SYPA 1: Plasma Astrophysics

Time: Thursday 14:00–18:00 Location: SPA Kapelle

Invited Talk SYPA 1.1 Thu 14:00 SPA Kapelle

Cosmic Particle Acceleration — •Gaetano Zimbardo and Silvia Perri — Università della Calabria, Dipartimento di Fisica, 87036 Rende, Italy

The most popular mechanism for the acceleration of cosmic rays, which is thought to operate in supernova remnant shocks as well as at heliospheric shocks, is the diffusive shock acceleration, which is a Fermi mechanism based on normal diffusion. On the other hand, in the last few years it has been shown that the transport of plasma particles in the presence of electric and magnetic turbulence can be superdiffusive rather than normal diffusive. The term 'superdiffusive' refers to the mean square displacement of particle positions growing superlinearly with time, as compared to the normal linear growth. In particular, superdiffusion is characterized by a non Gaussian statistical process called Levy random walk.

We show how diffusive shock acceleration is modified by superdiffusion, and how this yields new predictions for the cosmic ray spectral index, for the acceleration time, and for the spatial profile of energetic particles. A comparison with observations of particle acceleration at heliospheric shocks and at supernova remnant shocks is done. We discuss how superdiffusive shock acceleration allows to explain the observations of hard ion spectra at the solar wind termination shock detected by Voyager 2, of hard radio spectra due to synchrotron emission of electrons accelerated at supernova remnant shocks, and how it can help to explain the observations of 'thin rims' in the X-ray synchrotron emission.

Invited Talk SYPA 1.2 Thu 14:30 SPA Kapelle

Simulation of shock waves — •Felix Spanier — North-West University, Potchefstroom, Südafrika

Shock waves are a very common phenomenon in astrophysics. Almost every astrophysical source shows supersonic flows and clear shock fronts from the Sun, bow shocks on planets up to the scale of gamma-ray bursts and Active Galactic Nuclei.

The study of shock waves is not only by itself interesting, but also the importance of shocks for the acceleration of particles to nonthermal energies. The simulation of shock waves is strongly complicated by this matter: The already very sophisticated fluid simulations of shocks are no longer sufficient to understand the nonthermal interaction in the shocks.

I will review the importance of a kinetic description of shocks and present results from particle-in-cell simulations performed to understand the formation and properties of shock waves.

Invited Talk SYPA 1.3 Thu 15:00 SPA Kapelle

Dynamo experiments: A guide through dynamo theory — •Andreas Tilgner — Institut für Geophysik, Universität Göttingen

It is generally believed that planets, stars and even galaxies create their magnetic fields through the dynamo effect which converts the kinetic energy of the motion in an electrically neutral, but electrically conducting fluid into magnetic energy. It was an open theoretic question until the late 1950's whether dynamos can exist in planetary or stellar interiors, and laboratory experiments demonstrating the dynamo effect are available since 1999. Different experiments emphasize different aspects of dynamos occurring in nature and rely on different theoretical concepts. The Karlsruhe experiment exploits the scale separation between the size of eddies in the flow and the size of the whole conducting volume. This separation of scales leads to a simplification of the governing equations known as mean field magnetohydrodynamics which has proved to be very useful in dynamo theory.

Invited Talk SYPA 1.4 Thu 15:30 SPA Kapelle

Turbulent dynamo effects in astrophysical plasmas — •Wolfram Schmidt and Dominik Schleicher — Institut für Astrophysik, Göttingen

I will discuss how magnetic fields in astrophysical plasmas, particularly on cosmological scales, are amplified by turbulent dynamo effects. In numerical simulations of cosmological structure formation, two different amplification mechanisms are found. Primarily, the compression of the plasma due to gravity and shocks resulting from the accretion onto massive halos enhances magnetic fields. In addition, the fields are amplified by the shear of turbulent flows, which can be interpreted as turbulent dynamo. Both mechanisms yield significant contributions to the generation of strong and nearly saturated magnetic fields from very week seed fields. In numerical simulations, however, it is generally not possible to fully resolve turbulence. Moreover, the dissipation of magnetic energy by reconnection occurs on small scales below the resolution limit and is usually treated by numerical dissipation. The problem is further complicated by collisionless plasmas, such as the hot baryonic gas in galaxy clusters, in which the physical dissipation mechanism is not yet well understood. These issues can be addressed by novel subgrid scale models that incorporate magnetic field amplification by numerically unresolved turbulence as well as dissipative effects in the collisionless, kinetic regime. I will report on recent advances in this direction.

30 min. break

Invited Talk SYPA 1.5 Thu 16:30 SPA Kapelle

Physical Processes in the Turbulent Interstellar Medium — •Dieter Breitschwerdt[1], Miguel de Avillez[2], Michael Schulreich[1], Jenny Feige[3], and Christian Dettbarn[4] — [1]Department of Astronomy and Astrophysics, TU Berlin, Hardenbergstr. 36, 10623 Berlin, Germany — [2]Department of Mathematics, University of Évora, R. Romão Ramalho 59, 7000 Évora, Portugal — [3]Institute for Isotopic Research, University of Vienna, Währingerstr. 17, A-1090 Vienna, Austria — [4]ZAH, University of Heidelberg, Mönchhofstr. 12-14, 69120 Heidelberg, Germany

The interstellar medium (ISM) in star forming galaxies is a highly dynamical system, whose physical and chemical state is heavily determined by supersonic turbulence and non-linear feedback. To follow its evolution over an appreciable amount of time requires 3D high resolution numerical simulations on massive parallel processors. We will show movies and results from our investigations, spanning more than a decade. These include: (i) volume filling factors of the ISM both from hydro- and magnetohydrodynamical simulations, (ii) pdfs, which are lognormal, due to the coupling of scales by turbulence, (iii) time-dependent cooling and non-equilibrium ionization effects of the interstellar plasma, covering a large range in temperature, (iv) turbulent mixing of isotopes like ^{60}Fe, resulting from supernova explosions of a nearby moving stellar group in the local ISM; this will be compared to recent accelerator mass spectroscopy data from samples of the deep sea ferromanganese crust and sediments.

SYPA 1.6 Thu 17:00 SPA Kapelle

Turbulent heating of charged particles in imbalanced plasma turbulence — •Martin S. Weidl[1,2], Bogdan Teaca[2,3,4], and Frank Jenko[1,2] — [1]Max-Planck-Institut für Plasmaphysik, EURATOM-Assoziation, Boltzmannstraße 2, 85748 Garching, Germany — [2]Max-Planck/Princeton Center for Plasma Physics — [3]Applied Mathematics Research Centre, Coventry University, Coventry CV1 5FB, United Kingdom — [4]Max-Planck-Institut für Sonnensystemforschung, Max-Planck-Straße 2, 37191 Katlenburg-Lindau, Germany

Astrophysical plasmas such as the solar wind often exhibit characteristics of imbalanced magnetohydrodynamic (MHD) turbulence, in which the fluctuations of the bulk velocity and the magnetic field are strongly correlated. As a result, the spatial structure and the strength of the electric field changes compared to the more commonly studied case of balanced turbulence.

We study the transport and acceleration properties of charged particles in imbalanced MHD turbulence by performing test particle simulations in parallel with three-dimensional MHD simulations. The cross-helicity level, measuring the degree of imbalance of the MHD steady-state, is controlled by using a correlated forcing scheme for velocity and magnetic fields. We discuss the decrease of the turbulent heating rate in systems with non-zero cross-helicity and compare its scaling with theoretical predictions. Our results are expected to be relevant for any plasma in which turbulent heating is important, for example the heating of dust particles in the interstellar medium.

SYPA 1.7 Thu 17:15 SPA Kapelle

Influence of the anisotropic heating and guide field on the stability and non-linear evolution of a Harris current sheet

— •Patricio Muñoz, Patrick Kilian, and Jörg Büchner — Max-Planck-Institut für Sonnensystemforschung, Max-Planck-Str. 2, 37191 Katlenburg-Lindau, Germany

In this work, we investigate the influence of the anisotropic heating on the stability and evolution of collisionless current sheets. We started from an initial Harris equilibrium, considering cases under the influence of a guide magnetic field. A 2D PIC code is applied to describe the development of the tearing instability in this system, comparing growth rates with some theoretical estimations. We show that an appropriate choice of shape function and other numerical parameters are essential to avoid numerical electron heating and temperature anisotropies that can drive additional instabilities of the current sheet. Eventually, those instabilities can make the current sheet stable against the tearing mode.

SYPA 1.8 Thu 17:30 SPA Kapelle

Numerical plasma model for simulation of supernova remnant precursors — •Tatyana Liseykina[1], Galina Dudnikova[2], and Mikhail Malkov[3] — [1]Institut für Physik, Universität Rostock, Germany — [2]University of Maryland, USA — [3]University of California at San Diego, USA

We present a numerical plasma model for simulation of the physical processes in supernova remnant shock precursors. In this model only the cosmic ray (CR) population is modelled kinetically. For the treatment of the magnetic field and the velocity field of the background plasma the ideal compressible MHD equations with sources (CR current and CR pressure gradient) are used. An advantage of such a hybrid model is the possibility to study the most important CR driven instabilities on the ion timescale, neglecting the high-frequency modes associated with electrons. Moreover, the realistic CR-to-background density ratio ($\sim 10^{-5}$) and the realistic ion-to-electron mass ratio can be used. Furthermore, the hybrid approach can reduce the computational expense relative to a fully kinetic approach while treating some particle populations (CR population in our case) with greater accuracy than MHD allows.

SYPA 1.9 Thu 17:45 SPA Kapelle

Spectrally resolved sky-map of electromagnetic radiation from the Kelvin-Helmholtz instability — •Richard Pausch[1,2], Axel Huebl[1,2], Felix Schmitt[3], Heiko Burau[1,2], René Widera[1], David Pugmire[4], Alexander Debus[1], Guido Juckeland[3], Wolfgang Nagel[3], and Michael Bussmann[1] — [1]Helmholtz-Zentrum Dresden - Rossendorf — [2]Technische Universität Dresden — [3]Technische Universität Dresden - ZIH — [4]Oak Ridge National Lab

The Kelvin-Helmholtz instability (KHI) occurs at the interface between two neutral streams of plasma flowing past one another with different velocities. This instability is expected to take place in active galactic nuclei or in the afterglow of gamma-ray bursts, where it is a possible mechanism for non-thermal radiation.

We present results of a KHI scenario with relativistic velocity shear obtained in a petaflop scale run on the TITAN cluster at Oakridge using our relativistic 3D3V particle-in-cell code PIConGPU. From the dynamics of billions of macroparticle, we calculated angularly and temporally resolved radiation spectra based on classical Liénard-Wiechert potentials including the full coherence properties. Thus, in addition to the incoherent synchrotron-type radiation arising from DC magnetic fields in the KHI, we found rich radiation signatures, which we match with the dynamics and electron density structure of the KHI. We present a simple model, which explains these spectral features and connects them to the main quantities of the KHI.