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.