The effect of damped modes on turbulence and transport

G.G. Whelan, M.J. Pueschel, P.W. Terry

In order to develop capabilities predicting turbulent transport, it is important to understand the nonlinear physics that saturate the instabilities driving it. In gyrokinetics, an energy-conserving nonlinearity transfers energy between wavenumbers in triplets. For turbulence to be saturated, energy has to be transferred from unstable modes to stable ones. In classical hydrodynamics, the scales of energy production and dissipation are separated by an inertial range, whereas microturbulence is largely saturated by stable modes which dissipate energy at every wavenumber. This has a significant effect on the saturated amplitudes, the turbulent spectrum and transport.

Zonal flows are understood to be important in the saturation of ion temperature gradient instability (ITG), but not in electron temperature gradient instability (ETG). By comparing energy transfer involving zonal and nonzonal triplets, we can quantify this difference. ETG turbulence saturates through a cascade in toroidal wavenumber modulated through streamers, while the strong zonal flows present in ITG cause it to saturate through a cascade in radial wavenumber. Using a new GENE diagnostic that separately records the energy transfer between the unstable and stable branches of the distribution function shows that in either case an average of about 20% of the energy goes to stable modes in each triplet transfer. This effect is compounded to dissipate significant energy in the unstable wavenumber range. In ITG turbulence increasing plasma β decreases linear growth rates, but decreases turbulent intensities significantly more so. We find that increasing plasma β increases the proportion of energy transfer to damped modes, which could be responsible for this enhanced nonlinear β stabilization of ITG. Electromagnetic effects also contribute to a small but non-negligible electromagnetic inverse cascade. Increased temperature gradients decrease the ratio of energy transfer to damped modes to all energy transfer. We also quantify the effects of density gradients and dissipation mechanisms effects on this ratio.