SYSF 1: Turbulence in Space and Fusion Plasmas

Time: Wednesday 13:45–15:45 Location: ZHG101

Invited Talk SYSF 1.1 Wed 13:45 ZHG101
Addressing turbulence questions in the Wendelstein 7-X stellarator device - a combined experimental and theoretical approach — •Josefine Proll[1,2], Paul Mulholland[2], MJ Pueschel[2,3], Maikel Morren[2], Gavin Weir[1], Ksenia Aleynikova[1], Adrian von Stechow[1], Pavlos Xanthopoulos[1], Gabriel Plunk[1], and the W7-X Team[1] — [1]Max Planck Institute for Plasma Physics, Greifswald, Germany — [2]Eindhoven University of Technology, Eindhoven, The Netherlands — [3]DIFFER, Eindhoven, The Netherlands

With the advent of stellarators optimised for low collisional transport such as Wendelstein 7-X (W7-X), turbulence has become one of the main obstacles to a working fusion reactor. Tapping into the free energy of gradients in density and temperature, turbulence will cause outward transport of heat and particles and severely limit the achievable core density and temperature and thus the reactor performance. With W7-X, we can directly probe turbulence in the flexible magnetic geometry and compare against state-of-the-art gyrokinetic codes. In this talk, I will present recent findings on electrostatic and electromagnetic turbulence in W7-X, e.g. how, at much lower normalised plasma pressure beta than previously anticipated, kinetic ballooning modes appearing below the MHD threshold can lead to an increase in ITG turbulence or that heat-pulse propagation experiments confirm rather benign transport caused by electron-temperature gradient modes. I will close with an outlook of unanswered questions both from theory and experiment and how we plan to address them on W7-X.

Invited Talk SYSF 1.2 Wed 14:15 ZHG101
Particle acceleration and transport in astrophysical, magnetized turbulent plasmas — •Martin Lemoine — Astroparticule & Cosmologie (APC, CNRS, Universite Paris-Cite), F-75013 Paris, France

How charged particles are transported in phase space in magnetized turbulence is a broad topic in plasma physics with fundamental applications in astrophysics, from solar system plasmas to the more extreme plasmas of the high-energy multi-messenger universe. In its most standard formulation, such transport is described by a quasilinear formalism that ascribes pitch-angle scattering and momentum diffusion to wave-particle interactions. This talk examines an alternative picture, in which transport is rather mediated by coherent/intermittent structures. It will discuss the possibility that spatial transport occurs through localized interactions with sharp magnetic field bends and that particle acceleration can take place through interactions with coherent velocity structures. Finally, it will discuss these findings in the broader context of recent (kinetic and magnetohydrodynamic) numerical simulations of particle transport and acceleration.

Invited Talk SYSF 1.3 Wed 14:45 ZHG101
Turbulence in the young solar wind, results from Solar Orbiter and Parker Solar Probe — •Robert Wicks[1], Utsav Panchal[1], Julia Stawarz[1], Stefan Lotz[2], Du Toit Strauss[3], and Amore Nel[2] — [1]Northumbria University, Newcastle, NE1 8ST, UK — [2]South African National Space Agency, Hermanus, 7200, South Africa — [3]Center for Space Research, North-West University, Potchefstroom, 2522, South Africa

Five years of observations by Parker Solar Probe (PSP) and Solar Orbiter (SO) have revolutionised our view of the inner heliosphere, challenged established theories of solar wind acceleration and heating, and demonstrated the essential interaction of kinetic plasma physics and large-scale structure. Unexpected revelations include the prevalence of ion beams, kinetic waves, and magnetic inversions commonly called switchbacks - all key ingredients of the reorganisation of energy that defines the young solar wind.

In this talk, we will review results from PSP and SO that show that the inner 0.4 au of the heliosphere plays a role as significant as the coronal source region in determining the properties of the solar wind. Here, the young solar wind undergoes processes that modify the structure of the plasma as energy is exchanged between electromagnetic, kinetic, and internal energy of particle populations. In particular, we will look at the initialisation of turbulence, the dissipation of energy and its impact on ion and electron distributions as the highly structured near-coronal wind expands and evolves into the solar wind.

Invited Talk SYSF 1.4 Wed 15:15 ZHG101
Digital Solutions for EUROfusion — •Volker Naulin — EUROfusion — DTU, Lyngby, Denmark

EUROfusion is the European consortium uniting the efforts of 27 countries to advance towards a DEMO fusion device and support ITER in achieving its goal of a fusion power amplification of a factor of 10. As part of this mission, EUROfusion runs 16 Theory, Simulation, Validation, and Verification (TSVV) projects, which are dedicated to advancing the understanding of fusion plasma physics and enabling robust, predictive simulations. These efforts rely on professionally developed and validated codes, ensuring reliability and accuracy in capturing the complex physics of fusion systems.

Significant progress has been made in understanding plasma confinement, but larger challenges remain, particularly regarding the complex, multiscale, and nonlinear dynamics of fusion plasmas. Turbulence, the primary driver of transport processes, is being addressed by High-performance numerical codes, which have been instrumental in providing detailed insights so far, but new approaches are needed to address the remaining challenges.

Artificial intelligence (AI) and machine learning (ML) offer powerful tools to uncover missing physics. Surrogate models approximate the complex behavior of fusion plasmas. These methods can provide valuable insights into strongly nonlinear processes, such as structure formation and non-local transport, enabling better predictions and control of plasma dynamics.