P 4: Astrophysical Plasmas/Laser Plasmas

Time: Monday 14:00–16:00 Location: WW 1: HS

Invited Talk P 4.1 Mon 14:00 WW 1: HS

Ab initio calculations of conductivities under planetary interior conditions — •Martin Preising[1], Martin French[1], Maximilian Schörner[1], Mandy Bethkenhagen[2], Argha Roy[1], Uwe Kleinschmidt[1], and Ronald Redmer[1] — [1]Universität Rostock, Rostock, Germany — [2]École Polytechnique, Palaiseau, France

We summarize our recent efforts to calculate thermal and electrical conductivities under planetary interior conditions with ab initio simulations.

We applied our method to state-of-the-art models [Mankovich and Fortney, Astrophys. J., 889, 51 (2020)] for the gas giant planets Jupiter [French et al., Astrophys. J. Suppl. Ser., 202, 5 (2012)] and Saturn [Preising et al., Astrophys. J. Suppl. Ser., 269, 47 (2023)]. We found a profound impact of the proposed helium-rich layer above Saturn's core on thermal and DC conductivity profiles. The results will affect future magnetohydrodynamic simulations for Saturn's magnetic field.

The ice giant planets Uranus and Neptune are not too well constrained by observational data. We consider different mixtures of hydrogen and methane. Our results show a steady increase in DC conductivity along Uranus' P-T path [Roy et al., submitted (2024)].

A recent study of fcc and hcp iron over a P-T range covering Earth's core-mantle boundary and inner core boundary resulted in fit formulas for the DC and thermal conductivity [Kleinschmidt et al., Phys. Rev. B, 107, 085145 (2023)], applicable to all rocky planets with an iron core.

P 4.2 Mon 14:30 WW 1: HS

Kinetic simulations of strong non-relativistic shocks propagating in a turbulent medium — •Karol Fulat[1], Artem Bohdan[2,3], Michelle Tsirou[4], and Martin Pohl[1,4] — [1]Institute of Physics and Astronomy, University of Potsdam, D-14476 Potsdam, Germany — [2]Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, D-85748 Garching, Germany — [3]Excellence Cluster ORIGINS, Boltzmannstr. 2, D-85748 Garching, Germany — [4]Deutsches Elektronen-Synchrotron DESY, Platanenallee 6, D-15738 Zeuthen, Germany

Strong non-relativistic shocks are known to accelerate particles up to relativistic energies. However, for Diffusive Shock Acceleration electrons must have a highly suprathermal energy, implying a need for very efficient pre-acceleration. Most published studies consider shocks propagating through homogeneous plasma, which is an unrealistic assumption for astrophysical environments. To address this limitation, we have developed a novel simulation technique that provides a framework for studying shocks propagating in turbulent media from first principles. We have performed PIC simulations of non-relativistic high-Mach-number shocks propagating in an electron-ion plasma with a turbulent upstream medium. We have explored the impact of the fluctuations on electron heating and acceleration, the dynamics of upstream electrons, and the driving of plasma instabilities. We will also discuss our recent results from oblique shock simulations.

P 4.3 Mon 14:45 WW 1: HS

First operation of APEX-LD, a levitated dipole trap designed for e+e- plasmas — •Alexander Card — Max-Planck-Institut für Plasmaphysik — Technische Universität München

The mission of the APEX-LD (A Positron-Electron eXperiment - Levitated Dipole) trap is to provide a compact (˜10-liter) volume of closed dipole magnetic field lines, to be used for the confinement and study of low-temperature, long-lived e+e- pair plasmas. The requirements for this application posed a number of challenges for experiment design and engineering. (These included, e.g., the need to repeatedly make and break thermal contact with cryogenically cooled components in a vacuum environment; excitation of current in the superconducting "floating coil", followed by long-duration, feedback-stabilized levitation; and a demand for robustness to repeated quenches and possible mechanical shocks). A comparable number of experiment design and engineering solutions have been found and implemented, and APEX-LD has successfully started operation, enabling the first electron experiments to commence in late 2023. This talk will outline the design of the APEX-LD systems, then present the highlights of the experiment commissioning (e.g., efficient current induction to ˜0.5 T on axis, levitation times in excess of three hours, and slow/"gentle" quenching of the non-insulated HTS [high-temperature superconducting] coil). Finally, it will describe results from first experiments (i.e., magnetic field line visualizations and e- injection) and next steps for making e- plasmas and later injecting cold, dense pulses of e+.

P 4.4 Mon 15:00 WW 1: HS

Improved Conductivity model for fully ionized hydrogen plasma — •Uwe Kleinschmidt and Ronald Redmer — Universität Rostock, Institut für Physik, Albert-Einstein-Strasse 23-24, D-18059 Rostock, Germany

Electrical and thermal conductivities for matter under extreme conditions are an important input in magnetohydrodynamic simulations to model, e.g., the dynamo action in the deep interior of planets like Jupiter or the Ohmic dissipation rate in the atmosphere of hot Jupiters (see [1]). Such gas giant planets consist mainly of hydrogen and helium so that the calculation of corresponding conductivity data for a wide range of pressures and temperatures is an important task. In addition, the construction of conductivity models, e.g., by solving the Boltzmann equation in relaxation time approximation, as proposed by Lee and More [2] help to keep the computational costs low in such simulations. The Lee-More conductivity model provides reasonable results for weakly coupled high temperature plasmas but deviates strongly from ab initio methods like density functional theory molecular dynamics (DFT-MD) simulations for lower temperatures and stronger coupled plasmas (see [3]). We performed extensive DFT-MD simulations to calculate conductivities for fully ionized hydrogen plasma. We used this data to modify the conductivity model by Lee and More and to provide conductivity data for a wide range of temperature and density.

[1] S. Kumar et al., Phys. Rev. E 103, 063203 (2021)
[2] Y. T. Lee and R. M. More, Phys. Fluids 27, 1273 (1984)
[3] M. French et al., Phys. Rev. E 105, 065204 (2022)

P 4.5 Mon 15:15 WW 1: HS

Chirped plasma density gratings for compression of high-intensity laser pulses — •Götz Lehmann and Karl-Heinz Spatschek — Heinrich-Heine-Universität, Düsseldorf

Modern high-power chirped-pulse (CPA) laser systems are limited in several ways by optical damage thresholds and detrimental nonlinearities. Amplification, compression, and polarization control of intense laser beams is often ultimately limited by the ionization threshold of solid state materials. Hence, plasma-based optical elements, often referred to as damageless optics, are attractive alternatives.

We study the formation and optical properties of plasma density gratings which may act as reflective and transmissive optics for high-power pulses. The plasma gratings themselves are driven via laser pulses to ma- nipulate pulses of higher intensity. Our interest lies in chirped plasma gratings that then can be used for compression of chirped pulses similar to conventional compression gratings in modern high-power CPA systems. We demonstrate via simulations the formation of chirped gratings, discuss their compression capabilities, and outline parameter regimes for applications.

P 4.6 Mon 15:30 WW 1: HS

Nonmetal-to-metal transition in dense fluid nitrogen at high pressure — Armin Bergermann and •Ronald Redmer — Univ. Rostock, Institut für Physik, A.-Einstein-Str. 23, 18059 Rostock

The high-pressure phase diagram of solid nitrogen is extremely rich: 12 molecular phases, two nonmolecular phases, and an amorphous one have been reported so far [1]. Recent molecular dynamics (MD) simulations on dense fluid nitrogen using density functional theory (DFT) predict a first-order liquid-liquid phase transition (LL-PT) at about a megabar, see e.g. [2]. Static experiments using diamond anvil cells as well as dynamic shock-wave experiments have been applied to access the corresponding region.

We calculate the electrical conductivity and the equation of state of dense fluid nitrogen for high pressures up to several megabars by using DFT-MD simulations [3]. We determine the instability region of the first-order LL-PT which results from an abrupt dissociation of nitrogen molecules. This transition is accompanied by a nonmetal-to-metal transition (metallization) of the fluid and corresponding structural changes from a molecular to a polymeric phase. We compare our data with earlier theoretical results and available experiments.

[1] R. Turnbull et al., Nat. Commun. 9, 4717 (2018) [2] B. Boates,

S. A. Bonev, Phys. Rev. Lett. 102, 015701 (2009). [3] A. Bergermann, R. Redmer, Phys. Rev. B 108, 085101 (2023)

P 4.7 Mon 15:45 WW 1: HS

Negative Corona, free Electrons and their Role in the Creation of Ball Lightning — •Herbert Boerner — Mainz

Ball lightning (BL) is still an unexplained phenomenon of atmospheric physics. Until recently, all evidence came from reports by accidental observers, but in the last years, additional information became available, mainly from lightning location systems. In order to make progress in defining suitable experiments and in selecting a theory that is consistent with the observations, it is important to choose from the thousands of anecdotal reports those that are reliable and that also contain information on the physics involved. There are indications, that positive cloud-ground lightning (+CG) has a much higher probability to create these objects that negative CG lightning. Together with the fact that BL objects can be produced far away from lightning channels, this allows a definition of the conditions under which BL is created. The importance of negative corona in air, of Trichel pulses, and the role of free electrons is discussed and an experimental setup is proposed.