Recent gyrokinetic results on ETG modes

F. Jenko[1] and W. Dorland[2]
[1]*Max-Planck-Institut für Plasmaphysik, EURATOM Association, 85748 Garching, Germany*
[2]*IREAP, University of Maryland, College Park, Maryland 20742, USA*

Electron temperature gradient (ETG) modes are one possible source of anomalous electron heat transport in fusion plasmas. Their nonlinear behavior is full of surprises and reveals novel aspects of temperature gradient driven turbulence, both in the electron and in the ion channel. Recent developments in this area will be presented, based on nonlinear gyrokinetic Vlasov simulations.

First, the fully developed turbulent state will be characterized in terms of its statistical properties like amplitudes, spectra, correlations, and energy transfer paths. Pattern formation will be briefly discussed, highlighting the nature of high-amplitude radial streamers and the role of self-generated zonal flows and fields. Based on these simulation results, an analytical model is developed which captures several properties of adiabatic ETG and ITG turbulence reasonably well. The universality of certain turbulence features is evaluated numerically via tokamak-stellarator comparisons. Moreover, the impact of finite beta on ETG modes will be studied, especially with respect to the possibility of large electromagnetic transport on very small spatial scales like the collisionless skin depth.

In the second part, results on the cross-scale coupling of ion-scale turbulence and ETG turbulence will be presented. According to recent gyrofluid simulations by Li and Kishimoto [Phys. Rev. Lett. **89**, 115002 (2002); Phys. Plasmas **10**, 683 (2003)], ITG-induced ion heat transport may become bursty in the presence of strong (prescribed) ETG-scale zonal flows. This scenario is investigated for the first time by gyrokinetic studies including both ETG and ITG scales in a single simulation. The reverse effect, namely ITG-induced zonal flows acting on ETG turbulence is also considered. Furthermore, in the presence of ITG modes, trapped electron modes, or electron drift waves, new complex pseudo-equilibria are created for the ETG modes. The resulting linear and nonlinear effects will be addressed. Lastly, it is shown that ETG modes may provide a floor for H-mode edge transport. In particular, the combination of strong equilibrium shear flows and ETG-enhanced eddy viscosity could trigger a transition from ion-scale dominated transport in L-mode to an ETG-scale dominated H-mode regime.

The investigation of cross-scale coupling represents a demanding computational task, pushing both the software and the hardware to its limits. Each Vlasov simulation requires on the order of 10^9 grid points in five-dimensional phase space and up to 10^5 time steps. The employed `gene` code runs efficiently on multiple platforms, achieving, e.g., 280 MFlop/s per processor on a Hitachi SR-8000 and around 500 MFlop/s per processor on a IBM Regatta system. Typical output files are well in the GByte range. To achieve good performance on these new-generation machines, it was crucial to reconsider the parallelization strategy and rewrite significant portions of the code.

Preferred mode of presentation: oral.