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Phase-space turbulent cascade of entropy in magnetized weakly collisional plasmas[1]

TOMOYA TATSUNO, University of Maryland

Plasma turbulence is often observed in collisionless or weakly collisional environments, both in astrophysical objects and in fusion devices. The turbulence in these systems is damped at small spatial scales (high k), where the distribution functions $f_k(v)$ contain fine-scale structures which arise from phase mixing. Irreversibility comes from collisions, which tend to smooth the fine velocity-space structure, even when the collisionality parameter is small. In this kind of system, the turbulent cascade takes place in phase space (i.e., in velocity space as well as in real, or wavenumber, space). Here, we consider phase mixing that arises from nonlinear interactions. This phase mixing corresponds to an "entropy cascade". We present the first numerical simulations of this phase-space cascade in magnetized weakly collisional plasmas, using the electrostatic gyrokinetic model. Assuming the homogeneity along the field line, we have focused on a decaying turbulence problem using AstroGK [1] in a simplified four-dimensional phase space (2D in real space perpendicular to the field line and 2D in velocity space). Since the gyro-averaged ExB drift introduces a nonlinear phase mixing, we obtain velocity-space structures perpendicular to the ambient field [2], rather than parallel to the magnetic field, such as would be produced by conventional Landau damping. Kolmogorov-like dimensional arguments [3] predict that the perpendicular velocity structures are finer for the higher wave numbers, with specific spectral indices. Our simulations confirm these arguments. The cascade finally terminates at the dissipation scale derived from the collision operator in the velocity space, where the actual irreversibility is realized. All of these properties are realized in the gyrokinetic simulations. [1] http://astro.berkeley.edu/~ghowes/astrogk [2] W. Dorland and G. Hammett, Phys. Fluids B **5**, 812 (1993). [3] A. A. Schekochihin et al., to be published in Plasma Phys. Control. Fusion (2008); e-print arXiv:0806.1069.

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