INTERNATIONAL
SPACE
SCIENCE
INSTITUTE

Annual Report 2021

Cover Page

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

1. Exoplanetary Systems (Image Credit: ESA – C. Carreau)

2. Measurements in 2020 by the Copernicus Sentinel-5P satellite show that the ozone hole over the Antarctic is one of the largest in recent years. (Image Credit: ESA)

3. This view shows the orbits of more than 14 000 known asteroids (with the Sun at the center of the image) based on information from Gaia's data release. (Image Credit: ESA/Gaia/DPAC)

4. Global land-surface temperature as measured by Copernicus Sentinel-3. (Image Credit: Copernicus Sentinel data (2018), processed by ESA)

5. Many colorful stars are packed close together in this image of the globular cluster NGC 1805, taken by the NASA/ESA Hubble Space Telescope. (Image Credit: ESA/Hubble & NASA, J. Kalirai)

6. The orbit of Ulysses was chosen so as to chart the heliosphere – the sphere of influence of the Sun carved out by the solar wind that extends beyond the outer fringes of the Solar System – at all solar latitudes. (Image Credit: ESA – C. Carreau)

Table of Contents

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 program 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 Chairman of the Board of Trustees

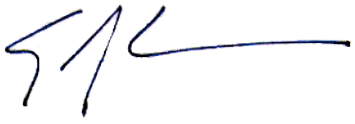
For the second year in a row, the Covid-19 pandemic has again severely perturbed all ISSI activities. The "raison d'être" of ISSI – bringing scientists in person together in Bern in a multi-disciplinary atmosphere with the aim of scientific added values – has been significantly slowed down. ISSI has adapted to these weird times in not canceling but postponing meetings to better times and in switching to mostly on-line interactions. The same crisis also delayed all meetings with ISSI Beijing. We look forward to resuming usual activities and further developing the already excellent and productive synergy between our two institutes.

It is with great sadness that we learned the passing away of Hans Balsiger on January 19, 2021, aged 83. During his term as Director of the Physics Institute of the University of Bern, he helped efficiently the creation process of ISSI. He served on the ISSI Science Committee and on the Board of Trustees for twenty years, between 1995 and 2014. We shall always be grateful to him.

During this past year, ISSI has experienced an unusual random conjunction of turnovers for three out its four director positions. Ruedi von Steiger retired on July 31, 2021, after 25 years as the only ISSI full-time director, in charge of solar and plasma physics. He was also the efficient secretary of the BoT. Joachim Wambsganss retired on September 30, 2021 as ISSI Director for Astrophysics and Cosmology and Anny Cazenave retired on December 31, 2021, as ISSI Director for Earth Observation. ISSI is deeply grateful to all three of them for their dedications and outstanding contributions to ISSI.

In August 2021, Maurizio Falanga took up his duties as new ISSI full-time director for Astrophysics and Cosmology, and new secretary of the BoT, consequence of an election by the BoT during its November 2020 meeting. In May 2021, the BoT elected Michael Rast as new ISSI Director for Earth Observation. During the same meeting, Roger Bonnet was elected as honorary director of ISSI, in recognition of his outstanding contributions to ISSI. Eventually, in November 2021, the BoT elected Thierry Dudok de Wit as new ISSI director for Solar and Plasma Physics. We welcome all of them.

We are grateful to all ISSI main actors, namely, its directorate and its staff, its Science Committee, and its BoT, for their excellent work and continuous dedication. ISSI is an Institute for Advanced Studies, one of a kind, at which scientists from all over the world come to work together to analyze and interpret space-based data, frequently in synergy with ground-based data. We are very grateful to all ISSI funding agencies. My sincere hope is that ISSI will be in a position of fully resuming its scientific activities and, hopefully, broadening them further through the simultaneous increases of the number of its funding agencies and of their financial support.



Georges Meylan
Chairman of the ISSI Board of Trustees
Ecole Polytechnique Fédérale de Lausanne (EPFL)
Lausanne, January 2022

From the Directors

ISSI's 26th business year was the first to start with the calendar year on Jan 1st 2021. The 25th business year had been extended by six months to synchronize the two.

The 26th business year saw significant changes in the ISSI directorate. First, Rudolf "Ruedi" von Steiger retired from both his director's position at ISSI and his professor's position at the University of Bern. Ruedi had been with the institute ever since its beginnings and had served as director covering the Solar and Plasma Sciences for 22 years. He has left a lasting impact, not least through the many volumes of the Space Science Series of ISSI that he has co-edited. ISSI organized a hybrid fare-well event on the penultimate day of his tenure. Many of his friends and colleagues participated in this moving event online and some in person in Bern.

Ruedi was followed by Maurizio Falanga who had served as ISSI science program manager for twelve years and was appointed as director and as professor at the University of Bern as of August 1st, 2021 Maurizio is well known to the ISSI community for his tireless service to the institute and its science program. Maurizio himself was succeeded by Mark Sargent who joined ISSI as the new science program manager in September.

Also in September, Joachim Wambsganss left after four years of service as the director for Space Science. Joachim has shaped the ISSI astrophysics program during his tenure and continues to do so as a workshop convener. ISSI's new director for Space Science Thierry Dudok de Wit – a renowned solar and plasma physicist – will start his tenure in 2022.

With the end of the year Anny Cazenave left after serving for almost nine years as Earth science director. Anny co-edited eight volumes in the Space Science Series and supported an even larger number of Workshops, Working Groups, Forums and International Teams. She is followed by Michael Rast, who took office in January 2022 but already helped ISSI during the fall of 2021, and previously as Earth Observation ESA ex-officio Science Committee member.

As in the preceding year, ISSI's science program continued to be impacted by the pandemic. Following a quiet winter and early spring forced by restrictions, ISSI had a comparatively active, rather smooth summer with lifted restrictions and visitors. Unfortunately, things took a turn for the worse once again at the very end of the year. Three Workshops could be held in 2021, the first already in January, which was the first in the new series on "Global Change and its Societal Impact". This Workshop was devoted to Global Change in Africa and due to the circumstances it was held fully online with Anny Cazenave and Lorena Moreira chairing from Bern. The Workshop was followed by a two-day online Forum on "Tipping Points in the Earth's Climate".

Two more Workshops and one Forum could be conducted in a hybrid mode in the summer and fall. Both Workshops had started their project using ISSI's new, alternative scheme involving substantial online collaboration prior to the actual workshop. The new scheme is also used by most Workshops planning for 2022 and 2023.

The enlarged seminar room, equipped with the latest hardware for hybrid meetings, proved to be essential. It was renamed "Johannes Geiss Auditorium" to honor the late founding father of the institute and to underline the importance of the refurbished room for ISSI.

Eight International Team meetings could be held in person at ISSI between September and early December. A significantly larger number of remote meetings took place, with Teams and Working Groups using the internet services that ISSI is providing. Among these are the online collaboration tools hosted at ISSI, which were very well received by the scientific community. A total of 143 visitors came to ISSI in person in the 26th business year, and a further ~220 individuals joined ISSI events as online participants to remote or hybrid events.

The Game Changers Online Seminar Series continued with a total of 31 talks. There were many highlights among the talks, including two by recent Nobel laureates Reinhard Genzel and Adam Riess. After presenting space missions that had "changed the game" in 2020, ISSI reshaped the series to more general subjects and themes.

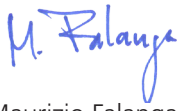
From the Directors

Five volumes in the Space Sciences Series of ISSI were added to the publication record, all volumes partially Open Access. Another volume in the ISSI Scientific Report Series was published Open Access. ISSI made a major step towards publishing the volumes fully Open Access from 2021 onward.

The ISSI Science Committee met for its two regular meetings, reviewing and discussing all future activities. In the Spring Meeting the Committee primarily reviewed 57 Team proposals and recommended 25 for implementation, three of which are joint with ISSI-Beijing. The Fall meeting was devoted to reviewing Workshop, Working Group, and Forum proposals as well as the Earth Science work plan and their implementation in the forthcoming year.

The institute is privileged to have an extraordinarily dedicated staff, for which the directorate is very appreciative! But we should not close without highlighting that Silvia Wenger celebrated her 30th anniversary of working for ISSI! She started working for the institute even before it was founded. ISSI is extremely grateful for all the work she has done through the years.

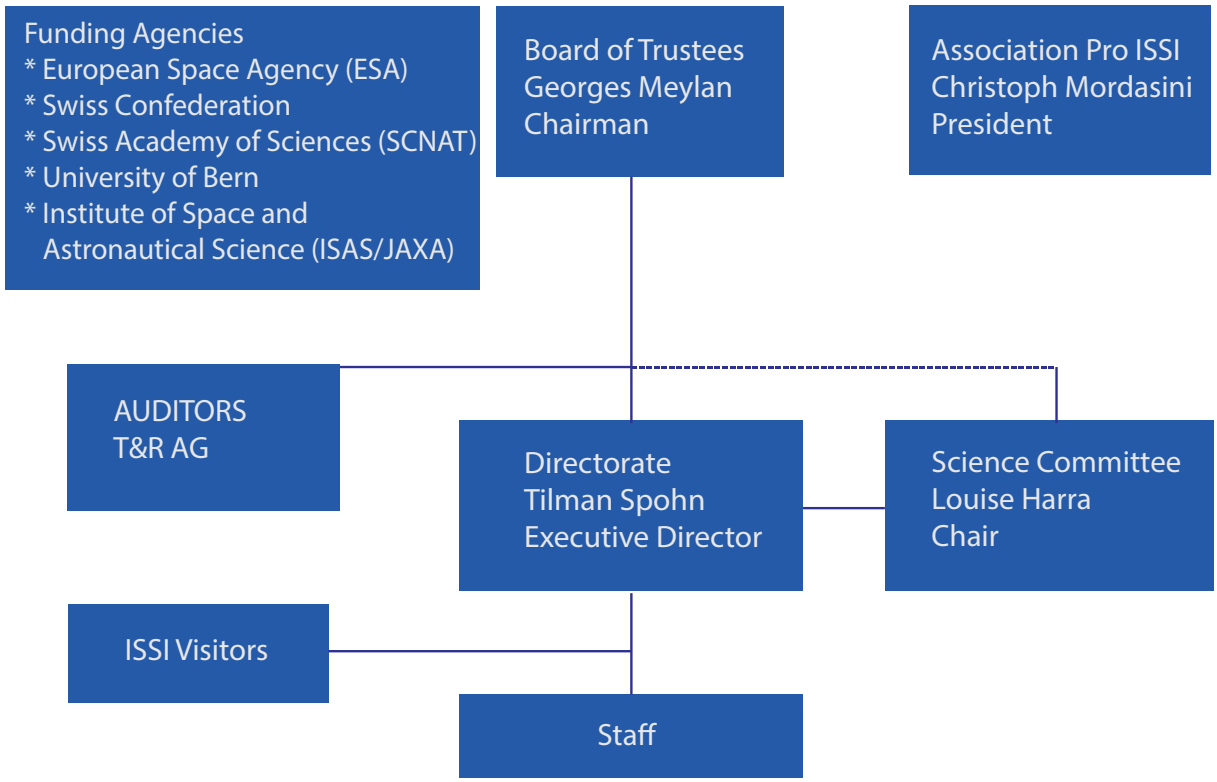
Tilman Spohn



Maurizio Falanga

Michael Rast

About the International Space Science Institute



The International Space Science Institute (ISSI) is a nonprofit organization 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. The US Universities Space Research Association USRA supports the participation of US scientists in ISSI events. 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. Furthermore the Board of Trustees may nominate up to five personalities representing the national and international science community, space industry and space politics for terms of three years. The Board of Trustees is presided over by Georges Meylan.

The **Science Committee**, chaired by Louise Harra, is made up of internationally known 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 Tilman Spohn (Executive Director), Maurizio Falanga (University of Bern), and Anny Cazenave (CNES, Toulouse, France). Michael Rast follows Anny Cazenave as of 1st January 2022.

The **Association Pro ISSI** promotes the idea of ISSI by organizing public lectures, where 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 Christoph Mordasini.

Scientific Activities: The 26th Year

The Program and its Elements

ISSI's mode of operation is generally fivefold: multi- and interdisciplinary Workshops, Working Groups, International Teams, Forum, and Visiting Scientists. The 26th business year 143 international scientists participated in the scientific activities of ISSI in person. The low number is due to the worldwide travel restrictions because of the pandemic in 2021.

Workshops consist of up to 50 invited scientists exchanging their views on a scientific theme, typically during a week's duration. 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 the 26th year, three Workshops were organized, 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-organized fashion. The results of these activities are customarily reported in scientific journals. Details can be found from page 18 on forward. Many face-to-face meetings had to be postponed or were replaced with online meetings.

A **Forum** is an informal and free-ranging debate consisting of some 25 high-level participants on open questions of a scientific nature or on science policy matters for about two days. A Forum does not necessarily lead to formal recommendations or decisions. In the reported period, two Forums were held.

Working Groups have a smaller number of members and meet repeatedly as necessary to achieve the assigned objective. Two new Working Groups started their projects in 2021. The results of the Working Groups are in general published as titles of ISSI Scientific Report Series.

Visiting Scientists spend between a week to months at ISSI to work on a science research project of their own, or to collaborate with ISSI's staff and/or with research institutes in Switzerland. In 2021, 4 individual visitors used the ISSI facilities during the year.

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 honor 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** Program is designed to bring PhD students and postdocs in contact with the community at work. These scientists are invited by ISSI to complement the membership of Workshops, Working Groups, International Teams and Forums. 15 young scientists participated in the ISSI activities in the course of the year.

How to use ISSI Tools

As a general rule, participation in ISSI's activities is by invitation only. The financial support for invited scientists covers the local accommodation expenses and a per diem while in Bern.

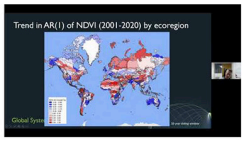
International Teams: A call for proposals is released every year in January. These proposals are evaluated by the ISSI Science Committee and approved by the Directorate.

Workshops, Working Groups, and Forums: There is no annual call. The scientific community may suggest at any time Workshops, Working Groups, and Forums by submitting an idea on a maximum of one page. The ISSI Science Committee will evaluate these suggestions and the ISSI Directorate will take a final decision.

Game Changers Online Seminars

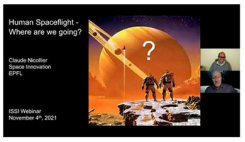
ISSI has continued its series of online seminar talks in 2021 that have become known as the Game Changer Seminars with participants from all over the world. In early 2021 there was a line of talks on Earth observation missions and mission families including oceanography missions and missions to map the gravity and magnetic fields of the Earth. This series was followed by a line of talks on "Ideas and findings about the Solar System, the Universe and our Terrestrial Environment", alternating between astro- and solar physics, planetary science, climate science and fundamental physics. Eminent speakers including two recent Nobel prize winners could be solicited. The Game Changer seminar talks were recorded and are part of ISSI's digital online library. They are available at www.issibern.ch/publications/game-changers-seminars/ where upcoming talks are being advertised, too. Between roughly 100 and 400 participants have attended the seminars, many as loyal participants throughout the series.

Tilman Spohn



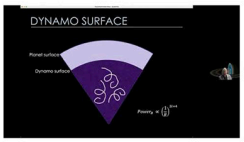
Tipping Positive Change to Avoid Climate Tipping Points with Tim Lenton

Energy Imbalance Observed with Space Geodesy with Benoit Meyssignac

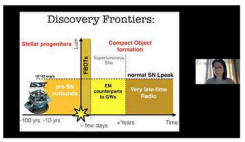


Human Spaceflight – Where Are We Going? Online Seminar with Claude Nicollier

Of Bubbles, Filaments, Echoes and Eruptions: First Results from eROSITA with Andrea Merloni



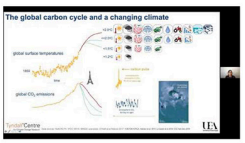
Planetary Magnetic Fields with Sabine Stanley



Discovery Frontiers in the New Era of Observations Gravitational Waves and Light Raffaella Margutti,

Seeing the Unseeable – Imaging Black Holes with the Event Horizon Telescope with Angelo Ricarte

Venus: The Next Target of Planetary Exploration with Richard Ghail



Contemporary Global Carbon Cycle and Impact of COVID-19 Pandemic on CO2 Emissions Corinne Le Quéré

All online seminars are recorded and are available on ISSI's webpage: https://www.issibern.ch/publications/game-changers-seminars/

How Missions Change(d) our View of the Solar System

Reshaping Earth: How the TOPEX and Jason Satellites Revolutionized Oceanography and Redefined Climate Science with Josh Willis (Jet Propulsion Laboratory, Pasadena, USA) – 14th January 2021

From Satellite Observations and Atmospheric Modeling to Air Quality Forecasts with Guy Brasseur (Max Planck Institute for Meteorology, Hamburg, Germany) – 21th January 2021

CRYOSAT, Sea & Land Ice with Andrew Shepherd (University of Leeds, UK) – 4th February 2021

SMOS, Soil Moisture and Sea Surface Salinity with Yann Kerr (CESBIO, France) – 11th February 2021

MAGSAT and the Earth's Magnetic Field with Mioara Mandea (CNES, France) – 18th February 2021

Weight-Watching from Space – Tracking Changes in Earth's Groundwater, Glaciers, Ice Sheets and Sea Level with GRACE and GRACE Follow-On with Felix Landerer (JPL, USA) – 25th February 2021

In Search for the Exit from the Heliosphere: The Odyssey of Voyagers 1&2 Interstellar Missions (1977-2021) with Stamatios Krimigis (Academy of Athens, Greece) – 4th March 2021

The Apollo Lunar Exploration Program: How Increasing Science Capabilities Resulted in a Revolutionary New View of the Moon with Jim Head (Brown University, USA) – 11th March 2021

The Rossi X-ray Timing Explorer: Timing the Extreme Universe with Tomaso Belloni (INAF – Osservatorio Astronomico di Brera, Italy) – 18th March 2021

Wind and Waves on the Ocean Surfaces: Insights from the CFOSAT Mission with Daniele Hauser (IPSL, France) – 25th March 2021

Ideas and Findings about the Solar System, the Universe and our Terrestrial Environment

Cascading Interactions Between Tipping Elements in the Anthropocene Earth System: Risks and Opportunities with Jonathan Donges (Potsdam Institute for Climate Impact Research, Germany) – 6th May 2021

The Hubble Constant Controversy with Adam Riess (Johns Hopkins University, USA) – 20th May 2021

Terrestrial Planetary Seismology with Philippe Lognonné (Institut de Physique du Globe de Paris, France) – 27th May 2021

Game Changers Online Seminars

Formation of the Solar System with Alessandro Morbidelli (Observatoire de la Cote d'Azur, Nice, France) – 3rd June 2021

The Merger History of the Milky Way – What Gaia Revealed with Eva Grebel (ZAH, Heidelberg University, Germany) – 10th June 2021

Do We Know What the Sun is Made of? The Puzzle of the Solar Composition with Sarbani Basu (Yale University, USA) – 17th June 2021

Weather Disasters in a Changing Climate with Stephen Belcher (MET Office, Exeter, UK) – 24th June 2021

Age and Formation of the Moon with Thorsten Kleine (Münster University, Germany) – 1st July 2021

Almost 50 years of Coronal Heating with Joan Schmelz (Universities Space Research Association (USRA), USA) – 8th July 2021

Testing the Massive Black Hole Paradigm with High Resolution Astronomy with Reinhard Genzel (Max Planck Institute for Extraterrestrial, Physics, Garching, Germany) – 15th July 2021

The Contemporary Global Carbon Cycle and the Impact of the COVID-19 Pandemic on CO_2 Emissions with Corinne Le Quéré (University of East Anglia, UK) – 22nd July 2021

V E N U S The Next Target of Planetary Exploration with Richard Ghail (Royal Holloway, University of London, United Kingdom) – 30th September 2021

Seeing the Unseeable – Imaging Black Holes with the Event Horizon Telescope with Angelo Ricarte (Harvard-Smithsonian Center for Astrophysics, USA) – 7th October 2021

Gravitational Waves with Raffaella Margutti (University of California Berkeley, USA) – 14th October 2021

Planetary Magnetic Fields with Sabine Stanley (Johns Hopkins University, USA) – 21st October 2021

Of Bubbles, Filaments, Echoes and Eruptions: First Results from eROSITA with Andrea Merloni (Max-Planck Institute fuer Extraterrestrische Physik, Garching, Germany) – 28th October 2021

Human Spaceflight – Where Are We Going? with Claude Nicollier (Swiss Space Center, EPFL Lausanne, Switzerland) – 4th November 2021

Earth Radiative Budget and Energy Imbalance Observed from Space with Benoit Meyssignac, (Centre National d'Etudes Spatiales (CNES), France) – 18th November 2021

Tipping Positive Change to Avoid Climate Tipping Points with Tim Lenton (University of Exeter, UK) – 2nd December 2021

Forecasting Problem Geomagnetic Storms: Are Stealth CMEs a New Space Weather Extreme? with Tamitha Skov, the Aerospace Corporation, Los Angeles, USA – 9th December 2021

Subsurface Life on Earth and on Other Planets in the Solar System with Barbara Sherwood Lollar, University of Toronto, Canada – 16th December 2021

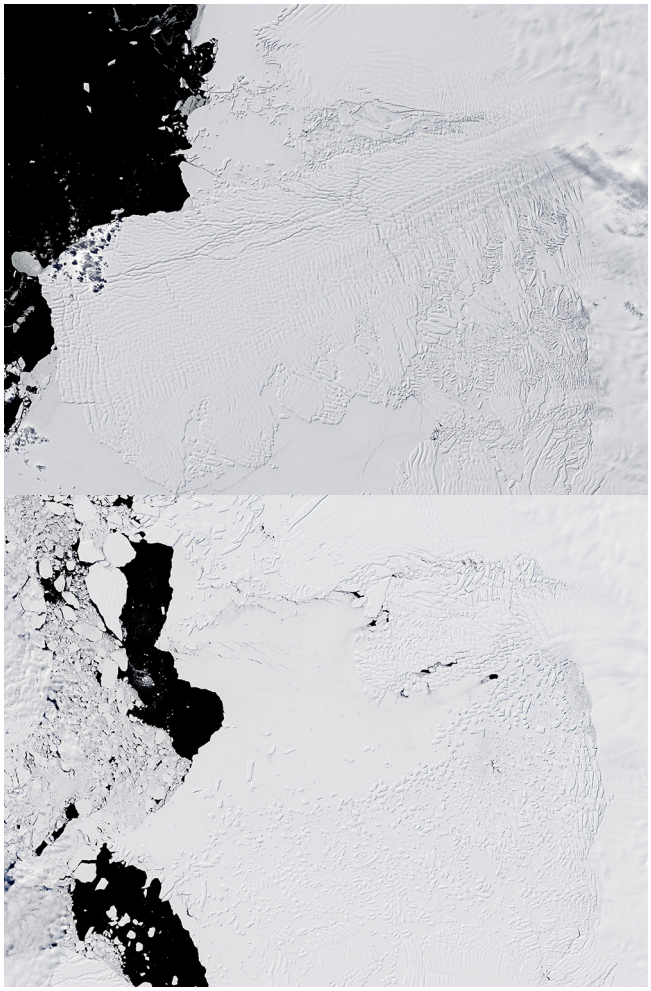
Tipping Points in the Earth's Climate

26–29 January 2021

The Forum was held online and brought modelers and the remote-sensing community (more than 40 participants remotely) together to discuss how Earth observations can contribute to our understanding of tipping elements in the climate system and help with early warning of potential irreversible changes. The Forum was hosted by ISSI and convened by the ESA Climate Office and the Future Earth AIMES project. This interdisciplinary meeting highlighted research opportunities, challenges, and recommendations. The thematic areas explored during breakout sessions were tipping elements in the cryosphere – the planet's snow and ice-covered regions; the terrestrial biosphere; and the atmosphere and ocean and its biota. Day 1 of the Forum focused on the current state-of-the-art for observing tipping elements across the different spheres, with overview presentations from science leaders and leaders for the breakout groups – Tim Lenton, Ricarda Winkelmann, Victor Brovkin, Alessandra Conversi and Didier Swingedouw. On day 2, the Forum considered policy needs for information about climate risk from tipping points, and the communication challenges between the research and policy communities. To seed discussions, perspectives were given by authors Roland Kupers of the University of Amsterdam, The Netherlands, and Liviu Stirbat of the EC DG Climate-Adaptation to Climate Change Unit. The focus for day 3 spanned techniques for improving the detection and quantification of tipping elements using remote sensing data. Different techniques were presented by Niklas Boers (Potsdam Institute for Climate Impact Research), Sebastian Bathiany (Wageningen University), Jonathan Donges (Potsdam Institute for Climate Impact Research) and Peter Cox (University of Exeter). In the final sessions the participants discussed research opportunities across ocean, cryosphere and land domains, and priorities for improving our understanding of tipping elements and their early warning using remote sensing. The feedback from the meeting was very positive. In particular, modelers reported that remote sensing was viewed as an emerging opportunity, and felt that holding the meeting on-line meant the group was more mixed and therefore more valuable for learning new information and making new contacts. There was strong enthusiasm for follow-up collaborations, including a future ISSI Workshop building on the same topic. The complete report can be found on https://climate.esa.int/en/news-events/remote-sensing-tipping-points-climate-system/.

Lorena Moreira and Anny Cazenave

Forums are informal and free-ranging debates among some twenty-five high-level participants on open questions of a scientific nature or on science policy matters. Forums do not necessarily lead to formal recommendations or decisions.



This image pair – showing Antarctica's Thwaites Glacier – demonstrates the changes that have occurred since the start of this century. The upper image, acquired with the Enhanced Thematic Mapper Plus (ETM+) on Landsat 7, shows the glacier's floating ice tongue on December 2, 2001 shortly before it calved Iceberg B-22. The lower image, acquired with the Operational Land Imager (OLI) on Landsat 8, shows the glacier on December 28, 2019. Both images show the glacier where it exits the land in West Antarctica and stretches over the Amundsen Sea as thick floating ice. Ice that originates on land can raise sea level if it is delivered to the ocean at a faster rate than it is being replaced inland by snowfall. The Thwaites Glacier is one of the largest contributors to global sea level rise from the West Antarctic Ice Sheet. (Image Credit: NASA Earth Observatory images by Lauren Dauphin, using Landsat data from the U.S. Geological Survey)

Ground and Space Astronomy: Challenges and Synergies

18–19 November 2021

The rationale behind this topic is the fact that fully achieving all scientific objectives of many space and many ground-based surveys increasingly relies on the combination of space data and ground-based observations. This is the case for ESA space missions aiming to characterize extrasolar planets, like Plato, but also for Galactic studies with Gaia, or cosmological missions like Euclid.

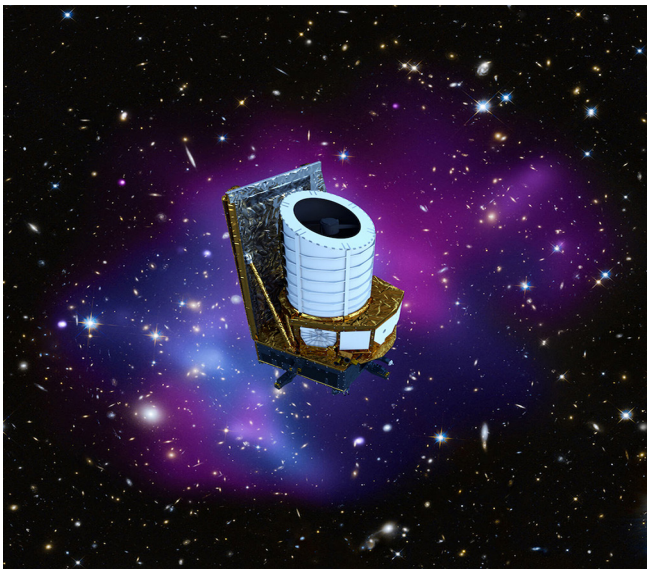
At this ISSI Forum, 25 international experts met in order to discuss these new challenges. Most of them could participate physically in Bern and around 20% joined online due to travel restrictions for non-European participants caused by the on-going pandemic. Underlying questions were: Which scientific topic can advance best with the combination of space and ground data, simultaneous or at least contemporary? How is data best archived and made accessible for all users? Which process should be followed when selecting space missions and ground facilities to ensure their complementarity, while retaining their independent committees, priorities and competitiveness?

Four keynote talks on the "Science view" (by E. van Dishoeck), on the "Space-based view" (by F. Favata), on the "Ground-based view" (by B. Leibundgut), and on the "Exoplanet view" (by W. Benz) formed the backbone of the Forum. In addition, three special contributions were given on the Japanese experience (by S. Miyazaki, online), the Gaia experience (by T. Prusti) and the US perspective (by S. Kahn). Further short contributions from attendees were included as part of the discussions.

A very important and interesting part of the Forum were the lively discussions, including online participants across different time zones. These discussions gave a very broad and comprehensive overview of the challenges and synergies in collaborating between ground and space astronomy. Technical aspects were addressed, as well as "cultural" differences among the scientific communities, and particularly programmatic challenges.

At the end of the Forum, it was felt that this "kick-off" should be followed by suitable further activities, within IAU and COSPAR. These are already being prepared for their corresponding assemblies in 2022.

Joachim Wambsganss and Álvaro Giménez



Euclid is an ESA mission to map the geometry of the Universe and better understand the mysterious dark matter and dark energy, which make up most of the energy budget of the cosmos. In the background, a composite image of the massive galaxy cluster MACS J0717.5+3745 based on X-ray data from NASA's Chandra X-ray Observatory (shown in blue and purple hues) and optical observations performed by the NASA/ESA Hubble Space Telescope. (Image Credit: ESA/ATG medialab (spacecraft); NASA, ESA, CXC, C. Ma, H. Ebeling and E. Barrett (University of Hawaii/IfA), et al. and STScI (background))

Workshops

Workshops are selected by the Directorate in consultation with the Science Committee. Proposals or suggestions for Workshops may originate from the external community. The program 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.

Global Change in Africa: Role of Space Observations

11–15 January 2021

The objective of the Workshop was to investigate the benefit of using Earth Observation data to monitor and understand global environmental changes due to natural phenomena and anthropogenic forcing factors over the African continent, and highlight a number of associated applications of high societal relevance. The main topics addressed concern water resources; land use and land cover change, and implications for agriculture and deforestation; exploitation of mineral resources and environmental impacts; floods, droughts and desertification; coastal zones changes. A large variety of remote sensing data can indeed help addressing these topics, e.g., multi-mission satellite altimetry, including the SWOT mission to be launched in 2022, SMOS, GRACE, radar and optical imagery from the Copernicus Sentinel missions, future missions of the Earth Explorer program of ESA, as well as Earth Observation missions from other space agencies worldwide. The Workshop was held hybrid and gathered more than 40 scientists from Europe and Africa (Ivory Coast, French Guyana, Morocco, Ghana, Senegal, Namibia, Uganda, Ethiopia and Niger). The Workshop offered an opportunity to discuss with scientists from different horizons the role of space-based observations for monitoring and understanding global changes in Africa, and investigate how this knowledge can be communicated to stakeholders to mitigate associated societal impacts. The Workshop started with an introductory session about Global Change in Africa given by members of the World Meteorological Organization (WMO) and the European Space Agency (ESA). The following four sessions addressed the water resources in Africa, the land use and deforestation and its impact on agriculture, exploitation of mineral resources and environmental impacts, floods and drought in Africa and coastal zonal changes. Discussions held following the

Official Participants picture of the remote Workshop on "Global Change in Africa: Role of Space Observation".

sessions led to the preparation of an interdisciplinary ISSI book with 8 chapters tackling different topics. They cover the challenges in environmental observations regarding the integration of in situ and Earth Observations data for monitoring African ecosystems; water resources in Africa under global change addressing the role of Earth Observations and models for monitoring surface waters; a different chapter on the topic of water resources but tackling the role of Earth Observation data to hydrodynamic modeling to derive African river discharge; the role of spaced-based observations for groundwater resource monitoring over Africa; hydro-meteorological extreme events: rainfall and floods; and an additional chapter about drought; mineral resources and environmental impacts; coastal zone changes in West Africa and a final chapter regarding a transdisciplinary integration of Science, application and societal needs and benefits. The Workshop was convened by Anny Cazenave (ISSI and LEGOS, France), Teodolina Lopez (CEREMA, France), David Baratoux (IRD, Ivory Coast), Jean Kan Kouamé (CURAT, Ivory Coast), Jérôme Benveniste (ESA, Italy) and Lorena Moreira (ISSI, Switzerland).

Lorena Moreira and Anny Cazenave

Workshops

The Workshop "Venus: Evolution Through Time" took place in the "new" larger Seminar Room called Johannes Geiss Auditorium. Because of the pandemic the Workshop was hybrid with about half of the participants joining remotely.

Venus: Evolution Through Time

13–17 September 2021

Venus has become a focus of the planetary exploration program of the space fairing agencies and nations. Shortly after ISSI had planned to start a Workshop and book project "Venus: Evolution Through Time" both NASA and ESA selected a total of three new Venus missions to fly in the coming decades. This adds to plans of the Indian space agency ISRO to launch an orbiter mission in 2023 and to projects being planned and discussed in Japan, China and Russia.

The evolution of Venus is, at present, poorly known, despite it being our closest planetary neighbor. The relatively small number of impact craters implies that its surface is much younger than that of Mars and the Moon; their quasi-random distribution shows that Venus does not exhibit Earth-like plate tectonics. This has led to suggestions of global resurfacing – but how this happened is an open question. Whether resurfacing occurred catastrophically or in a steady manner has major implications for interior and climate evolution. Another key question is the absence of plate tectonics and how interior processes are linked to the surface deformation and volcanism. There is evidence of subduction in up to a dozen locations. Subduction is the first step in initiating plate tectonics, raising the question of why Venus appears to lack plate tectonics.

Venus is particularly important to our understanding of habitability. Venus' enhanced D/H ratio suggests that it has lost large amounts (possibly several terrestrial oceans) of water, but it is not clear whether it condensed (as happened on Earth) or whether this water was lost in the steam atmosphere phase; if it had a liquid water ocean phase, Venus may have been habitable for billions of years. There is no consensus on how much water there is in Venus' interior, and how much of this water has been outgassed, a question which has important implications for Venus' atmospheric water and in turn for its habitability through time. Exoplanet transit detection surveys have a bias to detecting exoplanets close to their parent stars: the growing number of such Venus-like exoplanets discoveries emphasizes the relevance of Venus in the search for habitable exoplanets.

Now is a pivotal time in Venus exploration. Since the Magellan orbiter provided initial global radar imaging and altimetry (1989–1994), and Venera landers measured major and heat- producing elements in several locations (1975–1985), there have been considerable advances relevant to understanding Venus' evolution. There have been new observations of surface emissivity from Venus Express, and of surface properties from Arecibo; new analyses of existing data; new hypotheses for the origin of plate tectonics; advances in the numerical tools and laboratory simulation of interior convection; and new modeling of the evolution of rocky earth-sized exoplanets, requiring observational constraint with Venus as a reference point.

The project was the first to try a new scheme of getting from the Workshop to the final product, a book in ISSI's Space Science Series. Inventing the new scheme was mostly motivated by the restrictions caused by the pandemic but opened new ways of communications among the team. The project started with an online kick-off meeting early in 2021 that resulted in a table of contents and writing assignments. In September 2021 a hybrid Workshop was held with about 60% of the participants attending the Workshop in person. The Workshop centered on a discussion of the science of the book end the coordination of the book project and the chapters. Publication of the book is planned for 2022.

Tilman Spohn

The Heliosphere in the Local Interstellar Medium

8–12 November 2021

The Workshop was dedicated to the memory of ISSI's founding director Professor Johannes Geiss who contributed greatly in space physics and established the highly productive ISSI Workshops. This Workshop has gathered more than 50 researchers from all over the world working in space physics. The last ISSI Workshops on similar topics were ''Cosmic rays in the Heliosphere'' in April 2010 and ''From the Outer Heliosphere to the Local Bubble'' in October 2007. Since then major progress has been made. The initial reconnaissance of the outer heliosphere and local interstellar medium (LISM) with in situ measurements (Voyagers 1 and 2, V1 and V2 henceforth), remote sensing of energetic neutral atoms (ENAs) (IBEX and CASSINI) and hydrogen (Voyager and SOHO), and measurements of interstellar dust in the heliosphere (Ulysses) is complete. Both Voyager spacecrafts crossed the heliopause boundary region and entered the local interstellar medium. Before the heliopause crossing, V2 observed a solar cycle of variation in the heliosheath and revealed very different plasma flows and particle variations than observed at V1. ENA measurements from IBEX and CASSINI also span nearly a solar cycle. Modeling has shown the connection between the ENA and heliosheath particles that are their source and plays major roles in studies of the heliospheric shape, instabilities, and particle distributions. At the same time a number of important questions still need to be addressed. Is the heliospheric tail long or short? What is the role of reconnection in producing the energetic particle profiles and energies in the heliosheath? Why was the heliosheath so narrow in the V1 direction? Why are plasma flows and particle intensities in the heliosheath so different at V1 and V2? Why does the heliopause structure differ at V1 and V2? How is the IBEX ribbon formed? These and the other questions as well as the heliosphere's interaction with the LISM were the basic motivation of the Workshop and many of these were addressed and reviewed.

One of the purpose of this Workshop is to produce the new ISSI reference work describing the complete heliosphere, including the heliopause and the effects of the heliosphere on the LISM. The Workshop will cover observations and modeling and highlight what has been learned and what is still not understood. The results of the past decade, the full interaction from pickup ions to the termination shock to the LISM are covered, with the goal of making this a complete reference as the Space Science Reviews Topical Collection "The Heliosphere in the Local Interstellar Medium: Into the Unknown".

Traditional Group Picture of the Workshop Participants in front of the building at Hallerstrasse 6. Nevertheless a third of the participants had to participate remotely.

The Topical Collection covers the following main areas:

(i) Heliosphere structure and modeling and LISM. The wealth of heliospheric and LISM data obtained with multiple space missions is confronted with the models.

(ii) Pickup Ions and Energetic Neutrals from the data of New Horizons, Ulysses, Stereo, ACE and the recent models.

(iii) Cosmic Rays - both anomalous and galactic cosmic rays in the heliosphere and LISM.

(iv) Physical processes in the heliosphere and astrospheres modeling including the magnetic fields and dust dynamics.

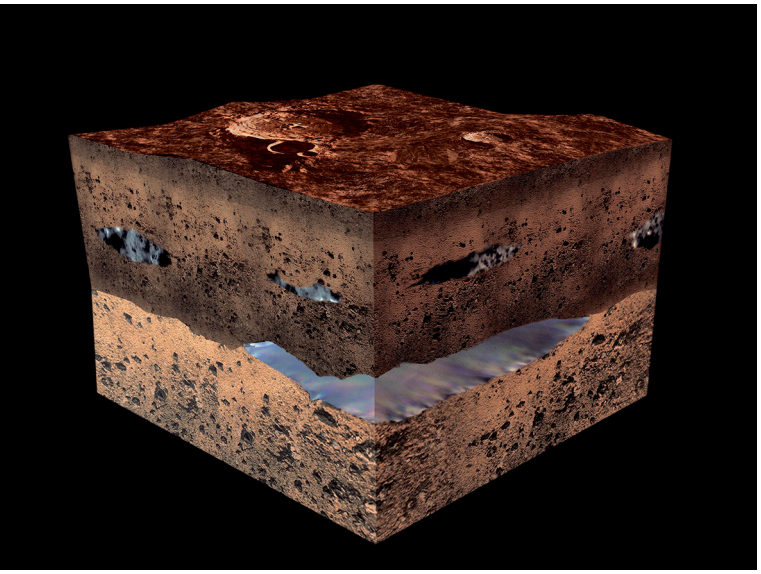
(v) Outlook and perspective of the field with new space missions.

The complete Topical Collection will be co-published as volume 88 in the Space Science Series of ISSI.

Andrei Bykov

Working Groups

Extant subsurface Life on Mars? Science, Tools & Missions Together



Artist's impression of water under the Martian surface. (Image Credit: Medialab, ESA)

One of the main drivers for planetary exploration has been the search for signs of life beyond our planet. Mars, in particular, has been a target for planetary missions, orbital and landed. But to date those missions have focused on the surface and on signs of extinct, ancient life. Or have – like the ongoing NASA InSight mission – studied the deep interior with limited exploration of near surface layers. Forty years of Mars exploration has shown the surface to be inhospitable to life as we know it, and it may have been inhospitable to surface life for as long as 3.5-4 billion years. While liquid water is not stable on the Martian surface, Phoenix lander observations showed that for short timescales, small amounts of salty brines can form. Ultimately liquid water is likely stable only at depths of kilometers. The exploration mantra in the quest for life has been to "follow the water" – assuming that liquid water is a requirement for life. Therefore, the Martian subsurface is the only place on Mars where life could still exist today. We have yet to send a dedicated mission to determine the modern-day subsurface habitability of Mars or to search for signs of extant subsurface life.

This Working Group is developing a strategy to explore Mars Underground along two axes: 1) developing the scientific rationale for subsurface exploration integrating knowledge gained over the past 15 years of spacecraft exploration, theoretical analysis and analog work, and 2) examining the available state of technology to access the planet's underground. The past year has seen some great progress for the Extant Subsurface Life on Mars Working Group, along with significant challenges and changes. The extreme lock-down conditions of 2020 and into 2021 definitely slowed the anticipated rate of progress for the Working Group.

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.

The Working Group reaffirmed their commitment to the goals and organized a virtual meeting in October of 2021, co-sponsored with the Canadian Institute for Advanced Research (CIFAR). The virtual meeting occurred in two four-hour sessions over two days. This meeting was attended by 15 scientists with excellent presentations and discussion. The group decided the next step would be to meet in person at ISSI in Bern in the summer of 2022.

The in-person meeting will be structured into two themes

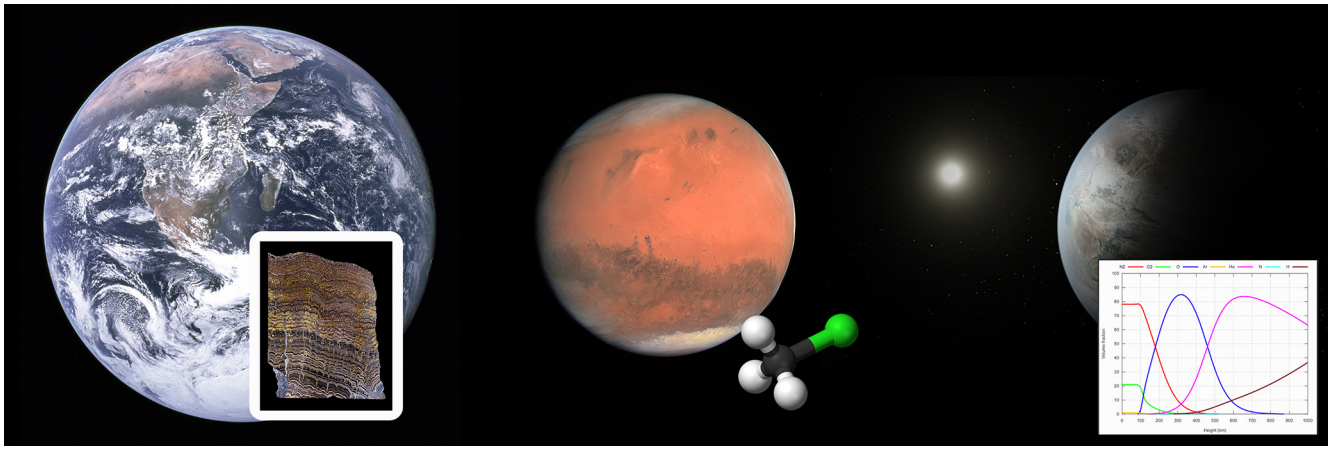
1) Science of the prospects of life in the Martian underground

2) The technology of drilling the first 100 meters of Mars

The Working Group consists of Jack Mustard (Brown University, USA), Barbara Sherwood Lollar (University of Toronto, Canada), Ina Plesa (DLR Germany), Wenzhe Fa (Peking University, China), Katarina Miljkovic (Curtin University, Australia), Cara Magnabosco (ETH, Zurich), Tilman Spohn (ISSI), Joe Michalski (University Hong Kong), Jesse Tarnas (Blue Origin), Vlada Stamenkovic (Blue Origin), Long Xiao (CUES, Wuhan, China), and Fengping Wang (IC-DLI, China).

Jack Mustard

Towards a Universal Tracers Portal in Astrobiology



The three domains that the Working Group will compare for quality and nomenclature of possible tracers of life and habitability: Earth, Solar System bodies, and exoplanets. Examples of tracers commonly cited but not unambiguous because of possible abiotic origin shown here are: a stromatolite showing the fossil record of Earth, organic matter as was already found on Mars, and an example atmospheric spectrum of an Earth-like exoplanet. (Image Credit: NASA, Wikimedia Commons)

Three fundamental questions need to be answered to enable the detection of life beyond Earth as well as the earliest life on Earth and beyond: (i) where do we need to search for life, (ii) how do we define what we are searching for, and (iii) how do we correctly interpret our findings. One of our greatest challenges is, to avoid misconceptions that can easily arise through this multilingual approach, potentially leading to false claims of life detection. In this Working Group we bring together a gender balanced, multinational, multidisciplinary group of scientists and philosophers of science who address the question of how to avoid misconceptions from a range of different perspectives. We concentrate our efforts on three different domains: (1) origin and earliest evolution of life on Earth, (2) tracers of habitability and past or present life on planets or moons in the Solar System, and (3) signatures of habitability and of biotic processes in exoplanetary atmospheres.

The online kick-off meeting was held from 15 to 19 November 2021. The aim of the meeting was to identify the steps towards the meeting in June 2022 at ISSI in Bern. We identified the following topics to further research in preparation for the ISSI meeting: (I) the development of a tracers search engine and the identification of keywords to build the search engine upon; (II) identification of gaps and open questions in tracer knowledge; (III) philosophical aspects of tracers definitions; (IV) online round table discussions with experts to inform public and media on the tracers debates

Working Group members currently include: Mickael Bacqué (DLR); Laurie Barge (JPL); Jo Barstow (Open University, UK); Karim Benzerara (Sorbonne Université, Muséum National d'Histoire Naturelle); Mark Claire (St. Andrews University); Charles Cockell (University of Edinburgh); Julie Cosmidis (Oxford University); Vinciane Debaille (Université Libre de Bruxelles); Eric Gaidos (University of Hawai'i at Manoa); Lee Grenfell (DLR); Kevin Heng (University of Bern); Emmanuelle Javaux (Université de Liège); Sarah Johnson (Georgetown University); Inge Loes ten Kate (Utrecht University); Laura Kreidberg (Max Planck Institute for Astronomy); Purificacion Lopez-Garcia (Université Paris-Saclay); Christophe Malaterre (Université du Québec à Montréal); Sean McMahon (University of Edinburgh); Victoria Meadows (University of Washington); Stephen Mojzsis; Lena Noack (Freie Universität Berlin); Lucas Patty (University of Bern); Raymond Pierrehumbert (Oxford University); Frank Postberg (Freie Universität Berlin); Chris Reinhard; Paul Rimmer (Cambridge University); Sarah Rugheimer (Oxford University); Monica Sanchez Roman (VU University Amsterdam); Franck Selsis (Université de Bordeaux); Nick Tosca (Cambridge University)

Inge Loes ten Kate

International Teams

International Teams consist of about 8–15 external scientists, addressing a specific scientific topic in a self-organized 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 prioritization done by the Science Committee.

Listed are Teams that had a meeting at ISSI in the period of the 26th business year. A rationale is given only for the Teams selected in 2020; for the others see the previous Annual Reports.

Teams selected in 2018

International Combination Service for Time-variable Gravity Field Solutions

Adrian Jäggi, University of Bern, Switzerland
Session: 11–15 January 2021

Teams selected in 2019

Complex Systems Perspectives Pertaining to the Research of the Near-Earth Electromagnetic Environment

Team leader: Georgios Balasis, University of Athens, Greece
Session: 15–19 November 2021

Sombreros and Lampposts: The Geometry of Accretion onto Black Holes

Team leaders: Andrzej Zdziarski, Polish Academy of Sciences, Warszawa, Poland, and Tomaso Belloni, INAF, Merate, Italy
Session: 29 November – 3 December 2021

Teams selected in 2020

Effects of Solar Wind High-Speed Streams on the Ionosphere-Thermosphere System

Team Leaders: Anita Aikio, University of Oulu, Finland, and Aurélie Marchaudon, Université de Paul Sabatier, France
Session at ISSI: *7–11 November 2022*
Scientific Rationale: The aim is to study how solar wind high-speed streams (HSSs) originating from the coronal holes on the Sun affect the terrestrial ionosphere-thermosphere (I-T) system. The versatile expertise of the Team covers state-of-the-art measurements and modeling. Due to the pandemic, the Team has so far only remote meetings. Progress has been made in data analysis specifically. During a selected long-lasting geomagnetic storm event caused by two interacting HSSs, both regional and global aspects have been studied, with the focus on changes in high and mid-latitude electron density and total electron content (TEC) changes. The versatile data set comprising of plasma parameters from the EISCAT radars, TEC and 3D ionospheric tomography from GNSS observations, AMPERE field-aligned currents, SuperDARN convection maps, TIMED/GUVI observations of the O/N2 ratio, and FPI observations of neutral winds give information of the physical processes involved. Modeling the event with the IRAP Plasmasphere Ionosphere Model (IPIM) and TIE-GCM simulation is in progress. The aim is to identify mechanisms behind the electron density and TEC depletions and increases at different locations and at different phases of the storm. Possible candidates to cause variations in electron density involve ion-neutral frictional heating and its effect on ion-neutral chemistry, neutral composition changes, plasma convection, neutral winds, ion-neutral momentum coupling, and atmospheric gravity waves.

Langmuir Probes, a 100 Year Workhorse: Easy to Fly but Difficult to Interpret

Team Leader: Laila Andersson, University of Colorado, USA
Session at ISSI: *tbd*
Scientific Rationale: Bulk measurement of the plasma is critical for our understanding the space environment. As an example, the electron temperature drives many reaction rates in the thermosphere and ionosphere regions. Therefore, electron temperature data are important for any attempt to model or predict the dynamics in this region. The only in situ instruments that can provide this information are Langmuir Probes. However, interpreting the measurements from a Langmuir Probe requires a scientific understanding of how the local plasma environment interacts with the probe and the spacecraft. With

more and more Langmuir Probes flying, there is a need to have a common scientific understanding of how these interactions impact the measurements. The literature on how to interpret Langmuir Probe measurements in space is incomplete, scattered, and often very focused on one particular spacecraft in one particular environment.
For design of new instruments or data analysis packages there is a need to collect and organize knowledge on topics such as: how do plasma flows change the potential around a spacecraft/sensor and thereby the current to the probe; can Langmuir probe measurements truly provide the spacecraft potential; how fast can the spacecraft/probe reach equilibrium with the surrounding plasma; the effect of magnetic fields, and what limits the lower and upper temperature range measured by a Langmuir probe? This Team includes representatives from different instrument teams such as MAVEN, ROSETTA, Akebono, DEMETER, C/NOFS, Swarm, many sounding rockets, and laboratory plasma studies. It will allow individuals actually working with the interpretation of measurements in different instrument teams to get together and discuss fundamental understanding of probe/spacecraft interaction and the local plasma environment. The goal is to provide information and guidance for future missions.

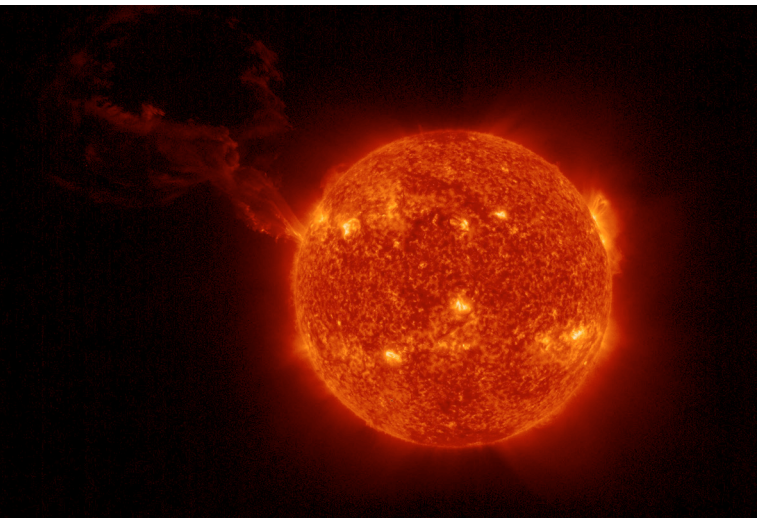
Use of Geostationary Satellites to Improve Air Quality Characterization and Forecasts (ISSI – ISSI Beijing Team)

Team Leaders: Guy Brasseur, Max Planck Institute for Meteorology, Hamburg, Germany, and Claire Granier, NOAA, Toulouse, France
Session at ISSI: *tbd*
Scientific Rationale: Space observations of the chemical composition of the atmosphere are a primary source of information on the formation and fate of large-scale and regional-scale air pollution. In the very recent period, there have been major advances in space observations of chemical species, with the launch of the Sentinel-4 satellite, which includes the TROPOMI instrument. This unique instrument observes several key air pollution species at a much higher spatial resolution than earlier instruments. Furthermore, in February 2020, a geostationary satellite, GEO-KOMPSAT-2, was successfully launched, which includes the Korean GEMS spectrometer, the first geostationary instrument measuring air pollution from space. GEMS is the Asian element of a constellation of three geostationary satellites, which will include in a few years' time the Sentinel-4 European component and the TEMPO component for North America.
The project will investigate and develop novel approaches to make the best use of these high temporal and spatial resolution satellite observations with the aim of improving regional and local air quality monitoring and forecasts. The Team is composed of experts in space observation retrievals, in-situ measurements, meteorological and chemical modeling, data assimilation and inverse modeling and surface emissions. Two projected meetings are planned: one in Beijing and one in Bern to provide the opportunity for a detailed discussion on the different issues related to the optimized use of the most recent and future high-resolution satellite datasets. The first meeting that will be organized in Beijing will give an excellent opportunity to share the first results from the geostationary GEMS instrument focusing on Asian pollution, and to contribute in the future to the analysis of the other space observations from geostationary satellites.

Artist's rendition of the deployed GEO-KOMPSAT-2A satellite (Image Credit: KARI)

SHoT: The Stellar Path to the Ho Tension in the Gaia, TESS, LSST and JWST Era

Team Leader: Gisella Clementini, INAF, Bologna, Italy
Session at ISSI: *4–7 July 2022*
Scientific Rationale: One of the most debated issues in modern astrophysics is the current sharp conflict existing between the measurements of the expansion rate of the Universe (the Hubble constant, H0) as inferred from the anisotropy of the cosmic microwave background (CMB) and as measured from different distance indicators in the local Universe (distance ladder measurements). The CMB measures the age of the Universe a few hundred thousand years after the Big Bang (Early-Universe probes), the distance ladder measures the age of the Universe now (Late-Universe probes).
If the Big Bang theory of the origin and evolution of our Universe is correct these measurements should agree on the value of H0 within the errors. However, currently there is clear disagreement at the 4-5 sigma level between Early-vs-Late Universe measurements.
This could point to a serious measurement error (which has not been identified despite several years of improve-



The "Full Sun Imager (FUI)" of the Extreme Ultraviolet Imager (EUI) on board the Solar Orbiter spacecraft captured a giant solar eruption on 15 February 2022. (Image Credit: Solar Orbiter/EUI Team/ESA & NASA)

ments), or imply the need to revise our understanding of the cosmos and its fundamental physical laws.
This project aims to raise the accuracy of the astronomical distance ladder and quantify the H0 tension by specifically tackling uncertainties and systematics affecting different methods to measure astronomical distances. This is pursued by exploiting the data products of Gaia (E)DR3 releases along with data from the Transiting Exoplanet Survey Satellite (TESS), the James Webb Space Telescope (JWST) and the Legacy Survey of Space and Time at the Vera Rubin Observatory (LSST@VRO) and building on the broad spectrum of competencies of the Team members and their direct involvement in such missions.

Data-driven 3D Modeling of Evolving and Eruptive Solar Active Region Coronae

Team Leaders: Georgios Chintzoglou, Lockheed Martin Solar and Astronphysics Lab, Palo Alto, USA, and Michael Wheatland, The University of Sydney, Australia
Session at ISSI: *24–29 April 2022*
Scientific Rationale: Over the last decades we have seen great progress in our understanding of how solar active regions (ARs) form from first principles thanks to advanced 3D magnetohydrodynamic (MHD) simulations covering the solar interior up to the solar corona. However, such simulations are extremely computationally expensive and they are not able to model the birth and evolution of real, observed ARs, because they are not explicitly constrained by the observations. We call such models "data-inspired", as in "inspired from observations". A separate class of 3D models has been developed, known as "data-constrained" because real observations of the magnetic field of the Sun at the photosphere are used to reconstruct the magnetic field in the solar atmosphere. However, they rely on simplifications, e.g., assuming the absence of plasma in the corona and that the magnetic field there is "force-free" (i.e., electric currents are aligned with the magnetic field) and static. Despite the strong assumptions and limitations, "data-constrained" models are still widely used by the scientific community. A new class of 3D models called "data-driven" are also based on the data available from observations but are able to simulate evolving ARs. Hence, they have advantages over the previous approaches. Several models have been developed by different teams around the world. However, each of these uses different methods for data-driving and/or make different assumptions for the coronal environment, e.g., whether it is plasma-free (nonlinear "force-free" modeling) or not (e.g., "data-driven" 3D MHD models). The goal is to develop, test, and assess the next generation of "data-driven" models. The results will improve the understanding of the physical evolution of the solar corona, bringing the field closer to the ultimate goal of accurate prediction of solar explosive events.

The Earth's Exosphere and its Response to Space Weather

Team Leaders: Hyunju Kim Connor, University of Alaska, Fairbanks, USA, and Jochen Zoennchen, University of Bonn, Germany
Session at ISSI: *14–18 November 2022*
Scientific Rationale: The Earth's exosphere is the outermost layer of our atmosphere above ~500km altitude (exobase), where atomic hydrogen (H) is the most dominant species. The exosphere gains and loses hydrogen atoms as a result of the Sun – solar wind – magnetosphere – upper atmosphere interaction via physical processes like atmospheric upwelling, photoionization, and charge-exchange between neutrals and plasmas. Study of the hydrogen density distribution and its variation is a key to understanding the past, present, and future of the Earth's exosphere, its role in Sun – Earth interactions, and the relevance of its physical drivers to other planetary atmospheric escape and evolution. The Team includes data analysts, theorists, modelers, and mission planners in the fields of the inner, middle, and outer exospheres, studying the Earth's exosphere as a complete system and specifically aim to address the following questions:
Q1. How is the exospheric hydrogen density (NH) distributed around the Earth?
Q2. How and why does the density vary during a solar cycle?
Q3. How and why does the density distribution vary during a geomagnetic storm?

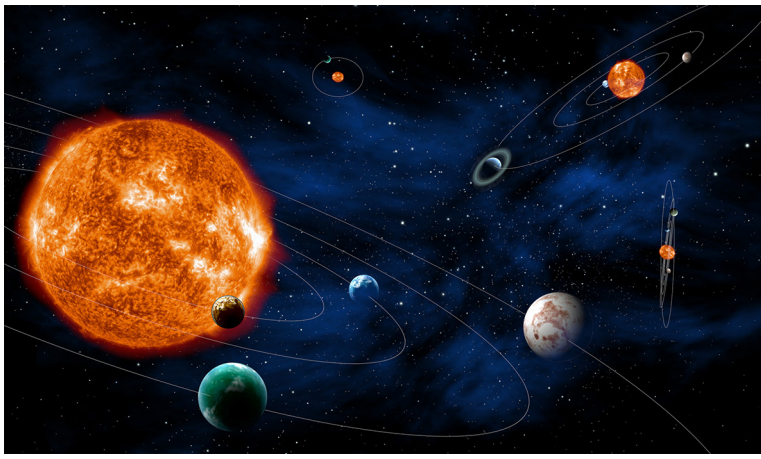
The Team gathers up-to-date understanding of the above questions and improves the currently available empirical NH models by considering space weather impact and/or expanding its spatial coverage. Additionally, the Team will discuss current gaps in our knowledge and suggest future directions, such as modeling and mission planning, to fill the gaps.

Getting Ultra-Precise Planetary Radii with PLATO: The Impact of Limb Darkening and Stellar Activity on Transit Light Curves

Team Leader: Szilard Csizmadia, University of Bonn, Germany

Session at ISSI: *tbd*

Scientific Rationale: Stellar limb darkening plays an important role in the analysis of many astrophysical data (e.g. transiting exoplanets, eclipsing binaries, microlensing events, interferometrically measured stellar radii, Baade-Wesselink analysis of pulsating variables etc). Both stellar and galactic astrophysics as well as exoplanet science could benefit from the improvement of its understanding. Direct measurements of limb darkening can be carried out only on the Sun. To calibrate the limb darkening laws as function of stellar type, well-detached, double-lined eclipsing binaries and multi/transiting planetary systems are needed with well-measured properties – this latter requirement increases the accuracy of the calibration of the limb darkening laws. PLATO (to be launched in 2026) is a European Space Agency M-class mission to detect and characterize primarily earth-like planets around solar-like stars in the habitable zone with 10% accuracy in planetary mass and 3% in planetary radius. Highly accurate masses and radii are needed to study the planetary interiors and habitability. Since such planets have one-year orbital periods, only two to three transits will be observed during PLATO's long pointings. Such transiting exoplanets were not characterized with this accuracy by other missions, e.g. Kepler. Stellar limb darkening and stellar activity are the main challenges to get the planetary radius with this accuracy from such a small number of transits of small planets. Limb darkening modifies the transit depth by a factor of two relative to the case when there is no limb darkening. Limb darkening coefficients can be determined simultaneously with the planet-to-star radius ratio if the signal-to-noise ratio (S/N) is sufficiently high, but that S/N cannot be reached here because the small number of transits and stellar activity do not allow us to increase S/N by averaging the transits. The aim of this ISSI group is to improve our understanding of stellar limb darkening to a higher accuracy than can be reached today. This will lead to a reduction in the systematic errors from the limitations in our modeling of this effect. These improvements are necessary to derive planetary radii with very high precision. Currently, there are deficits in our theoretical understanding of stellar atmospheres where the limb darkening occurs, and in how the stellar magnetic field, and other stellar activity phenomena (spots, plages, faculae, flares) play a role in this. The Team will investigate the effects of poorly known stellar limb darkening on the derived planetary radii and the effect of stellar activity on limb darkening and also on planetary radii. This is essential in order to reach the goals of PLATO.



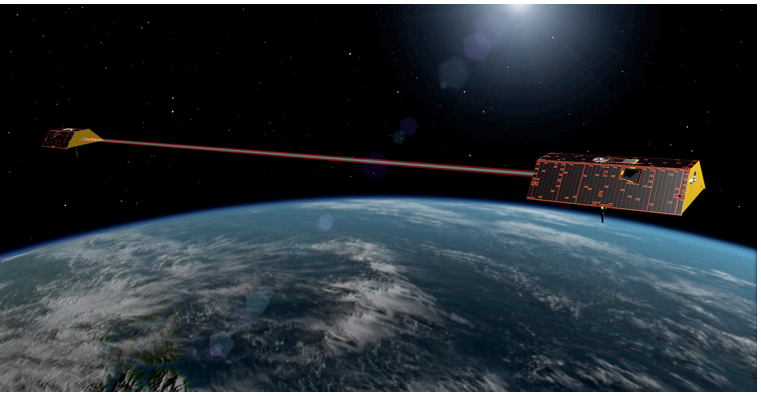
The PLATO (PLAnetary Transits and Oscillations of stars) mission will assemble the first catalogue of confirmed and characterized planets with known mean densities, compositions, and evolutionary ages/stages, including planets in the habitable zone of their host stars. PLATO is planned for launch by 2026.
(Image Credit: ESA,C. Carreau)

The Fireworks Finale in High-Redshift Distant Galaxy Proto-Clusters

Team Leaders: Hervé Dole, Université Paris-Saclay, Orsay, France, and Brenda Frye, The University of Arizona, Tucson, USA

Session at ISSI: *tbd*

Scientific Rationale: Clusters of galaxies allow the Team members to uniquely probe the most active sites of star formation in the universe. By undertaking such studies, the scientists gain insights into the physics underlying galaxy evolution in dense environments, the formation and growth of the structure early in the expansion of the Universe, and cosmological parameters. Despite a myriad of observational and theoretical challenges in detecting, characterizing, and modeling clusters, there has been remarkable progress in studying these structures. In recent years, many high-redshift galaxy clusters (z>1) and proto-clusters (z>2) have been detected, establishing a rudimentary understanding of how the most massive gravitationally bound structures formed and evolved.



GRACE Follow-On (GRACE-FO) is continuing GRACE's legacy of tracking Earth's water movement across the planet. (Image Credit: NASA/JPL-Caltech)

These observations and recent modeling have begun to answer some of the most crucial questions in contemporary astrophysics and cosmology: 1) How and when did cluster galaxies forme stars? 2) At what epoch and over what timescale? 3) What is the fate of the gas in clusters and what halts star formation in cluster galaxies?
The Team is leading a multiwavelength investigation based on photometric selection using Planck data, followed-up by Herschel, Spitzer, IRAM, and ALMA observations. The color selection approach hardwires the redshifts of the proto-clusters to be in the redshift range of 1.5 – 3. Astronomers have now transitioned to a data-rich phase in the investigation of these galaxy overdense regions. The proto-cluster sample will provide the missing link for understanding proto-cluster formation and then placing these structures into the overall context of galaxy evolution. The physics regulating the transition of galaxies in overdense region from objects which are among the most actively starforming in the universe to purely secularly-evolving is one of the major unsolved problems in contemporary astrophysics.

Feeding the Spinning Top – Spin Evolution of Accretion-Powered Pulsars in High-Mass X-Ray Binaries

Team Leader: Ilek El Mellah, KU Leuven, Belgium
Session at ISSI: 13–17 September 2021
Scientific Rationale: Neutron stars represent frequent outcomes for massive stars after they ran out of fuel and collapsed. These incredibly compact objects behave like spinning magnets which can capture surrounding material and emit tremendous amounts of light. In high-mass X-ray binaries, matter is supplied to a young and highly magnetized neutron star by an orbiting blue supergiant star. This inflow has long been suspected to be responsible for the variations of neutron star spin period, but the classic models currently fall short of accounting for the observed trends. Contrary to millisecond pulsars, their older, faster and lower magnetic field siblings found in other systems, the neutron stars in high-mass X-ray binaries exhibit steady phases of spinning up and down of unknown origin. They could either be due to a variable (or "clumpy") mass supply from the stellar companion, or to plasma instabilities at the outer rim of the magnetosphere which surrounds the neutron star, similarly to the magnetosphere around the Earth which interacts with the Solar wind. The Team builds upon past modeling efforts and brand new observations in order to develop a unified view on the capture of stellar material by neutron stars in high-mass X-ray binaries. The scientists make use of the most recent high performance computing techniques to simulate highly magnetized plasmas both at micro and macroscopic scales. These environments share many common points with space plasmas in the Solar system and mutatis mutandis, the members can adapt numerical tools in order to address the case of neutron star magnetospheres.

Time-Variable Gravity Field Modeling and Simulation from Present and Future Gravity Satellite Missions (ISSI – ISSI Beijing Team)

Team Leader: Wei Feng, Chinese Academy of Sciences, Hubei, China
Session at ISSI: *tbd*
Scientific Rationale: The Team works on Earth gravity field modeling based on the GRACE and GRACE-FO satellite missions with the joint effort from Chinese and European groups. These missions are dedicated to determine gravity field variations, hence mass transfers on the Earth, at a daily to monthly periodicity. The high precision gravity fields derived based on the Team's collaboration will deepen our understanding of mass variability in the Earth system and climate change, e.g., droughts and flooding, sea level change, groundwater depletion, glacier melting, etc.
The aim will be to join their effort for gravity field modeling especially the added contribution from China to generate established combined time-variable models to be included in the Combination Service for Time-variable Gravity Field Solutions (COST-G) and to establish so improved reference models as it has been demonstrated by the EGSIEM (European Gravity Service for Improved Emergency Management) project of the European Community. In addition, the simulation of constellation design for Chinese gravity satellites will be performed to pave the way to multi-pair gravity.
The Team has organized two online meetings in January and August 2021. The latest status of European and Chinese gravity missions has been discussed in the meet-

ings. The next step of the collaboration is to produce a combined gravity product with less uncertainty and higher spatial resolution. In addition, a synergistic observing scheme of German-US GRACE-FO and Chinese planned TainQin-2 will be investigated later. The collaboration of the Team will pave the way to retrieve temporal gravity fields with higher spatio-temporal resolutions and accuracy considering the efforts from different study groups and different gravity missions in China and Europe.

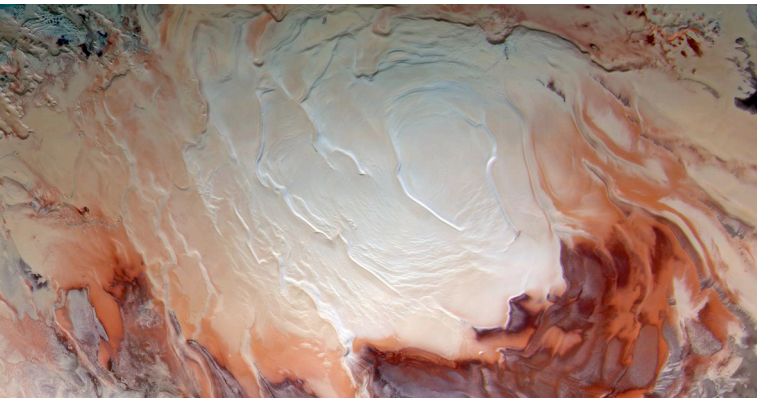
Advanced Three-Dimensional Modeling of the Magnetic Field in Active Regions on the Sun

Team Leader: Gregory D. Fleishman, New Jersey Institute of Technology, Newark, USA
Session at ISSI: *23–27 May 2022*
Scientific Rationale: Sunspots are the hallmark of solar activity. High resolution spectropolarimetry is rapidly progressing toward a better physical understanding of small-scale structures in sunspot penumbra and umbra. However, the understanding of the magnetic structure of sunspots in the chromosphere and corona is lagging behind. In the modeling of magnetic fields in the corona, the scientists still rely on various extrapolation methods, which do not include a realistic atmosphere nor are they constrained by the observations. The Team will explore different approaches to address this deficiency. Nonlinear force-free field reconstructions that employ routinely available full-disk photospheric vector magnetograms as bottom boundary conditions represent the state-of-the-art of coronal magnetic field modeling. Such reconstructions, however, are not unique and suffer from an inconsistency between a force-free coronal magnetic field and non-force-free photospheric boundary condition, from which the coronal reconstruction is performed. Realistic time-dependent MHD models could help greatly, but are not expected to be routinely available any time soon. The use of chromospheric vector magnetograms can aid the coronal part of the magnetic model, but does not help to build the magnetic model between the photospheric and chromospheric levels.
The Team will use a combination of state-of-the-art modeling with existing and near future high-resolution observations (e.g. from new DKI 4-meter aperture Solar Telescope, DKIST) to evaluate existing approaches in modeling the chromospheric and coronal magnetic fields and identify key failure points in such modeling. The goal is to integrate newly available chromospheric and/or coronal magnetic field data with the vector photospheric magnetograms to improve the magnetic field reconstructions. The Team will select several well-observed active regions, which have both chromospheric and coronal magnetic field diagnostics from optical and radio spectropolarimetry, construct their 3D coronal magnetic field models using various complementary techniques, and validate these models using the observations. As a result of this effort a better constrained models of the coronal magnetic field will be created, available for public use in the form of data cubes, codes, and scientific publications.

Stratospheric Age-of-Air: Reconciling Observations and Models

Team Leader: Hella Garny, DLR, Wessling, Germany
Session at ISSI: *7–10 June 2022*
Scientific Rationale: The large-scale transport circulation in the stratosphere, the Brewer-Dobson circulation (BDC), strongly influences the distribution of radiatively important trace gases like ozone and needs to be properly represented in atmospheric models for reliable climate predictions. Its strength is best understood through observations of trace species, and the most common measure for the circulation strength is the mean transport time from the surface to a point in the stratosphere, the so-called mean Age-of-Air (AoA). Global observations of trace gases by satellite instruments are the most promising way to obtain consistent global estimates of mean AoA, however few satellite-based AoA products exist at present. Complementary to satellite data, in-situ observations form a data base for estimations of mean AoA. The AoA estimates from different data sources show considerable difference, for a variety of reasons: sampling biases and retrieval uncertainties, the use of different trace gas species, and different methods to convert tracer mixing ratios to mean AoA. In addition to these inconsistencies between different observational estimates, global models also show a large inter-model spread in the simulation of mean AoA, indicating deficits in the simulation of transport processes in the stratosphere. Furthermore, long-term trends in AoA in global models are consistently negative, i.e. indicating a speed-up of the stratospheric transport circulation, while the currently available tracer-based observational estimates indicate a slight increase in mean AoA in the northern mid-latitude mid-stratosphere. The goal is to consolidate on the best possible method to calculate mean AoA from observations, and therewith homogenize observationally-based mean AoA data products. Further, the Team will identify which additional diagnostics can give information on individual transport processes, and will establish how such diagnostics can best be used reach conclusions regarding the reasons for the deficits of global models to simulate transport processes.

International Teams



The southern polar ice cap on Mars at the beginning of spring. (Image Credit: ESA/DLR/FU Berlin, CC BY-SA 3.0 IGO)

Similarities and Differences in the Plasma at Comets and Mars

Team Leader: Charlotte Goetz, ESTEC, Noordwijk, The Netherlands
Session at ISSI: 6–10 September 2021
Scientific Rationale: All objects in the solar system are embedded in the solar wind plasma emanating from the Sun. The interaction of this plasma with the atmospheres of the bodies can be roughly divided into two categories: Magnetized bodies, such as Earth, Mercury and the giant planets, and unmagnetized bodies, such as Mars, Venus, comets and some moons. Recently great strides have been made especially in the Mars and cometary environment due to more available data from the MAVEN and Rosetta missions. Comparative studies of these environments are helpful in understanding the different plasma physical processes at play. The Team focuses on the development of plasma boundaries at comets and Mars: How does Mars' atmosphere keep the solar wind from reaching the surface and how do remnant surface magnetic fields contribute to this? At comets, these fields do not exist, so how does this affect the most inner regions? While comets undergo large seasonal variations due to large orbital eccentricity, Mars has a smaller degree of variation. Is this reflected in the formation of the boundaries? Better understanding of these structures will help to further our knowledge of atmospheric escape processes at Mars and help interpret data at a comet, where the data quality is not optimal and reference measurements are often inadequate. While this Team focuses on Mars and comets, the Venus and Titan environment will also inform our investigations and allow us to dive deeper into these plasma environments.

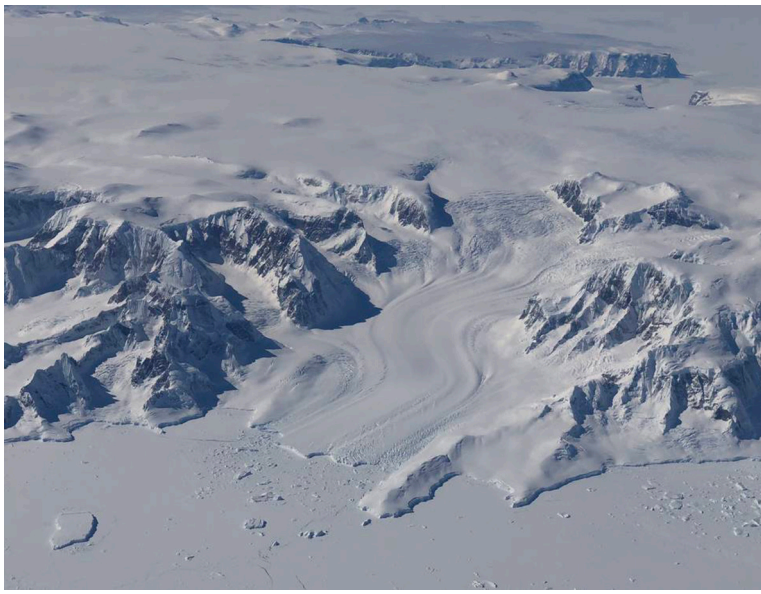
Towards Determining the Earth Energy Imbalance from Space

Team Leader: Margrit Haberreiter, World Radiation Center, Davos, Switzerland
Session at ISSI: *tbd*
Scientific Rationale: A positive Earth Energy Imbalance (EEI) is the energy, which is continuously stored by the Earth and will ultimately be released to the atmosphere, causing global warming. The "imperative to monitor Earth's energy imbalance" (von Schuckmann et al., 2016) has been continuously reported by the Earth's climate community. The EEI has been identified to be around 0.5 to 1.0 Wm^{-2}. To determine its exact value both the Total Solar Irradiance (TSI) and the Top of the Atmosphere (ToA) Outgoing Radiation (TOR) need to be measured with unprecedented accuracy and precision. However, so far, the EEI could not be determined as the measurements were not sufficiently accurate. This calls for improved instrument technologies as well as a traceable calibration chain of the space instrumentation. To pave the way in that direction, the Team work is dedicated to exploit the latest observations of the Earth outgoing radiation. Specifically, the Team analyses the Outgoing Longwave Radiation (OLR) measurements by PMOD/WRC's SI-traceable Compact and Light-weight Absolute Radiometer (CLARA) onboard NorSat-1 with the measurements from Radiometer Assessment using Vertically Aligned Nanotubes (RAVAN), as well as the measurements from the Belgian Sun-earth IMBAlance (SIMBA) satellite. The data will then be further compared with ongoing measurements obtained with NASA's Clouds and the Earth's Radiant Energy System (CERES). The key advantage of the CLARA instrument is that it measures both the TSI and OLR as SI-traceable variables. The Team will evaluate the performance and uncertainty of each of the instruments to identify observational challenges that need to be overcome to be able to measure both TSI and the Earth's outgoing radiation with the required accuracy to ultimately be able to determine EEI.

Multi-Sensor Observations of Antarctic Sea Ice and its Snow Cover

Team Leaders: Petra Heil, University of Tasmania, Hobart, Australia and Rachel Tilling, NASA Goddard Space Flight Center, Greenbelt, USA
Session at ISSI: *tbd*
Scientific Rationale: The Southern Ocean is unique within the Earth System as it closely integrates climatic, biogeochemical, and ecological systems into one complex unit. The Southern Ocean and Antarctic are also disproportionately important in their effect on the global system, which highlights the need to understand recently observed changes in the Earth's cryosphere. One dramatic

change has been the rapid reduction in the Antarctic sea ice during winter: after an all time record of just above 20 Million km^2 in 2014, the maximum extent of Antarctic sea ice has collapsed in the most recent austral winters. State-of-the-art ocean/sea-ice and climate models consistently underestimated this observed recent reduction in Antarctic sea ice. To explore this mismatch and to improve model physics of both, thermodynamic and dynamic processes, information on ice thickness and snow depth-on-sea ice are required. Ice thickness provides an integrated measure of changes in the energy budget, while snow on sea ice adds a key insulating layer and, in the Antarctic, contributes to sea-ice volume via snow-ice formation. While not readily observed, both these variables are critical for forecasting and navigation.
The Team will combine observations from several spaceborne sensors with those measured onboard of assets during field campaigns, as well as with in situ campaign observations and autonomous measurements. The primary objective of this project is to identify and prototype a processing chain to derive Antarctic sea-ice thickness from a range of remotely-sensed observations, in order to understand its spatial-temporal characteristics in response to change and variability in external forcing. While areal extent of sea ice is routinely monitored by satellite passive microwave sensors, deriving sea-ice (or snow) thickness from remote observation presents a matter of urgency in informing sea ice and climate research.



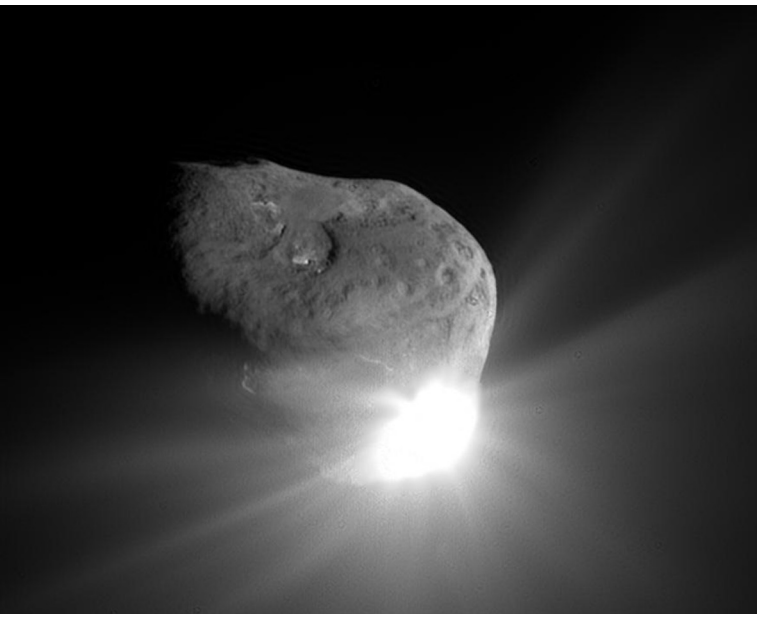
Using data from the ICESat and ICESat-2 laser altimeters, scientists precisely measured how much ice has been lost from ice sheets in Antarctica and Greenland between 2003 and 2019. The Antarctic Peninsula, seen here, was one of the fastest changing regions of the continent. (Image Credit: NASA GSFC/K. Ramsayer)

WaLSA: Waves in the Lower Solar Atmosphere at High Resolution

Team Leader: Peter Keys, Queen's University Belfast, United Kingdom
Session at ISSI: *19–22 April 2022*
Scientific Rationale: Heating in the solar atmosphere has been an open question and much debated topic for many decades. There are two main suggestions to explain the rise in temperature from the surface (photosphere) to the outer regions of the solar atmosphere (corona), namely: flaring and magnetohydrodynamic (MHD) waves. MHD waves have been observed in a wide array of magnetic structures (e.g., sunspots, pores) with many of the theoretically predicted MHD modes having been directly observed in these structures. Also, there is observed evidence that MHD waves transfer energy and momentum to various layers. Most studies on MHD wave guides in the solar atmosphere have focused on properties in the corona.
This Team aims to elucidate further on MHD waves in the less-studied lower solar atmosphere (i.e., the photosphere and the chromosphere). This is a challenging topic, as this is a highly dynamic region, where properties can change rapidly with height. As such, the Team is composed of experts on high-resolution observations, simulations and theory of MHD modes in the lower solar atmosphere. The goal is to obtain a comprehensive picture of wave propagation, from the generation of waves in sub-photospheric layers to their channeling and eventual dissipation in outer regions. To address these goals, the Team will use high resolution spectropolarimetric data to ascertain magnetic field and velocity variations with height for propagating waves, so that we can make more meaningful comparisons to both theory and advanced MHD wave simulations.

Resolving the Generation Mechanisms and Electrodynamical Effects of Medium Scale Traveling Ionospheric Disturbances (MSTIDs)

Team Leaders: Jeffrey Klenzing, NASA Goddard Space Flight Center, Greenbelt, and Katherine Zawdie, US Naval Research Laboratory, Washington, USA
Session at ISSI: *11–15 July 2022*
Scientific Rationale: In the Earth's ionosphere (the charged portion of the upper atmosphere between about 60-1000 km altitude) waves are a frequent feature and have been found to occur at all latitudes. These waves are typically referred to as Medium Scale Traveling Ionospheric Disturbances, or MSTIDs. Some of these waves have been observed to create a conjugate effect, which



This image of comet Tempel 1 was taken 67 seconds after it obliterated Deep Impact's impactor spacecraft. Tempel 1 is a Jupiter-family comet (JFC). JFCs are short-period comets with orbital periods less than 20 years. They are named as such since their current orbits are primarily determined by the gravitational influence of Jupiter. (Image Credit: NASA/JPL-Caltech/UMD)

means that a similar feature appears in the opposite hemisphere at the same magnetic longitude. It is believed that there are a number of processes responsible for MSTID generation, including: plasma instabilities, atmospheric gravity waves from Tropospheric storms, and high latitude forcing. While some criteria have been established to distinguish between types of MSTIDs, many questions remain regarding the mechanisms responsible for their formation. In addition, it is unclear if multiple types of MSTIDs are capable of creating conjugate effects. The goal is to better understand MSTIDs from a geophysical perspective and to revise the terminology and classification schemes accordingly. Specifically, the Team is working to better understand the origin of MSTIDs, how to best classify and identify different types of MSTIDs, and the conditions necessary to generate conjugate behavior. This work is being carried out through 1) comparative observations from space-based and ground-based assets, including Swarm, All-sky Imagers, Ionosondes, and Radar 2) comparison of proposed physical generation mechanisms through multiple model techniques, and 3) detailed data-model comparisons, including coordinated campaigns.

The Life Cycle of Comets

Team Leader: Rosita Kokotanekova, European Southern Observatory (ESO), Garching, Germany
Session at ISSI: *7–11 March 2022*
Scientific Rationale: Scientific Rationale: Jupiter-family comets (JFCs) are among the most intriguing objects in the Solar System. Traditionally, they were considered to be well-preserved planetesimals which have retained key evidence from the epoch of planet formation. However, recent studies have established that JFCs have been significantly altered and that tracing their evolution is key for understanding the conditions in the Solar System throughout its history.
Today's JFCs formed as planetesimals, beyond the orbits of the giant planets. During the epoch of planetary migration ~4 billion years ago, gravitational interactions with the giant planets scattered many millions of them into the outskirts of the Solar System. In the current epoch, some of the Trans Neptunian objects (TNOs) re-enter the middle Solar System, first as Centaurs (bodies with either a perihelion or a semi-major axis between those of the outer planets), and then as active JFCs. As Centaurs move closer to the Sun their temperatures rise, which triggers the onset of activity. JFCs orbit even closer to the Sun and their continuous activity leads to significant mass loss and noticeable surface changes with every apparition. Finally, JFCs are believed to gradually lose their activity until they become dormant comets.
The individual stages of the comet life cycle have been studied extensively over the past few decades. However, the findings about the different populations are rarely combined and a complete model of comet evolution is still missing. The Team working on telescope observations, theoretical models and spacecraft data will review the current knowledge on the life cycle of comets. The scientists will also focus on modeling and observations projects to address the missing knowledge on cometary evolution

The Metal-THINGS Survey of Nearby Galaxies

Team Leader: Maritza Lara-Lopez, Universidad Complutense de Madrid, Spain
Session at ISSI: *tbd*
Scientific Rationale: The star formation process is one of the least understood phenomena and one of the biggest open questions in astronomy, even though it is critical in every aspect of galaxy evolution. To truly understand how galaxies evolve, it is first essential to understand what determines the distribution in stellar masses produced from a burst of star formation, or initial mass function (IMF). The IMF influences most observable properties of stellar populations and thus galaxies. Constraining the variations in the IMF will have a profound impact on real-

istic modeling of the cosmological evolution of galaxies.
Another crucial open question associated to the star formation process is known as "downsizing": in which stars in more massive galaxies tend to have formed earlier and over shorter timescales; contrary to stars in low mass galaxies, which formed later and on longer timescales. Even though the IMF and downsizing are of extreme importance to understand how galaxies form and evolve, the physical processes responsible for them remain unknown.
With that aim, the Team designed the Metal-THINGS survey, which is obtaining Integral Field Spectroscopy of a unique sample of nearby galaxies from The HI Nearby Galaxy Survey. One of the main characteristics of the THINGS galaxies is that they have spatially well-resolved data across the entire electromagnetic spectrum, from X-rays to radio. Metal-THINGS will fill the currently missing, optical-spectroscopic observational gap for these galaxies by providing thousands of spatially-resolved spectra. In combination with the resolved multi-wavelength information, this will enable the high precision studies required to constrain the IMF and the origin of downsizing.

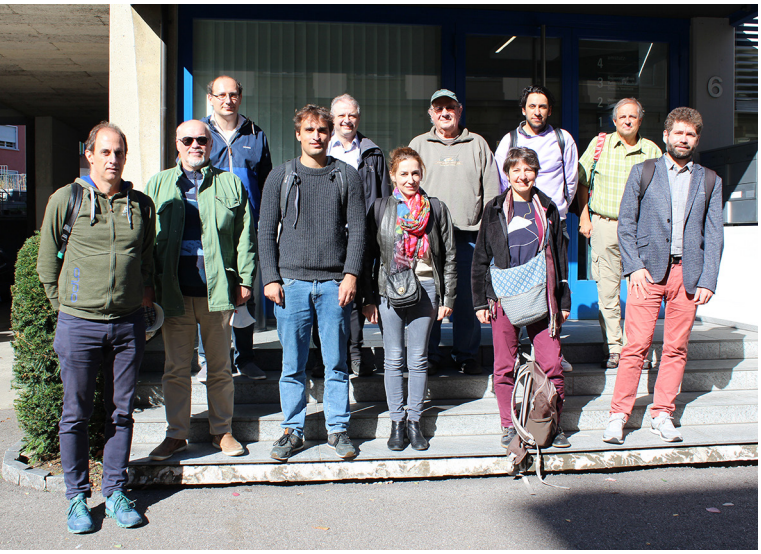
Sprites are extremely rare atmosphere phemomena caused by irregularities in the ionosphere, high above storm clouds, at altitudes of about 80 kilometers. Typically seen as groups of red-orange flashes. (Image Credit: P. Horálek/ESO)

Understanding Mesoscale Ionospheric Electrodynamics Using Regional Data Assimilation

Team Leader: Karl Magnus Laundal, University of Bergen, Norway
Session at ISSI: *14–18 March 2022*
Scientific Rationale: The ionosphere is the inner edge of space, starting at approximately 100-km altitude. Here the neutral atmosphere interacts with electrically charged particles (plasma). In the polar regions of the ionosphere the solar wind causes a large-scale circulation of plasma. This circulation is opposed by collisions with the neutral atmosphere. This tug-of-war leads to a host of phenomena which are both poorly understood, and potentially hazardous for human infrastructure in space and ground. For example, it causes rapid variations in the magnetic field that induce currents which can knock out the electric power grid in large regions. The understanding of such variations is still limited and our ability to predict them is poor. An accurate description of the state of the ionosphere is crucial for understanding the physics of Earth's coupling to space, including hazardous space weather phenomena. To this end, ground networks of magnetometer stations, GNSS receivers, optical instruments, and radars have been deployed, and are routinely used to map ionospheric parameters. However, the spatial coverage of such networks is naturally restricted by the distribution of land mass and access to necessary infrastructure. In regions with good coverage, maps of ionospheric electrodynamic parameters such as plasma convection, neutral winds, magnetic field perturbations, total electron content, and ionospheric currents, can be produced at high spatial and temporal resolution. However, mapping techniques for each of these parameters have been developed separately, and combining them into a complete picture of ionospheric electrodynamics has proven to be a very challenging task. To tackle this problem, this Team brings together specialists within data analysis, measurement techniques, and modeling.

Population-Dynamical Archeology of Galaxies (ISSI – ISSI Beijing Team)

Team Leaders: Ryan Leaman, Max Planck Institute for Astronomy, Heidelberg, Germany, and Ling Zhu, Chinese Academy of Sciences, Shanghai, China
Session at ISSI: *tbd*
Scientific Rationale: Driven by gravity, galaxies are expected to continuously grow through the merging of smaller systems. To derive their past merger history is challenging, as the accreted stars disperse quickly. Within this project, the Team has developed a population-orbit superposition method and applied it to two galaxies, NGC 1380 and NGC 1427, in the Fornax clusters observed by VLT/MUSE. Though the novel method, the scientists have been able to uncover and quantify the major merger that both of these galaxies underwent a long time ago. These past massive merger events are the first such events found in normal fully phase-mixed galaxies beyond the Milky Way and our neighbouring galaxy Andromeda. NGC 1380, with merger mass of ~30 billion solar masses and merger time of ~10 giga-year



The Team working on "Solar Extreme Events: Setting Up a Paradigm" led by Fusa Miyake and Ilya Usoskin met at ISSI for the first time in autumn 2021

ago, has the most ancient and massive merger discovered in the nearby Universe so far. The Team plans to apply the novel method to a large number of nearby galaxies to quantitatively unravel their merger histories.

Strong Gravitational Lensing Studies with CSS-OS and EUCLID (ISSI – ISSI Beijing Team)

Team Leader: Ran Li, National Astronomical Obsevatories of China, Chinese Academy of Science, Beijing, China
Session at ISSI: *tbd*
Scientific Rationale: Strong lensing systems provide a unique laboratory in which to study the fundamental physics of the Universe and the evolution of galaxies. Two next-generation space-based surveys, the Chinese Space Station Telescope survey (CSS-OS) and the ESA Euclid mission, will increase the number of known strong lenses by more than two orders of magnitude, and survey them all with high-resolution imaging in near-UV to infrared wavelengths. The Team comprises experts in strong lensing from both missions, to explore the potential scientific return of a joint analysis of the combined data. Specifically, the scientists try to address the following key problems: 1) How to efficiently search for strong lens systems in Euclid + CSS-OS data 2) How to model the distribution of dark matter in strong lens systems with multi-color imaging and 3) Optimum synergy between the two survey designs.

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 at ISSI: *tbd*
Scientific Rationale: The determination of atmospheric composition trends in the upper troposphere lower stratosphere (UTLS; between 8 to 20 km) is still highly uncertain. The project Observed Composition Trends And Variability in the UTLS (OCTAV-UTLS) will use different coordinate systems (for example, horizontal distance to the sub-tropical jet and vertical distance to the tropopause) to study the large spatial and temporal variability caused by competing transport, chemical, and mixing processes near the tropopause. The goal is to combine satellite, aircraft, balloon and ground-based observations with meteorological reanalysis in a physical consistent way in order to understand the impact of the dynamical and/or chemical processes (e.g., atmospheric winds and atmospheric temperature) driving the natural variability on the observed UTLS trends by the different sensors on different platforms. Thus, the success of this project depends on the participation of several satellite, reanalysis and UTLS experts complemented by airborne, balloon-borne, and ground-based specialiststo fully capture the UTLS complexities. This OCTAV-UTLS-ISSI project will focus mainly on reduction of ozone variability for the assessment of long-term changes in the UTLS leading to two publications and two publicly available datasets. This is the first time that datasets from many different platforms will be consistently analyzed using the same metrics derived from the model data.

Solar Extreme Events: Setting Up a Paradigm

Team Leaders: Fusa Miyake, Nagoya University, Japan and Ilya Usoskin, University of Oulu, Finland
Session at ISSI: 27 September–1 October 2021
Scientific Rationale: The Sun sporadically produces energetic eruptive events, which not only provide inside into unexplored physics but may affect the Earth's environment and form important hazards for our technological society. Such extreme events were not known before the recent discovery of a spike in cosmogenic isotope data ca. 774–775 AD (Miyake et al., 2012), which was shown to be an extreme solar particle storm (Usoskin et al., 2013; Mekhaldi et al., 2015). Several other similar events have been discovered later. Therefore new, earlier unknown types of data appear, leading to a paradigm shift, and a coordinated effort of the research community is needed to analyze them and produce a consistent view and set the paradigm. The Team brings together scientists

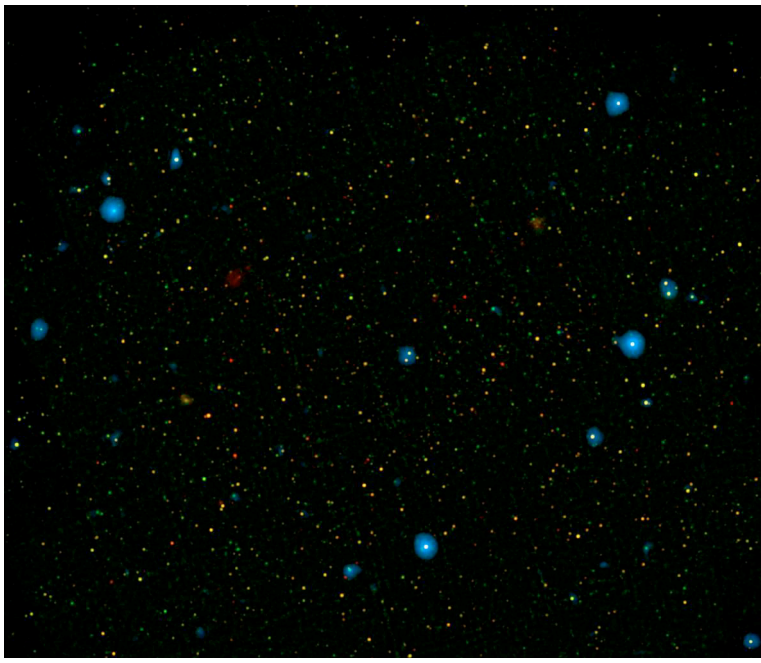
in related fields to attack the problem coherently and to develop a consensus view on solar extreme events, their physics, occurrence probability and consequences. Different sets of data and models are used: decades and centuries of direct scientific observations, millennia of historical records, ~10,000 years of cosmogenic isotope data, millions of years using lunar data, and the statistics of thousands of stellar observations during the last decade. The first meeting took place in September 2021 where the efforts were coordinated towards a common task. The questions considered were: what is an extreme solar event? How strong can it be? How often do they occur? What can be the worst-case scenario for such an event? A set of control tasks was decided to be addressed by the second meeting.

Multi-Scale Magnetosphere-Ionosphere-Thermosphere Interaction (ISSI – ISSI Beijing Team)

Team Leader: Toshi Nishimura, Boston University, USA
Session at ISSI: *11–15 July 2022*
Scientific Rationale: Localized structures in the Magnetosphere-Ionosphere-Thermosphere (M-I-T) system in space have major adverse impacts on radio communications and satellite operations. Although the existence of such structures has been known, efforts for understanding their quantitative properties and formation processes are severely limited. It is a scientifically challenging issue because coupling processes across scales (multi-scale) have to be handled. The Team will quantify the role of multiscale processes in the M-I-T system and advance community's understanding of how multi-scale structures form and evolve. The scientists will determine occurrence conditions and properties of key quantities over multi-scales (energetic particles, flows, currents, plasma density, and neutral density, wind, and temperature) by taking advantage of the growing network of high-resolution observations. Multi-scale numerical simulations will take the observed properties and examine reproducibility and physical mechanisms of formation of meso/small-scale structures. This investigation is timely because of the growing availability of high-resolution observation in space and on the ground, growing capability of high-resolution numerical simulations, and the significant community interest as demonstrated in several recent conferences and workshops.

Multiwavelength View on Massive Stars in the Era of Multimessanger Astronomy

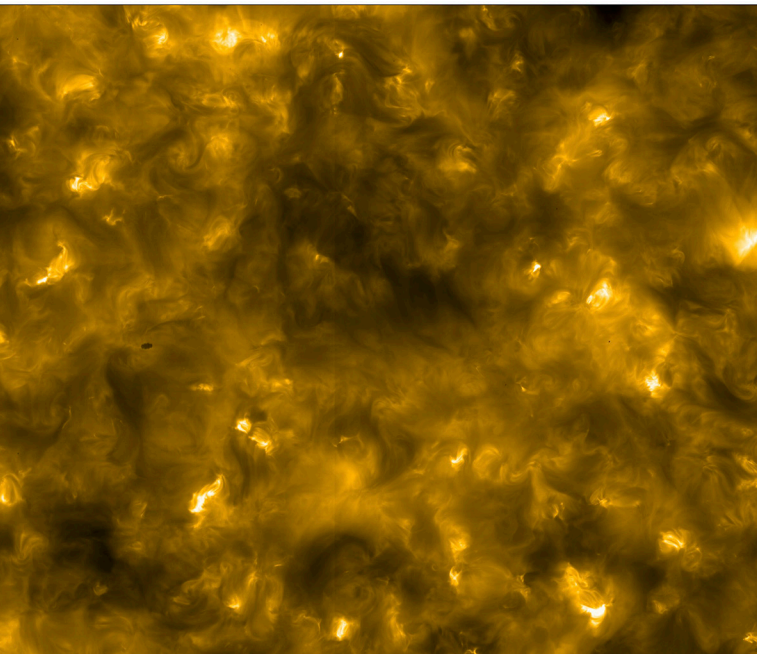
Team Leader: Lida Oskinova, University of Potsdam, Germany
Session at ISSI: 29 November–3 December 2021
Scientific Rationale: Stars which are born with masses



The blue dots in this field of galaxies, known as the COSMOS field, show galaxies that contain supermassive black holes emitting high-energy X-rays. (Image Credit: NASA/JPL-Caltech)

at least ten times larger than our Sun end their lives by collapsing into neutron stars or black holes, tirelessly supplying the Universe with these fascinating compact objects. Gravitational wave observatories are now routinely discovering merging black holes, while X-ray observatories allow to study compact objects which are accreting matter. The goal is to incorporate the gravitational wave, X-ray, and other multi-wavelength and multi-messenger observations of compact objects in the broad picture of how stars live and die. The Team members also strive to understand how stars and compact objects they produce influence their galactic surroundings. The stars which end up their lives as black holes are very hot and emit large amount of ionizing radiation. Their radiation blows matter away from stars generating powerful stellar winds. Stellar winds impact on and structure the circumstellar and even the interstellar medium. The scientists are particularly interested in stars and black holes in other, far away, galaxies which contain fewer oxygen and iron atoms than our own Milky Way galaxy. Studying stars in such «metal-poor» galaxies is needed to understand how the stars and black holes looked and worked at the times when the Universe was much younger. The Team assembles experts in theory, modeling, and observations of stars and compact objects. The multidisciplinary approach allows to bring forward fresh ideas and develop a unified view on stars, compact objects, and galaxies.

International Teams



An image of the Sun's outer atmosphere, the corona, taken with the Extreme Ultraviolet Imager (EUI) instrument onboard Solar Orbiter. (Image Credit: Solar Orbiter/EUI Team/ESA & NASA)

Unravelling Solar Wind Microphysics in the Inner Heliosphere

Team Leaders: Denise Perrone, Italian Space Agency, Rome, Italy, and Sergio Toledo-Redondo, Universidad de Murcia, Spain

Session at ISSI: *16–20 May 2022*

Scientific Rationale: Since the prediction and discovery of the solar wind, understanding its energy balance and transport has become one of the most compelling problems in space plasma science. Thanks to space missions, it has been well assessed that the solar wind temperature decreases with the distance from the Sun more slowly than expected for an adiabatic expanding gas, meaning that locally some heating mechanisms should be at work. Indeed, the solar wind plasma is strongly characterized by nonlinear processes, such as the generation of shocks, waves, coherent structures, magnetic reconnection and particle acceleration, and it represents the best natural laboratory to study in-situ plasma turbulence.

The aim of the Team, composed of 15 scientists with complementary expertises, from in-situ data analysis to kinetic plasma simulations, is to study the processes that lead to electromagnetic energy dissipation in the solar wind at kinetic scales and how such mechanisms evolve with the distance from the Sun. The scientists are taking advantage of the new observations in the inner heliosphere by Solar Orbiter and Parker Solar Probe, with the latter investigating a completely unexplored environment. Moreover, the Team members are using the Magnetospheric Multiscale mission for a detailed view of turbulent dissipation, down to electron scales, in the near-Earth environment. Finally, the observational analysis is supported by high-resolution, sophisticated plasma simulations.

Warm Coronae in AGN: Observational Evidence and Physical Understanding

Team Leaders: Pierre-Olivier Petrucci, Université Grenoble Alpes, Saint-Martin-d'Hères, France, and Giorgio Matt, Universita' degli Studi Roma Tre, Italy

Session at ISSI: 18–22 October 2021

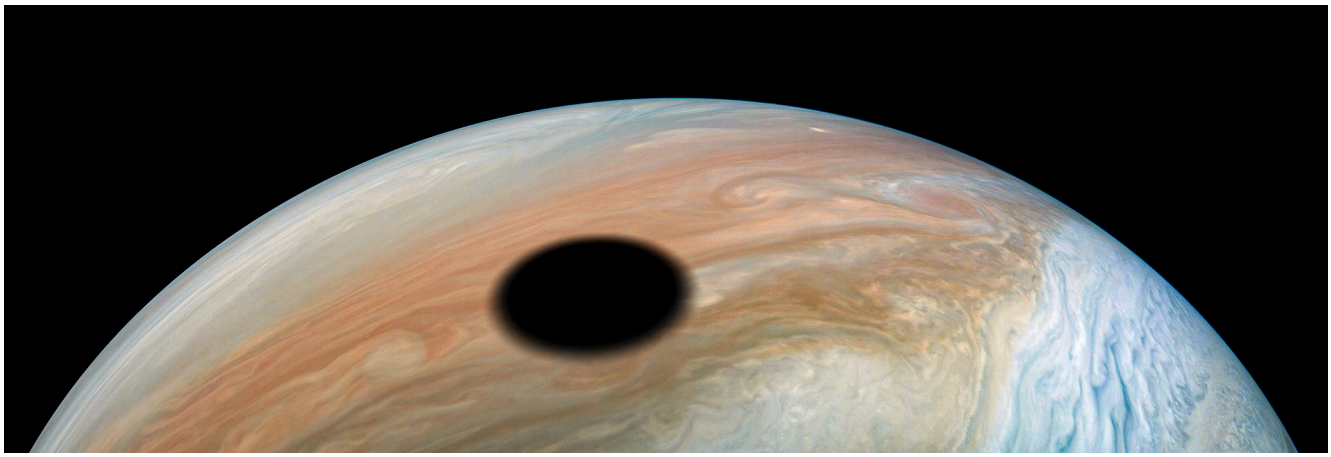
Scientific Rationale: Super-massive black holes (SMBH) are known to be located at the center of almost all galaxies with masses larger than a million times the mass of the sun. In most cases (90%) the SMBH is in a quiescent state. This is the case of the SMBH present in the center of our own Galaxy. When these black holes are strongly accreting, however, they appear as Active Galactic Nuclei (AGN) and show a tremendous release of radiative power especially at high energy (UV, X and γ). A majority of AGN shows the presence of a soft X-ray emission, below 2 keV, in excess with respect to extrapolation of the high-energy power law. The origin of this soft X-ray excess is a long-standing issue. Only two models now appear viable: either blurred ionized reflection in the accretion disk, or thermal Comptonization in an optically thick and warm (kT~1 keV) plasma (the so-called warm corona). The thermal Comptonization modeling of the soft X-ray excess has been given new life by Petrucci et al. (2013, 2018) who suggested that the warm corona could be a powerful, extended, and optically thick plasma covering an almost non-dissipative accretion disk, i.e., all the accretion power would be released mainly in the warm corona. Recent theoretical and numerical works (e.g. Rózanska et al. 2015, Ballantyne 2020, Petrucci et al. 2020) confirm that warm Comptonization is a physically sound model that can explain the origin of the soft X-ray excess. This project, carried out by a Team of experts on X-ray observations of AGNs and high energy radiative transfer modeling, aims at testing and better understanding the warm corona model as an explanation for the soft X-ray excess.

Mass Loss from Io's Unique Atmosphere: Do Volcanoes Really Control Jupiter's Magnetosphere?

Team Leader: Lorenz Roth, KTH Royal Institute of Technology, Stockholm, Sweden

Session at ISSI: *5–9 September 2022*

Scientific Rationale: The atmospheric loss from Io, a moon of planet Jupiter, is the main source of material for the



Jupiter's volcanically active moon Io casts its shadow on the planet in this dramatic image from NASA's Juno spacecraft. As with solar eclipses on the Earth, within the dark circle racing across Jupiter's cloud tops one would witness a full solar eclipse as Io passes in front of the Sun. Such events occur frequently on Jupiter because it is a large planet with many moons. (Image Credit: Enhanced Image by Kevin M. Gill (CC BY 3.0) based on images provided Courtesy of NASA/JPL-Caltech/SwRI/MSSS)

magnetosphere, which is the region around the planet controlled by its magnetic field. Io is also the volcanically most active body in the Solar System and the volcanism plays a key role for sustaining the moon's atmosphere. Within the magnetosphere and plasma community, it is therefore very often assumed that aperiodic changes or transient phenomena in Jupiter's magnetosphere are triggered by sudden and strong changes in the mass loss from Io, supposedly related to volcanic outbursts.

The assumption of direct "volcanic control" of the magnetosphere is, however, neither supported by the current understanding of the dynamics of Io's atmosphere, nor by observations of the atmospheric abundance. Io's atmosphere has been found to be primarily sustained by sublimation of surface frost and to a lesser extent by direct outgassing at volcanoes. The atmospheric loss is predominantly through collisions with the surrounding plasma and not through direct thermal escape. Changes in volcanic activity are thus not expected to lead to strong changes in the atmospheric density or loss rate. Furthermore, observational monitoring of the atmospheric gas column density has not provided any evidence for sudden changes but only revealed seasonal atmospheric variability. On the other hand, there are so far no alternative explanations for the observed magnetospheric changes from studies suggesting the "volcanic control" scenario. And some correlations indeed point to Io as the trigger.

The Team will work towards resolving the issue of these allegedly contradictory understandings of the variability of Io's mass loss. While this topic is very defined, the Io-Jupiter system is the prime example for various geophysical and plasma physical processes; a correct understanding of Io's role is crucial, far beyond Jupiter and the Solar System.

Coronal Dimmings and Their Relevance to the Physics of Solar and Stellar Coronal Mass Ejections

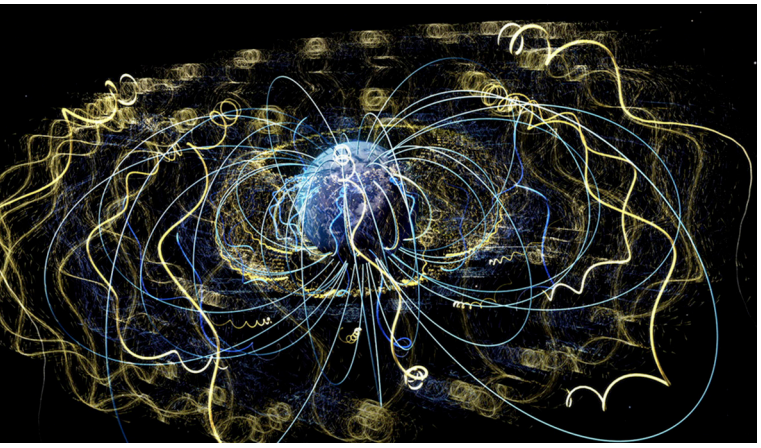
Team Leaders: Astrid Veronig, University of Graz, Austria and Karin Dissauer, NorthWest Res. Ass., Boulder, USA

Session at ISSI: *19–23 September 2022*

Scientific Rationale: Solar and stellar Coronal Mass Ejections (CMEs) are huge eruptions of magnetized plasma from the Sun and stars. Solar CMEs can cause severe space weather disturbances impacting radio communications, GPS, power grids, and satellites near and on Earth, whereas stellar CMEs may pose a hazard to the habitability of exoplanets. Coronal dimmings have been observed as strong but temporary reductions of extreme-ultraviolet and soft X-ray emission associated with solar CMEs in the low corona for more than 45 years. Dimming regions map to closed field lines that become either stretched or temporarily opened during the eruption and are a result of the depletion of coronal plasma caused by the expansion and mass loss due to the CME. Coronal dimmings are unique as they appear during the entire evolution of a solar CME, from the pre-eruption phase to the post-event recovery of the corona. Recently post-flare coronal dimmings have been systematically identified in irradiance profiles of solar-like stars, indicative of stellar mass ejections.

The multi-disciplinary Team aims to understand the initiation, magnetic configuration, and mass loss of solar CMEs through the investigation of the magnetic and thermodynamic evolution of the associated coronal dimmings. Experts in solar and stellar research will perform detailed case studies, combining observations and simulations and will relate these results to Sun-as-a-star observations to further investigate the potential of coronal dimmings for detection and characterization of CMEs on Sun-like stars.

International Teams



The complex motion of charged particles in the Earth's magnetosphere. (Image Credit: Brian Monroe and Tom Bridgman, NASA GSFC)

Towards a Unifying Model for Magnetic Depressions in Space Plasmas

Team Leader: Martin Volwerk, SRI, Austrian Academy of Sciences, Graz, Austria
Session at ISSI: *tbd*
Scientific Rationale: Magnetic Depressions (MDs) are strong reductions of the magnetic field strength that appear in all magnetoplasmas in our solar system. Although they have been known since the late 1970s, there are still many questions surrounding these structures such as: the relation between the two types, mirror modes and magnetic holes; their origin in the solar wind; their temporal development, etc. Magnetic depressions in space plasmas are ubiquitous throughout the solar system, observed from close to the Sun at Mercury's orbit, to high solar latitudes at 1 AU, and far in the deep confines of the heliosheath. They appear in the solar wind as well as in planetary magnetosheaths, and can be categorized into two types: Mirror Modes (MMs), where there is a train of MDs, and Magnetic Holes (MHs). These two types of structures both show a reduction of the magnetic field and thereby of the magnetic pressure, and an increase of plasma pressure, making them diamagnetic objects in magnetoplasmas. How the two are related is, up to now, still unknown, but it is often assumed that MHs are the final stage of MMs. The Team concentrates on finding the origin of the magnetic depressions, i.e. the physical mechanisms that produce them, and the characterization and evolution of these structures, through data analysis, theory and numerical simulations.

Molecular and Metallic Ions in the Magnetosphere

Team Leader: Masatoshi Yamauchi, Swedish Institute of Space Physics, Kiruna, Sweden
Session at ISSI: *2–6 May 2022*
Scientific Rationale: Very heavy (mass $\geq$ 27) ions and atoms carry essential information of the evolution of the Earth and near-earth small bodies. Understanding these heavy ions and atoms is also important from the viewpoint of space safety because, in the near future, the Team expects a substantial increase of human-made heavy ions and molecules (e.g., aluminium with mass 27) by the self-fragmentation of space debris if no new countermeasures are taken within a decade.
Unfortunately, these heavy ions and atoms are vastly unexplored in near-Earth space, with only few terrestrial missions equipped with dedicated instrumentation to separate these molecular and metallic ions for only a limited energy and mass ranges (cold ions of < 50 eV and energetic ions of ~100 keV, both for $\leq$ 50 amu). Nevertheless, existing data including those not designed for the required mass separation are capable of detecting many of these ions with available tools. By combining these patchy and incomplete data, the scientists can obtain several features that indicate sources of these heavy ions and their amount. For example, metallic ions were recently found in the magnetosphere and thus existing data from past and on-going missions are capable of detecting them.
During the Team activities so far, all meetings were remote due to covid-19 pandemic, the members first made a list of relevant data and software including those taken by instruments not designed for very heavy ions and those relevant to the major four sources that were identified during the meetings: mesospheric/ionospheric metal layer, solar wind, moon sputtering, and direct ablation of meteors and space debris. While work is still underway, the Team found the moon source much more important than previously thought for magnetospheric metallic ions. The remaining task is to identify the types of instruments for future observations.

International Teams approved in 2021

The following listed teams have been selected for implementation from the proposals received in response to the 2021 Call for International Teams:

Star Formation Within Evolving Galaxies: The Revolution of Upcoming Space Missions
Team Leader: Angela Adamo, Stockholm University, Sweden

Energy Partition Across Collisionless Shocks
Team Leader: Amano Takanobu, The University of Tokyo, Japan

Revisiting Star Formation in the Era of Big Data
Team Leaders: Marc Audard, Université de Genève, Switerland and Odysseas Dionatos, University of Vienna, Austria

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

Imaging the Invisible: Unveiling the Global Structure of Earth's Dynamic Magnetosphere
Team Leader: Natalia Buzulukova, NASA Goddard Space Flight Center, USA

Understanding the Connection Between Coastal Sea Level and Open Ocean Variability Through Space Observations
Team Leaders: Francisco Mir Calafat, National Oceanography Centre, Liverpool, United Kingdom and Svetlana Jevrejeva, National Environment Agency, Singapore

Modelling Mercury's Dynamic Magnetosphere in Anticipation of BepiColombo
Team Leader: Jan Deca, University of Colorado Boulder, USA and Sae Aizawa, CNRS, Toulouse, France

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

Bridging New X-ray Observations and Advanced Models of Flare Variability: A Key to Understanding the Fundamentals of Flare Energy Release
Team Leaders: Laura Hayes, Trinity College Dublin, Ireland and Andrew Inglis, NASA Goddard Space Flight Center, USA

How Heavy Elements Escape the Earth: Past, Present, and Implications to Habitability
Team Leaders: Raluca Ilie, University of Illinois at Urbana-Champaign, USA and Rona Oran, Massachusetts Institute of Technology, USA

Heliospheric Energy Budget: From Kinetic Scales to Global Solar Wind Dynamics
Team Leaders: Maria Elena Innocenti, Ruhr Universität Bochum, Germany and Anna Tenerani, The University of Texas at Austin, USA
Session: 22–26 November 2021

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

Measuring Solar Flare Hard X-ray Directivity using Stereoscopic Observations with Solar Orbiter/STIX and X-ray Instrumentation at Earth (ISSI – ISSI Beijing Team)
Team Leaders: Natasha Jeffrey, Northumbria University, United Kingdom and Samuel Krucker, Fachhochschule Nordwestschweiz, Switzerland

Understanding Interhemispheric Asymmetry in MIT Coupling
Team Leader: Hyomin Kim, New Jersey Institute of Technology, USA

Characterization of the Transition from Supervolatiles-Driven Activity to Water-Driven Activity in inbound Dynamically New Comets
Team Leader: Fiorangela La Forgia, University Parthenope Naples, Italy

Space Observations of Dwarf Galaxies from Deep Large Scale Surveys: The MATLAS Experience
Team Leader: Oliver Müller, Ecole Polytechnique Fédérale de Lausanne (EPFL), Switzerland

Unraveling Surges: A Joint Perspective from Numerical Models, Observations, and Machine Learning
Team Leader: Daniel Nobrega-Siverio, Instituto de Astrofisica de Canaries (IAC), Spain

Magnetotail Dipolarizations: Archimedes Force or Ideal Collapse?
Team Leader: Evgeny Panov, Austrian Academy of Sciences, Graz, Austria

International Teams approved in 2021

This image is one of the most photogenic examples of the many turbulent stellar nurseries the NASA/ESA Hubble Space Telescope has observed during its 30-year lifetime. The portrait features the giant nebula NGC 2014 and its neighbor NGC 2020 which together form part of a vast star-forming region in the Large Magellanic Cloud, a satellite galaxy of the Milky Way, approximately 163 000 light-years away. (Image Credit: NASA, ESA, and STScI)

Data Assimilation in the Ionosphere and Thermosphere (ISSI – ISSI Beijing Team)
Team Leader: Nicholas Pedatella, NCAR/UCAR, USA

Ice Beyond Earth: Laboratory Investigations of Planetary Ices
Team Leader: Ganna Portyankina, University of Colorado in Boulder, USA

The Habitability of Titan's Subsurface Water Ocean
Team Leaders: Christophe Sotin, Laboratoire de Planétologie et Géodynamique, France and Rosaly Lopes, NASA Jet Propulsion Laboratory, USA

The Early Milky Way
Team Leader: Else Starkenburg, University of Groningen, the Netherlands

Distribution of Interstellar Neutral Hydrogen in the Sun's Neighborhood
Team Leader: Pawel Swaczyna, Princeton University, USA

AsteroCatS – A Legacy Catalogue for Spectroscopic Surveys
Team Leaders: Marica Valentini and Guillaume Guiglion, Leibniz-Institut für Astrophysik Potsdam (AIP), Germany

Understanding the Evolution and Transitioning of Distant Proto-Clusters into Clusters
Team Leader: Benedetta Vulcani, Osservatorio Astronomico di Padova, INAF, Italy

Johannes Geiss Fellows and Visiting Scientists

Johannes Geiss Fellows

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 honor 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 Johannes Geiss Fellowship (JGF) started in 2015. George Gloeckler from the University of Michigan, USA has been elected as the first JGF recipient. Followed up by Kurt Lambeck from the Australian National University, Australia in 2016. In 2017, Gary Zank from the University of Alabama, USA, was elected as third JG Fellow. Karel Schrijver (Lockhead Martin, Palo Alto, USA) was elected as the Johannes Geiss Fellow 2018, followd by Bruno Leibundgut, (ESO, Germany) who was elected as Johannes Geiss Fellow 2019.
Weiqing Han (University of Colorado at Boulder, USA) and Sabine Schindler (University of Innsbruck, Austria) have been elected as the 2020 Johannes Geiss Fellows. Weiqing Han is a world-renowned oceanographer who specializes in Global Sea Level Change, in particular, in coastal regions. Sabine Schindler is a highly recognized astrophysicist who specializes in the observation and modeling of galaxies and galaxy clusters.
Due to the worldwide pandemic and the travel restrictions the Call for Johannes Geiss Fellowship 2021 was paused.

Visiting Scientists

Individual Scientists are invited for extended periods to work on scientific subjects at the forefront in areas of interest to ISSI. 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 26th year:

Dennis Höning, Department Earth System Analysis, Potsdam, working period: 4.–24.10.2021.

Herbert Palme, University of Cologne, Germany, working period: 1.–30.9.2021.

Arnaud Salvador, Department of Astronomy and Planetary Science, CEFNS, USA, working period: 31.8.–17.9.2021.

Sabine Schindler, Johannes Geiss Fellow 2020, working periods: 18.10.–5.11.2021 and 12.–28.11.2021.

Earth Magnetosphere / Multi-satellite Missions in the Field of Plasma Physics – Online Lecture Course Alpbach Summer School 2021

Impressions from the Online Summer School Alpbach 2021 (Image Credit: Alpbach Summer School)

Summer Schools in topics related to scientific space research have been held yearly in Alpbach, Austria, since 1975, supported by the Austrian Research Promotion Agency (FFG), the European Space Agency, DLR and the International Space Science Institute, Bern, Switzerland. Each year, the Summer School treats a different topic related to space research. It is open to 60 students from Europe, with diverse backgrounds in both space sciences and aerospace engineering. Usually, the school starts with lectures by international experts in the selected scientific topics and in space mission design. However, the bulk of the ten days (and nights) of the School is devoted by four teams of 15 students each to define, design and propose an original space mission that addresses aspects of the year's Summer School topic.

In 2021 the format had to be adjusted to comply with the restrictions caused by the pandemic situation. It was not possible to join 60 students together, working close to each other in classrooms. It was therefore decided to limit the activities to a 5-day remote lecture program. The remote Summer School addressed the difficult topic of how to prepare a multi-satellite space mission for research in the field of Plasma Physics.

Large parts of the Universe are filled with plasma, a highly ionized form of matter. The plasma environments are always highly dynamic and can be observed from nearby in the Earth's magnetosphere out to far away supernovae and active galaxies. Ionized matter is threaded by magnetic fields, producing complex interaction processes and phenomena such as shock waves and charged particles accelerated to high energies. Observations of cosmic plasmas can be made both in-situ (in the solar system) and remotely.

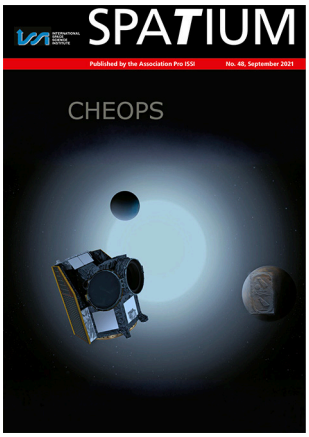
The program started with a couple of lectures by renowned experts introducing the scientific background, the state of the art and unresolved questions to be addressed with new space missions, explaining plasma, describing the Earth magnetospheres as plasma lab and extending the view to plasma around other planetary bodies. In-situ measurements of plasma including examples from mission flown (or studied) were presented, followed by an introduction of instrumentation for both in-situ and remote measurements. Multiscale and Multipoint measurements were addressed in a separate lecture. Thereafter, lectures on the topics of mission and system design, mission analysis and system engineering, spacecraft constellations were offered by well experienced engineers in the field. All spacecraft subsystems, as well as the art of a proper requirements flow down, ESA's concurrent engineering approach were presented. An earlier ESA study (THOR) was explained as practical exemplary case. Also, the topic how to realize a mission from proposal to implementation was addressed.

Each lecture ended with an extended question and answer session, which allowed for a rather extensive exchange and discussion between the students and lecturers. The overall aim of the remote Summer School was to offer an in-depth understanding of the process starting from scientific questions over definition of requirements to flow down into engineering solutions under consideration of typical constraints of a space mission. According to the very positive feedback from the participants this aim was achieved, despite the remote nature of the Alpbach Summer School 2021.

Peter Falkner, Head Tutor Alpbach Summer School

The Association Pro ISSI

The Pro ISSI Association 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 Swiss public. With the creation of the Foundation International Space Science Institute (ISSI) in 1995 the first objective had been reached. Pro ISSI focuses now on providing a bridge between leading space scientists and its members, representing universities, industry, politics and public administration. The Association offers public lectures on new insights in space science, and publishes two to three SPATIUM issues per year. The Pro ISSI Association, which consists presently of 124 members, meets once per year for its general assembly. The Board of Pro ISSI consists of Christoph Mordasini (President), Anuschka Pauluhn (Editor Spatium), Andreas Verdun (Editor Spatium), Annette Jäckel (Treasurer) and Yasmine Calisesi (Secretary).



In the reported period, the SPATIUM No. 47 and 48 have been published by the Association Pro ISSI.

Public Lectures

This is the second reporting period during which the Pro ISSI activities took place under special circumstances as a consequence of the Covid-19 pandemic. As in 2020, it was again possible to organize mostly only online events. To compensate for the absence of in person meetings and to compensate also for the reduced activities in the previous year affected by the pandemic, a higher number of public lectures than usually was organized:

On 20th January 2021, Dr. Andrea Fortier (University of Bern) gave a virtual lecture on the CHEOPS, the CHaracterising ExOplanet Satellite which was launched in December 2019 from French Guyana. The CHEOPS satellite that searches photometrically for extrasolar planets was selected in 2012 as the first ESA Small Mission. It is the first time that Switzerland leads within an international consortium of 11 European countries an ESA mission.

On 24th of March 2021, former Pro ISSI President Prof. Adrian Jäggi gave an online talk on Exploring the Earth's Time-Variable Gravity Field using Satellite Observations. Time-variable gravity data as derived from ultra-precise inter-satellite ranging is the only observational method to provide integrative measures of total water storage variations on a global scale. As such it has applications in numerous scientific fields like for example in hydrology, climate modeling, oceanography, atmospheric and environmental sciences.

The third online event was a new addition besides the classic long Pro ISSI talks given by one (typically senior) speaker. On 12th May 2021, the two ISSI postdoctoral researchers delivered two shorter lectures on their current research subjects. Dr. Julia Venturini gave a presentation on Super-Earths, Mini-Neptunes and the Radius Valley in the Extrasolar Planet Population. The second talk was given by Dr. Lorena Moreira on Interannual Variability in the Sea Level. This new format which gives a platform to junior ISSI scientists earned a lot of positive returns motivating its continuation in future years.

Finally, on 24th November 2021 the General Assembly was held in a hybrid form: the General Assembly itself was held in presence, while the subsequent lecture by Prof. Weiqing Han (University of Colorado and Johannes Geiss Fellow) on A Warming Indian Ocean on Planet Earth: Changes in Ocean Circulation, Sea Level was given remotely.

SPATIUM

The Association's magazine SPATIUM elaborates on selected lectures offered by Pro ISSI. It usually appears twice to three times per year. During the reporting period, issue no. 47 was published in May 2021, reporting on Modern Cosmology – nearly perfect but incomplete, prepared by Dr. Bruno Leibundgut (Johannes Geiss Fellow 2019 and former ESO Director for Science). This issue gives an overview of the current state-of-the-art in cosmology and the different observations on which our modern understanding is based.

Issue 48 entitled CHEOPS by Dr. Andrea Fortier was published in September 2021. The author has been the CHEOPS Instrument Scientist since 2013. After three months of in-orbit commissioning, CHEOPS has started its nominal operations at the end of March 2020 acquiring images that allow for precise measurements of the exoplanets' radii through the transit photometry technique. The CHEOPS mission is a follow-on in the well-known tradition of exoplanet detection and study at several research institutions in Switzerland. The SPATIUM issue in particular addresses the genesis of the mission, the challenges of ultra-high precision photometry, and the first scientific results obtained by CHEOPS.

These publications together with all previous issues of SPATIUM can be found on Pro ISSI's homepage www.issi-bern.ch/association-pro-issi/spatium/

Christoph Mordasini

Financial Overview

The 26th financial year of ISSI starts now, for the first time, from January 1st and ends on December 31st, i.e., the table gives the budget in terms of calendar years as provided by the funding bodies for the time span 2021. The result of the year is a surplus of almost 21 kCHF, equaly to a balanced budget surplus of 20 kCHF. This positive result was essentially caused by a significant reduction of the operating costs due to Covid-19: Several meetings, notably those of the Board of Trustees and the Science Committee, were held online, and travel costs of ISSI scientists were also strongly reduced. The costs for Workshops, WGs, Teams, and visitors, however, were nominal or as budgeted even though more than half of the activities had to be postponed. This is because the budgeted costs were accrued for future use whenever it will become possible again for these groups to meet at ISSI.

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) were received as budgeted and are gratefully acknowledged, as is the contribution from our Japanese partner, JAXA/ISAS. In addition, the Lunar and Planetary Institute (LPI) is a new ISSI partner with an annual indirect contribution to support US planetary scientists coming to ISSI.

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.

Maurizio Falanga

Statement of Operations (in CHF) for the 26th Financial Year (1.1.2021-31.12.2021)

	Expenses	Revenues
ESA Science Directorate		1'340'400.00
ESA Earth Observation Programme		331'985.00
Swiss Confederation		1'010'000.00
Swiss Academy of Sciences (SCNAT)		215'000.00
ISSI Partners: ISAS/JAXA		26'687.50
Salaries and related costs [1]	1'287'185.13	
Fixed costs	286'372.65	
Operating costs [2]	204'814.84	
Investment (depreciated)	348'937.96	
Workshops, Working Groups, Teams, Visitors [3]	784'502.43	
Other income or cost [4]		8'529.95
Result of the year	20'789.44	
Total	**2'932'602.45**	**2'932'602.45**

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 organizational, 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 due to variations in monetary exchange rates.

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Christoph Mordasini
Pro ISSI Association, Bern
Switzerland

Aude Pugin
APCO Technologies
Aigle, Switzerland

Ji Wu
National Space Science
Center (CAS) and
ISSI Beijing, China

Lev Zelenyi
Space Research Institute (IKI)
Russian Academy of Sciences
Moscow, Russia

Secretary of the Board
Maurizio Falanga
ISSI, Bern, Switzerland

The list shows the status at the end of the 26th business year on 31st December 2021.

The Science Committee

Chair *Louise Harra*
PMOD WRC
Davos, Switzerland

Elena Amato
INAF
Firenze, Italy

Svetlana Berdyugina
Leibnitz Inst. für Sonnenphysik
Freiburg, Germany

Roberto Bruno
IAPS INAF
Rome, Italy

Peng-Fei Chen
Nanching University
China

Frédéric Courbin
EPFL, Obs. de Sauverny
Versoix, Switzerland

Xiaolong Dong
ISSI-Beijing, Beijing
China (ex officio)

Lisa R. Gaddis
LPI, Houston
USA (ex officio LPI/NASA)

Vladislav Izmodenov
IKI, Moscow
Russia (ex officio RAS)

Emmanuelle J. Javaux
Université de Liège
Belgium

Catherine L. Johnson
University of British
Columbia, Canada

Karl-Ludwig Klein
Observatoire de Paris
LESIA, France

Benjamin Koetz
ESA ESRIN, Frascati
Italy

Philippa J. Mason
Imperial College London
United Kingdom

Mark McCaughrean
ESA ESTEC, Noordwijk
The Netherlands (ex officio ESA)

Céline Peroux
ESO, Garching
Germany

Kanako Seki
University of Tokyo
Japan

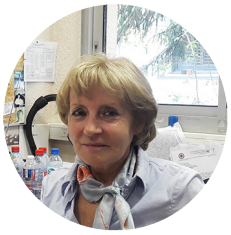
Giovanna Tinetti
UCL, Didcot
United Kingdom

Karina von Schuckmann
Mercator Océan, Ramonville
Saint-Agne, France

Endawoke Yizengaw
Aerospace Corporation
Los Angeles, USA

ISSI Staff

Tilman Spohn
Executive Director



Anny Cazenave
Director Earth Science
(term finished as of 31st December 2021)

Maurizio Falanga
Director

Michael Rast
Director Earth Science
(as of 1st January 2022)

Roger-Maurice Bonnet
Honorary Director

Andrei Bykov
Discipline Scientist

Álvaro Giménez
Senior Discipline Scientist

Lorena Moreira
Postdoc

Julia Venturini
Postdoc

Jennifer Fankhauser
Secretary

Andrea Fischer
Editorial Assistant

Yemisi Momoh
Secretary

Mark Sargent
Science Program Manager
Secretary of the
Science Committee

Irmela Schweizer
Librarian

Willi Wäfler
Computer Engineer

Silvia Wenger
Assistant to the Executive Director

The list shows the status at the end of the 26th business year on 31st December 2021.

Staff Activities

Listed are activities in which ISSI staff scientists participated in 2021. This includes presentations given, meetings attended, outreach, honors received, and chairmanships held.

Presentations

18 January 2021 – J. Wambsganss: ISSI Workshop on Strong Gravitational Lensing, Online Kick-Off, Plenary #1, online

28 January – 4 February 2021 – R. von Steiger: Talk at 43rd COSPAR Scientific Assembly, Sydney, Australia (virtual), "COSPAR Task Group on Establishing a Constellation of Small Satellites: Opportunities for Earth Sciences"

3 February 2021 – J. Venturini: "Super-Earths, mini-Neptunes and the Radius Valley", Internal ISSI Seminar (online)

4 February 2021 – A. Cazenave: Sea level and climate change, Shanghai Summer School, China

24 February 2021 – R. von Steiger: "Von der Mondlandung zum ISSI: Bern im Weltraum", Talk at RC Bern-München-buchsee, Switzerland

28 February 2021 – A. Cazenave: Climate change; the role of space observations; Aligarh Muslim University Centenary, India

4 March 2021 – J. Venturini: "The origin of the Radius Valley", Invited seminar, NCCR PlanetS virtual seminars (online)

9 March 2021 – J. Venturini: "The origin of the Radius Valley" Contributed talk, NCCR PlanetS Domain 2 Science Meeting (online)

25 March 2021 – J. Wambsganss: "Sonne, Mond und Sterne: Was Albert Einstein und Stephen Hawking begeisterte", Stephen-Hawking-Schule, Neckargemünd, Germany

29 March 2021 – R.-M. Bonnet & M.L. Chanine: Humage à Jacques-Émile Blamont, Académie de l'Air et de l'Espace, Toulouse, France

14 April 2021 – J. Wambsganss: "Predicting astrometric microlensing events with Gaia: How to measure the mass of an isolated star", Internal ISSI Seminar (online)

19–30 Apr 2021 – L. Moreira and A. Cazenave: Sea level fingerprints due to ongoing land ice melt in altimetry data, EGU General Assembly 2021, vPICO session, (online) EGU21-10950, (29 April 2021), https://doi.org/10.5194/egusphere-egu21-10950,

12 May 2021 – J. Venturini: "Super-earths, mini-Neptunes and the Radius Valley of Exoplanets", Pro ISSI Talk, Bern, Switzerland (online)

12 May 2021 – L. Moreira: "Origin of the Regional and Interannual Variability in Sea Level", Pro ISSI Talk, Bern, Switzerland (online)

14 June 2021 – J. Venturini: Public science talk at the Science Flashmob organized by 500 Women Scientists Bern-Fribourg during the 2021 Swiss Frauenstreik. https://www.500womenscientistsfribourgbern.ch/news

30 June 2021 – J. Venturini: "Super-Earths, mini-Neptunes and the Radius Valley", Contributed talk, European Astronomical Society Annual Meeting (online)

2 August 2021 – J. Wambsganss: "Searching for Extrasolar Planets with Gravitational Microlensing: Challenges and Exciting Results", ASL (Astronomisches Sommerlager), VEGA (Vereinigung für Jugendarbeit in der Astronomie), (online)

2 August 2021 – J. Venturini: "The Origin of the Radius Valley: insights from formation and evolution models", contributed talk, TESS Science Conference 2 (online)

14 September 2021 – A. Cazenave: The Global Water Cycle, MeteoSwiss, Bern, Switzerland

16 September 2021 – J. Venturini: "Planet Formation on the Outer Disk", Invited talk at the Europlanet Science Congress 2021 (online)

17 September 2021 – J. Venturini: "Super-Earths, mini-Neptunes and the Radius Valley: linking theory with observations", Invited talk at the Annual Meeting of the German Astronomical Society (online)

19 September 2021 – J. Wambsganss: "O du, mein holder Abendstern: Unser Nachbarplanet Venus und ein paar Kleinplaneten aus dem Wagner-Universum", Festveranstaltung "100 Jahre Richard-Wagner-Verband Heidelberg", Heidelberg, Germany

30 September 2021 – R.-M. Bonnet: Le Télescope Spatial Hubble, 30 ans de découvertes, symbole du génie humain

21–23 November 2021 – A. Cazenave: several lectures on Observing the Earth from Space, Sea level and climate, etc., Université de Ziguinchor, Senegal

24 November 2021 – T. Spohn: Could Earth have Desert and Ocean Planet Siblings with Plate Tectonics? Online Presentation, EAI Academy Seminar: https://youtu.be/6HgNjLcN6Ic

2 December 2021 – J. Wambsganss: "Who wants to be(come) an Astronomer?", IMPRS (International Max-Planck Research School) Retreat, Heidelberg

13–17 December 2021 – L. Moreira and A. Cazenave: Sea-level fingerprints due to present-day water mass redistribution in observed sea-level data, AGU Fall Meeting, New Orleans, LA and Online Everywhere, eLightning Session, 15 December 2021

29 December 2021 – R.-M. Bonnet: A decade of Venus Exploration-A Multi-Agency Perspective

Meetings

7–8 January 2021 – R. von Steiger: SHARP H2020 project kickoff meeting (online)

January – December 2021 – J. Wambsganss: ISSI Workshop on Strong Gravitational Lensing, Online Plenary Meetings #1–#10

14 January 2021 – J. Venturini: "Super-Earths, mini-Neptunes and the Radius Valley", Invited seminar at the Hebrew University of Jerusalem (online)

8 March 2021 – T. Spohn: HP3 Overview, InSightSeer Program, 21. InSight Science Team Meeting (online)

18 March 2021 – J. Wambsganss: 20th Meeting of Rat für Informationsinfrastrukturen (RfII) (online)

22 March 2021 – J. Wambsganss: Spring Meeting of Rat deutscher Sternwarten (RdS, Council of German Observatories) (online)

24 March 2021 – J. Wambsganss and A. Gimenez: Conveners' Meeting for "ISSI Forum Ground & Space Astronomy: Challenges & Synergies" (online)

29 March 2021 – R.-M. Bonnet: Hommage à Jacques-Émile Blamont, Académie de l'Air et de l'Espace, Toulouse, France

14 April 2021 – R. von Steiger: Swiss National Committee of SCOSTEP Board Meeting, FHNW Brugg-Windisch, Switzerland

10 May 2021 – R. von Steiger: Evaluation Commission of SNSF Eccellenza Grants and Fellowships) (online)

17–18 June 2021 – J. Wambsganss: 21st Meeting of Rat für Informationsinfrastrukturen (RfII) (online)

20 June 2021 – T. Spohn: HP3 Overview, InSightSeer Program, 21. InSight Science Team Meeting (online)

10 July 2021 – R.-M. Bonnet: ISSI Beijing Board of Trustees, (online)

29 July 2021 – R. von Steiger, R.-M. Bonnet, M. Falanga, T. Spohn, S. Wenger: Farewell Symposium, ISSI, Switzerland

13–17 September 2021 – J. Wambsganss: Annual Meeting of Astronomische Gesellschaft (online)

20 September 2021 – J. Wambsganss: Fall Meeting of Rat deutscher Sternwarten (RdS, Council of German Observatories) (online)

20–22 September 2021 – R. von Steiger: Evaluation Commission of SNSF Eccellenza Grants and Fellowships (online)

8 October 2021 – M. Sargent: SSAA/SGAA general assembly (online)

25 October 2021 – T. Spohn: HP3 Overview, InSightSeer Program, 21. InSight Science Team Meeting (online)

3–5 November 2021 – J. Wambsganss: Workshop on "Dark Matter", Royal Society, London, UK

8–12 November 2021 – R. von Steiger: The Heliosphere in the Local Interstellar Medium 2.0, ISSI, Switzerland

18–19 November 2021 – J. Wambsganss and A. Gimenez: ISSI Forum "Ground & Space Astronomy", Bern, Switzerland

25 November 2021 – M. Sargent: Joint Workshop of the SKA Extragalactic Continuum and HI science working groups (online)

1–2 December 2021 – J. Wambsganss: 22nd Meeting of Rat für Informationsinfrastrukturen (RfII) (online)

9 December 2021 – J. Venturini: Invited Public Talk about Exoplanets at the Universidad de la Republica (in Spanish, online)

29 December 2021 – R.-M. Bonnet: A decade of Venus Exploration-A Multi-Agency Perspective (online)

Staff Activities

ISSI Scientists in the Media

14 January 2021 – Mars-Maulwurf ist am Ende seiner Reise angekommen, Article with T. Spohn, press release by DLR and NASA InSight's 'Mole' Ends Its Journey on Mars, press release by NASA

15 January 2021 – Auf dem Mars hat es sich ausgehämmert, Article with T. Spohn, FAZ

15 January 2021 – Mars-Mission InSight - Deutscher Maulwurf beendet Grabung, Article with T. Spohn by J.-C. Hanika, BR 24

15 January 2021 – Der Mars-"Maulwurf" gräbt nicht mehr, press release (DLR/dpa)

20 January 2021 – The 'mole' on Mars will dig no more, NASA says, Article with T. Spohn by E. Howell, space.com

5 February 2021 – Interview about scientific careers for the group "Fisicamente Posible" (Physically possible), a group of Uruguayan female teenagers dedicated to promote women in Physics (In Spanish), https://youtu.be/t7jGV4lpC-o

18 February 2021 – Interview with T. Spohn, Der alte Menschheitstraum vom Mars, Deutschlandfunk.

25 February 2021 – Interview (In Spanish) with J. Venturini about exoplanets and space exploration for the newspaper "El Eco", Colonia, Uruguay

Mai 2021 – T. Spohn: Ein Ausserirdischer Krimi – Ende der Mission des DLR-Marsmaulwurfs, DLR Magazin

1 August 2021 – M. Falanga: New appointed University Bern Professor and Director at ISSI, webpage University of Bern and ISSI.

18 November 2021 – "Let's talk about... galaxy evolution", Interview with M. Sargent, Contact: The SKA Magazine (#09)

15 December 2021 – Warum einige Astronomen Pluto wieder zum "Planeten" ernennen wollen, Article with T. Spohn by Ch. von Eichhorn, Süddeutsche Zeitung

Chairman- and Memberships, Honors

Roger-Maurice Bonnet:
- President of IFHE's Aubinière Price Award, France
- President of the Alpbach Summer School Jury 2018 and 2019, Austria
- Member of Institut Français d'Histoire de l'Espace, France
- Member ISSI-BJ Board of Trustees
- Member Royal Swedish Academy of Sciences
- Member Academia Europaea
- Member Royal Society of Sciences, Liège, Belgium
- Member International Academy of Astronautics (IAA), Van Karman Awardee 2009
- Member Academy of Air and Space
- "Hall of Fame" National Air and Space Museum, Washington DC, USA
- Asteroid 18627 1998DH33 named ROGERBONNET

Anny Cazenave:
- Elected foreign member of the Royal Society (UK Academy of Sciences)
- Nominated chair of the Earth Science panel of ESSC (European Space Science Committee)
- Nominated member of the panel «LEVERAGING COMMERCIAL SPACE FOR EARTH AND OCEAN REMOTE SENSING», NRC (National Research Council, The National Academies, USA)

Maurizio Falanga:
- Member of the Astronomy & Astrophysics Journal Board of Directors, Swiss representative
- Editorial Committee member of Space Science Reviews
- Member of International Astronomical Union (IAU)
- Member of International Academy of Astronautics (IAA)
- Member of European Astronomical Society (EAS)
- Member of Swiss Society for Astrophysics and Astronomy (SSAA)
- Member of the Einstein Probe mission science team, scheduled for launch in 2023
- Member of the HUBS Milky Way and Local Group Science Working Group
- Member of the COSPAR Task Group to Develop an Actionable Plan for an International Constellation of Small Satellites (TGCSS)

Mark Sargent:
- Member of International Astronomical Union (IAU)
- Member of European Astronomical Society (EAS)
- Member of Swiss Society for Astrophysics and Astronomy (SSAA)
- Member of the Royal Astronomical Society (RAS)
- Chair of the e-MERLIN radio telescope time allocation committee, Jodrell Bank Centre for Astrophysics/ UKRI Science and Technology Facilities Council, UK
- Co-chair of the SKA Extragalactic Continuum science working group
- Reviewer for Astronomy & Astrophysics
- Reviewer for European Research Council (ERC) grant proposals
- Reviewer of Giant Metrewave Radio Telescope (GMRT) proposals, National Centre for Radio Astrophysics (NCRA), India

Tilman Spohn:
- Fellow American Geophysical Union
- Full member Academy of Astronautics,
- Academy of Astronautics, Board of Trustees
- Member Academia Europaea
- European Astrobiology Inst. Management Committee
- Planetarium Berlin, Board of Trustees
- Principal Investigator for the Heat Flow and Physical
- Properties Package HP3 on the NASA InSight mission to Mars
- Asteroid 12062 1998FB10 named TILMANSPOHN

Rudolf von Steiger:
- President of the Heinrich Greinacher Foundation
- Board member of the Phil.-nat. Faculty, University of Bern
- Member of the Evaluation Committee for Eccellenza Fellowships and Grants of the Swiss National Science Foundation
- Evaluator and Rapporteur for HE-MSCA-PF 2021 Marie Skłodowska-Curie Fellowships of the European Commission
- External Advisory Board member of the SHARP H2020 project
- Vice-chair of the COSPAR Task Group to Develop an Actionable Plan for an International Constellation of Small Satellites (TGCSS)
- Full member of the International Academy of Astronautics
- Editorial Committee member of Space Science Reviews
- Specialty Chief Editor of Frontiers in Space Science
- Editorial Board member of Living Reviews in Solar Physics

Joachim Wambsganss:
- Member of Astronomische Gesellschaft (German Astronomical Society, AG)
- Member of European Astronomical Society (EAS)
- Member of American Astronomical Society (AAS)
- Member of International Astronomical Union (IAU)
- Member of "Rat für Informationsinfrastrukturen" (German Council for Information Infrastructure)
- Member of Executive Committee of Rat deutscher Sternwarten (Council of German Observatories)

Staff Publications

Listed are all papers written or co-authored by ISSI staff members that were submitted or that appeared in 2021.

Algera, H. S. B. (incl. M. Sargent) et al. COLDz: Probing Cosmic Star Formation With Radio Free–Free Emission. Astrophysical J 924, 76 (2022). https://doi.org/10.3847/1538-4357/ac34f5.

Angelis, A. D. (incl. A. Bykov) et al. Gamma-ray astrophysics in the MeV range. Exp Astron 51, 1225–1254 (2021). https://doi.org/10.1007/s10686-021-09706-y

Barnoud, A. (incl. A. Cazenave) et al. Contributions of Altimetry and Argo to Non-Closure of the Global Mean Sea Level Budget Since 2016. Geophys Res Lett 48, (2021). https://doi.org/10.1029/2021GL092824

Baroch, D. (incl. A. Gimenez) et al. Analysis of apsidal motion in eclipsing binaries using TESS data. Astron Astrophys 649, A64 (2021). https://doi.org/10.1051/0004-6361/202040004

Birol, F. (incl. A. Cazenave) et al. The X-TRACK/ALES multi-mission processing system: New advances in altimetry towards the coast. Adv Space Res-series 67, 2398–2415 (2021). https://doi.org/10.1016/j.asr.2021.01.049

Bonnet R-M., Proposals for the Implementation of an ISSI Space Science History Collection, 2021.

Breuer, D. (incl. T. Spohn) et al. Interiors of Earth-Like Planets and Satellites of the Solar System. Surv Geophys 1–50 (2021). https://doi.org/10.1007/s10712-021-09677-x

Breuer, D. (incl. T. Spohn) et al. Correction to: Interiors of Earth-like planets and satellites of the Solar System. Surv Geophys 1–2 (2022). https://doi.org/10.1007/s10712-021-09687-9

Cassan, A. (incl. J. Wambsganss) et al. Microlensing mass measurement from images of rotating gravitational arcs. Nat Astronomy 6, 121–128 (2022). https://doi.org/10.1038/s41550-021-01514-w

Chen, J. (incl. A. Cazenave and L. Moreira) et al. Applications and Challenges of GRACE and GRACE Follow-On Satellite Gravimetry. Surv Geophys 1–41 (2022). https://doi.org/10.1007/s10712-021-09685-x

Compaire, N. (incl. T. Spohn) et al. Seasonal variations of subsurface seismic velocities monitored by the SEIS-InSight seismometer on Mars. Geophys J Int 229, ggab499-(2021). https://doi.org/10.1093/gji/ggab499

Connor, T. (incl. J. Wambsganss) et al. Gaia GraL: Gaia DR2 Gravitational Lens Systems. VII. XMM-Newton Observations of Lensed Quasars. Astrophysical J. Submitted (2021).

Dieng, H. B., Cazenave, A., Gouzenes, Y. & Sow, B. A. Trends and inter-annual variability of altimetry-based coastal sea level in the Mediterranean Sea: Comparison with tide gauges and models. Adv Space Res-series 68, 3279–3290 (2021). https://doi.org/10.1016/j.asr.2021.06.022

Falanga, M. et al. Exploring higher order images with Fe K α-lines from relativistic discs: black hole spin determination and bias. Mon Not R Astron Soc 504, 3424–3434 (2021). https://doi.org/10.1093/mnras/stab1147

Falanga, M. et al. Phase-resolved hard X-ray emission of the high-mass binary LS 5039: a spectral hardening above 50 keV detected with INTEGRAL. Astron Astrophys 654, A127 (2021). https://doi.org/10.1051/0004-6361/202141102

Forget, F. (incl. J. Venturini) et al. Editorial: Topical Collection on Understanding the Diversity of Planetary Atmospheres. Space Sci Rev 217, 51 (2021). https://doi.org/10.1007/s11214-021-00820-z

Giessen, S. A. van der (incl. M.T. Sargent) et al. Probing star formation and ISM properties using galaxy disk inclination III: Evolution in dust opacity and clumpiness between redshift $0.0 < z < 0.7$ constrained from UV to NIR. Astron Astrophys submitted (2022).

Gómez-Guijarro, C. (incl. M.T. Sargent) et al. GOODS-ALMA 2.0: Source catalog, number counts, and prevailing compact sizes in 1.1 mm galaxies. Astron Astrophys 658, A43 (2022). https://doi.org/10.1051/0004-6361/202141615

Gómez-Guijarro, C. (incl. M.T. Sargent) et al. GOODS-ALMA 2.0: Starbursts in the main sequence reveal compact star formation regulating galaxy evolution prequenching. Astron Astrophys (2021). https://doi.org/10.1051/0004-6361/202142352

Grott, M., Spohn, T. et al. Thermal conductivity of the martian soil at the Insight landing site from HP3 active heating experiments. J. Geophys. Res.: Planets, 126, e2021JE006861 (2021). https://doi.org/10.1029/2021JE006861

Guichandut, S., Cumming, A., Falanga, M., Li, Z. & Zamfir, M. Expanded Atmospheres and Winds in Type I X-Ray Bursts from Accreting Neutron Stars. Astrophysical J 914, 49 (2021). https://doi.org/10.3847/1538-4357/abfa13

Guilera, O. M. (incl. J. Venturini) et al. The importance of thermal torques on the migration of planets growing by pebble accretion. Mon Not R Astron Soc 507, 3638–3652 (2021). https://doi.org/10.1093/mnras/stab2371

Horwath, M. (incl. A. Cazenave) et al. Global sea-level budget and ocean-mass budget, with a focus on advanced data products and uncertainty characterisation. Earth Syst Sci Data 14, 411–447 (2021). https://doi.org/10.5194/essd-14-411-2022

Khan, A. (incl. T. Spohn) et al. Upper mantle structure of Mars from InSight seismic data. Science 373, 434–438 (2021). https://doi.org/10.1126/science.abf2966

Klüter, J., Bastian, U., Demleitner, M. & Wambsganss, J. Prediction of Astrometric-Microlensing Events from Gaia eDR3 Proper Motions. Astrophysical J in press (2021).

Kondo, I. (incl. J. Wambsganss) et al. OGLE-2018-BLG-1185b: A Low-mass Microlensing Planet Orbiting a Low-mass Dwarf. Astronomical J 162, 77 (2021). https://doi.org/10.3847/1538-3881/ac00ba

Kropotina, J. A. (incl. A. Bykov) et al. Solar Wind Discontinuity Transformation at the Bow Shock. Astrophysical J 913, 142 (2021). https://doi.org/10.3847/1538-4357/abf6c7

Lebbe, T.B. (incl. A. Cazenave) et al. Designing Coastal Adaptation Strategies to Tackle Sea Level Rise. Frontiers Mar Sci 8, 740602 (2021). https://doi.org/10.3389/fmars.2021.740602

Li, Z. S. (incl. M. Falanga) et al. Broadband X-ray spectra and timing of the accreting millisecond pulsar Swift J1756.9–2508 during its 2018 and 2019 outbursts. Astron Astrophys 649, A76 (2021). https://doi.org/10.1051/0004-6361/202140360

Li, Z., Pan, Y. & Falanga, M. Discovery of Transition from Marginally Stable Burning to Unstable Burning after a Superburst in Aql X-1. Astrophysical J 920, 35 (2021). https://doi.org/10.3847/1538-4357/ac1f15

Lozovsky, M. (incl. J. Venturini) et al. Why do more massive stars host larger planets? Astron Astrophys 652, A110 (2021). https://doi.org/10.1051/0004-6361/202140563

Marti, F. (incl. A. Cazenave) et al. Altimetry-based sea level trends along the coasts of Western Africa. Adv Space Res-series 68, 504–522 (2021). https://doi.org/10.1016/j.asr.2019.05.033

Moreira, L., Cazenave, A. et al. Influence of interannual variability in estimating the rate and acceleration of present-day global mean sea level. Global Planet Change 199, 103450 (2021). https://doi.org/10.1016/j.gloplacha.2021.103450

Moreira, L., Cazenave, A. et al., Sea-Level Fingerprints Due to Present-Day Water Mass Redistribution in Observed Sea-Level Data. Remote Sens-basel 13, 4667 (2021). https://doi.org/10.3390/rs13224667

Mueller, N. (incl. T. Spohn) et al. Near Surface Properties of Martian Regolith Derived From InSight HP3 - RAD Temperature Observations During Phobos Transits. Geophys Res Lett 48, (2021). https://doi.org/10.1029/2021GL093542

Parenti, S. (incl. R von Steiger) et al. Linking the Sun to the Heliosphere Using Composition Data and Modelling. Space Sci Rev 217, 78 (2021). https://doi.org/10.1007/s11214-021-00856-1

Pfeffer, J., Cazenave, A. et al. Analysis of the interannual variability in satellite gravity solutions: detection of climate modes fingerprints in water mass displacements across continents and oceans. Clim Dynam 1–20 (2021) doi:10.1007/s00382-021-05953-z.

Piqueux, S. (incl. T. Spohn) et al. Soil Thermophysical Properties Near the InSight Lander Derived From 50 Sols of Radiometer Measurements. J Geophys Res Planets 126, (2021). https://doi.org/10.1029/2021JE006859

Plesa, A. C. (incl. T. Spohn) et al. Seismic Velocity Variations in a 3D Martian Mantle: Implications for the InSight Measurements. J Geophys Res Planets 126, (2021). https://doi.org/10.1029/2020JE006755

Puglisi, A. (incl. M.T. Sargent) et al. Submillimetre compactness as a critical dimension to understand the main sequence of star-forming galaxies. Mon Not R Astron Soc 508, 5217–5238 (2021). https://doi.org/10.1093/mnras/stab2914

Sollberger, D. (incl. T. Spohn) et al. A Reconstruction Algorithm for Temporally Aliased Seismic Signals Recorded by the InSight Mars Lander. Earth Space Sci 8, e2020EA001234 (2021). https://doi.org/10.1029/2020EA001234

Spohn, T. et al. The InSight HP^3 mole on Mars: Lessons learned from attempts to penetrate to depth in the Martian soil. Adv Space Res in press (2021). https://doi.org/10.1016/j.asr.2022.02.009

Spohn, T. et al. The InSight HP3 Penetrator (Mole) on Mars: Soil Properties Derived From the Penetration Attempts and Related Activities. Space Sci Rev submitted (2021).

Stern, D. (incl. J. Wambsganss) et al. Gaia GraL: Gaia DR2 Gravitational Lens Systems. VI. Spectroscopic Confirmation and Modeling of Quadruply Imaged Lensed Quasars. Astrophysical J 921, 42 (2021). https://doi.org/10.3847/1538-4357/ac0f04

Team, I. A. (incl. A. Cazenave) et al. Altimetry for the future: Building on 25 years of progress. Adv Space Res-series 68, 319–363 (2021). https://doi.org/10.1016/j.asr.2021.01.022

Thomas, N., Hussmann, H., Spohn, T. et al. The BepiColombo Laser Altimeter. Space Sci Rev 217, 25 (2021). https://doi.org/10.1007/s11214-021-00794-y

Visitor Publications

Listed are all papers written or co-authored by ISSI visitors, with acknowledgment to ISSI, that appeared or were accepted for publication in refereed journals in 2021.

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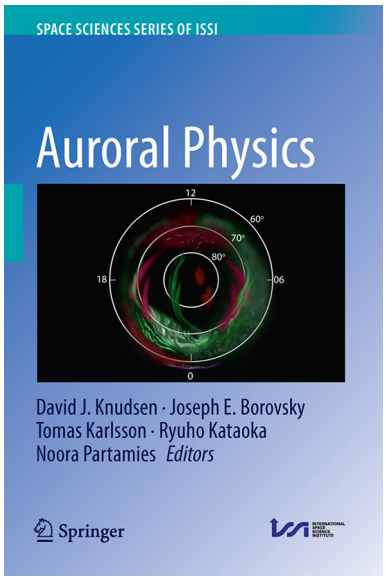

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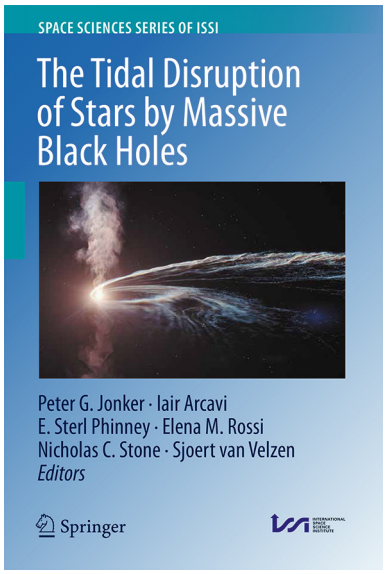

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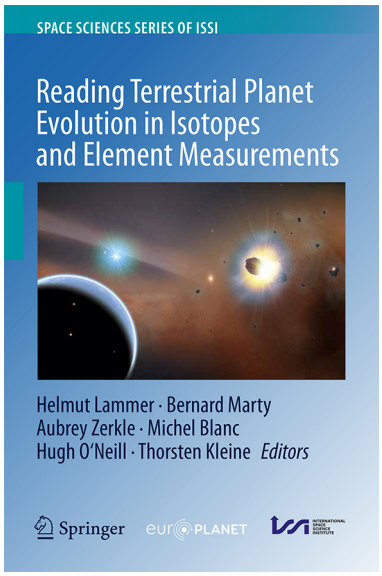

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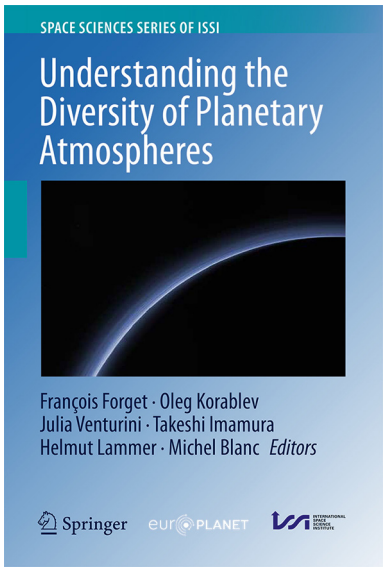

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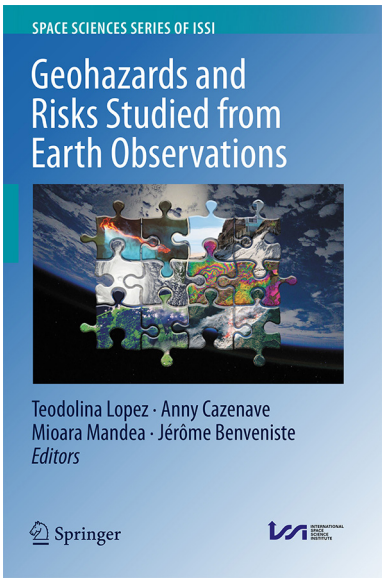

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The International Space Science Institute-Beijing (ISSI-BJ) was jointly established by the International Space Science Institute (ISSI) and the National Space Science Center (NSSC) with the support of the International Cooperation Bureau and the Space Science Strategic Project of the Chinese Academy of Science (CAS). ISSI-BJ is a close cooperation partner of ISSI. Both institutes share the same Scientific Committee, the same study tools, and other information of mutual relevance and interest. However, both use independent operational methods and different funding sources. ISSI-BJ is a non-profit research institute.

Because of the COVID-19 pandemic, all ISSI-BJ activities were limited to online seminars. Some International Teams and Workshops had organized webinars to carry on scientific discussions in lieu of in-personal meetings.

Forums

- Performing High-Quality Science in Astronomy on Space Stations *(meeting at ISSI-BJ postponed)*
- The Lunar Scientific Station *(meeting at ISSI-BJ postponed)*
- Detecting Missing Baryons in the Universe *(meeting at ISSI-BJ postponed)*

Workshops

Exploring the Jovian satellite system: from formation to habitability

A New Moon in the New Century

Online pre-workshop of "Exploring the Jovian satellite system: from formation to habitability" – Prof. Michel Blanc(France):

Sept.9, 2021: the first pre-Workshop of the workshop on the Jovian satellite system

Oct. 20, 2021: Pre-workshop of WG 4: Tidal/gravitational interactions and orbital evolution

Oct. 22, 2021: Pre-workshop of WG 5: Jupiter-Moon-magnetosphere electrodynamic interactions

International Teams

The following Team were active in 2021:

Step forward in solar flare and coronal mass ejection (CME) forecasting led by F. Zuccarello F. (IT) and Bingxian LUO (CN)

Interaction between magnetic reconnection and turbulence: From the Sun to the Earth led by San U (CN)

Measuring Solar Flare Hard X-ray Directivity using Stereoscopic Observations with Solar Orbiter/STIX and X-ray Instrumentation at Earth (ISSI - ISSI Beijing Team) led by S. Krucker (CH) and N. Jeffrey (UK)

Data Assimilation in the Ionosphere and Thermosphere (ISSI - ISSI Beijing Team) led by Pedatella N. (US)

Toward a 3-D Observation of the Ocean Color: Benefit of Lidar Technique (ISSI - ISSI Beijing Team) led by C. Jamet . (FR) and D. Dionisi (IT)

Magnetohydrodynamic wavetrains as a tool for probing the solar corona led by Bo LI (CN) and V. Nakariakov (UK)

Feb. 4, 2021: "The morphology of auroras at Earth and giant planets: characteristics and their magnetospheric implications" – Prof. Zhonghua YAO China and Quanqi SHI (China)

Nov. 17, 2021: "The morphology of auroras at Earth and giant planets: characteristics and their magnetospheric implications" – Prof. Zhonghua YAO, China and Quanqi SHI (China)

Outreach Activities

Because of the pandemic, ISSI-BJ organizes online seminars, including three series. **"On Things to Come"** focuses on current and future space missions, **"1001 Space Nights"** aims to introduce the research and result of outstanding Chinese women scientists, and **"Space Science Bazaar"** is for young scientists presenting their work within international team program of ISSI-BJ. The details of all online seminars and other activities can be found on its webpage: www.issibj.ac.cn. Subscribe to the Newsletter to be up to date on the events organized by ISSI-BJ: https://bit.ly/37OPtRW.

Yinong Li and the ISSI Beijing Staff

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