Anisotropic MHD/EMHD Turbulence

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Abstract:
The solar wind and the interstellar medium are permeated by large-scale magnetic fields that render magnetohydrodynamic (MHD) turbulence anisotropic. In the weak-turbulence limit in which three-wave interactions dominate, analytical and numerical results based on random scattering of shear-Alfvén waves propagating parallel to a large-scale magnetic field demonstrate rigorously an anisotropic energy spectrum that scales as $k^{-2}$, instead of the famous Iroshnikov-Kraichnan spectrum of $k^{-3/2}$ for the isotropic case. Even in the absence of a background magnetic field, when the energy spectrum is globally isotropic, anisotropy is found to develop with respect to the local magnetic field. Because of anisotropy, the weak turbulence assumption in the Iroshnikov-Kraichnan theory is subject to question. We study the strong turbulence regime by means of simulations and phenomenological arguments. In the two-dimensional case, we obtain the Iroshnikov-Kraichnan spectrum, rather than the Kolmogorov spectrum, despite local anisotropy. Collisionless turbulence is studied in electron magnetohydrodynamics (EMHD), where whistler waves mediate the anisotropic energy cascade. Comparisons are made with MHD turbulence, especially with respect to global and local anisotropy in both inertial and dissipation ranges.