P 7: Magnetic Confinement III

Time: Tuesday 16:15–18:55 Location: KH 02.016

Invited Talk P 7.1 Tue 16:15 KH 02.016

Post-puff SOL broadening on MAST-U: evidence for cross-field transport changes — •Yacopo Damizia[1], Saskia Mordjick[1], Nick Walkden[2], Jack Lovell[3], Steven Thomas[4], and Ekin Ozturk[1] — [1]William & Mary, Williamsburg, VA, USA — [2]UKAEA, Culham Campus, Abingdon, Oxfordshire, OX14 3DB, UK — [3]Oak Ridge National Laboratory, Oak Ridge, TN, USA — [4]MIT Plasma Science and Fusion Center, Cambridge, MA, USA

We test whether density shoulder formation and evolution in the MAST-U scrape-off layer are governed by parallel draining or cross-field transport. Two L-mode discharges with similar parameters each receive a 50 ms deuterium puff and are measured with Thomson scattering, Dα and Langmuir probes. In both cases the divertor stays attached/high reciclyng while an upstream shoulder forms, but its post-puff decay is much slower in the lower upstream collisionality shot, indicating that shoulder persistence is set by modified cross-field transport rather than parallel draining.

P 7.2 Tue 16:45 KH 02.016

Gyrokinetic studies in pedestal plasmas — •facundo sheffield[1], tobias goerler[1], gabriele merlo[1], lidija radovanovic[2], felix wilms[1], elisabeth wolfrum[1], clemente angioni[1], frank jenko[1], and the asdex upgrade team[3] — [1]Max Planck Institute for Plasma Physics, Bolzmannstraße 2, Garching, Germany — [2]Institute of Applied Physics, TU Wien, Fusion@ÖAW, Wiedner Hauptstr. 8-10, Vienna, Austria — [3]See author list of H. Zohm et al, https://doi.org/10.1088/1741-4326/ad249d

The pedestal region in tokamak plasmas plays a critical role in determining overall confinement and performance. However, given the steep pressure gradients, high shaping and the interplay between several transport channels, the rich physics of the pedestal remains to be fully understood.

We therefore aim to shed light into key aspects of pedestal physics with high fidelity gyrokinetic simulations using the GENE and GENE-X codes. First we showcase the implementation and importance of parallel magnetic fluctuations in global pedestal simulations. Then, we study electron-scale pedestal instabilities propagating in the ion diamagnetic direction and show how they are still electron temperature gradient modes despite their unusual drift direction. Finally, we focus on the effects of shaping on the pedestal via changes in turbulent transport at multiple scales. Overall, our work advances the understanding of pedestal microinstabilities, clarifies the role of pedestal shape in turbulent transport, and showcases the relevance of parallel magnetic fluctuations in these systems.

P 7.3 Tue 17:10 KH 02.016

Reduced Models for Turbulent Transport in W7-X — •Don Lawrence Carl Agapito Fernando[1], Ionut-Gabriel Farcaş[2], Gabriele Merlo[1], Alejandro Bañón Navarro[1], and Frank Jenko[1] — [1]Max-Planck-Institut für Plasmaphysik, Garching, Germany — [2]Virginia Tech, Blacksburg, Virginia, USA

High-fidelity, first-principles simulations have become indispensable for understanding the complex turbulence dynamics in fusion plasmas. However, their high computational cost limits their use for rapid profile prediction, parameter scans, and optimization studies. This motivates the development of reduced models with robust predictive accuracy.

Here, we present reduced models for turbulent heat and particle fluxes in W7-X. These models are constructed from a database of adiabatic-ion electron-scale and kinetic-electron ion-scale simulations generated with the GENE-KNOSOS-Tango framework, supplemented by a number of simulations driven by a structure-exploiting sparse grid approach. An active-learning algorithm was used to identify the most informative data points for model construction and regression.

The resulting models depend on key plasma parameters such as normalized temperature gradients, the ratio of temperature to density gradients, and the E × B shear. Model predictions show good agreement with reference gyrokinetic fluxes within the training domain and at additional test positions. We also investigate strategies to generalize the models across arbitrary radial positions. These turbulent transport models for W7-X paves the way for faster profile prediction and reduces the computational effort of simulation-heavy workflows.

5 min break

P 7.4 Tue 17:40 KH 02.016

GENE-X edge/SOL gyrokinetic turbulence simulations with fluid neutrals — •Sabine Ogier-Collin, Philipp Ulbl, Wladimir Zholobenko, and Frank Jenko — Max-Planck Institute for Plasma Physics, Garching bei München, Germany.

In magnetic confinement fusion devices, the plasma edge and scrape-off layer (SOL) is not fully ionised. Neutral particles, by interacting with the plasma, affect radial profiles, gradient-driven instabilities, particle transport across the separatrix, and blob dynamics in the SOL. Understanding these processes is critical for optimising reactor core performance while ensuring efficient heat and particle exhaust.

We present the neutrals extension of GENE-X, a first-principles gyrokinetic turbulence code for edge and SOL transport in realistic magnetic geometries. This extension couples GENE-X's continuum full-f electromagnetic, collisional plasma model to a neutrals density evolution equation, as a first step towards a comprehensive neutrals fluid description. Charge-exchange reactions are modelled using a diffusion equation, and specially tailored conservative Krook operators have been derived for ionisation, recombination, and associated radiation.

Relaxation studies of electrons, deuterium ions, and deuterium atoms enable isolation of the effect of each coupling term on equilibration dynamics and plasma velocity-space structure. We also present first turbulence simulations in diverted geometry, targeting validation against the TCV-X21 dataset. This development enables gyrokinetic-level studies of how neutrals influence plasma turbulence in reactor-relevant regimes.

P 7.5 Tue 18:05 KH 02.016

Microtearing mode turbulence and its role in high-density-gradient plasmas in Wendelstein 7-X — •Hugo Isaac Cu-Castillo[1], Alejandro Bañón Navarro[1], Gabriele Merlo[1], Felix Reimold[2], Thilo Romba[2], Oliver Ford[2], Sebastian Bannmann[2], Markus Wappl[2], Joachim Geiger[2], Lila Vanó[2], Alessandro Zocco[2], and Frank Jenko[1] for the w7-x team-Collaboration — [1]Max-Planck-Institut für Plasmaphysik, 85748 Garching, Germany — [2]Max-Planck-Institut für Plasmaphysik, 17491 Greifswald, Germany

Following the successful optimization of the stellarator Wendelstein 7-X (W7-X) to reduce neoclassical transport, microturbulence prevails as the primary transport mechanism limiting its plasma confinement.

Using the gyrokinetic code GENE, we demonstrate that Microtearing Modes (MTMs) dominate turbulent transport in a W7-X experimental scenario with high a/L_{n_e}, corresponding to a plasma heated purely by only Neutral Beam Injection. The appearance of MTMs is attributed to the absence of competing instabilities under these plasma conditions and the stabilizing influence of the nearly max-J configuration of W7-X. Additionally, moderate collisionality and low magnetic shear further enable the appearance of MTM. Our simulations show that, when MTM turbulence dominates, they reproduce additional experimental signatures observed in W7-X plasmas with $a/L_{n_e} > 1$: (i) the turbulent heat flux is unaffected by the density gradient, and (ii) the electron heat channel by far exceeds the ion channel.

P 7.6 Tue 18:30 KH 02.016

Geometry-dependent energetic bounds on gyrokinetic instabilities — •Paul Costello and Gabriel Plunk — Max-Planck-Institut für Plasmaphysik, Wendelsteinstraße 1, 17491 Greifswald, Germany

Outward turbulent transport of heat and particles largely dictates the necessary size of a viable tokamak or stellarator power plant. This turbulence is initiated by micro-scale plasma instabilities that are driven by the radial gradients of temperature and density in the plasma. Gyrokinetic theory forms the basis of our understanding of these instabilities, and gyrokinetic simulations are a relied-upon, albeit expensive, tool for computing their growth rates. Here, we present a complementary approach to understanding linear instabilities: constructing energetic upper bounds on instability growth. These upper bounds are computed via a variational principle by seeking perturbations that maximize the extraction of free energy from the plasma gradients. In many cases, these upper bounds are governed by a low-dimensional system of equations, while still capturing the dependence of the linear growth rate on key parameters. We demonstrate methods to include magnetic geometry into the upper bound analysis through two main pieces of work. Firstly, we consider the effect of including trapped electrons in the analysis, finding a new stabilising mechanism possessed by quasi-isodynamic stellarators. Secondly, we present a method by which the upper bound can systematically be made tighter to the linear growth rate. We highlight the potential applicability of this approach to the optimisation of stellarators to reduce turbulent transport.