Extraterrestial Physics Division
Fachverband Extraterrestrische Physik (EP)

Miriam Sinnhuber
Karlsruhe Institute of Technology
Institute for Meteorology and Climate Research
Atmospheric Trace Gases and Remote Sensing
Hermann-von-Helmholtz-Platz 1
76344 Eggenstein-Leopoldshafen
miriam.sinnhuber@kit.edu

Overview of Invited Talks and Sessions

(Lecture halls ELP 1: HS 1.22 and ELP 6: HS 2; Poster ELP 6: Foyer)

Plenary Talk of the Extraterrestial Physics Division

PV VII	Thu	9:00– 9:45	ELP 6: HS 3+4	**Progress in solar flare modeling** — •Rony Keppens

Invited Talks

EP 1.1	Mon	14:30–15:00	ELP 1: HS 1.22	**Gravity wave vertical coupling from the troposphere to the thermosphere** — •Markus Rapp, Bernd Kaifler, Natalie Kaifler, Andreas Dörnbrack, Sonja Gisinger, Robert Reichert, Stefanie Knobloch, Hella Garny
EP 2.3	Tue	15:00–15:30	ELP 1: HS 1.22	**Interdisciplinary science through space plasma physics: the example of Jupiter's radiation belts** — •Elias Roussos
EP 2.8	Tue	17:00–17:30	ELP 1: HS 1.22	**Learning more about planets: What we expect from PLATO** — •Heike Rauer
EP 3.1	Wed	11:00–11:30	ELP 1: HS 1.22	**Arne Richter, Rekonnexion und das ebenso wechselhafte Schicksal der AEF** — •Jörg Büchner
EP 3.2	Wed	11:30–12:00	ELP 1: HS 1.22	**The Sun in Focus: Current Findings and Challenges in Solar Physics** — •Markus Roth
EP 3.3	Wed	12:00–12:30	ELP 1: HS 1.22	**Vortical motions in the solar atmosphere: observations, physics, cause and effect** — •Oskar Steiner, José Roberto Canivete Cuissa, Fabio Riva, Gangadharan Vigeesh

Invited Talks of the joint Symposium Plasmas in the Solar System (SYPS)

See SYPS for the full program of the symposium.

SYPS 1.1	Thu	11:00–11:30	ELP 6: HS 4	**Energetic Particles in the Turbulent Heliosphere** — •Horst Fichtner
SYPS 1.2	Thu	11:30–12:00	ELP 6: HS 4	**Persistent solar wind forcing of the F2-region ionosphere observed at Tromsø** — •Claudia Borries, Pelin Iochem
SYPS 1.3	Thu	12:00–12:30	ELP 6: HS 4	**In-orbit diagnostics for artificial plasmas created by electric propulsion systems: The Heinrich Hertz Satellite Mission** — •Thomas Trottenberg
SYPS 1.4	Thu	12:30–13:00	ELP 6: HS 4	**Plasma-based space propulsion: status and scientific challenges** — •Kristof Holste

Sessions

EP 1.1–1.8	Mon	14:30–17:50	ELP 1: HS 1.22	**Near-Earth Space and Space Weather**
EP 2.1–2.13	Tue	14:30–18:45	ELP 1: HS 1.22	**Planets in their Environment**

EP 3.1–3.3	Wed	11:00–12:30	ELP 1: HS 1.22	**Sun and Heliosphere I with Arne-Richter Lecture**
EP 4	Wed	12:45–13:45	ELP 1: HS 1.22	**Members' Assembly / Mitgliederversammlung**
EP 5.1–5.6	Wed	14:15–15:45	ELP 1: HS 1.22	**Astrophysics**
EP 6.1–6.9	Wed	16:30–18:30	ELP 6: Foyer	**Postersession**
EP 7.1–7.13	Thu	14:00–17:45	ELP 6: HS 2	**Sun and Heliosphere II**

Members' Assembly of the Extraterrestial Physics Division

Wednesday 12:45–13:45 ELP 1: HS 1.22

EP 1: Near-Earth Space and Space Weather

Time: Monday 14:30–17:50 Location: ELP 1: HS 1.22

Invited Talk EP 1.1 Mon 14:30 ELP 1: HS 1.22

Gravity wave vertical coupling from the troposphere to the thermosphere — •Markus Rapp, Bernd Kaifler, Natalie Kaifler, Andreas Dörnbrack, Sonja Gisinger, Robert Reichert, Stefanie Knobloch, and Hella Garny — Deutsches Zentrum für Luft- und Raumfahrt, Institut für Physik der Atmosphäre, Oberpfaffenhofen, Germany

It is now well established that momentum and energy transport by gravity waves as well as its interaction with the mean flow is a key driver of middle atmospheric circulation. The latter in turn has important consequences for the middle atmospheric mean state. Unfortunately, though, gravity wave dynamics covers a very large range of spatial and temporal scales such that a comprehensive characterization both in terms of observations and modelling is still a major scientific challenge. This paper reviews efforts in both observations and modelling over the past 10 years during which ground based, airborne and satellite borne gravity wave observations were combined with models to shed light on several fundamental aspects of gravity wave dynamics and wave-mean flow interaction. Comprehensive data sets of gravity wave observations were collected from the Arctic to the South Pole which were used to characterize gravity wave processes and their role in climate. Examples will be presented and an outlook will be given how we plan to extend these studies into the thermosphere in order to gain better understanding of the role of neutral atmosphere vertical coupling for driving space weather phenomena.

EP 1.2 Mon 15:00 ELP 1: HS 1.22

A possible cause for the October effect in the D-region — •Vivien Wendt[1], Helen Schneider[1], Daniela Banys[1], Marc Hansen[1], Mark Clilverd[2], and Tero Raita[3] — [1]Institute of Solar-Terrestrial Physics, DLR, Neustrelitz, Germany — [2]British Antarctic Survey, Cambidge, UK — [3]Sodankylä Geophysical Observatory, University of Oulu, Sodankylä, Finland

Radar waves with very low frequency (VLF) are reflected in the D-region, the lower edge of the ionosphere. The D-region (60 - 90km) is influenced by the solar zenith angle and space weather from above and by the mesosphere's dynamic and chemical processes. During October there is a sharp decrease of the daytime VLF amplitude between transmitter and receiver combinations whose great circle paths lie in polar latitudes. Until now we do not know what causes the October effect. Space weather phenomena can be ruled out as a cause since their time scales are too short or too long. The solar zenith angle can also be ruled out as a similar behavior is not observed in spring. Thus, there is an assumption that dynamical processes in the mesosphere play a major role. Previous studies showed that a strong warming occurs in the lower mesosphere shortly before the October effect is observed. While the characteristics of this warming help us to explain why the October effect occurs during daytime only, the warming alone cannot explain the sharp decrease in the VLF daytime amplitude. We suspect and confirm that the water vapor in the lower mesosphere, having similar characteristics as the warming and the VLF amplitude decrease, plays a crucial role in the formation mechanism of the October effect.

EP 1.3 Mon 15:20 ELP 1: HS 1.22

The CHerenkov Atmospheric Observation System (CHAOS) for the 2024 Balloon Experiments for University Students (BEXUS) Campaign — •Hannes Ebeling, Ava Pohley, Pierre Bornfleth, Hannah Sophie Grimm, Janna Martens, Jasper Mess, Justus Mickausch, Clara Pittschellis, Nicolas Rohrbeck, and Tom Ruge — Christian-Albrechts-Universität, Kiel, Germany

The Earth is continuously exposed to high-energy charged particles, so-called Galactic Cosmic Rays (GCRs). When these particles hit the Earth's atmosphere, they create a cascade of secondary particles. CHAOS uses a new detector design developed at the Department of Extraterrestrial Physics at Kiel University by a team of students to measure the different particle species of the primary GCRs above the so-called Regener-Pfotzer Maximum. To perform these measurements a combination of multiple solid state detectors and a bismuth germanium oxide (BGO) scintillator is used to measure the energy depositions of the particles. The use of an additional Cherenkov aerogel scintillator allows to separate between electrons and protons. Because electrons are much lighter than ions, electrons with energies above ~ 1.1 MeV will trigger the Cherenkov detector whereas ions with the same energy are much slower and will not trigger the Cherenkov detector. In this talk we present the design and functionality of CHAOS as well as its current status. CHAOS is supposed to fly on a stratospheric balloon as part of the BEXUS program in fall 2024. More information about CHAOS can be found at `https://www.bexus.org/`.

EP 1.4 Mon 15:40 ELP 1: HS 1.22

EPP-climate link by reactive nitrogen polar winter descent revisited: MIPAS v8 reprocessing and future benefits by the EE11 candidate mission CAIRT — •S. Bender[1], B. Funke[1], M. López Puertas[1], M. Garcia-Comas[1], T. von Clarmann[2], M. Höpfner[2], B.-M. Sinnhuber[2], M. Sinnhuber[2], Q. Errera[3], G. Poli[4], and J. Ungermann[5] — [1]IAA-CSIC, Spain — [2]KIT, Germany — [3]BIRA, Belgium — [4]IAP "Nello Carrara", Italy — [5]FZJ, Germany

Polar winter descent of NOy produced by energetic particle precipitation (EPP) in the mesosphere and lower thermosphere affects polar stratospheric ozone by catalytic reactions. This, in turn, may affect regional climate via radiative and dynamical feedbacks. NOy observations by MIPAS/Envisat during 2002–2012 have provided observational constraints on the solar-activity modulated variability of stratospheric EPP-NOy. These constraints have been used to formulate a chemical upper boundary condition (UBC) for climate models in the context of solar forcing recommendations for CMIP6. Recently, a reprocessed MIPAS version 8 dataset has been released. We assess how the changes in this new data version impact the EPP-NOy quantification and the formulation of the UBC.

ESA's Earth Explorer 11 candidate Changing Atmosphere Infra-Red Tomography (CAIRT) will observe the atmosphere from about 5 to 115 km with an across-track resolution of 30 to 50 km within a 500 km wide field of view. CAIRT will provide NOy and tracer observations with unprecedented spatial resolution. We assess its potential to advance our understanding of the EPP-climate link in the future.

30 min break

EP 1.5 Mon 16:30 ELP 1: HS 1.22

Atmosphere-Magnetosphere Coupling During Geomagnetic Storms — •Alina Grishina[1,2], Yuri Shprits[1,2,3], Alexander Drozdov[3], Miriam Sinnhuber[4], Florian Haenel[4], Dedong Wang[1], Mátyás Szabó-Roberts[1], Jan Maik Wissing[5], and Stefan Bender[6] — [1]GFZ German Research Centre for Geosciences, Potsdam, Germany — [2]University of Potsdam, Potsdam, Germany — [3]University of California, Los Angeles, Los Angeles, CA, USA — [4]Karlsruhe Institute of Technology, Karlsruhe, Germany — [5]DLR German Aerospace Center Neustrelitz, Neustrelitz, Germany — [6]Instituto de Astrofísica de Andalucía, CSIC, Granada, Spain

The electron and ion flux in the near-Earth environment can change by orders of magnitude during geomagnetically active periods, which can lead to intensification of particle precipitation into the Earth's atmosphere. In our study, we concentrate on ring current electrons, and investigate precipitation mechanisms and their effect on the atmosphere using a numerical model. We validate our results against observations from the Polar Operational Environmental Satellites (POES) mission, as well as the Van Allen Probes. We calculate the altitude-dependent atmospheric ionization rates, and validate them against Atmospheric Ionization during Substorm (AIMOS 2.1-Aisstorm) and Special Sensor Ultraviolet Spectrographic Imagers (SSUSI) values, which shows good agreement at high geomagnetic latitudes during the storm time.

EP 1.6 Mon 16:50 ELP 1: HS 1.22

Atmospheric impact of extreme solar eruptions — •Miriam Sinnhuber[1], Thomas Reddmann[1], Jan Maik Wissing[2], and Ilya Usoskin[3] — [1]Karlsruher Institut für Technologie — [2]DLR Neustrelitz — [3]University of Oulu, Finland

Large solar eruption - solar flares and coronal mass ejections - can have a significant impact on the chemical composition and dynamics of the polar middle atmosphere. For solar events of the space age since 1957, this is well quantified and understood. However, evidence for much larger events has been derived from paleonuclide records within the last 10000 years. Here, we show results from model experiments comparing the well-known "Halloween" solar storm of October 2003 with an extreme event of AD774/775. Both events had a significant impact on atmospheric composition which lasted for several months. Due to its harder spectrum and larger fluxes, this impact affected lower atmospheric layers during and after the AD774 event. Due to radiative-dynamical feedbacks, both events affected atmospheric temperatures and dynamics as well with larger changes during the event and during polar summer for the stronger AD774 event. However, during polar winter, the preconditioning of the atmosphere seems to play a role as well.

EP 1.7 Mon 17:10 ELP 1: HS 1.22

The Atmospheric Ionization during Substorm Model (AISstorm 2.1) — •Jan Maik Wissing[1] and Olesya Yakovchuk[2] — [1]DLR Neustrelitz — [2]Universität Rostock

AISstorm derives the global atmospheric ionization due to particle precipitation based on in-situ particle measurements. The model covers auroral precipitation as well as solar particle events on an altitude range of about 250km down to 16km for protons and down to 70km for electrons. Alpha particle ionization is included as well but on a smaller altitude range. The overall structure splits up into an empirical model that determines the 2D precipitating particle flux and a numerical model that determines the ionization profile of single particles. The combination of these two results in a high resolution 3D particle ionization rate pattern. The AISstorm is the successor of the Atmospheric Ionization Module Osnabrück (AIMOS).

The main benefit of the updated ionization rates are higher dynamics during substorms and during the onset of geomagnetic storms in particular in the mesosphere - in agreement with observations.

The internal structure of the model has been completely revised in AISstorm with the main aspects being: a) an internal magnetic coordinate system, b) including substorms characteristics, c) higher time resolution, d) higher spatial resolution, e) energy specific separate handling of auroral precipitation, polar cap precipitation and crosstalk affected areas, f) better MLT resolution.

The contribution will compare the new ionization rates to AIMOS 1.6, AISstorm 2.0 and the HEPPA III multi-model study.

EP 1.8 Mon 17:30 ELP 1: HS 1.22

Solar Wind monitoring for Space Weather impact prediction — •Jens Berdermann[1], Erik Schmölter[1], Martin Kriegel[1], and Henrike Barkmann[2] — [1]German Aerospace Center (DLR), Institute for Solar-Terrestrial Physics — [2]German Aerospace Center (DLR), German Remote Sensing Data Center

Applications in safety-critical communication, precise navigation and remote sensing require comprehensive information on the current and future state of the ionosphere. Of particular interest are monitoring and prediction of solar activity driven disturbances, which significantly impact the operation of these services. This in turn requires a sufficiently good database as well as powerful models and simulation tools. Additionally, early knowledge of the relevant sources of ionospheric disturbances, primarily solar radiation and wind, are necessary for forecasting. Therefore, near real time solar wind data are crucial for assessing and predicting the impact of space weather on the ionosphere and on technical systems. DLR is part of the Real Time Solar Wind network coordinated by the US National Oceanic and Atmospheric Administration, and therefore responsible for receiving the DSCOVR satellite in the European sector. We will provide information about the solar wind receiving facility, data acquisition and the product processing at the Ionosphere Monitoring and Prediction Center of DLR in Neustrelitz. In addition, we present storm events from the current space weather situation near solar maximum and their effects on the ionosphere and technical systems. Finally, we give a brief outlook on upcoming solar wind missions and future forecasting products.

EP 2: Planets in their Environment

Time: Tuesday 14:30–18:45 Location: ELP 1: HS 1.22

EP 2.1 Tue 14:30 ELP 1: HS 1.22

Conformal mapping for the astrophysical flow and magnetic field problems — •Yasuhito Narita[1], Daniel Schmid[2], and Henry Holzkamp[1] — [1]Institut für Theoretische Physik, TU Braunschweig, Germany — [2]Space Research Institute, Austrian Academy of Sciences, Graz, Austria

Determining the plasma flow and magnetic field in the magnetosehath domain is a challenge both in space and astrophysical plasmas. We develop a novel algorithm of the conformal mapping to exactly transform the Kobel-Flückiger magnetosheath scalar potential onto a user-specified, arbitrary geometry of the magnetosheath domain. The algorithm starts with the outer and innter boundary models (e.g., bow shock and magnetopause locations in the case of planetary magnetospheres). The shell variable v is constructed by smoothly interpolating between the two boundaries, and the connector variable u (connecting between the two boundaries in an orthogonal fashion to the shell variable) is determined by evaluating the gradient of the shell variable along the shell segment under the Cauchy-Riemann relations. The conformal mapping method is computationally by far inexpensive, and retains the exactness character of the steady-state magnetosheath solution. The method has a wide range of applications such as validating the numerical simulations, planning the space (planetary and heliospheric) missions, and even estimating the solar wind condition from the magnetosheath data.

EP 2.2 Tue 14:45 ELP 1: HS 1.22

MHD jump condition tool for planetary and astrophysical shock problems — •Daniel Schmid[1] and Yasuhito Narita[2] — [1]Space Research Institute, Graz, Austria — [2]Institut für Theoretische Physik, Technische Universität Braunschweig, Braunschweig, Germany

Shock waves in the collisionless astrophysical plasmas are known to form in planetary, heliospheric, and interstellar systems. One of the common challenges in the observational shock studies is to determine the shock parameters such as the upstream flow speed, the density jump, the angle of the upstream magnetic field to the shock normal, and the plasma beta, given by the ratio between thermal and magnetic pressure. We develop a novel analysis tool by incorporating the pertubative Grabble-Cairns solution of the magnetohydrodynamic (MHD) jump condition into the de Hoffmann-Teller frame. The tool determines the density jump across the shock and the upstream Alfven Mach number as a function of the magnetic field jump and the plasma beta. A particular example where the analysis tool can be helpful are planetary missions with limited plasma data where only the magnetic field data are available with a sufficient time resolution for the shock wave analysis. The tool is successfully tested against the magnetic field and plasma data of Cluster mission's shock crossing of the Earth's bow shock. We further apply the tool to BepiColombo's flyby magnetic field data at Mercury, and discuss the possibility of the tool inversion to determine the magnetic field jump for the astrophysical shocks in interstellar space.

Invited Talk EP 2.3 Tue 15:00 ELP 1: HS 1.22

Interdisciplinary science through space plasma physics: the example of Jupiter's radiation belts — •Elias Roussos — Max Planck Institute for Solar System Research, Goettingen, Germany

In this presentation I will use the example of Jupiter's radiation belts for demonstrating the interdisciplinary character of space plasma physics investigations. The choice of Jupiter is not random: Jupiter is a planet of superlatives and its magnetosphere is no exception to that. The planet's magnetosphere acts as a very powerful charged particle accelerator, giving rise to the most hazardous particle radiation environment in our solar system: Jupiter's radiation belts. The radiation belts of Jupiter trap electrons, protons and heavy ions with energies characteristic for cosmic rays, albeit at intensities orders of magnitude higher that the latter. What our existing measurements indicate is that particle acceleration, transport and loss processes operating at Jupiter are unparalleled in our solar system and offer us insights into the dynamics of astrophysical magnetospheres that we only probe remotely. At the same time, material interactions resulting from collocation of the belts with jovian moons and rings has far reaching implications, ranging from space weathering to astrobiology. Any plans to explore Jupiter cannot thus ignore the links between the different and seemingly diverse components of this system, explaining why Jupiter's space environment is always in the spotlight, even for non-space physics focused missions to the planet.

EP 2.4 Tue 15:30 ELP 1: HS 1.22

MHD simulations of Europa's interaction with the jovian magnetosphere: insights from the Juno flyby — •Sebastian Cervantes[1], Joachim Saur[1], Stefan Duling[1], Stephan Schlegel[1], Jamey Szalay[2], Frederic Allegrini[3], and Jack Connerney[4,5] — [1]Universität zu Köln, Institut für Geophysik und Meteorologie, Cologne, Germany — [2]Princeton University, Princeton, USA — [3]Southwest Research Institute, San Antonio, USA — [4]Space Research Corporation, Annapolis, USA — [5]NASA Goddard Space Flight Center, Greenbelt, USA

We model the plasma interaction of Jupiter's magnetosphere with Europa and its atmosphere for the conditions of the flyby performed by NASA's Juno spacecraft. We apply the three-dimensional magnetohydrodynamic (MHD) single fluid PLUTO code based on Mignone et al., [2007], and we include in our model electromagnetic induction in a subsurface water ocean, collisions between ions and neutrals, plasma production due to electron impact ionization, and loss due to dissociative recombination. We model the effect of the recently detected electron beams by Allegrini et al. [2023] as sheets of locally enhanced electron impact ionization. We compare our simulations with the magnetic field and the total ion number density measurements from the magnetometer and the JADE detector onboard Juno, respectively. Our results show that the electron beams are essential in the plasma interaction by producing large variations of the magnetic field consistent with the magnetometer data, and by filling the wake with newly ionized plasma downstream of Europa.

EP 2.5 Tue 15:45 ELP 1: HS 1.22

Europa's asymmetric electron temperature — •Stephan Schlegel and Joachim Saur — University of Cologne, Cologne, Germany

Far ultraviolet emissions of Jupiter's moon Europa have been used as a diagnostic for its atmosphere and plasma environment. Hubble Space Telescope observations have shown time and spacial variability of the OI1356 oxygen line. The observations suggest that the side of Europa facing the dense plasma sheet is brighter at this wave length. The brightness is associated with electron density, electron temperature and neutral particle density along the line of sight. Therefore, the question arises, which effect controls this asymmetry in the brightness.

We conducted a study of the electron temperature and density around Europa. For that purpose we carried out simulations of the system that solve the ideal MHD equations and inferred the electron temperature. In our study, the electrons are cooled down by the interaction with the atmosphere and are reheated by heat conduction along the magnetic field lines. The asymmetry in available thermal energy between the plasma sheet facing and opposite site leads to a fast cooling of the latter and leads to an asymmetry in electron temperature. This could explain the asymmetries in the HST observations.

EP 2.6 Tue 16:00 ELP 1: HS 1.22

Permittivity sensor to investigate the ice crust of the Jovian moon Europa — •Fabian Becker, Enrico Ellinger, and Klaus Helbing — Bergische Universität Wuppertal, Wuppertal, Deutschland

The icy moons in our solar system are attracting increased interest for the next space missions. This is due to the large deposits of liquid water, which are located under an ice crust and could be a possible habitat for extraterrestrial life. After the phase of satellite missions, which explore moons such as Europa, Ganymed, Callisto or Enceladus from orbit, it would be the next step to develop missions for landing and exploring the ice crust and the big oceans.

Our concept to look inside the crust or travel through the big ice layer to the liquid water is using melting probes. For these probes, a sensor system was developed to measure the permittivity ε_r of the surrounding ice. The primary goal is to correct radar data to plan the trajectory of the melting probe, where the radar antennas are integrated inside the melting head. Furthermore, it could bring first insights into the structure and composition of the moon's crust.

The concept is based on reflection measurements at an open coaxial output. The entire measuring system is integrated into a compartment of the melting probe, which is pressure-neutral. This has already been fully assembled in the project TRIPLE-FRS. The first tests were done in terrestrial cryospheres such as alpine glaciers.

EP 2.7 Tue 16:15 ELP 1: HS 1.22

Detectability of Local Water Reservoirs in Europa's Surface Layer Under Consideration of Coupled Induction — •Jason Winkenstern and Joachim Saur — Institute of Geophysics and Meteorology, University of Cologne, Cologne, Germany

Jupiter's icy moon Europa is a primary target for the study of ocean worlds. Its subsurface ocean is expected to be subject to asymmetries on global scales (tidal heating) and local scales (chaos regions, fractures). We approximate local asymmetries by considering a reservoir of liquid water entrapped in Europa's icy crust and investigate the possibility to resolve the resulting induced magnetic field of such a small-scale body with magnetometer measurements. The consideration of two conductive bodies introduces non-linear magnetic field coupling between them, for which we develop an analytical model to describe these coupling processes. With the Europa Clipper spacecraft launching this year, we calculate the induction response at 25 km altitude to assess detectability with the next generation's mission. Additionally, we investigate the detectability at Europa's surface to motivate a potential future lander mission.

30 min break

Invited Talk EP 2.8 Tue 17:00 ELP 1: HS 1.22

Learning more about planets: What we expect from PLATO — •Heike Rauer — Institut für Planetenforschung, DLR — Freie Universität Berlin

Exoplanet statistics from missions like Kepler/K2 and TESS have revealed a large diversity among extrasolar planets but also showed structure in the distribution of planets like, e.g., the so-called radius valley. While these data already provide significant inputs to planet formation and evolution models, our knowledge on well-known low-mass/small planets is restricted to orbital periods much less than 100 days. Low-mass planets on intermediate orbits remain to be explored. PLATO, the ESA M3 mission, is designed to detect and characterize extrasolar planets by photometric transits with a focus on small planets around bright stars, including terrestrial planets in the habitable zone of solar-like stars. With the complement of radial velocity observations from ground, planets will be characterized for their radius, mass, and age with high accuracy. The mission will provide a large-scale catalogue of well-characterized small planets up to intermediate orbital periods. In parallel, PLATO will study (host) stars using asteroseismology, allowing us to determine the stellar properties with high accuracy. The talk will provide an overview of our current knowledge on small exoplanet properties and an outlook to the expected impact from the PLATO mission.

EP 2.9 Tue 17:30 ELP 1: HS 1.22

ANDES - The high resolution spectrograph for the ELT and its calibration unit(s): Current baseline Design — •Philipp Huke[1], Ansgar Reiners[2], Michael Debus[2], Sebastian Schäfer[2], Richard McCracken[3], Derryck Reid[3], Yuk Shan Cheng[3], Kamalesh Dadi[3], Mirsad Sarjlic[4], Christopher Broeg[4], Omar Gabella[5], Michael Lehmitz[6], Wolfgang Gaessler[6], Driss Kouach[7], Jörg Knoche[8], Lea Bonhomme[9], Piotr Maslowski[10], and Alessio Zanutta[11] — [1]Institute for Laser and Optics, University of applied Sciences Emden /Leer — [2]Institute for Astrophysics and Geophysics, Georg-August-University Göttingen — [3]Institute of Photonics and Quantum Sciences, Herriot-Watt-University Edinburgh — [4]Center for Space and Habitability, University of Bern — [5]Laboratoire Univers et Particul de Montpellier — [6]Max-Planck Institut für Astronomie, Heidelberg — [7]Observatoire Midi-Pyrénées, Université de Toulouse — [8]University of Hamburg — [9]Observatoire Midi-Pyrénées — [10]Nicolaus-Copernicus University — [11]Osservatorio Astronomico die Trieste

The ANDES-project entered phase B in January 2022. Among its main scientific goals are the detection of atmospheres of exoplanets and the determination of fundamental physical constants. For this, high radial velocity precision and accuracy are required. Even though the ANDES-spectrograph is designed for maximum intrinsic stability, calibration is mandatory. This talk provides and update of the current baseline design of the spectrograph with special emphasis on the calibration unit(s).

EP 2.10 Tue 17:45 ELP 1: HS 1.22

Atomic oxygen on the dayside and nightside of Venus measured by SOFIA — •Heinz-Wilhelm Hübers[1,2], Heiko Richter[1], Urs Graf[3], Rolf Güsten[4], Bernd Klein[4], Jürgen Stutzki[3], and Helmut Wiesemeyer[4] — [1]DLR, Institut für Optische Sensorsysteme, Berlin, Deutschland — [2]Humboldt-Universität zu

Berlin, Deutschland — [3]Universität zu Köln, Deutschland — [4]MPI für Radioastronomie, Bonn, Deutschland

Atomic oxygen is important for the photochemistry in the mesosphere and thermosphere of Venus and can be used as tracer for atmospheric dynamics. It is mainly generated through photolysis of CO2 on the dayside from where it is transported to the nightside. The altitude region in which atomic oxygen predominantly occurs is above the retrograde super-rotating zonal flow between 90 km and 130 km. We have detected atomic oxygen on the dayside as well as on the nightside of Venus by measuring its ground-state transition at 4.74 THz with the upGREAT heterodyne spectrometer on board SOFIA [1]. This is a direct detection in contrast to most of past and current detection methods, which are indirect and rely on photochemical models. We have determined the concentration and temperature of atomic oxygen as well as the brightness temperature of Venus between 15:00 and 21:00 hours local time. The measurements indicate a maximum concentration around 100 km and provide insight into the atmospheric dynamics. The new method will support detailed investigations of the Venusian atmosphere and support of future space missions.

[1] H.-W. Hübers et al., Nature Communications, 14:6812 (2023)

EP 2.11 Tue 18:00 ELP 1: HS 1.22

Atmospheric Modelling Studies of Venus as an Exoplanet — •John Lee Grenfell[1], Jörn Helbert[1], Gabriele Arnold[1], Konstantin Herbst[2], Miriam Sinnhuber[3], Juan Cabrera[1], and Heike Rauer[1,4] — [1]Institute for Planetary Research, German Aerospace Centre (DLR), Berlin, Germany — [2]Christian-Albrechts-Universltät (CAU), Kiel, Germany — [3]Karlsruher Institut für Technologie (KIT), Karlsruhe, Germany — [4]Freie Universität Berlin (FUB), Germany

The recently selected Venus missions EnVISION and VERITAS offer new opportunities for studying Venus but will also contribute to furthering our knowledge of Venus as an exoplanet. Hot rocky planets are favored targets due to generally more frequent transits than cooler Earth-like objects. In this work we simulate Venus as an exoplanet varying stellar, orbital, planetary and atmospheric parameters and study the effect upon atmospheric composition, climate and spectral detectability with the LIFE (Large Interferometer For Exoplanets) telescope.

EP 2.12 Tue 18:15 ELP 1: HS 1.22

Investigation of the Influence of Stellar Energetic Particles (SEPs) on the Atmosphere of TRAPPIST-1e — •Andreas Bartenschlager[1], Miriam Sinnhuber[1], John Lee Grenfell[2], Nicolas Iro[2], Benjamin Taysum[2], and Konstantin Herbst[3] — [1]KIT Karlsruhe — [2]DLR Berlin — [3]CAU Kiel

New instruments (JWST) open up the possibility of studying the composition of exoplanetary atmospheres in habitable zones. On explanets around very active M-stars like TRAPPIST-1, the impact of SEPs on the atmosphere plays an important role and is investigated with the ion chemistry model ExoTIC (Herbst et al., 2022). Within the INCREASE project, we perform model experiments with different N_2 or CO_2 dominated atmospheres, depending on the initial CO_2 partial pressure, as well as humid and dry conditions (Wunderlich et al., 2020). A further specification is the distinction between dead and alive atmospheres, whose composition is characterized by initial lower/higher O_2 fractions. Further model development gives the possibility to simulate the ion chemistry's impact on the atmospheric composition of multiple ionization events with different strengths and frequencies, based on the observed flaring frequency of TRAPPIST-1. Preliminary results show a significant impact of SEP events on the chemical composition of the atmosphere, including biosignatures such as O_3, especially in the recovery of the ozone layer after multiple SEP events. These changes have an impact on the observed transmission spectra. The strength and structure of these impacts depend on the initial composition, in particular on the availability of O_2, N_2 and H_2O.

EP 2.13 Tue 18:30 ELP 1: HS 1.22

On the Comprehensive 3D Modelling of the Radiation Environment of Proxima Centauri b: a New Constraint on Habitability? — •Klaus Scherer[1], Konstantin Herbst[2], Eugene Engelbrecht[3], Juandre Light[3], DuToit Strauss[3], and Juandre Light[3] — [1]RUB — [2]CAU — [3]NWU

The combined influence of stellar energetic particles (StEPS) and galactic cosmic rays (GCRs) on the radiation environment, and hence potential habitability, of Earth-like exoplanets is relatively unknown. The present study, for the first time, comprehensively models the transport of these particles in a physics-first manner, using a unique suite of numerical models applied to the astrosphere of Proxima Centauri. The astrospheric plasma environment is modelled magnetohydrodynamically, while particle transport is modelled using a 3D *ab initio* GCR modulation code, as opposed to previous 1D approaches to this problem. StEP intensities are also calculated using observed stellar event profiles for Proxima Centauri as inputs. Computed intensities are then used to calculate possible atmospheric ionization effects and dose rates. We demonstrate the significant contribution of GCRs to these quantities and propose a novel constraint on exoplanetary habitability based on the unique 3D modelling approach presented here.

EP 3: Sun and Heliosphere I with Arne-Richter Lecture

Time: Wednesday 11:00–12:30 Location: ELP 1: HS 1.22

Invited Talk EP 3.1 Wed 11:00 ELP 1: HS 1.22

Arne Richter, Rekonnexion und das ebenso wechselhafte Schicksal der AEF — •Jörg Büchner — Max-Planck für Sonnensystemforschung, Göttingen — Zentrum für Astronomie und Astrophysik, TU Berlin

Eigentlich würde ich gern nur über Rekonnexion sprechen. Doch Arne Richter war ja mehr ein Mann der Stoßwellen. Aber auch jemand, dem die extraterrestrische Physik viel zu verdanken hat. Nicht nur durch seine Originalbeiträge, als er noch Wissenschaftler am MPAe war (wer weiß noch, was so hieß?), sondern später auch als aktiver Gestalter der Wissenschaftslandschaft. Einer der wesentlich dazu beitrug, die EGS als EGU zum europäischen Pendant der AGU zu etablieren, auf dass die AGU inzwischen nicht mehr allein die ganze große weite Welt der Extraterrestrik betagen muss. Als erfolgreicher Mitgestalter von Wissenschaftsorganisationen war Arne dann auch wesentlich beteiligt an der Rettung des der Arbeitsgemeinschaft Extraterrestrischen Physik/ Forschung vor ihren Liquidatoren.

Und nun der Bogen zur Rekonnexion, die inzwischen neben den Stoßwellen nicht mehr wegzudenken ist aus der plasmaphysikalischen Weltraumforschung: Wie die Extraterrestrik erlebte die Rekonnexion Jahrzehnte des Auf und Ab: Von ignoriert und gescholten durch die etablierten Krösusse bis zur glücklichen Rettung. Bei beiden zum Besten der Wissenschaft. Von Tiefen und Höhen ist also zu berichten. In der Hoffnung auf Ermutigung der Wissenschaftler nächster Generation, wenn es mal nicht so rund läuft.

Invited Talk EP 3.2 Wed 11:30 ELP 1: HS 1.22

The Sun in Focus: Current Findings and Challenges in Solar Physics — •Markus Roth — Thüringer Landessternwarte Tautenburg

We are living with the Sun in our solar system – a star which has served as a paradigm for astrophysics for many decades. Even though this star is the closest to us it still holds a multitude of secrets, and fascinates astronomers and physicists alike. With dedicated instruments in space and on the ground the various aspects of these secrets are revealed, ranging from the structure and dynamics of the outer solar atmosphere to the deep solar interior. Current research projects and technological advances aim to study the Sun with unprecedented precision. Hence solar physics plays a crucial role in astrophysics and in understanding the origins of space weather. This talk will offer exciting new insights into the fascinating world of solar research and its growing relevance for astrophysics and beyond.

Invited Talk EP 3.3 Wed 12:00 ELP 1: HS 1.22

Vortical motions in the solar atmosphere: observations, physics, cause and effect — •Oskar Steiner[1,2], José Roberto Canivete Cuissa[2], Fabio Riva[2], and Gangadharan Vigeesh[1] — [1]Kiepenheuer-Institut für Sonnenphysik, Freiburg, Germany — [2]IRSOL–Istituto ricerche solari Aldo e Cele Daccó, Locarno, Switzerland

A relatively recent addition to the solar zoo are vortical motions or swirls on very small scales in the photospheric and chromospheric layers of the solar atmosphere. Because of their very small size, their ubiquitousness has only recently been fully recognised. Often, swirls in the deep photosphere and surface layers of the convection zone harbour magnetic fields, which leads to a twist in the magnetic lines of force that propagates with Alfvén speed into the outer layers of the atmosphere. From numerical simulations, we have so far only rough estimates of the energy flux carried by these swirls and got only very recently hints on their dissipation from observations and simulations. Also from numerical simulations we have hints that coronal loops may harbour swirling motions too, which may have their origin in the surface layers of the convection zone or in the chromosphere. This talk briefly summarizes what we know from observations before diving into the physics of magnetic tornadoes and a discussion of the physical quantities used for their characterisation and detection. Finally, we speculate on their effect on the chromosphere and the outer solar atmosphere including coronal loops.

EP 4: Members' Assembly / Mitgliederversammlung

Time: Wednesday 12:45–13:45 Location: ELP 1: HS 1.22

Mitgliederversammlung

EP 5: Astrophysics

Time: Wednesday 14:15–15:45 Location: ELP 1: HS 1.22

EP 5.1 Wed 14:15 ELP 1: HS 1.22

Astrophysical test of the equality of active and passive gravitational mass — •Claus Lämmerzahl and Eva Hackmann — ZARM, University of Bremen, Gemany

Each body possesses three types of a mass: the inertial mass, the passive gravitational mass (or weight), and the active gravitational mass (or gravitating mass). The equivalence of inertial and passive gravitational mass, also known as the Weak Equivalence Principle, has been confirmed at the level of 10^{-15} by the recent space mission MICROSCOPE.

The precision of tests of the equivalence of the active and passive gravitational mass scales with the strength of the gravitational field created by the participating masses. This makes laboratory tests very difficult yielding an estimate of the order 10^{-6}, only. On the other hand, one can show that gravitationally bound astrophysical masses with their strong gravitational fields are not suited for corresponding tests. The only viable situation for an astrophysical test is a solid body composed of different masses of different composition moving in a gravitational field of another body. Our Moon with non-concentric iron and aluminum dominated parts provides such an example.

In the presentation we will provide the theoretical background and describe our data analysis of more than 50 years of Lunar Laser Ranging. As a consequence, with Lunar Laser Ranging, any non-equivalence of the active and passive gravitational mass is now bound by $4 \cdot 10^{-14}$. In addition, new planned laboratory tests will be shortly described.

EP 5.2 Wed 14:30 ELP 1: HS 1.22

Lévy flight model for the superdiffusive transport and acceleration of particles at shocks* — •Sophie Aerdker[1,2], Lukas Merten[1,2], Frederic Effenberger[1,2], and Horst Fichtner[1,2] — [1]Theoretical Physics IV, Faculty of Physics and Astronomy, Ruhr University Bochum — [2]Ruhr Astroparticle and Plasma Physics Center (RAPP Center), Germany

In the heliosphere, power laws in space and time profiles of energetic particles at shock fronts are observed. It has been proposed that they result from superdiffusive transport, which can be modelled by Lévy flights. Such anomalous, non-Gaussian, transport regimes may arise as a consequence of intermittent magnetic field structures.

Superdiffusive particle transport can be described by a space-fractional Fokker-Planck equation. Numerical solutions can be obtained by solving the corresponding Stochastic Differential Equations (SDEs). In contrast to Gaussian diffusion, where the SDE is driven by a normal distribution, for superdiffusion random numbers are drawn from a symmetric alpha-stable Lévy distribution.

We investigate particle transport and acceleration at a shock front and use the SDE approach to solve the space-fractional Fokker-Planck equation. With a modified version of CRPropa3.2 the time-dependent solutions of the number density and energy spectrum at the shock are obtained. Our simulations lead to results that are compatible with the expected power-law particle distribution upstream of a shock. We also find slightly flatter energy spectra at the shock, analogously to previous work on Lévy walks. *Supported by DFG (SFB1491)

EP 5.3 Wed 14:45 ELP 1: HS 1.22

MHD simulations of turbulent galactic outflows — •Jens Kleimann and Horst Fichtner — Theoretische Physik IV, Ruhr-Universität Bochum, Germany

Simulations of the wind-filled halos of starburst galaxies are performed in the framework of magnetohydrodynamics (MHD), suitably extended to track additional turbulence-related quantities. These quantities comprise the turbulent energy density, the cross-helicity, and the turbulent lengthscale. After a brief discussion of these extended equations and the employed numerical approach, I will present first simulation results, both for non-magnetized benchmark runs as well as for tests using the full system of equations. The dominant and unexpected feature of the former is a macroscopic flow instability near the rotational axis that prevents the outflow from reaching a steady state. Methods to determine the cause and nature of this instability are presented. The talk concludes with an analysis of the resulting turbulent properties, comparing them to the solutions found from similar work targeting the outer heliosphere.

EP 5.4 Wed 15:00 ELP 1: HS 1.22

ComPol - A Compton polarimeter in a Nanosat — •Matthias Meier[1,2], Ion Cojocari[3], Carlo Fiorini[4], Peter Hindenberger[1,2], Philippe Laurent[3], Martin Losekamm[1,2], Susanne Mertens[1,2], Jonas Schlegel[1,2], Lorenzo Toscano[4], and Michael Willers[1,2] — [1]Excellence Cluster ORIGINS, Garching, Germany — [2]Technical University of Munich, Munich, Germany — [3]Alternative Energies and Atomic Energy Commission, Paris, France — [4]Polytechnic University of Milan, Milan, Italy

It is hardly possible to resolve the geometry of astrophysical compact objects due to their small size. One way to indirectly learn about their structure are polarization measurements. Especially in the hard X-ray range polarization data is still partially missing. Therefore, the aim of the CubeSat mission ComPol is to fill this gap and to improve the physical model of the black hole binary system Cygnus X-1.

The detector system is composed of a Silicon drift detector (SDD) used as a scatterer and a CeBr3 calorimeter to capture the full Compton kinematics. From the measured interaction points and energies it is possible to perform an event-wise reconstruction and infer the polarization of the initial radiation.

The talk will give an overview of the scientific motivation, the underlying physics and the detector setup.

This research is supported by the Excellence Cluster ORIGINS which is funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) under Germany's Excellence Strategy - EXC-2094-390783311

EP 5.5 Wed 15:15 ELP 1: HS 1.22

Angular dependence of the muon neutrino flux — •Leonora Kardum, Karolin Hymon, Mirco Hünnefeld, Pascal Gutjahr, and Jean-Marco Alameddine — Technische Universität Dortmund

The IceCube Neutrino Observatory, a cubic kilometer detector nestled in the ice at the geographic South Pole, exhibits the capability to detect particles across a broad energy range, spanning from several GeV up to PeV. This enables precise measurements of the diffuse neutrino spectrum made from three components: astrophysical (originating from extraterrestrial sources), conventional (resulting from pion and kaon decays in atmospheric Cosmic Ray cascades), and the as-yet-undetected prompt component from the decay of charmed hadrons.

This work reveals the angular dependence and the all-component flux. The unfolding method, a composite model-independent technique, is employed to derive values from related quantities, eliminating the impact of assumptions made in the process. Specifically, we unfold the muon neutrino energy spectrum, incorporating a novel technique for rebinning the observable space to ensure adequate event numbers in the low statistic region at the highest energies.

Our presentation includes the unfolded energy and zenith angle spectrum reconstructed from IceCube data compared to model expectations and previous measurements, providing valuable insights into the accuracy of predicted angular dependencies in the atmospheric neutrino flux.

EP 5.6 Wed 15:30 ELP 1: HS 1.22

Trajectory-Dependent Photo Emission and Detection of Scintillation Light in a Bismut Germanium Oxide Scintillator Crystal — •Tom Ruge, Stephan Böttcher, and Ava Pohley — Christian-Albrechts-Universität zu Kiel IEAP - Extraterrestrische Physik

The Earth is continuously exposed to high-energy charged particles, so-called Galactic Cosmic Rays (GCRs). When these particles hit the Earth's atmosphere, they create a cascade of secondary particles. CHAOS (CHerenkov Atmospheric Observation System) is a particle telescope that is developed at the Department of Extraterrestrial Physics at Kiel University by a team of students to measure the different particle species of the primary GCRs. It consists of multiple solid-state detectors, a Cherenkov aerogel scintillator and a BGO scintillation calorimeter. The hexagonal BGO crystal with a side length of 52 mm and a thickness of 20 mm is one of the largest BGO crystals ever used for particle detection, which is why geometric effects within the BGO are more interesting than ever. When a charged particle interacts with the crystal, isotropic light is emitted that is measured by attached photodiodes. As part of my bachelor thesis, I am investigating in an experiment how much light is measured by the individual photodiodes, depending on where the particle has flown through the crystal. CHAOS is supposed to fly on a stratospheric balloon as part of the BEXUS (Balloon Experiments for University Students) program in fall 2024. This is why it is essential to investigate the properties of the used BGO. I will present my experiment and the findings.

EP 6: Postersession

Time: Wednesday 16:30–18:30 Location: ELP 6: Foyer

EP 6.1 Wed 16:30 ELP 6: Foyer

The Exo-Restart project — •Elena Vchkova Bebekovska[1], Vladimir Bozhilov[2], Desislava Antonova[2], Denitza Stoeva[2], Evelina Zaharieva[2], and Trifon Trifonov[2,3] — [1]Ss. Cyril and Methodius University in Skopje, Faculty of Natural Sciences and Mathematics-Skopje, Institute of Physics, Arhimedova 3, 1000 Skopje, North Macedonia — [2]Department of Astronomy, Sofia University "St Kliment Ohridski", 5 James Bourchier Blvd, BG-1164 Sofia, Bulgaria — [3]Max-Planck-Institut für Astronomie, Königstuhl 17, 69117 Heidelberg, Germany

We present the aims of the "EXOplanetary dynamics and stability: Reverse Engineering of STable multi-planetary ARchitecTures" (EXO-RESTART) project, grant KP-06-DV/5. The existing exoplanet-detection techniques often neglect planetary dynamics, leading to a notable bias in their characterization. For deeper insights into planet formation, it is essential to focus on the dynamical properties of these systems, particularly the osculating orbital parameters, as opposed to relying solely on the Keplerian best-fit parameters reported in the literature. Our primary goal is to conduct the first homogeneous dynamical modeling effort of high-precision Doppler and transit photometry data for multiple-planet systems and complement them with an extensive long-term stability analysis, unveiling the current dynamic architecture of exoplanet systems. The comprehensive analysis of statistical, dynamical, and physical properties within EXO-RESTART is anticipated to reveal the primordial planet-disk conditions essential for constructing the observed planetary architectures.

EP 6.2 Wed 16:30 ELP 6: Foyer

Magnetosphärische Induktion beim Planeten Merkur — •Daniel Heyner und Kristin Pump — TU Braunschweig

Merkur besitzt ein schwaches Dipolfeld und ist einem intensiven Sonnenwind ausgesetzt. Dies führt zur Ausbildung einer kleinen Magnetosphäre. Es gibt periodische Änderungen im Sonnenwind wie der 88 Tage-Rotation auf dem elliptischen Orbit um die Sonne, die zu Änderungen in der Magnetosphäre führen. Eine weitere Periodizität stammt von der Eigenrotation des Planeten. Diese Änderungen des externen Magnetfeldes induzieren Ströme im Planeteninneren und rufen damit ein induziertes, internes Magnetfeld (sekundär) hervor. Durch ein empirisches Modell der Magnetosphäre und einem 1D-Modell der elektrischen Leitfähigkeit lässt sich diese Situation modellieren und die zu erwartenden sekundären Magnetfelder darstellen.

EP 6.3 Wed 16:30 ELP 6: Foyer

Solar Flare-Induced Changes in the Ionospheric D-Region Plasmas: A Machine Learning Perspective — •Filip Arnaut, Aleksandra Kolarski, and Vladimir Srećković — Institute of physics Belgrade, University of Belgrade, Pregrevica 118, 11080, Belgrade, Republic of Serbia

We explored the feasibility of utilizing a multi-output machine learning algorithm to estimate ionospheric plasma parameters (sharpness and reflection height). The ionospheric plasma parameters are crucial for determining the properties of ionospheric plasma, such as electron density, rate coefficients, and cross sections for ionization/recombination processes. We examined the feasibility of employing two single-output algorithms, such as a combination of Random Forest (RF) and XGB, for the target variables. The findings revealed that during the in-sample testing phase, the multi-output model (XGB-XGB) consistently yielded the most favorable outcomes in terms of the RMSE. However, a close alternative was observed in the combination of RF and XGB models, where RF was employed for the sharpness parameter and the XGB algorithm was utilized for the reflection height parameter. During the out-of-sample validation, there was minimal variation observed among the four algorithm combinations. The most significant difference was observed between the RF-XGB and RF-RF combinations (7.6% decrease in RMSE). The utilization of different algorithms and combinations of algorithms may yield marginal improvements, suggesting that the most significant improvement can be achieved through the expansion of the database.

EP 6.4 Wed 16:30 ELP 6: Foyer

European Space Weather Activities on ISWI — •Daniela Banyś[1] and national ISWI coordinators[2] — [1]German Aerospace Center (DLR), Neustrelitz, Germany — [2]various institutions

The International Space Weather Initiative (ISWI) is an international space weather program inspired by the activities of the International Heliophysical Year 2007. Each country is invited to assign a national coordinator to strengthen international coordination and cooperation on space weather activities. Special emphasis is placed on the deployment of instruments and the exchange of data. It serves as a platform for developing operational analysis, modelling and forecasting methods, which are sought by communication and navigation industries and government agencies. Through annual workshops and schools, ISWI establishes scientific insight into space weather related topics and communicates these results to the public. This poster presents highlights on European space weather activities.

EP 6.5 Wed 16:30 ELP 6: Foyer

Mechanical Design of the CHerenkov Atmospheric Observation System (CHAOS) — •Jasper Mess, Hannes Ebeling, Ava Pohley, Pierre Bornfleth, Hannah Sophie Grimm, Janna Martens, Justus Mickausch, Clara Pittschellis, Nicolas Rohrbeck, and Tom Ruge — Christian-Albrechts-Universität, Kiel, Germany

The Earth is continuously exposed to high-energy charged particles, so-called Galactic Cosmic Rays (GCRs). When these particles hit the Earth's atmosphere, they create a cascade of secondary particles. CHAOS (CHerenkov Atmospheric Observation System) is a particle telescope that is developed at the Department of Extraterrestrial Physics at Kiel University by a team of students (CHAOS collaboration) to measure the different particle species of the primary GCRs. It consists of multiple solid-state detectors, a Cherenkov aerogel scintillator and a BGO scintillation calorimeter. It has been accepted to the BEXUS program (Balloon EXperiment for Univerity Students), so it will fly on a stratospheric balloon above the Regener-Pfotzer maximum in fall 2024. Through the nature of this experiment there are a few mechanical challenges that need to be met, like the g-forces after the cutoff from the balloon as well as the impact upon landing. A pressure housing is needed to avoid possible corona discharges due to the use of high voltages. On this poster we want to present how CHAOS faces the challenges through its design. More information on `www.bexus.org`.

EP 6.6 Wed 16:30 ELP 6: Foyer

Measurements of cosmic rays by a mini neutron monitor aboard the German research vessel Polarstern — •B. Heber[1], S. Burmeister[1], H. Giese[1], K. Herbst[1], L. Romaneehsen[1], C. Gnebner[2], R.D. Strauss[3], and M. Walter[2] — [1]Christian Albrechts Universität, Kiel, Germany — [2]Deutsches Elektronen-Synchrotron DESY in Zeuthen, Germany — [3]Center for Space Research, North-West University, Potchefstroom 2520, South Africa

Neutron monitors are ground-based devices that measure the secondary particle population, i.e., neutrons produced by, e.g., galactic cosmic rays (GCRs). Due to their functionality, they are integral counters whose flux is proportional to the variation of the input spectrum. However, the measured flux also depends on the geomagnetic position and the static pressure at the monitor's location. To better understand the instrument response, the Christian-Albrechts-Universität zu Kiel, DESY Zeuthen, and the North-West University in Potchefstroom, South Africa, agreed on regular monitoring of the GCR intensity as a function of latitude, by installing a portable device aboard the German research vessel Polarstern in 2012. The vessel is ideally suited for this research campaign because it covers extensive geomagnetic latitudes at least once per year. In this contribution we give an update of our measurements over a full 11 year solar cycle.

The Kiel team received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 870405. The team would like to thank the crew of the Polarstern and the AWI for supporting our research campaign.

EP 6.7 Wed 16:30 ELP 6: Foyer

Detection of protons and helium >50 MeV/nuc on Chandra/EPHIN — •Janna Martens — Christian-Albrechts-Universität zu Kiel

This study presents an in-depth examination of cosmic rays, focusing on protons and helium nuclei, utilizing data from the Electron Proton Helium INstrument (EPHIN) aboard the Chandra X-ray Observatory. The research delves into the energy spectra of these particles, paying particular attention to the influence of solar modulation on their behavior.

The analysis process includes various techniques employed to enhance data resolution. The study also addresses the challenges encountered, such as interference from satellite transits through Earth's radiation belts and issues related to instrument malfunctions, which significantly impact the volume of data suitable for analysis.

In exploring the energy spectra of cosmic rays, the study critically evaluates the force field approach, a prevalent method in cosmic ray propagation research, discussing its limitations. Additionally, the cosmic ray spectrum for the year 2005 is computed, and the integral channel of Chandra/EPHIN is analyzed. This serves as a bridge between its channels for stopping particles and the data collected by the Payload for Antimatter Matter Exploration and Light nuclei Astrophysics detector (PAMELA).

The findings of this research offer valuable insights into the nature of cosmic rays and the functionality of EPHIN, laying a solid foundation for future investigations in this domain.

EP 6.8 Wed 16:30 ELP 6: Foyer

Time-Domain Spectroscopy for Space Exploration — •Yookyung Ha[1,2], Jonas Woeste[2,1], Dominic Azih[2,1], Oliver Gueckstock[3], Georgios Kourkafas[4], Jovana Petrovic[6], Mihailo Rabasovic[5], Aleksandar Krmpot[5], Tom S. Seifert[3,7], Andrea Denker[4], Tobias Kampfrath[3,7], Nikola Stojanovic[1], and Michael Gensch[1,2] — [1]DLR Institute of Optical Sensor Systems, Berlin, Germany — [2]Technical University of Berlin, Berlin, Germany — [3]Free University of Berlin, Berlin, Germany — [4]Helmholtz-Zentrum Berlin, Berlin, Germany — [5]Institute of Physics Belgrade, University of Belgrade, Belgrade, Serbia — [6]Vinca Institute of Nuclear Sciences, National Institute of the Republic of Serbia, University of Belgrade, Belgrade, Serbia — [7]TeraSpinTec GmbH, Berlin Germany

Recently, space-qualified femtosecond laser systems have become available [1,2]. Time-domain spectroscopy techniques, which revolutionised spectroscopy in laboratory environments, are now hence becoming true alternatives as modern spectroscopic sensors for space exploration. Bulky opto-mechanical components can thereby be replaced with compact electro-optic photonic components. Here, we show our progress enroute to time-domain spectroscopy instrumentation that is able to detect Raman- or infrared-active resonances in matter with a bandwidth of 30THz (1000 cm-1) and a resolution of 100GHz (3.3 cm-1). [1]. J. Lee, K. Lee, Y. Jang, et al. Scientific Reports, vol. 4, pp. 5134, (2014). [2]. M. Lezius, T. Wilken, C. Deutsch, et al., Optica 3, 1381 (2016).

EP 6.9 Wed 16:30 ELP 6: Foyer

The Liquid Metallic Hydrogen Model of the Sun — •Alexander Unzicker — Pestalozzi-Gymnasium München

Instead of being interpreted within the paradigm of the standard solar model based on a gaseous plasma, a considerable amount of experimental evidence may also be explained by assuming a real, liquid surface of the sun, as proposed by Robitaille (Progress in physics vol.3, 2011). The differences and respective problems of both models are discussed.

EP 7: Sun and Heliosphere II

Time: Thursday 14:00–17:45 Location: ELP 6: HS 2

EP 7.1 Thu 14:00 ELP 6: HS 2

New results on solar energetic electron events obtained from combined in-situ and remote-sensing observations from Solar Orbiter — •Alexander Warmuth and Frederic Schuller — Leibniz-Institut für Astrophysik Potsdam (AIP)

We present the first statistical results on energetic electron events obtained by joint observations of remote-sensing and in-situ instruments on Solar Orbiter. We use the Energetic Particle Detector (EPD) to measure the properties of the electrons (time profile, anisotropy, inferred injection time at the source, etc.), as well as to determine the composition of the associated energetic ions. X-ray observations from the Spectrometer/Telescope for Imaging X-rays (STIX) constrain the energetic electrons in the solar flare in terms of timing, spectrum, and location. Type III radio bursts detected by the Radio and Plasma Waves (RPW) instrument are used to link the nonthermal X-ray peaks to the interplanetary electron beams. Finally, the Extreme Ultraviolet Imager (EUI) provides context on the flare evolution. We have compiled a large sample of 330 events obtained during the first 2.5 years of the Solar Orbiter mission, which covers a wide range of radial distances ranging from as close as 0.3 au to 1 au. For the first time, this allows us to study the relationship between energetic electron events and associated flares as a function of heliocentric distance. This is crucial to constrain particle propagation effects.

EP 7.2 Thu 14:15 ELP 6: HS 2

Separating fundamental and harmonic emission in LOFAR solar type III radio burst images — •Christian Vocks[1], Mario Bisi[2], Bartosz Dabrowski[3], Diana Morosan[4], Peter Gallagher[5], Andrzej Krankowski[3], Jasmina Magdalenic[6], Gottfried Mann[1], Christophe Marque[6], Barbara Matyjasiak[7], Hanna Rothkaehl[7], and Pietro Zucca[8] — [1]Leibniz-Institute for Astrophysics Potsdam (AIP), Germany — [2]RAL Space, United Kingdom — [3]University of Warmia and Mazury, Olsztyn, Poland — [4]University of Helsinki, Finland — [5]DIAS, Dublin, Ireland — [6]Royal Observatory of Belgium, Brussels, Belgium — [7]Polish

Academy of Sciences, Warsaw, Poland — [8]ASTRON, Dwingeloo, Netherlands

LOFAR spectroscopic imaging observations of solar type III radio bursts during an M class flare show distinct compact sources with variations in their positions and intermittent dual structures. These are interpreted as fundamental and harmonic emission, with the one or other being dominant at times. Sources of fundamental emission at one observed frequency, and harmonic emission from a coronal region with plasma frequency of half the observed frequency, can be clearly separated. Thus, it is possible to yield separate lightcurves, and to compare the flux evolution of fundamental - harmonic pairs, e.g. 35 MHz and 70 MHz. Both fundamental and harmonic emission should originate simultaneously from the same coronal source region. Variations in burst onset times and apparent source position then provide information on transport effects, like scattering and refraction, of radio waves in the solar corona.

EP 7.3 Thu 14:30 ELP 6: HS 2

The alignment of STEREO-A and Earth: A unique opportunity to improve solar energetic proton forecasting capabilities — •B. Heber[1], D. Banys[2], J. Berdermann[2], H. Dröge[1], M. Hörlöck[1], A. Kollhoff[1], P. Kühl[1], O. Malandraki[3], J. Martens[1,2], A. Posner[4], and H. Sierks[5] — [1]Christian Albrechts Universität, Kiel, Germany — [2]German Aerospace Center, Institute for Solar-Terrestrial Science — [3]National Observatory of Athens, Greek — [4]NASA, USA — [5]Max-Planck Institute for Solar System Research, Germany

A major impact on human and robotic space exploration activities is the sudden and prompt occurrence of solar energetic ion events. The fact that near relativistic electrons (1 MeV electrons have 95% of the speed of light) travel faster than ions (30 MeV protons have 25% of the speed of light) and are always present in Solar Energetic Particle (SEP) events can be used to forecast the arrival of protons from SEP events with real-time measurements of near relativistic electrons. The Relativistic Electron Alert System for Exploration (REleASE) forecasting scheme uses this effect to predict the proton flux. In 2023 and 2024, STEREO is approaching the Earth from a behind position, soon passing Earth inside its orbit and thereafter moving ahead of Earth. STEREO thus offers several unique opportunities during this passage to test the accuracy and extent of the REleASE system as is, and to enhance REleASE beyond its current capabilities.

EP 7.4 Thu 14:45 ELP 6: HS 2

Solar Energetic Proton forecasting with REleASE during STEREO-A's flyby of Earth — •Henrik Dröge[1], Bernd Heber[1], Alexander Kollhoff[1], Patrick Kühl[1], Olga Malandraki[3], and Arik Posner[2] — [1]Institut für Experimentelle und Angewandte Physik, Christian-Albrechts-Universität zu Kiel, Germany — [2]NASA/HQ, Washington, DC 20546, USA — [3]National Observatory of Athens, Athens, Greece

Solar Energetic Particle (SEP) events can pose a significant radiation hazard for human and robotic space exploration acivities. Therefore SEP forecasting systems are needed to support operations. The REleASE system (A. Posner, 2007) utilizes the fact that near relativistic electrons (1 MeV electrons have 94% of the speed of light) travel faster than ions (30 MeV protons have 25% of the speed of light) and are always present in hazardous SEP events. Their early arrival can be used to forecast the expected proton flux. Originally REleASE uses realtime data from SOHO/EPHIN near Earth. Since the instrument is aging we recently adapted the method to STEREO-A/HET and used the period from June to November, 2023 when STEREO-A passed the Earth to compare the REleASE forecasts from the different instruments.

EP 7.5 Thu 15:00 ELP 6: HS 2

Measurements of ultra-relativistic electrons during solar energetic particle events - Results from the Ulysses Kiel Electron Telescope — •Carlotta Jöhnk, Bernd Heber, and Marlon Köberle — Christian-Albrechts-Universität zu Kiel, Germany

Solar energetic particle (SEP) events are increases of ions and electrons caused by solar activity namely flares and coronal mass ejections. While the most energetic ion population is well studied, SEP events accelerating electrons above 20 MeV have only been reported from measurements by ISEE III in the 1980s and the Kiel Electron Telescope (KET).

The KET aboard Ulysses launched in 1990 and measured the electron flux in the energy range from 4 MeV to above 6 GeV. Here we report on observations of ultra-relativistic electrons and show spectra of electron events during solar cycle 22 and 23 until the end of 2008. The maximum electron energy exceeded 100 MeV during the August 16, 2001 SEP event.

EP 7.6 Thu 15:15 ELP 6: HS 2

Charge sign dependence of recurrent Forbush Decreases in 2016 — •Lisa Romaneehsen, Johannes Marquardt, and Bernd Heber — Christian-Albrechts-Universität zu Kiel, Germany

This study investigates the periodicities of cosmic rays attributed to corotating interaction regions (CIRs) using AMS-02 data from late 2016 to early 2017. These data enable the first-time examination of recurrent Forbush decrease amplitudes induced by CIRs, considering rigidity and charge sign dependence. The findings from the Lomb-Scargle algorithm and Superposed Epoch Analysis were compared. Results reveal that the rigidity dependence of proton decreases attributed to the northern coronal hole aligns with existing literature, while that of the southern coronal hole does not. The amplitude of the Helium modulation exceeds that of protons, in line with previous observations. For positrons statistical limitation prevent definitive conclusions. In comparison to the positively charged ions the modulation behavior of electrons can not be understood in the current paradigma of modulation by diffusion barriers.

EP 7.7 Thu 15:30 ELP 6: HS 2

Quasi-Discontinuous Solar Wind Models — •Lukas Westrich[1,2], Horst Fichtner[1], and Bidzina Shergelashvili[1,2] — [1]Ruhr-Universität Bochum, Institute for theoretical physics IV — [2]Ilia State University, Faculty of Natural Sciences and Medicine, Tbilisi, Georgia

In this talk the heating of the solar wind above the Heliobase will be examined. Based on the discontinuous solar wind solutions from Shergelashvili et al. (2020) we developed new quasi-discontinuous solar wind models. First we will present the basic concept of discontinuous solar wind solutions and the quasi-discontinuous solar wind models, which is basically the assumption of a localized heating source above the Heliobase in a case of 1D quasi- adiabatic radial expansion of the solar wind. Furthermore, we will discuss the differences and the similarities of these. These models contain high gradients in the physical properties. Therefore, after an discussions of the characteristics of these solutions we will examine, how heat conduction could weaken those. It will be shown, that heat conduction is not strong enough to flatten the basic flow structure. As a result, the idea behind these models, that a damping of plasma waves near the trans-sonic point could produce such solar wind structures, is still reasonable.

EP 7.8 Thu 15:45 ELP 6: HS 2

Impact of diffusion models on the spectra obtained by diffusive shock acceleration — •Dominik Walter, Horst Fichtner, Yuri Litvinenko, and Frederic Effenberger — Ruhr-Universität-Bochum

The process of shock acceleration has long been a topic in astrophysics. A very prominent point of discussion is the shock spectrum, which has prooved quite universal over the last decades. In recent years, however, there have been modifications made to the diffusive behaviour of the acceleration process, some of which seem to alter said shock spectrum. Mentioned modifications are based on e.g. fractional or nonlinear diffusion approaches. This presentation will give a few examples and discuss, when a change of the spectral behaviour is to be expected and why.

30 min break

EP 7.9 Thu 16:30 ELP 6: HS 2

Energetic particle transport modelling with PARADISE — •Edin Husidic[1,2], Nicolas Wijsen[1], Stefaan Poedts[1,3], and Rami Vainio[2] — [1]Centre for mathematical Plasma Astrophysics, KU Leuven, Leuven, Belgium — [2]Department of Physics and Astronomy, University of Turku, Turku, Finland — [3]Institute of Physics, University of Maria Curie-Skłodowska, Lublin, Poland

Solar energetic particles (SEPs) constitute high-energy charged particles originating from solar eruptive phenomena. In particular, protons with energies ranging from tens of MeV to a few GeV per nucleon, pose a significant threat to satellites and astronauts. The intensities of SEPs are substantially influenced by the large-scale solar wind configuration, incorporating structures like coronal mass ejections (CMEs) or stream interaction regions (SIRs), which perturb the interplanetary (IP) magnetic field and ultimately affect the transport of SEPs. Despite decades of research, the precise acceleration mechanisms remain not fully known. Numerical models capable of simulating SEP events have proven to be valuable tools in the study of the transport and acceleration of SEPs. Here, we share recent findings derived with the energetic particle transport code PARADISE. The code utilises realistic background solar wind configurations as input, derived from magnetohydrodynamic (MHD) models such as EUHFORIA or the Icarus test case of the MPI-AMRVAC framework. By employing a stochastic approach to solve the focused transport equation, PARADISE obtains SEP intensities in the inner heliosphere. The presented studies focus on particle acceleration at IP shocks associated with CMEs and SIRs.

EP 7.10 Thu 16:45 ELP 6: HS 2

Solar energetic particle transport, gamma ray flares and intermittent turbulence — •Frederic Effenberger, Jeremiah Lübke, Julien Dörner, Horst Fichtner, and Rainer Grauer — Theoretische Physik, Ruhr-Universität Bochum, Germany

The detailed understanding and ultimately the ability to forecast solar energetic particle (SEP) events is critical in our efforts to mitigate space weather risks. I will discuss current issues in SEP modelling and observations with a particular focus on non-thermal particle sources in solar flares and CME shocks, and cross-field transport effects due to solar wind structures and field line random walk. Of particular interest are coherent features in the solar wind turbulence that can influence particle transport behaviour. Synthetic fields to study particle transport are typically generated from superpositions of Fourier modes with a prescribed power spectrum and uncorrelated random phases, bringing the advantage of covering a wide range of turbulence scales at manageable computational effort. However, almost all of these models to date only account for second-order Gaussian statistics and thus fail to include intermittent features. We have developed a novel method to account for this shortcoming based on a minimal Lagrangian map approach. We investigate the particle transport properties by solving a large number of particle orbits in these synthetic turbulence realisations and specifically look for non-diffusive regimes and non-standard energy dependences resulting from the intermittency of the generated fields. Applications to SEP transport and the production of gamma rays from solar events will be discussed.

EP 7.11 Thu 17:00 ELP 6: HS 2

Structured Synthetic Turbulence and Solar Energetic Particle Transport — •Jeremiah Lübke[1], Frederic Effenberger[2], Mike Wilbert[1], Horst Fichtner[2], and Rainer Grauer[1] — [1]Institute for Theoretical Physics I, Ruhr-University Bochum, Universitätsstr. 150, 44801 Bochum — [2]Institute for Theoretical Physics IV, Ruhr-University Bochum, Universitätsstr. 150, 44801 Bochum

Turbulence is ubiquitous in the solar wind, however its impact on the transport of solar energetic particles is poorly understood, since global simulations of the heliosphere are not able to resolve the turbulent length scales properly. This issue can be mitigated by employing synthetic turbulence, which is usually modelled as scale-invariant "smart noise" via sums of waves with a prescribed power spectrum and random uncorrelated phases. We present a novel model for synthetic turbulence, which is more faithful to the complex intermittent character of realistic turbulence, which is dominated by low-curvature coherent structures and high-curvature intense scattering sites. The model is a combination of a log-normal cascade and the multiscale minimal Lagrangian mapping approach. We investigate the resulting vector fields with regard to structure function scaling, fieldline geometry and energetic particle transport properties. Magnetohydrodynamic simulations of turbulence are consulted for comparison. We find that energetic particle diffusion is significantly enhanced by a combination of extended coherent structures and intense high-curvature scattering sites. Finally, applications to specific phenomena in the heliosphere, such as CME sheath turbulence, are discussed.

EP 7.12 Thu 17:15 ELP 6: HS 2

Linear theory of oblique plasma instabilities for reguarlized Kappa-distributions — •Dustin Lee Schröder[1], Horst Fichtner[1], and Marian Lazar[1,2] — [1]Ruhr-Universität Bochum, Bochum, Deutschland — [2]KU Leuven, Löwen, Belgien

A linear plasma solver is employed to investigate proton firehose and electron firehose instabilities for oblique propagation directions in the context of regularized Kappa-distributions.

EP 7.13 Thu 17:30 ELP 6: HS 2

Flux rope formation prior to CME onset by confined precursor flares—a statistical study — •Bernhard Kliem — University of Potsdam, Institute of Physics and Astronomy

I present a statistical study of flare ribbons in confined eruptions which precede a major ejective eruption (coronal mass ejection, CME), using the complete sample of CMEs associated with $>$ M5.0 flares in 2011–2015 and source distance from Sun center of $<$ 50 deg (32 events, from Baumgartner et al. 2018). Ribbons of precursor events within 12 hr from the onset of the CME-associated (eruptive) flare are compared with the ribbons of the main event to assess a potential contribution of the precursor events to the buildup of a flux rope prior to CME onset. It is found that 26 CMEs (81%) have one or several precursors with bright ribbons that cover a part of the ribbons in the main event, hence, clearly contribute to the buildup of the flux rope that later erupts and drives the CME. Two further events (6%) develop such ribbons during an enhancement that is part of the event's slow-rise phase, i.e., also prior to CME onset. Two CMEs only possess precursors with weak, very short, or very transient ribbons, indicating at least a minor contribution to the buildup of the flux rope erupting in the CME, and the final two events do not show any such indication. Of the last four events, however, three are characterized by a large ribbon separation from their onset, suggesting a high-lying flux rope that may have formed at earlier times. Overall, a significant role of flare reconnection for the buildup of a flux rope prior to CME onset is indicated for the great majority (88%) of the considered CME sample.