High-Resolution Stereoscopic Observations and Numerical Simulations
Team Leader: Krzysztof Barczynski, PMOD/WRC, Switzerland
Session: *February 10–14, 2025*
Scientific Rationale: The evolution of active regions on the Sun is still an open issue. The Team aims to understand the evolution of an active region using coordinated observations from new-generation solar satellites, ground-based telescopes, and simulations. The Team will focus on three key scientific questions: (1) how does the coupling between the corona and underlying solar atmosphere evolve in active regions over different time scales? (2) how do small-scale features in the solar atmosphere affect the active region's evolution? (3) what mechanisms drive the plasma upflows at the border of the active region? To address these questions, the Team will use coordinated observations obtained with satellite observatories: Solar Orbiter, Interface Region Imaging Spectrograph (IRIS), Hinode, Solar Dynamics Observatory (SDO), a groundbased telescope: Daniel K. Inouye Solar Telescope (DKIST), and advanced numerical simulations.

Multiphase Outflows in Galaxies at Cosmic Noon
Team Leaders: Sirio Belli, University of Bologna, Italy, and Rebecca Davies, Swinburne University of Technology, Australia
Session: *March 24–28, 2025*
Scientific Rationale: Galaxy growth is regulated by many physical processes that cycle gas between galaxies and their surroundings. Outflows powered by supernovae and supermassive black holes are hypothesised to shut off star-formation by ejecting gas from galaxies. How-

ever, the total amount of mass and energy in outflows has long been poorly constrained owing to the difficulty of observing gas over a wide range of temperatures and densities. The James Webb Space Telescope (JWST) has revolutionised this field by making it possible for the first time to observe outflows of neutral gas from massive galaxies in the early Universe, revealing that this cooler phase may contain significantly more mass than the better understood ionised phase. The Team will combine space- and ground-based data to undertake the first direct comparison of ionised and neutral outflow properties for a large sample of distant galaxies. The Team focuses on the period of the Universe's history called Cosmic Noon, about three billion years after the Big Bang, when galaxies were reaching maturity and starting to transform into the quiescent systems that populate the Universe today. The project is based on a sample of galaxies with existing JWST observations, to which the Team will add 1) new JWST observations performed at a higher spectral resolution, and 2) ground-based observations from the optical telescopes MMT and Keck. In the future, the Team may also add submillimetre ALMA observations probing the molecular gas phase. The results will provide powerful new constraints on the total mass and energy ejected by outflows and will significantly improve the ability to test and refine outflow models.

EXploiting Precision AstroNomical Distance INdicators in the Gaia (EXPANDING) Universe (ISSI–ISSI Beijing Team)

Team Leader: Anupam Bhardwaj, Inter University Center for Astronomy and Astrophysics (IUCAA), Pune, India
Session: *no meeting in 2024*
Scientific Rationale: The fundamental method for determining distances to astrophysical objects is through the measurement of their geometric parallaxes. Distance determinations beyond these geometric methods rely on standard candles, which have known intrinsic luminosities. The absolute calibration of the luminosities of stellar standard candles forms the first rung of the cosmic distance ladder used to determine the Hubble constant – the expansion rate of the Universe. Currently, the Hubble constant values based on a variety of standard candles observed with the Hubble and James Webb space telescopes, are in an intriguing discord with the measurement from the Planck space mission. This so-called Hubble Tension points to new physics in the cosmological model and must be evaluated against all sources of measurement errors. One of the main systematic uncertainties is the absolute luminosity scale of stellar standard candles, which have not yet reached 1% accuracy despite unprecedented geometric distances of ~1.5 billion sources in the Gaia space mission data. This is mainly due to caveats associated with Gaia parallax offsets, lack of complementary multiband photometry and high-resolution spectroscopy, and highly debated effects of composition and age on the luminosities, among other uncertainties.
The Team aims to strategically address these shortcomings before the nominal five-year Gaia mission data release to achieve 1% calibration of stellar distance indicators. For this purpose, the Team is using state-of-the-art stellar evolution and pulsation models, multi-wavelength datasets from space- and ground-based facilities together with machine-learning approaches, leveraging the Team's competences and expertise in a multidisciplinary context. The projects will provide cross-investigation of 1% precise luminosity scales of a variety of stellar standard candles with high accuracy and fidelity to firmly rule out (or confirm) measurement uncertainties as the origin of the Hubble tension. These precise luminosity calibrations will be the primary resource for the astronomical distance determination in the era of space- and ground-based large observational facilities in the next decade.

Small-scale eruptions in the Sun (ISSI-ISSI Beijing Team)

Team Leaders: Jie Chen, National Astronomical Observatories of China, China & Robertus Erdelyi, University of Sheffiled, UK
Session: *no meeting in 2024*
Scientific Rationale: Small-scale eruptions are ubiquitous in the solar atmosphere. With different sizes and dominant temperatures, these eruptions are observed at different wavelengths and have been given various names, including spicules, macro-spicules, micro-jets, jets, X-ray bright-points, campfires, etc. These small-scale eruptions are often accompanied by or associated with small-scale dynamic solar magnetic phenomena. While they were first observed in the late 19th century, the knowledge of these eruptive phenomena has greatly improved in the last few decades. This was possible thanks to the parallel developments of MHD and plasma astrophysics theories, the improvement in computational modelling, and the advent of state-of-the-art observatories with broad wavelength coverage and high resolution in the spatial, spectral, and temporal domains. However, key details about the origin and impact of these phenomena in the heliosphere are still not understood. For example, what drives and sets the different scales of jets, how much energy and mass they can transport, and how they are related to the solar wind. The Team will address this problem using an unprecedented combination of multi-messenger space observations (SDO, IRIS, ASO-S, PSP, and Solar Orbiter), complemented by state-of-the-art numerical models and the highest resolution ground-based observations (e. g. DKIST, BBSO, SST, NVST, and AIMS), many of which have

only just become available. The multi-disciplinary Team is uniquely suited to addressing small-scale eruptions in the solar atmosphere, and we expect to make a significant contribution to the understanding of their underlying formation, transmission, and dissipation mechanism.

Small-scale magnetic flux ropes under the microscope with Parker Solar Probe and Solar Orbiter

Team Leaders: Iulia Chifu and Maria Madjarska, Max Planck Institute for Solar System, Germany
Session: *January 6–10, 2025*
Scientific Rationale: Coronal mass ejections (CMEs) have been intensively studied for several decades. More attention is given to the large energetic CMEs, as they may produce strong effects on Earth. CMEs are studied in both remote sensing and in-situ observations. On the Sun, images from telescopes on board different missions show CMEs that occur on all scales, including jets and mini-CMEs (seen in extreme-ultraviolet (EUV) and X-rays) and narrow-CMEs (in white-light images). The sources of the latter CMEs are believed to be small-scale magnetic flux ropes (SMFRs). Mini-filaments are the presumed observable proxy of these flux ropes. The energetics of the eruption of these SMFRs and their ability to escape into the heliosphere are poorly understood. The present fleet of space missions, including Parker Solar Probe (PSP), Solar Orbiter, Solar Dynamics Observatory (SDO), and Interface Region Imaging Spectrograph (IRIS) together with numerous ground-based observatories gives us an unprecedented opportunity to obtain a long-overdue understanding of the eruption and propagation of SMFRs in the solar corona and the heliosphere. The Team will use the advantage of the closer-than-ever orbits of the PSP and the ability of the Wide Field Imager (WISPR) telescope on board PSP to image the upper corona in unprecedented detail together with observations from the EUV imager and METIS coronagraph on board Solar Orbiter. The Team will combine observational and theoretical expertise to study SMFRs from their formation, eruption and evolution in the solar corona and into the interplanetary medium, employing multi-instrument data analysis and various modelling approaches.

Understanding the Onset of Solar Eruptions

Team Leaders: Georgios Chintzoglou, Lockheed Martin Solar & Astrophysics Laboratory and Tibor Török (US)
Session: *July 7–11, 2025*
Scientific Rationale: Despite intense research efforts over the past decades, the physical mechanisms that initiate large-scale solar eruptions such as flares and coronal mass ejections (CMEs) are still not well understood, which strongly hampers the ability to forecast their occurrence and, ultimately, their impact on Earth and other planets. Uncovering these mechanisms, therefore, remains one of the most significant and challenging tasks in solar and heliospheric physics. To achieve progress, the Team needs to (1) better understand the roles of key processes such as ideal magnetohydrodynamic (MHD) instabilities and magnetic reconnection and (2) unravel the contribution of the preceding slow rise phase, which entails a potential paradigm shift in our conception of the onset of solar eruptions. Upcoming missions will, for the first time, enable us to directly observe reconnection in the corona and study it in the whole chromosphere-to-corona region (rapid Doppler imaging in EUV with the MUlti-slit Solar Explorer [MUSE]; wide temperature range [full VUV] plasma diagnostics with the Extreme UltraViolet high-throughput Spectroscopic Telescope [EUVST] onboard Solar-C). Paired with the continuous advances in the numerical modelling of solar eruptions, this creates a timely opportunity for a concentrated effort to tackle these scientific tasks. The Team assembled world-leading observers and modellers to systematically address the most important open questions related to the onset of solar eruptions and to formulate strategies for making best use of the observational capabilities of upcoming missions such as MUSE and Solar-C.

Opening new avenues in identifying coherent structures and transport barriers in the magnetised solar plasma

Team Leaders: Suzana de Souza e Almeida Silva and Viktor Fedun, University of Sheffield, UK
Session: *30 June – July 4, 2025*
Scientific Rationale: Fundamental solar phenomena (e.g. dynamo, magnetic field reconnection, atmospheric heating, flares/CMEs, space weather) are directly linked to the plasma motion and magnetic field transport that can be quantified by Lagrangian Coherent Structures (LCS) which are specific surfaces that have the unique property of either pulling nearby fluid elements closer or pushing them away. LCS play a crucial role in minimising the stretching of fluid areas and encircling regions with extreme vorticity. Essentially, they act as transport barriers, i.e. important boundaries that control the movement of plasma within the fluid flow. The current state of the art in LCS identification that is well-developed for non-magnetised flows is, however, of limited applicability for solar/space plasmas. The creation of new methodologies for compressible and magnetised flows for identification of LCS in magnetic fields are essential to achieve breakthroughs in the investigation of solar/space plasma dynamics especially in the era of high-resolution space- and ground-based observations provided by, e.g. Hinode, Solar Orbiter, SUNRISE, IRIS, DKIST, SST. The project offers an

ideal opportunity to combine the complementary skills of participants in the theory of LCS, nonlinear flows, hydrodynamics, magnetohydrodynamics, numerical modelling of plasmas and solar observations to determine ways of implementing LCS methodologies for the analysis of magnetised flows in the solar atmosphere. The goals are to answer the following key solar science question: How can dynamical, coherent structures, which act as building blocks of solar plasma flows, be identified?

Energetic Particle Transport in Space Plasma Turbulence

Team Leaders: Frederic Effenberger, Ruhr-University Bochum, Germany and Eugene Engelbrecht, North West University, South Africa
Session: *March 3–7, 2025*
Scientific Rationale: A proper understanding of the transport of energetic charged particles in space plasmas, whether heliospheric or in other, broader, astrophysical contexts, requires insight into how such particles are affected by plasma turbulence. This is especially necessary in heliospheric scenarios, where accurate, and above all realistic, numerical particle transport models can play a significant role in the mitigation of the harmful effects of these particles on human endeavours in space. In the past, much insight has been gained from direct simulations of test particle interactions with synthetic turbulent magnetic fluctuations, particularly in terms of particle diffusion and drift coefficients. For most models, however, the synthetic turbulence did not reproduce many of the features of magnetic turbulence observed in the solar wind. This project aims to bring together experts in various fields, broadly centred on the study of plasma turbulence and comprised of specialists in theory, data analysis, and charged particle transport modelling. This will take advantage not only of recent advances in our understanding of space plasma turbulence thanks to careful analyses of in-situ spacecraft observations in the inner heliosphere (such as those performed by Parker Solar Probe and Solar Orbiter), but also of the latest developments in the numerical simulation of turbulence over multiple orders of magnitude in length scales. Simulations and data analyses pursued by the Team serve as inputs for the next generation of numerical test-particle models. This includes the effects of coherent features such as current sheets and flux ropes in the turbulence, which in turn will enable novel insights into how particle transport and acceleration are modified with regard to effective diffusion coefficients and non-diffusive propagation regimes. The results will be incorporated into existing particle transport models for heliospheric and astrophysical scenarios, with direct predictions for radiation signatures and validation with in-situ spacecraft particle observations.

1-100 keV Electrons in the Earth's Magnetosphere: Unique and Unpredictable?

Team Leaders: Natalia Ganjushkina and Michael Liemohn, University of Michigan, USA
Session: October 28 – November 1, 2024
Scientific Rationale: The focus is on compiling what is known and what is still unknown regarding the physics of plasma-sheet and inner magnetospheric 1-100 keV electrons and their precipitation into the ionosphere. While several studies, including recent machine-learning models, have quantified the hours-and-longer flux variations of these electrons, their most intense fluctuations occur on a time scale of minutes with strong local time (MLT)-dependence. Models cannot account for these large changes on smaller spatial and temporal scales. Furthermore, while we know the fundamental connections between plasma waves and keV-electron scattering, predicting when and how much precipitation will occur for any particular space weather event is difficult. That is, it has been very hard to find definite dependencies for the drivers of precipitation. This Team will conduct a thorough review of the state of knowledge about keV electrons to codify what is known, then use this to create a list of goals for achieving significant advancement on this topic.

A First Peek at the Galactic Center with JWST

Team Leaders: Daryl Haggard, Mc Gill University, Canada and Sebastiano von Fellenberg, Max-Planck Insitute for Radio Astronomy, Germany
Session: October 21–25, 2024
Scientific Rationale: The Team developed cutting-edge tools required to analyse never-before-collected James Webb Space Telescope mid-infrared observations of the supermassive black hole Sgr A* in the Galactic Centre. These observations are part of an accepted medium-sized proposal executed in April and September 2024, simultaneous with global radio observations by the Event Horizon Telescope, the Submillimeter Array, and the NRAO Very Large Array, as well as X-ray observations with the Chandra X-ray Observatory. The observations are helping to determine the origin of the variable infrared to X-ray emission of Sgr A* and constraining the electron acceleration in the accretion flow.

KHIWI: Kelvin-Helmholtz Instability Wave Investigation

Team Leader: Kyoung-Joo Hwang, Southwest Research Institute, USA
Session: October 28 – November 1, 2024
The near-Earth space serves as the most accessible laboratory for studying the interaction between the Sun and

a magnetised planet, providing insights into various heliospheric/astrophysicalsystems throughout the Universe. Two key physical processes that govern the Sun-Earth interaction are magnetic reconnection (RX) and the Kelvin-Helmholtz instability (KHI). The former is triggered by a large magnetic-field shear, while the latter is powered by a large flow-velocity shear. The understanding of the former has greatly advanced since the recently-launched MMS spacecraft with its high-resolution measurements, while the latter leaves room for comprehension. Recent studies revealed that KHI can lead to the onset of RX and vice versa. This highlights the close linkage between KHI and RX, the effects of which can propagate to the entire global system. For instance, Kelvin-Helmholtz waves (KHWs) and Kelvin-Helmholtz vortices (KHVs) can contribute to the magnetosphere-ionosphere coupling and the dawn-dusk magnetospheric asymmetry, and act as conduits not only for solar wind transport but also for the escape of energetic particles from Earth. However, diverse pathways via KHWs/KHVs in the Sun-Earth interaction remain elusive. The Team brings existing and new pieces of information together to bridge these important gaps in understanding the roles and impacts of KHI in the terrestrial environment, with implications for heliophysics and astronomy. Multi-spacecraft and groundbased observations, theory, and modelling of KHI/RX will advance our understanding of the coupled KHI/RX physics and predictive capabilities regarding the global response of Earth to various solar drivers.

Excitation and Dissipation of Kinetic-Scale Fluctuations in Space Plasmas

Team Leader: Kristopher Klein, University of Arizona, USA
Session: *March 24–28, 2025*
Scientific Rationale: this project will answer the science question: "How are kinetic-scale fluctuations excited and dissipated in space plasmas?" Kinetic-scale fluctuations play important roles in driving the behaviour of collisionless plasma systems such as those found in the solar wind or planetary magnetospheres. Exploiting the latest developments in space-plasma observations and numerical tools, the project achieves three objectives: First, the Team applies novel tools (including modern generalised solvers to the linear Vlasov-Maxwell dispersion relation and machine-learning methods) to evaluate measured high-resolution velocity distributions regarding their stability or instability against kinetic-scale fluctuations. Second, the Team combines the observation-driven linear-theory results with nonlinear kinetic plasma models such as particle-in-cell and quasilinear simulations. Third, the Team identifies and evaluate the global impact of kinetic-scale fluctuations on the evolution of space plasmas. This objective will allow to link the understanding of the excitation and dissipation of kinetic-scale fluctuations to the global behaviour of collisionless space plasma systems.

Physical Processes and Drivers of Particle Acceleration in the Heliospheric Tail As Seen Through ENAs and Interstellar Lyman-alpha Absorption

Team Leader: Marc Kornbleuth, Boston University, USA
Session: June 10–13, 2025
Scientific Rationale: The shape of the heliosphere is still a topic of great debate in the heliophysics community. Models suggest that the heliosphere may have either a long comet-like tail extending for thousands of au or a short tail with plasma flows in the shocked solar wind being diverted to two high latitude jets. Currently, the primary means of observing the heliotail are indirect: energetic neutral atoms (ENAs) and interstellar Lyman-alpha (Lyα) absorption. It is currently impossible to distinguish models of the tail of the heliosphere partially due to the source region of ENAs being shorter than the heliotail itself or due to a lack of appropriate global modelling and observations for Lyα to date. The Team will use the available measurements of ENAs, Lyα absorption spectra towards nearby stars, and different magnetohydrodynamic (MHD) models of the heliosphere, as well as different ENA and Lyα models in conjunction with a kinetic-fluid model to identify observational signatures related to potential turbulence and magnetic reconnection in the heliotail. Thus, the Team applies a new method of discerning physical phenomena in the heliotail through particle acceleration in turbulent regions, which extends viewing path lengths for ENAs. The Team compares the ENA and Lyα model results with present observations to investigate signatures for turbulence and reconnection in the heliotail. This study will set a foundation for the data interpretation of the upcoming IMAP mission that will extend the energy range for ENA measurement to probe deeper into the heliosphere.

Understanding ground magnetic disturbances due to field-aligned currents driven by magnetotail activity (ISSI-ISSI Beijing Team)

Team Leader: Vanina Lanabere, Swedish Institute of Space Physics IRF, Sweden
Session: November 25–29, 2024
The Team advances the understanding of the physical connections between the ionosphere and the magnetosphere using magnetotail–ionosphere–ground conjugate observations from past and present multi-point missions. Exploiting the 10-years overlap of large quantities of Swarm–THEMIS/MMS/Cluster–ground geomagnetic data the Team studies the connections between field-

aligned currents and ground magnetic perturbations during explosive processes in the terrestrial magnetotail. This observational study will be complemented with numerical simulations using the space weather modeling framework (SWMF) Geospace model. Specifically, the two main scientific questions to be addressed will be:
SQ1: How do Bursty Bulk Flows properties relate to the field-aligned current density at their ionospheric footprint? What is the response in Earth's ground magnetic field?
SQ2: What are the key parameters involved in the energy transfer between the ionosphere and the magnetosphere during magnetotail activity that drive localised field-aligned currents?

Advancing Titan's Atmospheric Chemistry Knowledge (ATACK)

Team Leaders: Panayotis Lavvas, Université de Reims Champagne-Ardenne, and Athena Coustenis, Paris-Meudon Observatory, France
Session: *February 10–14, 2025*
Scientific Rationale: The purpose is to significantly enhance the scientific understanding of the chemistry in Titan's dense nitrogen-dominated atmosphere. An icy moon with unique physical processes, Titan offers major opportunities to study prebiotic chemistry. Titan was explored by the Cassini-Huygens mission (2004-2017), is currently observed with JWST and ground-based observatories (e.g. ALMA, IRTF, etc), and will be investigated in the near future by the Dragonfly in-situ mission to launch in 2028. The goal is to investigate the formation of complex species of astrobiological interest in Titan's atmosphere and their potential detectability, as well as the role of catalytic processes on the surface of haze particles. The timely results will assist both in the interpretation of existing data and in the preparation of future measurements.

Multi-scale Understanding of Surface-Exosphere Connections (MUSEC)

Team Leaders: Liam Morrissey, Memorial University, Canada and Sébastien Verkercke, LATMOS/CNRS, Sorbonne Université, France
Session: *February 24–28, 2025*
Scientific Rationale: The goal is to update the boundary conditions for models of exospheres in direct contact with planetary surfaces using atomistic and granular simulations. The Team investigates using a multi-scale approach to improve model predictions or key species in the exospheres of airless bodies such as the Moon and Mercury. The work creates higher-fidelity physical models of gas trapping, diffusion, and emission within the first top few centimeters of regolith. The outputs assist efforts to use existing and/or future measurements to characterise and better understand the composition and evolution of the exospheres on airless bodies such as the Moon and Mercury.
Specifically, the Team uses modelling on different dimensional scales to study the underlying physics and energetics of key ejection processes on the surfaces of airless bodies and how they affect their predicted global exosphere. Here, the Team uses molecular dynamics (MD) simulations to study these processes on the atomistic scale as a function of surface composition, surface energetics (bond state and crystallinity) and emitted atom type. The scientists incorporate these MD-derived parameters into granular-scale models to quantify the effect of the planetary regolith, retention, and emission processes and then incorporate these granular-scale results into global exosphere formation model to quantify the effects of gas-surface interactions on the predicted exospheres of the Moon and Mercury.

The search for the most chemically and physically pristine material of the early Solar System

Team Leader: Raphael Marschall, Observatoire de la Côte d'Azur, France
Session: *July 14–18, 2025*
Scientific Rationale: The first solid bodies forming in a protoplanetary disc, so-called planetesimals, are key building blocks of planets. Asteroids, comets, and other small body populations are generally considered to be leftover planetesimals. As such, they are believed to have preserved crucial information about the planet-forming era. However, recent studies suggest that small bodies may have undergone more significant processing than previously assumed. If these findings hold, it becomes crucial to identify which properties were conserved over time, i.e., are pristine, thus directly constraining the conditions at the beginning of planet formation and which have evolved. Furthermore, identifying where we might still find the most physicochemically pristine material is important because a) such material would directly inform protoplanetary disc properties, b) it will link Solar System science to the astrophysics of planet formation in general, and c) ongoing planning for sample return missions relies on this context. This Team will assess 1) to which degree the physicochemical properties of small bodies have been altered since formation, 2) where the most pristine material may still be found today, 3) what these constraints tell us about the protoplanetary disc, and 4) which present-day objects represent the planetary building blocks most. While the Team's focus is primarily on our Solar System, investigating planet formation from small bodies goes beyond Solar System research. It will

inform studies of protoplanetary discs, planet-forming regions, and exoplanets beyond our system where this information is not available.

The Impact of Solar Flare Irradiance on the Earth's Ionosphere

Team Leaders: Ryan Milligan, Queen's University Belfast, UK, and Louise Harra, PMOD, World Radiation Center, Switzerland
Session: *January 20–24, 2025*
Scientific Rationale: Variations in solar irradiance are known to influence the composition and dynamics of Earth's atmosphere, which can impact modern technologies such as radio communication, GPS accuracy, and satellite drag. However, the consequence of increases in solar radiation during solar flares on Earth's ionosphere is still not fully understood. The Team comprises experts in solar flares and ionospheric aeronomy, two interconnected areas that have been studied quite separately historically. The Team determines how the ionosphere responds to flares of different magnitudes, spectral properties, locations, at different times of year and solar cycle. The studies help to understand how and why ionisation rates, particle temperatures and densities vary during ionospheric disturbances caused by solar flares. To comprehensively study this solar-terrestrial connection, the Team combines solar flare observations from a range of space-borne instruments, as well as spectral irradiance and radiative hydrodynamic models, with ionospheric measurements and theoretical predictions. The findings will piece together the physical mechanisms responsible for producing geoeffective emission during flares and the impact those emissions have on various layers of Earth's ionosphere. Obtaining a comprehensive understanding of the relevant physical processes, and improving our predictive capability, are increasingly important in space weather research.

INFO-QBO: INvestigating the Feedback from Ozone in the Quasi-Biennial Oscillation

Team Leaders: Alison Donna Ming, University of Cambridge, UK, and Clara Orbe, NASA Goddard Institute for Space Studies, US
Session: *March 31 – April 4, 2025*
Scientific Rationale: The Quasi-Biennial Oscillation (QBO) is the main source of year-to-year variability in the tropical stratosphere with far reaching teleconnections to other parts of the climate system from extratropical variability to tropical convection. Historically it has exhibited a remarkably regular period of ~28 months, but recent, unprecedented disruptions indicate this periodicity may be fragile. It has long been recognised that radiative and dynamical feedbacks from stratospheric ozone can impact the QBO but a clear mechanistic description is still lacking. Moreover, simulating a realistic QBO in climate models is still challenging and many numerical models only include a simplified version by nudging their tropical winds to observations. The ozone feedback on the QBO has been examined mainly in the context of recent historical climate, with one recent study on the future changes in response to an increase in carbon dioxide. A review of the literature reveals large uncertainties in the magnitude of the ozone feedback on both the QBO period and amplitude. The aim of this team is to use high-resolution satellite observations of tropical stratospheric temperature and composition to assess the representation of ozone-QBO feedbacks and associated dynamical processes in these new model runs.
The outcome of this activity will improve the understanding of the interactions between composition and the QBO, contributing to improving the fidelity of future model projections of the QBO and its teleconnections.

Climate Impacts of Stratospheric Water Vapour

Team Leaders: Felix Plöger and Christian Rolf, Forschungszentrum Jülich GmbH Germany
Session: *May 19–23, 2025*
Scientific Rationale: Water vapour variations in the extratropical upper troposphere and lower stratosphere (UTLS) have been shown to crucially affect atmospheric circulation and climate. For example, climate feedbacks due to stratospheric water vapour are dominated by trends in this region. However, UTLS water vapour has not been a focus of past research activities and progress in understanding these important climate impacts has been particularly challenging, because satellite and in-situ observations have large uncertainties and atmospheric models exhibit their largest biases in the UTLS. The Team includes experts from the different fields of satellite and in-situ observations, process and climate modelling, dynamics and process understanding to make significant progress in understanding, observing and simulating water vapour in the UTLS. The Team: (i) explores capabilities of existing satellite and in-situ datasets in the UTLS, (ii) assesses the representation of stratospheric water vapour in climate and weather forecast models, (iii) estimates water vapour trends in the UTLS and impacts on circulation, climate and predictability, and (iv) identifies future needs for observations and models.

International Teams approved in 2024

The nature and fate of obscured massive galaxies: from the HST-dark galaxies to the JWST red dots

Team Leaders: Giulia Rodighiero, UNiversity of Padova, and Carlotta Gruppioni, INAF - Osservatorio Astronomico di Bologna, Italy

Session: *February 17–21, 2025*

Scientific Rationale: The Team intends to gather a number of experts in observational as well as in theoretical extragalactic astrophysics, involved in the exploitation and development of the best currently available data and models in the field of early massive galaxy formation, obscured star formation and AGN activity, dust production and evolution at early epochs. The goal is to capitalise on the unique opportunity represented by the huge increase in superb data quality and availability during the operation of the James Webb space Telescope (JWST), to obtain a physical understanding of the stellar mass assembly and dust formation processes in high-redshift galaxies. The Team meetings provide a very effective way to organise this work, enabling the studies to be progressed rapidly and in a timely manner by putting together the main experts in the field tackling the problem from different perspectives (either theoretical or observational, the latter using different techniques and wavelength data). It will also establish the basis for the preparation of new observing proposals and of publications detailing the project's development.

What must we learn to make accurate space-weather predictions?

Team Leaders: Andrey Samsonov, University College London, UK, and Ute Amerstorfer, GeoSphere Austria

Session: *May 12–16, 2025*

Solar wind parameters and their variations greatly influence magnetospheric activity and determine space weather conditions in the magnetosphere and on the ground. The two most important parameters determining the solar wind energy penetrating the magnetosphere are the solar wind velocity and interplanetary magnetic field (IMF) Bz. The strongest magnetospheric disturbances are caused by interplanetary coronal mass ejections (ICMEs) and their embedded magnetic fields, which can often be described as magnetic flux ropes (MFRs). In many cases, it is not fully clear what IMF features lead to the largest disturbances in the magnetosphere. Is the most crucial the duration of the negative Bz interval, the minimum Bz, or some integrated electric field that characterises the solar wind energy flux? Which magnetic structures are more geoeffective: The highly fluctuating ones, where large negative Bz alternates with positive Bz, or sustained intervals with moderately negative Bz? We will use solar wind and ICME models to simulate different IMF structures. These numerical results as well as spacecraft data at L1 will be used systematically as input for global magnetospheric simulations. In this way, we can study the response of the magnetosphere to different IMF configurations. Our results will be evaluated and validated with spacecraft data from heliospheric missions, geomagnetic indices, and other global magnetospheric parameters. The project brings together experts in solar wind, ICME, and magnetospheric research. The results contribute to a better understanding of the geoeffectiveness of IMF disturbances and, thus, will lead to an advance in space weather predictions.

Snow/Sea Ice Emission and Backscatter Modelling

Team Leaders: Melody Sandells, Northumbria University UK, and Christian Mätzler, University of Bern, Switzerland

Session: *January 6–10, 2025*

This Team attempts to address the long-standing question on how to represent snow and ice surfaces efficiently in coupled data assimilation frameworks for numerical weather prediction (NWP), and for better monitoring of polar regions.

Models for snow emission and backscatter have proven successful at long wavelengths, but it remains a challenge to have a physically consistent model able to perform well across a wide range of wavelengths. Development of a reference-quality model for ocean surface emissivity and backscatter from the microwave to the infrared was successfully achieved. That model was named PARMIO (Passive Active Reference Microwave Infrared Ocean). This activity will develop similar capability for snow and sea ice.

Bringing PASSAGEers together from around the world to solve the Epoch of Reionization

Team Leaders: Claudia Scarlata, University of Minnesota, USA and Matthew Hayes, Stockholm University, Sweden

Session: *January 20–24, 2025*

The goal is to understand the Universe's reionisation history using data from 57 independent fields observed by the JWST PASSAGE survey. The exploitation of these data requires a reliable catalogue of emission-line galaxies. The catalogue will include thousands of galaxies with redshifts and emission-line measurements over most of the age of the Universe. The catalogue, with an associated publication, will be released to the community. The primary scientific outcomes of the project will be the constraint of the z>8 galaxy luminosity function, the measure of the Lyman-alpha properties of these objects and ultimately the measure of the Universe's neutral fraction. Team members will also pursue additional science projects related to the formation and evolution of galaxies, taking advantage of the vast sample with spatially resolved information, which is a unique feature of the

PASSAGE survey.

AsteroSHOP: large Spectroscopic surveys HOmogenisation Program

Team Leader: Guillaume Thomas, Instituto de Astrofísica de Canarias IAC, Spain
Session: *February 3–7, 2025*
Scientific Rationale: In modern Galactic astronomy, stellar spectroscopy has a pivotal role in complementing large photometric and astrometric surveys, such as Gaia, PLATO and TESS. Spectroscopic observations provide crucial data on stellar parameters, chemical compositions, and radial velocities, enabling deeper insights into the chemical evolution and chemo-dynamical mechanisms of the Milky Way and its satellites. Several large spectroscopic surveys have already provided data for millions of stars, with many more underway, promising to significantly expand our understanding of the formation and the evolution of our Galactic environment. Despite the wealth of data from these surveys, systematic differences in derived spectroscopic parameters raise challenges. Efforts to harmonise these surveys onto a common scale are essential to maximise their scientific legacy. Machine learning techniques offer promising avenues for homogenising spectroscopic surveys on the same base, but they require addressing issues such as parameter space coverage of the training set and the compatibility of different survey methodologies. Additionally, the creation of benchmark catalogues and the development of common metrics are critical steps in evaluating and improving homogenisation methods. The project brings together experts with different backgrounds to tackle these challenges collaboratively. Through discussions and collaborative efforts, the Team aims to establish a comprehensive understanding of the homogenisation process and develop new methodologies to ensure the compatibility and accuracy of spectroscopic surveys. By defining the applicability domain of homogenisation methods and developing common metrics, the project aims to provide valuable guidance for future spectroscopic surveys, maximising their scientific impact and ensuring their seamless integration with other surveys.

Quantifying Space Weather Impacts caused by Extreme Solar Energetic Particle Events

Team Leaders: Simon Thomas, ESSP-SAS Spain and Stephanie Yardley, Northumbria University, UK
Session: *June 30 – July 4, 2025*
Scientific Rationale: Space weather effects near Earth and in planetary environments are driven by intense flashes of radiation, known as solar flares and large eruptions of plasma and magnetic field, known as coronal mass ejections (CMEs) from the million-degree atmosphere of the Sun and other stars. Magnetic reconnection processes during solar flares and shocks driven by CMEs can accelerate particles (mainly protons) to very high energies (up to GeV). Such high-energy particles, known as solar energetic particles (SEPs), pose a severe radiation risk for spaceflight and aviation, and a significant threat to technological assets in space and on the ground. SEPs have also been found to influence the atmospheric chemistry and electricity at Earth and other planets. Understanding the hazardous environment caused by SEP events and predicting their occurrence is becoming increasingly important in light of upcoming, long-term human space exploration missions planned to travel to the Moon and Mars. To track and forecast SEPs, recently launched missions in the inner heliosphere, such as Solar Orbiter (SolO), Parker Solar Probe (PSP), JUICE and BepiColombo, now include energetic particle detectors onboard. Novel, state-of-the-art 3-dimensional solar wind models are being developed to forecast SEP fluences throughout the inner heliosphere, along with atmospheric radiation dosage models for the aviation industry. This Team brings together research across multiple disciplines to quantify the influences and risks intense SEP events can have on Earth, planetary bodies, human life and technology.

Magnetosheath structures as seen by spacecraft observations and numerical simulations

Team Leader: Martin Volwerk, Austrian Academy of Sciences, Austria
Session: *March 10–14, 2025*
Scientific Rationale: The interaction of the solar wind with a planetary body results in the creation of a bow shock, where the super-magnetosonic wind is decelerated, compressed and heated. The magnetoplasma then flows around the planet in the magnetosheath, a region that is highly dynamical, with enough energy to originate various plasma wave modes and structures. Some of these wave modes find their origin in the upstream solar wind, e.g., through upstream ion pick-up (mass-loading). The energisation of the mass-loaded plasma, when it crosses the quasi-perpendicular bow shock (where the interplanetary magnetic field direction is near-perpendicular to the bow shock normal), can lead to the creation of mirror modes in the magnetosheath, whose behaviour is a source of information about energy conversion and plasma wave diffusion from the solar wind to the magnetosphere. In the case of the quasi-parallel bow shock (where the angle between the IMF and the shock normal is less than 45 degrees), downstream localised dynamic pressure enhancements, known as magnetosheath jets, can be formed. These jets can again be the source of other plasma waves in the magnetosheath and have an impact on the magnetopause and magnetosphere. In-

terestingly, these two structures are sometimes seen simultaneously, begging the question if and how they are related.

Precipitation of Energetic Particles from Magnetosphere and Their Effects on the Atmosphere

Team Leaders: Dedong Wang, Deutsches GeoForschungs-Zentrum GFZ, Germany, and Chao Yu, Beijing University, China
Session: September 30 – October 4, 2024
Scientific Rationale: Energetic particles in the magnetosphere can precipitate into the atmosphere as a result of wave-particle interactions, Coulomb scattering, and field line curvature scattering. The collisions between the precipitated energetic particles and neutral particles in the atmosphere release photons and form auroras. Precipitated energetic electrons contribute to the presence of nitric oxide (NOx) in the upper atmosphere, influencing ozone levels, temperatures, and wind patterns. Geomagnetic activity has been incorporated into climate models for the first time, reflecting its role in atmospheric dynamics. However, uncertainties remain regarding the accuracy of data on atmospheric ionisation rates derived from precipitated electron fluxes, which could affect model predictions. A recent study revealed that there is or are missing precipitation mechanism(s) of energetic electrons. It can be due to the waves or other mechanisms not taken into account. On the other hand, the role of electromagnetic ion cyclotron waves in causing the loss of energetic electrons is still under debate, especially about which energies of electrons are affected significantly by these waves.
In this project, using methods of satellite observation, theoretical analysis and modelling, our team will unveil the mysterious missing precipitation mechanism(s) and shed light on the question under debate. We will also quantify the consequent effects on the atmosphere and carefully validate the simulation results against satellite observations.

Multi-scale Variability in Solar and Stellar Magnetic Cycles

Team Leader: Teimuraz Zaqarashvili, University of Graz, Austria
Session: *no meetings in 2024*
Scientific Rationale: The Team is composed of experts who will identify the current knowledge of magnetic field generation in the Sun and Sun-like stars and establish a scientific collaboration to make breakthroughs in the understanding of this process. Their expertise combines skills in theory, numerical simulations, and ground- and space-based observations. The Team focuses on three main points: 1) Magnetic activity in the Sun and stars shows cyclic variations over different time scales. The Team aims to discuss how the properties of the activity cycles change along with stellar evolution; 2) The mechanism for the generation of cycles in solar/stellar magnetic activity is a dynamo. Some progress has been made on simulating solar cycle properties, but many uncertainties still remain. Solar dynamo models are still lacking the simulation of longitude-dependent cycle features like the spatio-temporal distribution of active regions at the surface. 3) Different types of stellar dynamo require different configurations, which may change throughout stellar evolution. Thus stellar dynamos can shed light on solar dynamo models. Properties of magnetic cycles, varying during stellar evolution, can be studied through suitable stellar samples. This will provide information on the past and the future of our Sun. The main expected outcome of the project is to share knowledge and to establish collaboration between solar and stellar communities working on magnetic activity/cycles, and to make crucial progress on theoretical descriptions of dynamo theory by understanding the interaction of magnetic fields with turbulent flows.

Johannes Geiss Fellow

Exploring Exoplanets and Brown Dwarfs: A Conversation with Johannes Geiss Fellow Michael Meyer

Watch the full interview with Prof. Michael Meyer and explore other discussions with leading scientists on ISSIcast: https://www.issibern.ch/outreach/issicast/

As part of ISSI's ongoing ISSIcast interview series, Science Communication Specialist Fabio Crameri sat down with Prof. Michael Meyer from the University of Michigan. Being a leading astrophysicist, Michael shared insights into his research on exoplanets, brown dwarfs, and the future of space exploration, offering a fascinating glimpse into the evolution of planetary systems and the search for habitable worlds.

What inspired you to pursue astrophysics?

I was deeply influenced by watching "Cosmos" by Carl Sagan as a young student. It sparked my curiosity about the Universe and led me on a path to studying astrophysics. I've always been fascinated by space exploration and the possibility of discovering new worlds. In middle school, I began to explore how I could contribute to this field, which eventually led me to my current research in planetary formation and exoplanet characterisation.

Why are brown dwarfs so interesting for astronomers?

Brown dwarfs are an intriguing middle ground between stars and planets. Unlike stars, they don't sustain hydrogen fusion, yet they share many characteristics with both planetary bodies and stellar objects. They form similarly to stars but lack the necessary mass to initiate full nuclear fusion. Studying them helps us understand star formation and planetary evolution as part of a continuous process. Additionally, brown dwarfs provide a natural laboratory to examine atmospheric properties and compositions in ways that can inform our study of exoplanets.

The Johannes Geiss Fellowship (JGF) is established to attract to ISSI – for limited duration visits – international scientists of stature, who can make demonstrable contributions to the ISSI mission and increase ISSI's stature by their presence and by doing so will honour Johannes Geiss for his founding of ISSI and his contributions to ISSI, and for his many contributions to a broad range of space science disciplines.

How do new telescopes advance our understanding of exoplanets?

Recent breakthroughs with the James Webb Space Telescope (JWST) have allowed us to explore exoplanetary atmospheres in unprecedented detail, revealing complex molecules and climate patterns that hint at the diversity of planetary systems. In the coming years, the Extremely Large Telescope (ELT) will further revolutionise our ability to directly image small, rocky planets around nearby stars, bringing us closer to understanding habitability beyond Earth. Combining the high spectral and spatial resolution of ground-based telescopes with space-based observatories will allow for complementary investigations, paving the way for future discoveries in astrobiology and planetary science.

What was your experience like as a Johannes Geiss Fellow at ISSI?

It was a truly rewarding experience. ISSI provided a quiet and focused environment where I could dedicate uninterrupted time to research. I also had the opportunity to collaborate with colleagues across Switzerland, engaging in stimulating discussions on exoplanet science and planetary system evolution. The setting allowed me to complete a significant portion of a research paper, which I submitted during my stay. Additionally, my time in Bern gave me a chance to explore the city's cultural and historical landmarks, from its beautiful old town to the newly developed bear park, which I enjoyed visiting with my children.

Visiting Scientists

The ISSI Visiting Scientist programme enables short-duration visits to ISSI to conduct research based on data from space-based observatories or space missions. The programme is open to all scientists, regardless of career stage, nationality or institutional affiliation. Small groups of two or three individuals, who would like to meet at ISSI to pursue collaborative work in space science or Earth observation, are also welcome to apply.
Applications can be submitted four times a year (March 1, June 1, September 1, December 1).
The results of this research are to be published as books or in major scientific journals, with appropriate acknowledgment to ISSI.

The following Visiting Scientists have worked at ISSI in the course of the 29th year:

Sudip Bhattacharyya, TIFR Mumbai, India, working period: 24.6.-12.7.2024

Eric Gaidos, University of Hawai'i, Mãnoa, Honolulu, working period: 20.5.-10.6.2024

Duncan Galloway, Monash University, Melbourne, Australia, working period: 3.-22.11.2024

Gozaliasl Ghassem, University of Finland, Finland, working period: 3.-24.8.2024

Octavio Guilera, Universidad Nacional de La Plata, La Plata, Argentina, working period: 17.2.-27.3.2024

Peter Hoppe, Max-Planck-Institut für Chemie, Mainz, Germany, working period: 29.4.-8.5.2024

Raluca Ilie, University of Illinois, USA, working period: 10.-30.11.2024

Immanuel Jebaraj, University of Turku, Finland, working period: 1.7.–10.8.2024

Vladimir Krasnosselskikh, LPCEE - CNRS, Orléans, France, working period: 30.6.–6.4.2024

Sarah Leslie, Leiden University, Belgium, working period: 28.4.- 9.5.2024

Zhaosheng Li, Nanjing University, China, working period: 24.-30.11.2024

Charles Lineweaver, Australian National University, working period: 5.-20.4.2024

Michael Meyer, Johannes Geiss Fellow 2024, working period: 24.6.-24.7.2024

René Šprňa, Institute of Physics, Silesian University in Opava, Czech Republic, working period: 29.9.–2.10.2024

Ilya Usoskin, University of Oulu, Finland, working periods: 20.5.–16.6.2024

Peter Zeidler, Space Telescope Science Institute, USA, working period: 8.-18.9.2024

Game Changers Online Seminars

Starting in the summer of 2020, the International Space Science Institute has organised the weekly on-line seminar series called "Game Changers". After six series of weekly talks on the themes of "Missions that Changed the Game in Solar System, Astrophysics and Earth Sciences", "Ideas and Findings about the Solar System, the Universe and our Terrestrial Environment","Habitability – From Cosmic to Microbial Scales", "Viewing Earth from Space – the Changing Environment and Climate of our Planet", and "Captivating Cosmology: From the Big Bang to Tomorrow" and the topic "Space Environmental Hazards: Mitigation and Prediction", the webinar series continues on a monthly basis.

ISSI has continued its series of webinar talks that have become known as the **Game Changers Online Seminars** with speakers from all over the world.
The webinars were recorded and are available at www.issibern.ch where upcoming talks are also advertised. Between roughly 100 and 200 participants have attended the live webinars, many as loyal participants throughout the series.

Exoplanet Atmospheric Spectroscopy in the Era of JWST" with David Sing (Johns Hopkins University, USA) – 25 January 2024

The Digital Twin Earth - Webinar with Peter Bauer (ECMWF, Germany) – 29 February 2024

The Population of Infant Black Holes in the Early Universe Revealed by JWST with Roberto Maiolino (Cambridge University, UK) – 21 March 2024

100th Game Changers Webinar with Tilman Spohn (DLR, Germany) – 25 April 2024

From OSIRIS-REx to OSIRIS APEX: Mission Results and Future Exploration with Amy Simon (NASA GSFC, USA) – 30 May 2024

Eruptive Events on the Sun – from Small to Large scale with Louise Harra (PMOD, Davos Switzerland) – 20 June 2024

Seeing the Unseen – Accurate and Inclusive Colour Scales in Space Science with Fabio Crameri (ISSI, Switzerland) – 5 September 2024

How to See the Unseen: Learning about the Geometry of the Emitting Region in Accreting Black Holes and Neutron Stars using X-ray Polarimetry
with Juri Poutanen (University of Turku, Finland) – 25 September 2024

Plasma Acceleration in Near-Earth Space with Vassilis Angelopoulos (UCLA, USA) – 24 October 2024

The Rise of Artificial Intelligence (AI) for Space Applications with Pierre-Philippe Mathieu (ESA, Italy) – 5 December 2024

The public event and panel discussion attracted many visitors

Cosmic Beginnings

ISSI hosted a highly anticipated public event on March 14 2024 at the University of Bern, drawing significant local and international interest. Centred around the revolutionary observations of the James Webb Space Telescope (JWST) – one of the most ambitious scientific experiments of the 21st century – the event brought cutting-edge cosmological science to the public in an engaging and accessible format.

The evening featured captivating lectures by Susan Kassin (Space Telescope Science Institute) and Pascal Oesch (University of Geneva), offering insights into JWST's groundbreaking discoveries about the Universe's first billion years. A thought-provoking panel discussion followed, featuring international experts, including Jane Rigby (NASA GSFC), Alice Shapley (UCLA), and Willy Benz (University of Bern), who addressed fundamental questions about the origins of stars, galaxies, and the evolving cosmological framework.

The event fostered meaningful engagement between the public and scientists. One highlight was an inspiring exchange between Susan Kassin and a teenage attendee aspiring to study space science. The lively reception that concluded the event provided further opportunities for informal discussions, with participants praising the unique chance to interact with leading experts in a welcoming environment.

With a vibrant turnout and active audience participation, the event exemplified ISSI's commitment to fostering scientific dialogue and public outreach, enhancing its reputation as a hub for international collaboration and knowledge-sharing.

Watch the full event recording here: https://www.issibern.ch/outreach/special-events/

ISSI Shines at IAU GA 2024 in Cape Town

The world of astronomy gathered in South Africa for the first time at the IAU General Assembly held in August 2024. ISSI, passionate about space science research and fostering interdisciplinary collaboration, made an unforgettable appearance.

ISSI representatives Antonella Nota and Fabio Crameri connected with the global astronomical community in Cape Town. The two ISSI booths, one on-site and one online, welcomed scientists and new faces eager to learn about ISSI's unique opportunities. Visitors were delighted by ISSI goodies, including stylish lanyards, pens, and knowledge-packed hardcover books from the SSSI, Space Science Series of ISSI. Delicious Swiss chocolate was a crowd favourite.

ISSI representatives Antonella Nota and Fabio Crameri talking with IAU visitors.

The booth offered an immersive experience, showcasing the ISSI facility in Bern and engaging ISSIcast videos. Its vibrant atmosphere highlighted the fantastic work of the event organisers, led by Kevin Govender. The General Assembly's organisation prioritised placing Africa's space science and scientists at the heart of astronomy, connecting space scientists as envisioned by Govender.

Among the 3,000+ participants, the booth welcomed Nomalungela Gina, the Deputy Minister of South Africa's Science and Innovation Department, and inspired Capetonian schoolchildren. ISSI's presence at the IAU General Assembly 2024 celebrated its mission to connect space scientists globally, fostering collaboration.

Lastly, our heartfelt congratulations go to Prof. Dr Willy Benz, chair of the ISSI Board of Trustees, for becoming IAU president. To the future of the IAU and the 2027 General Assembly in Rome, Italy!

Fabio Crameri

The Association Pro ISSI

The Association Pro ISSI was founded in 1994 under Swiss law with the goals to create a Space Science Institute in Switzerland, and to communicate the fascinating results of space sciences to the public. With the creation of the Foundation ISSI in 1995, the first objective was reached. Today, Pro ISSI focuses on providing outreach activities for ISSI. It forms a bridge between ISSI and the general public via its members, who are mostly laypeople but often have links to universities, industry, politics, and administration. The Association organises public events, publishes the SPATIUM magazine, and supports further ISSI outreach activities. The Association Pro ISSI, which consists presently of 113 members, also meets once per year for a general assembly.

In 2024 a number of changes occurred in Pro ISSI. The first one regards the Board of Pro ISSI: after five years as vice-president and president of the association, Prof. Dr Christoph Mordasini was succeeded in November 2024 by Prof. Dr Michele Weber, who is the director of the Laboratory of High Energy Physics of the University of Bern. Dr Anuschka Pauluhn and PD Dr Andreas Verdun were succeeded as editors of SPATIUM by Dr Fabio Crameri, who is the science communication specialist at ISSI. PD Dr Martin Rubin and Prof. Dr Jonas Kühn continue to serve as vice-president and treasurer, respectively, while Dr Oliver Müller (EPFL) finished his term as secretary at the end of 2024.

Events

As in past years, in 2024 three in-person events were (co-)organised. Some of them followed the traditional format of an individual public lecture of an outstanding international scientist at the ISSI premises. This has been the format of the past Pro ISSI events in the last years. However, some other events were organised with distinctly new formats, implementing in this way recommendations identified in the October 2023 Pro ISSI strategy meeting to increase the attractiveness of the Pro ISSI association.

The first event with a new format was the large podium event entitled "Cosmic beginnings: unveiling the First Billion Years in the History of the Universe with Revolutionary New JWST Observations" that took place on 14 March 2024. Co-organised by a number of partners (in particular ISSI and Pro ISSI), it implemented the recommendations to better exploit synergies between ISSI and Pro ISSI through the involvement in outreach of some of the excellent scientists passing through ISSI (here the ISSI Breakthrough Workshop), and to diversify the activities including large radiating events. Taking place in the large lecture hall of the Institute for Exact Sciences of the University of Bern, this large event had been advertised over multiple channels and attracted a very high number of attendees. It included excellent presentations from Dr Susan Kassin (Space Telescope Science Institute, Baltimore, USA) and Prof. Pascal Oesch (University of Geneva, Switzerland), a panel discussion with eminent scientists, and a reception.

The second event, taking place on 24 April 2024, was held in the traditional format at the ISSI premises. In his excellent and well-attended talk, Dr Michael Biermann from the renowned Astronomisches Recheninstititute in Heidelberg (Germany) gave a fascinating insight into the science enabled by the Gaia Satellite, which is ESA's astrometric space observatory that is revolutionising our view of the Milky Way.

The third event was a combination of traditional and new formats and took place on 5 and 6 November 2024. This large event was co-organised by Pro ISSI and the Center for Space and Habitability of the University of Bern, thereby implementing the strategic recommendation to intensify the communication and collaboration with related associations and organisations. Under the umbrella of the "Bernese Space Days", this event included public lectures by Dr Athena Coustenis (LESIA, Paris) and by Prof. Dr Thomas Zurbuchen (ETHZ) on "Whispers from other worlds – NASA's search for life in the cosmos", both held in the large lecture hall of the Institute for Exact Sciences, while the third element, following the traditional format at the ISSI premises, was the talk by Prof. Dr Michael Meyer (University of Michigan and ISSI Johannes Geiss Fellow 2024), entitled "Origins of Stars, Planets, and Life: Highlights from Early Science with JWST". All these elements were very well attended. Besides these public parts, the event also included a VIP lunch including the three aforementioned speakers, the French ambassador Marion Paradas, Nobel prize winner Prof. Dr Didier Queloz, several high-ranking representatives of the University of Bern, communication experts of the involved units, and the ISSI and Pro ISSI directorates. 6 November 2024 was also the date of the annual general assembly of the Association Pro ISSI.

To increase the international reach, the events at ISSI were also live-streamed online. They are also recorded and available via the ISSI homepage and via YouTube. The in-person events and in particular the well-known receptions make it possible to have ample personal interactions between Pro ISSI members and the speakers.

SPATIUM

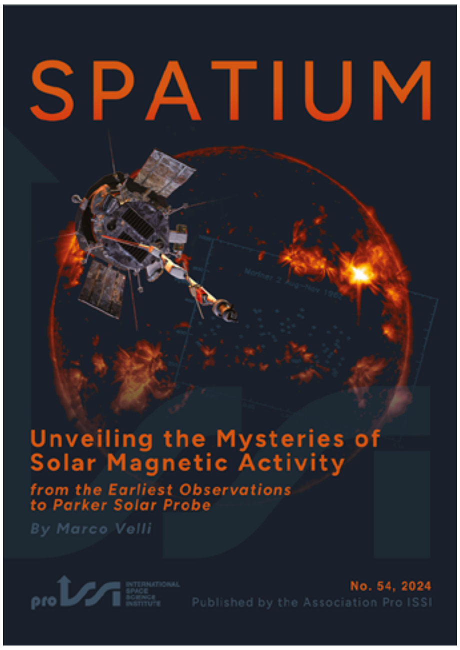
The association's magazine SPATIUM elaborates on selected Pro ISSI lectures, presenting them in a professional and visually attracting form. It usually appears twice per year. During the reporting period, two SPATIA were published:
Volume 54 entitled "Unveiling the Mysteries of Solar Magnetic Activity: from the Earliest Observations to Parker Solar Probe" authored by Prof. Dr Marco Velli (UCLA) and edited by Dr Anuschka Pauluhn and PD Dr Andreas Verdun. This volume is based on the 2023 Pro ISSI lecture by Prof. Dr Marco Velli during his Johannes Geiss Fellowship. This SPATIUM was published in February 2024. Importantly, it is the first volume which sports the new modern design of the magazine. This fresh design was developed by Dr Fabio Crameri and uses different colour schemes to give different SPATIUM volumes at the same time a diverse but also unifying appearance. This forms another element of change in the association.

The second volume published in 2024 (No. 55) was prepared based on the Pro ISSI talk by Dr Michael Biermann. It is entitled "Gaia: The astrometric space observatory that is revolutionising our view of the Milky Way". In it the author Dr Michael Biermann and the editor PD Dr Andreas Verdun cover the breakthroughs in almost all fields of astronomy enabled by the Gaia satellite.

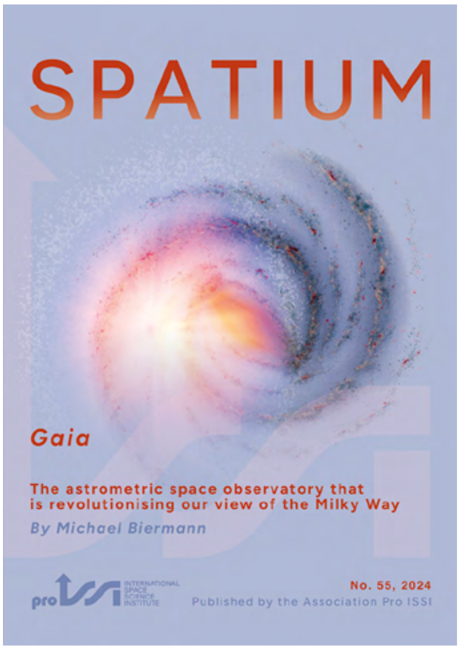
Together with all previous issues of SPATIUM, these editions can be found in open access on Pro ISSI's homepage at www.issibern.ch/association-pro-issi/spatium/

While the last few years had seen a slow but steady decrease in the number of members of Pro ISSI, in 2024 a turnaround could be observed with an increase in the number of members.

Christoph Mordasini



SPATIUM Volume 54



SPATIUM Volume 55

Financial Overview

The 29th financial year of ISSI resulted in a deficit of around 9 kCHF. This relatively small deficit was achieved through careful planning of operational costs. Owing to the slightly expanded ISSI premises, the fixed costs were increased, as were those for the science activities, which helped recover from the backlog caused by the COVID pandemic. Some unexpected financial income (mainly due to the Euro-CHF exchange rate) reduced the deficit, if not quite to the budgeted amount but to the cited 9 kCHF. The deficit is still fully covered by positive results from previous years.

On the revenue side the contributions from ESA (Directorates of Science and of Earth Observation) and from the Swiss Confederation (State Secretariat for Education, Research and Innovation SERI and Swiss Academy of Natural Sciences SCNAT) are gratefully acknowledged, as is the contribution from our Japanese partner, JAXA/ ISAS.

In addition to the direct contributions listed here, it is important to note that ISSI also receives indirect contributions that do not appear in the table below: One of the directors is employed directly by the University of Bern, and ISSI also benefits from the University through in-kind contributions such as internet connectivity etc.

Antonella Nota

Statement of Operations (in CHF) for the 29th Financial Year (1.1.2024-31.12.2024)

	Expenses	Revenues
ESA Science Directorate and Earth Observation		1’536’638.40
Swiss Confederation		1’353’500.00
Swiss Academy of Sciences (SCNAT)		225’000.00
ISSI Partners: ISAS/JAXA		24’016.25
Salaries and related costs [1]	1’252’923.16	
Fixed costs	333’328.10	
Operating costs [2]	217’095.84	
Investment (depreciated)	16’314.17	
Workshops, Working Groups, Teams, Visitors [3]	1'405'459.16	
Other income or cost [4]		76’786.82
Result of the year		9’178.96
Total	**3’225’120.43**	**3’225’120.43**

Remarks:

[1] **Salaries:** It should be noted that the majority of the ISSI staff members (including directors) are scientists actively conducting research as well as taking care of organisational, editorial, and administrative tasks.

[2] **Operating costs** include repair and maintenance, insurance, supplies, administration, and public relations.

[3] **Workshops, etc**. also include the balance from income and expenses of guest apartments.

[4] **Other income or cost** includes extraordinary income, interest income, and income due to variations in monetary exchange rates.

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The list shows the status at the end of the 29th business year on 31 December 2024.

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The list shows the status at the end of the 29th business year on 31 December 2024.

Staff Activities

Listed are activities in which ISSI staff scientists participated in 2024. This includes presentations given, meetings attended, outreach, honors received, and chairmanships held.

Presentations

23 January 2024 - M. Sargent: "ESO-SKA synergies for extragalactic survey science", contributed talk at the 2024 winter meeting of the SKACH consortium, Neuchatel, Switzerland

10 April 2024 – M. Falanga: TeleBern Space Talk https://www.telebaern.tv/spacetalk/space-talk-mit-dem-astrophysiker-maurizio-falanga-teil-1-156761715

15 April 2024 – R. Hohensinn: On the uncertainty of the uncertainty of long-term trends derived from geophysical and climate time series, Oral Presentation, EGU General Assembly 2024, Vienna, Austria.

16 April 2024 – F. Crameri: Geodynamics 101: Numerical modelling Short Course , EGU General Assembly, Vienna, Austria

17 April 2024 – F. Crameri: Creative collaboration: working with artists to communicate science Short Course, EGU General Assembly, Vienna, Austria

17 April 2024 – R. Hohensinn, Y. Bock: Gauging the Sensitivity of GNSS for Resolving Vertical Land Motion Over Europe, Oral Presentation, EGU General Assembly 2024, Vienna, Austria.

7–9 May 2024 – F. Crameri: Masterclass about Scientific graphic design, The University Center in Svalbard, Norway

9 May 2024 – M. Falanga: Das Unsichtbare sichtbar machen – Schwarze Löcher fotografieren, Presentation at the exhibition "Fantasy Basel", Basel, Switzerland

15 May 2024 – M. Falanga: Study Neutron Stars through type-I X-ray bursts, invited talk, Xiangtan University, China

23–24 May 2024 – F. Crameri: Workshop about The art of academic graphic design, ETH ERDW PhD student retreat, Davos, Switzerland

13–15 August 2025 – M. Falanga: Lecture on Equation of States for White Dwarfs and Neutron Stars, Silesian University in Opava, Czechia

5 September 2024 – F. Crameri: Seeing the Unseen: Accurate and Inclusive Colour Scales in Space Science, ISSI Game Changer, Virtual

24 September 2024 – F. Crameri: Plenary Talk about The theory of accurate and accessible colour use, Austrian Physics Society (OEPG) Meeting, Linz, Austria

13 October 2025 – M. Falanga: Interactions of pulsar magnetosphere with planets & a short introduction to the International Space Science Institute in Bern, UCLA, USA

29 October 2024 – F. Crameri: Workshop about Figure design + Scientific use of colour, TU Delft, the Netherlands

2-4 December 2024 – M. Rast: Panel Moderation and Participation (title: Moderated Discussion: 'Strategic Future of Earth Observation: Priorities, Policy, and Public-Private Collaboration') at the European Space Imaging (EUSI) Conference, Munich, Germany

11 December 2024 – M. Mlynczak, "Design Considerations for the Future Geospace System Observatory", Invited talk at the American Geophysical Union Meeting, December, 2024, Washington, DC, United States.

11 December 2024 – A. Nota: Final Remarks to "Italian Space Science and Industry visit" day at STScI, with Italian Embassy.

13 December 2024 – R. Hohensinn, Y. Bock: Impact of geophysical transients and non-linear effects on GNSS-based estimates of plate tectonic velocities and secular vertical land motion, Oral Presentation, AGU Fall Meeting 2024, San Francisco, USA.

Staff Activities

Meetings

22-23 January 2024 – M. Sargent: SKACH Consortium meeting, Neuchâtel, Switzerland

11–15 March 2024 – A. Nota: Convener of First ISSI Breakthrough Workshop "The First Billion Years, according to JWST", with Angela Adamo (Stockholm University), Pascal Oesch (Geneva Univ.), Dan Coe (STScI), Jane Rigby (NASA GSFC), Gabe Brammer (Dawn)

18–22 March 2024 – M. Sargent: Cosmology in the Alps, Les Diablerets, Switzerland

8–12 April 2024 – R. Nakamura: The Geoscience of Exoplanets: Going beyond habitability, ISSI Workshop

22–26 April 2024 – T. Dudok de Wit, R. Nakamura: Electron kinetic physics, ISSI Workshop

13–24 May 2024 – M. Falanga: Visiting the "Xiangtan University", Hunan Province, China

4–6 June 2024 – A. Nota: Co-convener of Forum on" International Cooperation in Space to advance science", with Alvaro Gimenez (ISSI), Fabio Favata

June 2024 – A. Nota: Science Organising Committee (SOC) member of conference "JWST at the Gates of Cosmic Dawn", in honour of Prof. Garth Illingworth with Tim Heckman (JHU), Jonathan Gardner (NASA GSFC), Eric Smith (NASA), Massimo Stiavelli (STScI)

8–10 July 2024 – M. Falanga: Alpbach Summer School 2024, Alpbach, Austria

12–16 August 2024 – M. Falanga: Visiting the "Silesian University in Opava", Czechia

2 September 2024 – M. Falanga: National Science Center, Krakow, Poland

1–4 December 2024 – M. Rast: 7th Biennial Symposium (Symbiosis of Science, Society and Nature)of the International Centre for Earth Simulation (ICES), Geneva, Switzerland

Media Coverage

24 October 2024 – A. Nota: Mention in BBC Sky at Night Magazine

24 October 2024 – A. Nota: The Planetary Society – Article: "NASA mission spots" Cosmic Wreath displaying Stellar circle of life

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25 October 2024 – A. Nota: Space.com – Article: "James Webb Space Telescope finds 1st 'failed star' candidates beyond the Milky Way".

28 October 2024:"Die ersten Braunen Zwerge außerhalb der Milchstraße" article by Stefan Deiters, Astronews.com

October 2024 – A. Nota: Reddit – Discussion on JWST image of a star cluster in the Small Magellanic Cloud: "The James Webb Space Telescope takes a look into the Small Magellanic Cloud".

18 December 2024 – A. Nota: NASA.gov – Article: "Chandra and Webb Spy a Cosmic Wreath".

December 2024: Podcast Media INAF "Houston" – Interview with Valentina Guglielmo about the Hubble Space Telescope: "Interview on YouTube".

Staff Publications

Listed are all papers written or co-authored by ISSI staff members that appeared in 2024.

Adamo, A. (incl. A. Nota) et al. The First Billion Years, According to JWST. submitted (2024) doi:10.48550/arxiv.2405.21054.

Afghan, Q., Jones, G.H., Battams, K., Price, O. & Coates, A. J. Characterization of the Dust and Sodium Tails of Comet C/2020 F3 (NEOWISE) from Parker Solar Probe and Amateur Observations. Planet. Sci. J. 5, 264 (2024).

Alfonso-Garzón, J. (incl C. Malacaria) et al. Unveiling the origin of the optical and UV emission during the 2017 giant outburst of the Galactic ULX pulsar Swift J0243.6+6124. Astron. Astrophys. 683, A45 (2024).

Bait, O. (incl. M.T. Sargent) et al. Low-redshift Lyman Continuum Survey (LzLCS). Astron. Astrophys. 688, A198 (2024).

Bendt, A., Chapman, S. & Wit, T. D. de Wit. The Relative Prevalence of Wave Packets and Coherent Structures in the Inertial and Kinetic Ranges of Turbulence as Seen by Solar Orbiter. Astrophys. J. 971, 179 (2024).

Bowen, T. A. (incl. T. D. de Wit) et al. Extended Cyclotron Resonant Heating of the Turbulent Solar Wind. Astrophys. J. Lett. 972, L8 (2024).

Bowen, T. A. (incl. T. D. de Wit) et al. Mediation of collisionless turbulent dissipation through cyclotron resonance. Nat. Astron. 1–9 (2024) doi:10.1038/s41550-023-02186-4.

Bozzo, E. (incl. M. Falanga) et al. Chandra/HETG Doppler velocity measurements in stellar coronal sources. Mon. Not. R. Astron. Soc. 528, 4591–4622 (2024).

Bykov, A. M., Petrov, A. E., Ponomaryov, G. A., Levenfish, K. P. & Falanga, M. PeV proton acceleration in Gamma-ray Binaries. Adv. Space Res. (2024) doi:10.1016/j.asr.2024.01.021.

Choi, K.-E. (incl. T. D. de Wit) et al. Whistler Waves in the Young Solar Wind: Statistics of Amplitude and Propagation Direction from Parker Solar Probe Encounters 1–11. Astrophys. J. 971, 177 (2024).

Christian, C. A., Nota, A., Grice, N., Madura, T. & Hurd, D. 3D printing for teaching and exploration in astronomy for individuals with blindness/visual impairment: textured representations of imagery. Int. J. Sci. Educ., Part B ahead-of-print, 1–21 (2024).

Crameri, F. & Hason, S. Navigating color integrity in data visualization. Patterns 5, 100972 (2024).

Ducci, L. (incl. C. Malacaria) et al. Probing the emission mechanism and nature of the pulsating compact object in the X-ray binary SAX J1324.4–6200. Astron. Astrophys. 685, A148 (2024).

Fletcher, C. (incl. C. Malacaria) et al. A Joint Fermi-GBM and Swift-BAT Analysis of Gravitational-wave Candidates from the Third Gravitational-wave Observing Run. Astrophys. J. 964, 149 (2024).

Fu, T. (incl. M. Falanga) et al. A comprehensive study of type I (thermonuclear) bursts in the new transient SRGA J144459.2$-$604207. submitted (2024) doi:10.48550/arxiv.2412.05779.

Gozaliasl, G. (incl. M.T. Sargent) et al. COSMOS brightest group galaxies. Astron. Astrophys. 690, A315 (2024).

Hohensinn, R., Aichinger-Rosenberger, M., Wareyka-Glaner, M. F. & Ravanelli, M. Natural-hazard monitoring with global navigation satellite systems (GNSS). Adv. Geophys. 1–123 (2024) doi:10.1016/bs.agph.2024.06.002.

Hohensinn, R., Ruttner, P. & Bock, Y. Sensitivity of GNSS to vertical land motion over Europe: effects of geophysical loadings and common-mode errors. J. Geodesy 98, 68 (2024).

Li, Q.-X., Li, Z., Pan, Y.-Y. & Falanga, M. Search for thermonuclear burst oscillations in the Swift/BAT data set. Front. Astron. Space Sci. 11, 1477677 (2024).

Li, Z. S. (incl. M. Falanga) et al. Broadband X-ray spectral and timing properties of the accreting millisecond X-ray pulsar IGR J17498–2921 during the 2023 outburst. Astron. Astrophys. 691, A92 (2024).

Lu, Y., Li, Z., Yu, W., Pan, Y. & Falanga, M. Discovery of a Long Thermonuclear X-Ray Burst from the Ultracompact Binary 4U 1850–087. Astrophys. J. 969, 15 (2024).

Mahecha, M. D., Kraemer, G. & Crameri, F. Cautionary remarks on the planetary boundary visualisation. Earth Syst. Dyn. 15, 1153–1159 (2024).

Mainieri, V. et al. The Wide-field Spectroscopic Telescope (WST) Science White Paper, submitted (2024) doi:10.48550/arxiv.2403.05398.

Staff Publications

Malacaria, C. et al. Discovery of spin-phase-dependent QPOs in the supercritical accretion regime from the X-ray pulsar RX J0440.9+4431. Astron. Astrophys. 681, A25 (2024).

Ng, M. (incl. C. Malacaria) et al. NICER Discovery that SRGA J144459.2–604207 Is an Accreting Millisecond X-Ray Pulsar. Astrophys. J. Lett. 968, L7 (2024).

Ng, M. (incl. C. Malacaria) et al. X-Ray and Radio Monitoring of the Neutron Star Low-mass X-Ray Binary 1A 1744-361: Quasiperiodic Oscillations, Transient Ejections, and a Disk Atmosphere. Astrophys. J. 966, 232 (2024).

Peng, Z. (incl. M. Falanga) et al. Quenching and recovery of persistent X-ray emission during a superburst in 4U 1820$-$30. submitted (2024) doi:10.48550/arxiv.2412.05785.

Rawat, N. (incl. M. Falanga) et al. Indications of magnetic accretion in Swift J0826.2–7033. Astron. Astrophys. 691, A264 (2024).

Rossi, Y. (incl. R. Hohensinn) et al. Unscented Kalman Filter–Based Fusion of GNSS, Accelerometer, and Rotation Sensors for Motion Tracking. J. Struct. Eng. 150, 05024002 (2024).

Sargent, M. T. et al. The molecular gas content throughout the low-z merger sequence. submitted (2024) doi:10.48550/arxiv.2409.06572.

Schmelzbach, C., Hohensinn R. (Ed.), Space Geodesy for Environmental Monitoring Volume, ISBN 9780443314605, (2024).

Wang, Y. (incl. M.T. Sargent) et al. Cosmic evolution of radio-excess active galactic nuclei in quiescent and star-forming galaxies across $0 < z < 4$. Astron. Astrophys. 685, A79 (2024).

Yu, W. (incl. M. Falanga) et al. NICER views moderate, strong, and extreme photospheric expansion bursts from the ultracompact X-ray binary 4U 1820–30. Astron. Astrophys. 683, A93 (2024).

Zalot, N. (incl. C. Malacaria) et al. An in-depth analysis of the variable cyclotron lines in GX 301–2. Astron. Astrophys. 686, A95 (2024).

Zeidler, P. (incl. A. Nota) et al. Discovering Subsolar Metallicity Brown Dwarf Candidates in the Small Magellanic Cloud. Astrophys. J. 975, 18 (2024).

Visitor Publications

Listed are all papers written or co-authored by ISSI visitors, with acknowledgment to ISSI, that appeared for publication in refereed journals in 2024.

Abalo, L. et al. Variable structures in the stellar wind of the HMXB Vela X-1. Astron. Astrophys. 692, A188 (2024).

Adamo, A. et al. Bound star clusters observed in a lensed galaxy 460 Myr after the Big Bang. Nature 632, 513–516 (2024).

Adhikari, L. et al. MHD Inertial and Energy-containing Range Turbulence Anisotropy in the Young Solar Wind. Astrophys. J. 965, 94 (2024).

Adhikari, L. et al. Turbulence, and Proton and Electron Heating Rates in the Solar Corona: Analytical Approach. Astrophys. J. 966, 52 (2024).

Agiwal, O. et al. Current Events at Saturn: Ring–Planet Electromagnetic Coupling. Planet. Sci. J. 5, 134 (2024).

Akhavan-Tafti, M. & Soni, S. L. In Situ Mechanisms are Necessary for Switchback Formation. Astrophys. J. Lett. 970, L26 (2024).

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Anderson, R. I. et al. VELOcities of CEpheids (VELOCE). Astron. Astrophys. 686, A177 (2024).

Anderson, R. I., Koblischke, N. W. & Eyer, L. Small-amplitude Red Giants Elucidate the Nature of the Tip of the Red Giant Branch as a Standard Candle. Astrophys. J. Lett. 963, L43 (2024).

Antolin, P., Auchère, F., Winch, E., Soubrié, E. & Oliver, R. Decomposing the AIA 304 Å Channel into Its Cool and Hot Components. Sol. Phys. 299, 94 (2024).

Archer, M. O. et al. Crucial future observations and directions for unveiling magnetopause dynamics and their geospace impacts. Front. Astron. Space Sci. 11, 1430099 (2024).

Archer, M. O. et al. Magnetopause MHD surface wave theory: progress & challenges. Front. Astron. Space Sci. 11, 1407172 (2024).

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Arge, C. N., Leisner, A., Antiochos, S. K., Wallace, S. & Henney, C. J. Proposed Resolution to the Solar Open Magnetic Flux Problem. Astrophys. J. 964, 115 (2024).

Arndt, S., Maaß, N., Rossmann, L. & Nicolaus, M. From snow accumulation to snow depth distributions by quantifying meteoric ice fractions in the Weddell Sea. Cryosphere 18, 2001–2015 (2024).

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Arsenović, P. et al. Global impacts of an extreme solar particle event under different geomagnetic field strengths. Proc. Natl. Acad. Sci. 121, e2321770121 (2024).

Asvestari, E. et al. Coronal Models and Detection of the Open Magnetic Field. Astrophys. J. 971, 45 (2024).

Attree, N. et al. The Results of ISSI Team #547: Understanding the Activity of Comets Through 67P's Dynamics. (2024) doi:10.5194/epsc2024-82.

Attree, N. et al. Varying water activity and momentum transfer on comet 67P/Churyumov-Gerasimenko from its non-gravitational forces and torques. Astron. Astrophys. 690, A82 (2024).

Attree, N., Schuckart, C., Bischoff, D., Gundlach, B. & Blum, J. Localised ejection of dust and chunks on comet 67P/Churyumov-Gerasimenko: testing how comets work. Mon. Not. R. Astron. Soc. stae2315 (2024) doi:10.1093/mnras/stae2315.

Augustin, R. et al. MUSE-ALMA Haloes X: the stellar masses of gas-rich absorbing galaxies. Mon. Not. R. Astron. Soc. 528, 6159–6166 (2024).

Balboni, M. et al. CHEX-MATE: A LOFAR pilot X-ray – radio study on five radio halo clusters. Astron. Astrophys. 686, A5 (2024).

Ballantyne, D. R. et al. Unveiling energy pathways in AGN accretion flows with the warm corona model for the soft excess. Mon. Not. R. Astron. Soc. 530, 1603–1623 (2024).

Bate, W. et al. Unveiling the True Nature of Plasma Dynamics from the Reference Frame of a Superpenumbral Fibril. Astrophys. J. 970, 66 (2024).

Bathiany, S. et al. Ecosystem Resilience Monitoring and Early Warning Using Earth Observation Data: Challenges and Outlook. Surv. Geophys. 1–37 (2024) doi:10.1007/s10712-024-09833-z.

Batubo, P., Morra, G., Oppo, D. & Moore, A. A Medium-Sized Paleo-Tsunami Reconstruction by a Deep Neural Network Processing Sedimentary Deposits. Earth Space Sci. 11, (2024).

Becker, M. et al. Coastal Flooding in Asian Megadeltas: Recent Advances, Persistent Challenges, and Call for Actions Amidst Local and Global Changes. Rev. Geophys. 62, (2024).

Beggan, C. D. et al. Digitized Continuous Magnetic Recordings for the August/September 1859 Storms From London, UK. Space Weather 22, (2024).

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Bera, R. K., Fraternale, F. & Pogorelov, N. V. Three-dimensional Modeling of the Solar Wind and Local Interstellar Medium Interaction with Pickup Ions in the Presence of Heliospheric Current Sheet. J. Phys.: Conf. Ser. 2742, 012010 (2024).

Berg, J. P. van den, Els, P. L. & Engelbrecht, N. E. An Evaluation of Different Numerical Methods to Calculate the Pitch-angle Diffusion Coefficient from Full-orbit Simulations: Disentangling a Rope of Sand. Astrophys. J. 977, 174 (2024).

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Bian, N. H., Strauss, R. D., Li, G. & Engelbrecht, N. E. Heliospheric Diffusion of Stochastic Parker Spirals in Radially Evolving Solar Wind Turbulence. Astrophys. J. 962, 186 (2024).

Birrer, S. et al. Time-Delay Cosmography: Measuring the Hubble Constant and Other Cosmological Parameters with Strong Gravitational Lensing. Space Sci. Rev. 220, 48 (2024).

Blasl, K. A. et al. Lower-Hybrid Wave-Induced Plasma Mixing Related to Kelvin-Helmholtz Vortices During Southward IMF. J. Geophys. Res.: Space Phys. 129, (2024).

Bollo, V. et al. ALMACAL. Astron. Astrophys. 690, A258 (2024).

Boula, S. S., Niemiec, J., Amano, T. & Kobzar, O. Quasi-perpendicular shocks of galaxy clusters in hybrid kinetic simulations. Astron. Astrophys. 684, A129 (2024).

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Buldgen, G. et al. Helioseismic determination of the solar metal mass fraction. Astron. Astrophys. 681, A57 (2024).

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Astron. Astrophys. 689, A106 (2024).

Chapman, S. C. & Wit, T. D. de. A solar cycle clock for extreme space weather. Sci. Rep. 14, 8249 (2024).

Chatzistergos, T. A Discussion of Implausible Total Solar-Irradiance Variations Since 1700. Sol. Phys. 299, 21 (2024).

Chen, R. H. et al. Subauroral TEC Enhancement, GNSS Scintillation, and Positioning Error During STEVE. J. Geophys. Res.: Space Phys. 129, (2024).

Chen, Y., Mandal, S., Peter, H. & Chitta, L. P. Bidirectional propagating brightenings in arch filament systems observed by Solar Orbiter/EUI. Astron. Astrophys. 692, A119 (2024).

Chen, Y., Peter, H. & Przybylski, D. Investigating explosive events in a 3D quiet-Sun model: Transition region and coronal response. Astron. Astrophys. 693, A29 (2024).

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Contopoulos, I., Dimitropoulos, I., Ntotsikas, D. & Gourgouliatos, K. N. A New Solution of the Pulsar Equation. Universe 10, 178 (2024).

Cramer, W. J. et al. Resolved UV and Optical Color Gradients Reveal Environmental Influence on Galaxy Evolution at Redshift z ~1.6. Astrophys. J. 975, 144 (2024).

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Ćuk, M. et al. Long-Term Evolution of the Saturnian System. Space Sci. Rev. 220, 20 (2024).

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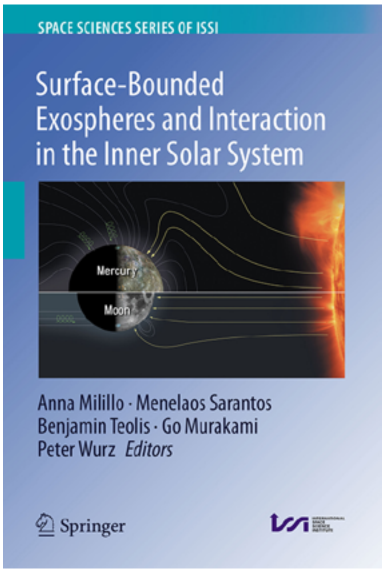

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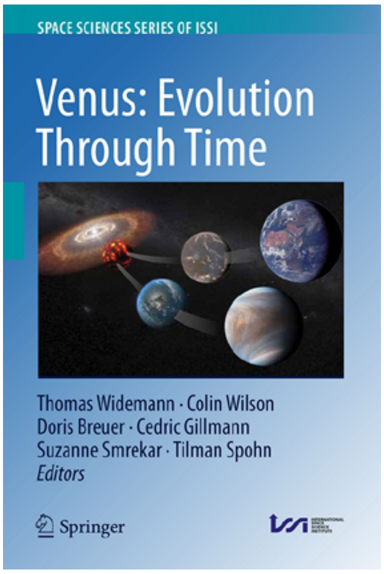

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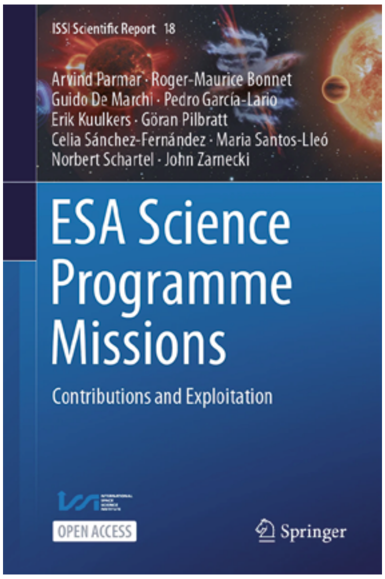

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