Scale-separation between ion and electron heat transport

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Traditionally, turbulent transport is thought to be carried mainly by long-wavelength modes with $k_\perp \rho_i \sim 0.2$. While this seems to be generally true for the ion heat channel, there is experimental evidence that the electron heat fluxes behave differently – both in transport barriers and beyond. Thus, theory and simulation are challenged to explain these findings.

In the present contribution, we will examine the spectral properties of electron heat transport from TEM and ETG turbulence, focussing on contributions from shorter wavelengths than the ones mentioned above. This is done by means of nonlinear gyrokinetic simulations with the GENE code. Some simulations treat both ion and electron space-time scales fully self-consistently and are therefore very challenging. They are done on many hundreds of processors of a new SGI Altix system at Garching.

In a first step, pure TEM turbulence is investigated. Here, the plasma parameters are chosen such that both ITG and ETG modes are linearly stable. This corresponds (more or less) to the situation in various dedicated experiments over the last several years. We find that under these conditions, the electron heat fluxes exhibit clear peaks around $k_\perp \rho_i \sim 0.2$, and fall off quickly for higher wavenumbers. This is in line with the usual expectations.

In a second step, we study the case in which TEMs, ITG modes, and ETG modes all coexist. It is shown that the spectral properties change completely: A wide range of wavenumbers with $k_\perp \rho_i \gg 0.2$, from ion scales all the way to electron scales, can contribute to the overall electron heat transport. This implies that the latter is now dominated by high-wavenumber TEMs and ETG modes, while the direct contribution from long-wavelength ITG modes is relatively small. Special attention is being paid to steep gradient regimes like edge transport barriers where ITG modes and TEMs are strongly suppressed, and ETG modes exist on spatial scales down to $k_\perp \rho_i \ll 1$.