Features of Saturation of Ion Temperature Gradient Turbulence by Damped Modes in Gyrokinetic Models

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Direct diagnosis of gyrokinetic simulations shows that ITG turbulence saturates by transfer of energy to a broad array of damped modes in the wavenumber range of the instability.[1] This implies that instability-driven plasma turbulence is quite different from conventional turbulence pictures in that all scales are dissipated, including the scales of instability, and cascades to small scale are not the sole factor in saturation energetics. We explore a number of ramifications of this type of turbulence.

When saturation of CYCLONE-base-case ITG turbulence is analyzed using proper orthogonal decomposition, all modes except a few of the least damped modes, are found to have equal amplitude attenuation rates. This condition serves as an organizing principle that dictates how energy is distributed among many modes, and leads to a spectrum with respect to singular value. The principle can be related to general mode coupling properties in a damped-mode decomposition, and can also be cast into a general scaling theory. Departures from equipartition for weakly damped modes are associated with wavenumber cascades, which limit damped mode amplitudes when damping is weak. Equipartition also applies to the weak coupling of modes on times that are long compared to a nonlinear correlation time. Equipartition among weakly interacting modes admits a statistical theory of states describing how the amplitude dissipation is apportioned among the stable modes. The theory gives a probability distribution for amplitude attenuation rate.

The effect of damped modes on transport fluxes is also examined. It is shown that the many damped modes excited in gyrokinetics have a weak effect, in aggregate, on the heat flux. This contrasts with low-moment fluid models in which a limited number of modes have a significant effect on heat, particle, and momentum fluxes. This situation is investigated with respect to the velocity space properties of modes in a singular value decomposition of the gyrokinetic distribution and how they contribute to fluxes constructed from low order velocity moments.

1. D.R. Hatch, et al., Phys. Rev. Lett., in press.