P 10: Theory and Modelling I

Zeit: Dienstag 10:30–13:15 Raum: HZO 50

Hauptvortrag P 10.1 Di 10:30 HZO 50

Theorie und Simulation dichter Plasmen — •Martin French, Andreas Becker und Ronald Redmer — Universität Rostock, Universitätsplatz 3, 18051 Rostock

Im Gegensatz zu niederdichten Plasmen, welche mit kinetischen Modellen, Massenwirkungsgesetzen und Störungstheorie gut verstanden werden können, müssen die langreichweitigen Coulombkräfte zwischen den Teilchen in dichten Plasmen systematisch berücksichtigt werden. Moderne Methoden zielen hier auf direkte, numerische Simulation der quantenmechanischen Wechselwirkungen zwischen den Teilchen. Dies geschieht entweder mit der Pfadintegral-Montecarlo-Methode oder mittels Dichtefunktionaltheorie (DFT), welche üblicherweise mit einer klassischen Molekulardynamik (MD) für die Ionen gekoppelt ist. Damit lassen sich sowohl die thermodynamischen Eigenschaften (Zustandsgleichungen, Phasendiagramme) dichter Plasmen als auch Transporteigenschaften (elektrische Leitfähigkeit, Wärmeleitfähigkeit, Viskosität) mit hoher Genauigkeit vorhersagen. Ein großer Vorteil der DFT-MD ist außerdem, dass sie nicht nur auf Plasmen beschränkt ist, sondern auch direkt den Übergang zur kondensierten Materie (Flüssigkeiten, Festkörper) beschreiben kann. Ein Hauptanwendungsgebiet für die thermophysikalischen Eigenschaften dichter Plasmen ist die Modellierung des inneren Aufbaus, der Evolution und der Magnetfelder großer Planeten wie Jupiter und Saturn. Mit Hilfe der DFT-MD können dafür bedeutsame Phänomene wie die Entmischung von Wasserstoff und Helium qualitiativ und quantitativ verstanden werden.

P 10.2 Di 11:00 HZO 50

The reduction of distant blazars' inverse Compton cascade emission by plasma instability induced beam plateauing — •Ulf Menzler — Ruhr-Universität Bochum, Theoretische Physik IV

The attenuation of TeV γ-rays from distant blazars by the extragalactic background light produces collimated relativistic electron-positron pair beams. The pair beams traversing the intergalactic medium are unstable to linear two-stream instabilities of both electrostatic and electromagnetic nature. We investigate the case of weak blazars where the back reaction of generated electrostatic turbulence leads to a parallel plateauing of the electron energy spectrum. We determine the inverse-Compton cascade flux reduction above a certain normalized energy x_l resulting from the incorporation of plasma effects on the beam particles distribution functions. Deriving the exact reduction factors for a steady state and a flaring scenario, where we also investigate the influence of time averaging observations, we can show, that in most cases the reduction is well approximated with a function $R(x_l)$ resulting in the steady state scenario. For a typical blazar scenario the cascade flux reduction factor above 10 GeV is ~ 0.1. Application of our findings to the spectrum of 1ES 0229+200 show, that the incorporation of plasma effects leads to a natural explanation of the reduced GeV flux. Claims on the lower bound of the intergalactic magnetic field strengths, made by several authors to explain the flux reduction while neglecting plasma effects, are thus put into question.

P 10.3 Di 11:15 HZO 50

The marginal instability condition of the aperiodic ordinary mode for counter-stream bi-Maxwellian distribution function — •Sergei Vafin and Reinhard Schlickeiser — Institut für Theoretische Physik, Lehrstuhl IV: Weltraum- & Astrophysik, Ruhr-Universität, Bochum, Germany

In situ observations of solar wind temperature anisotropy do not fit predictions in the low parallel plasma beta regime. At the same time the aperiodic O-mode might be additionally destabilized at low plasma betas by counter-streams, which implies an excess of free energy in the direction parallel to the ordered magnetic field. This fact has been recently discovered analytically and confirmed numerically, solving the dispersion equation of O-mode for both equal-mass and electron proton plasmas, assuming different counter-stream parameter scalings. The marginal instability condition exhibits a sensitive behaviour on a counter-stream parameter scaling and under certain assumptions can explain the observations.

P 10.4 Di 11:30 HZO 50

Plasma Effects on Extragalactic Ultra-high-energy Cosmic Ray Hadron Beams in Cosmic Voids — •Steffen Krakau and Reinhard Schlickeiser — Institut fur Theoretische Physik, Lehrstuhl IV: Weltraum- und Astrophysik, Ruhr-Universität Bochum

The linear instability of an ultrarelativistic hadron beam ($\Gamma_b \approx 10^6$) in the unmagnetized intergalactic medium is investigated with respect to the excitation of collective electrostatic and aperiodic electromagnetic fluctuations. This analysis is important for the propagation of extragalactic ultrarelativistic cosmic rays ($E > 10^{15}$eV) from their distant sources to Earth. We calculate minimum instability growth times which are orders of magnitude shorter than the cosmic ray propagation time in the IGM. Due to nonlinear effects, especially the modulation instability, the cosmic ray beam stabilize and can propagate with nearly no energy loss through the intergalactic medium.

P 10.5 Di 11:45 HZO 50

Quasilinear theory of spontaneously emitted field fluctuations and the genesis of cosmological magnetic fields — •Ulrich Kolberg and Reinhard Schlickeiser — Institut für Theoretische Physik, Lehrstuhl IV: Weltraum- und Astrophysik, Ruhr-Universität Bochum

Any fully-ionized collisionless plasma with finite random particle velocities contains electric and magnetic field fluctuations. The fluctuations can be of three different types: weakly damped, weakly propagating or aperiodic. The kinetics of these fluctuations in general unmagetized plasmas, governed by the competition of spontaneous emission, absorption and stimulated emission processes, is investigated, extending the well-known results for weakly damped fluctuations. The generalized Kirchhoff radiation law for both collective and non-collective fluctuations is derived, which in stationary plasmas provides the equilibrium energy densities of electromagnetic fluctuations by the ratio of the respective spontaneous emission coefficient and the true absorption coefficient. As an illustrative example the equilibrium energy densities of aperiodic transverse collective electric and magnetic fluctuations in an isotropic thermal electron-proton plasmas of density n_e is calculated as $|\delta B| = \sqrt{(\delta B)^2} = 2.8(n_e m_e c^2)^{1/2} g^{1/2} \beta_e^{7/4}$ and $|\delta E| = \sqrt{(\delta E)^2} = 3.2(n_e m_e c^2)^{1/2} g^{1/3} \beta_e^2$, where g and β_e denote the plasma parameter and the thermal electron velocity in units of the speed of light, respectively. For densities and temperatures of the reionized early intergalactic medium $|\delta B| = 6 \cdot 10^{-18}$G and $|\delta E| = 2 \cdot 10^{-16}$G result.

P 10.6 Di 12:00 HZO 50

Die Rolle der Elektron-Elektron-Stöße für Transporteigenschaften warmer dichter Materie — •Sebastian Rosmej, Heidi Reinholz und Gerd Röpke — Universität Rostock, Institut für Physik, 18051 Rostock, Deutschland

Die Frage nach dem Einfluss von Elektron-Elektron-Stößen auf Transporteigenschaften dichter Plasmen wird diskutiert. Insbesondere wird die Gleichstromleitfähigkeit untersucht. Bei geringen Dichten im klassischen Grenzfall ist das Spitzer-Verhalten bekannt, bei höheren Dichten im entarteten Bereich die viel verwendete Ziman-Formel. Beide Grenzfälle können ausgehend von der von uns verwendeten Linearen-Response-Theorie abgeleitet werden, sodass eine konsistente und die Grenzfälle enthaltene Näherung bei beliebiger Entartung vorliegt. Im klassischen Bereich ist der Einfluss der Elektron-Elektron-Stöße nicht vernachlässigbar, nimmt jedoch mit zunehmender Entartung als Folge des dort dominanten Pauli-Blockings ab. Es wird daher ein Korrekturfaktor vorgeschlagen, der die Berücksichtigung der Elektron-Elektron-Stöße bei der Behandlung der Leitfähigkeit für beliebige Entartung enthält. Analytische Fitformeln, die in einem weiten Dichte-Temperaturbereich gültig sind, werden angegeben.

P 10.7 Di 12:15 HZO 50

Numerical study of impeller-driven turbulence and dynamo action using a penalization method — •Sebastian Kreuzahler[1], Holger Homann[2], Yannick Ponty[2], and Rainer Grauer[1] — [1]Institut für Theoretische Physik I, Ruhr-Universität Bochum, D-44780 Bochum, Germany — [2]Université de Nice-Sophia, CNRS, Observatoire de la Côte d'Azur, BP 4229 06304 Nice Cedex 4, France

The process, in which magnetic fields are amplified exponentially by flows of electrically conducting fluids, is known as dynamo action. It is believed to be the origin of many magnetic fields in the universe. One successful laboratory experiment investigating the underlying mechanisms is the Von Kármán Sodium device, a cylindrical vessel filled with liquid sodium, stirred by two counter-rotating soft-iron impellers. Nevertheless the experiment leaves unresolved questions regarding the interaction of liquid metal and solid impellers.

It is our aim to design and to perform direct numerical simulations of spatially and temporally resolved flow and magnetic fields, inaccessible to experimental measurements. The geometry of rotating impellers similar to experimental configurations is implemented in a massively parallel pseudospectral MHD solver via a penalization technique.

The investigation of hydrodynamic properties of the system shows a good quantitative agreement with experimental results. Simulations of the full MHD system reveal effects of the magnetic permeability of the impellers on the magnetic field growth and shape.

P 10.8 Di 12:30 HZO 50

Rydberg atoms in dense plasma — •Chengliang Lin, Heidi Reinholz, and Gerd Röpke — Universität Rostock, Institut für Physik, Deutschland

The transition rates of a Rydberg atom in plasma are derived by means of a quantum master equation approach. The coupling of the Rydberg atom with the plasma causes pressure broadening and is described by the density-density correlation function. It is shown that the transition rates can be obtained describing the highly excited Rydberg electron as a coherent quasi-classical state. The coherent state is constructed from Gaussian weighted eigenstates of the Rydberg electron. The calculated transition rates are shown to be in a good agreement with classical Monte-Carlo-simulation results.

P 10.9 Di 12:45 HZO 50

Self-Consistent Three-Dimensional Plasma and Neutral Gas Modeling — •Robert Henrich and Christian Heiliger — I. Physikalisches Institut, Justus-Liebig-University of Giessen, Germany

Designing and optimizing micro-Newton radio frequency ion thrusters (μN-RITs) for applications in space are challenging and ongoing processes. For that, the plasma parameters of the inductively coupled discharge are of main importance. These values are tedious to measure without influencing the discharge due to the small size of the discharge chamber which is a few centimeters.

As a result of this we have developed our three-dimensional "particle in Cell" (PIC) code "PlasmaPIC" from scratch. We will show that the three-dimensional description is necessary due to the broken rotational symmetry of the slope of the coil as well as the grid system. A main feature of "PlasmaPIC" is the ability of an excellent massive parallelization of the computation, which scales linearly up to a few hundred cpu cores. Moreover, "PlasmaPIC" includes the support of arbitrary geometries as well as the interaction of the neutral gas and the plasma discharge. Because the neutral gas and the plasma simulation are acting on different time scales we perform the simulation of both separately in a self-consistent treatment, whereas the neutral gas distribution is calculated using the "direct simulation Monte Carlo method" (DSMC).

With our "PlasmaPIC" simulation tool we are now on the verge of predicting performance parameters for new designs of our thrusters on a microscopic level.

P 10.10 Di 13:00 HZO 50

Ab initio thermodynamic results for the degenerate electron gas at finite temperature — Tim Schoof, Simon Groth, Jan Vorberger, and •Michael Bonitz — ITAP, Christian-Albrechts-Universität Kiel Leibnizstr. 15, 24098 Kiel, Germany

The uniform electron gas (UEG) at finite temperature is of key relevance for many applications in dense plasmas, warm dense matter and laser excited solids. Recently, first principle restricted path integral Monte Carlo results became available [1] which, however, due to the Fermion sign problem (FSP), are confined to moderate degeneracy, i.e. low to moderate densities with $r_s = \bar{r}/a_B \gtrsim 1$ [$\bar{r}$ is the mean interparticle distance and a_B the Bohr radius]. Here we present novel first principle configuration PIMC [2,3] results for polarized electrons, for $r_s \lesssim 1$ that close this gap and indicate that the previous data of Ref. [1] are inaccurate [4]. We also present quantum statistical data within the e^4-approximation which agree very well with our CPIMC results at high densities.

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[1] E. Brown et al., Phys. Rev. Lett. **110**, 146405 (2013). [2] T. Schoof et al., Contrib. Plasma Phys. **51**, 687 (2011). [3] T. Schoof, S. Groth, and M. Bonitz, Contrib. Plasma Phys. (2015), DOI: 10.1002/ctpp.201400072. [4] T. Schoof et al., submitted to Phys. Rev. Lett.