P 1: Helmholtz Graduate School I - Theory

Time: Monday 10:30–13:00 Location: A 0.112

P 1.1 Mon 10:30 A 0.112

Fully kinetic simulations of kinetic-scale collisionless plasma turbulence — •Daniel Groselj[1], Silvio Cerri[2], Alejandro Banon Navarro[1], Alfred Mallet[3], Christopher Willmott[4], Daniel Told[1], Nuno Loureiro[4], Francesco Califano[5], and Frank Jenko[1] — [1]Max-Planck-Institut für Plasmaphysik, Garching, Germany — [2]Department of Astrophysical Sciences, Princeton University, Princeton, NJ, USA — [3]Space Science Center, University of New Hampshire, Durham, NH, USA — [4]Plasma Science and Fusion Center, MIT, Cambridge, MA, USA — [5]Physics Department "E. Fermi", University of Pisa, Pisa, Italy

We present an overview of recent results obtained from a set of two- and three-dimensional, first-principles kinetic simulations of collisionless plasma turbulence with applications to the solar wind. The properties of the turbulence are compared against theoretical predictions as well as with results obtained from reduced-kinetic (gyrokinetic and hybrid-kinetic) simulations. The findings compare favorably against experimental measurements and demonstrate—from first physics principles—that the sub-ion-scale plasma turbulence under solar wind conditions is predominantly of kinetic Alfvén type. Furthermore, results from three-dimensional simulations show that the kinetic-scale turbulence naturally develops a scale-dependent anisotropy with respect to the local mean magnetic field, consistent with theoretical expectations for a so-called critically balanced kinetic Alfvén cascade.

P 1.2 Mon 10:55 A 0.112

Gyro-kinetic simulations of tokamaks and stellarators including collisions — •Christoph Slaby, Axel Könies, and Ralf Kleiber — Max-Planck-Institut für Plasmaphysik, Wendelsteinstraße 1, 17491 Greifswald

Gyro-kinetic particle-in-cell simulations are a versatile numerical tool that we use to compute the non-linear dynamics of energetic-ion-driven Alfvénic perturbations. Collisions, though often neglected in numerical simulations, play an important role, since they can significantly modify the non-linear saturation levels and thus influence particle transport out of the plasma. Especially with regard to a future fusion reactor, gaining an understanding of the underlying physics is crucial.

The non-linear dynamics and saturation of toroidicity-induced Alfvén eigenmodes is studied in tokamak and Wendelstein 7-X (W7-X) geometry. In the tokamak case, the numerical findings agree with the analytically predicted $\nu^{2/3}$-scaling from the Berk-Breizman model. On the other hand, the stellarator W7-X which is not covered by analytical theory shows a different scaling.

Lastly, hybrid simulations are performed for a realistic W7-X scenario looking for unstable modes that could be experimentally relevant. This W7-X case includes neutral beam injection, as foreseen for the up-coming operation phase 1.2b, and a realistic slowing-down distribution function for the fast ions coupled with a slowing-down collision operator.

P 1.3 Mon 11:20 A 0.112

Studying Alfvén eigenmodes driven by energetic particles in fusion plasmas using hybrid-gyrokinetic modelling — •Thomas Hayward-Schneider and Philipp Lauber — Max-Planck-Institut für Plasmaphysik (IPP), 85748 Garching, Germany

Although current fusion experiments see energetic particles (eps) from their heating systems, the suprathermal alpha particle population born from the fusion reactions of future burning plasmas will have a much greater ability to interact with Magnetohydrodynamic (mhd)-like modes. We introduce Alfvén eigenmodes (aes), and describe how the toroidicity of tokamak plasmas introduces the toroidicity-induced Alfvén eigenmode (tae) gap. Perturbative modelling of these taes is presented, using the nonlinear perturbative drift-kinetic initial value code hagis and the linear gyrokinetic eigenvalue code ligka. We show that reduced models can be used for the eigenvalue problem, allowing fast semi-analytical results applicable for wide parameter scans. For the projected iter 15 mega ampere scenario, we present both linear tae physics results comparing these models, and also nonlinear mode saturation results, making predictions about the saturated perturbation amplitudes and the transition between different ep transport regimes for iter.

P 1.4 Mon 11:45 A 0.112

Splitting Schemes and Compatible Spaces for Linearized MHD — •Mustafa Gaja[1,2], Emmanuel Franck[3], Eric Sonnendruecker[1,2], Ahmed Ratnani[1,2], Jalal Lakhlili[1], and Mariarosa Mazza[1] — [1]Max Planck Institute fuer Plasma Physik, Garching, Germany — [2]Technische Universitaet Muenchen, Muenchen, Germany — [3]Inria Nancy Grand Est and IRMA, Strasbourg, France

We investigate the linearized Magnetohydrodynamics (MHD) model for the evolution of the perpendicular components of the velocity and the magnetic fields in the context of tokamaks via the novel technique of Isogeometric Analysis (IgA) with high degree B-Splines. The discretization is based on compatible finite element spaces that preserve the natural properties (i.e, divergence-free condition) of the resulting operators to avoid spurious modes and related numerical instabilities. The geometry is planar and is written to be easily generalized to a torus case. We present results on the compatible discretization and couple this investigation with a hamiltonian splitting in time which allows to deconstruct the system into 'building-blocks' operators that could be inverted individually. Such operators, Laplacian like and Mass operators (H1 and L2 projectors, respectively) for example, are inverted using a robust and optimal ad-hoc multigrid (MG) designed using the Generalized Locally Toeplitz (GLT) theory. This MG is used as a preconditioner for Krylov-Type solvers where the GLT theory is used to construct an efficient smoother for the MG that eliminates the pathology ensuing from using high order B-Splines discretization.

P 1.5 Mon 12:10 A 0.112

An aligned discontinuous Galerkin method for anisotropic diffusion and variants — •Benedict Dingfelder[1,3], Florian Hindenlang[1], Ralf Kleiber[2], Axel Könies[2], and Eric Sonnendrücker[1,3] — [1]Max-Planck-Institut für Plasmaphysik, Garching, Germany — [2]May-Planck-Institut für Plasmaphysik, Greifswald, Gearmany — [3]Technische Universität München, Garching, Germany

In magnetized plasmas of fusion devices the strong magnetic field leads to highly anisotropic physics. If only diffusion processes are considered, the diffusion along the magnetic field is dominating. In the limit of vanishing perpendicular diffusion, we obtain the anisotropic diffusion equation with a semidefinite diffusion tensor whose associated eigenvalue problem reads

$$-\nabla \cdot (bb \cdot \nabla\phi) = \omega^2\phi \qquad \text{in } \Omega \subset \mathbb{R}^2$$

for the two-dimensional fully periodic domain Ω and direction of the magnetic field b. This eigenvalue problem is difficult to solve due to the non-coercivity of the differential operator. We propose a discontinuous Galerkin (DG) method on a non-conforming mesh with locally aligned cells which allows us to coarsen the resolution parallel to the magnetic field. The resulting distribution of resolution is particularly suited for calculating small eigenvalues.

P 1.6 Mon 12:35 A 0.112

Analysing the performance of neural networks on reconstructing edge plasma properties in Wendelstein 7-X — •Marko Blatzheim[1,2], Daniel Böckenhoff[1], Hauke Hölbe[1], Thomas Sunn Pedersen[1], and Roger Labahn[2] — [1]MPG IPP, Greifswald, Germany — [2]University Rostock, Rostock, Germany

Artificial neural networks are a key technology to benefit from large amounts of data. The nuclear fusion experiment Wendelstein-7X is a fully optimized stellarator with the main goal to demonstrate steady state capability of fusion reactors. It is tried to analyse the edge plasma properties by artificial neural networks. Most data is based on simulations because experiment time is very limited. The same neural network should be able to deal with simulated results or experimental camera data as input. In a pre-processing step, characteristics of the simulation results and the camera images are extracted. These are expected to be sufficiently similar. The neural network performance for different such parametrizations is compared. Depending on the parametrization dimensionality, more complex neural network structures can be investigated. The most promising parametrizations will be used for more complicated plasma property reconstructions and predictions.