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Kinetic effects on slab turbulence in solar wind plasmas

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We numerically investigate the role of kinetic effects on 1D slab turbulence in solar wind plasmas, in the range of wavenumbers around and beyond the Hall wavenumber k_i, by using a newly developed hybrid-Vlasov code [1], that solves the Vlasov-Maxwell set of equations for a non-relativistic plasma, in the hybrid approximation, where the Vlasov equation is solved for the ion distribution function and the electrons are treated as a fluid. The low frequency approximation is used by neglecting the time derivative of the electric field, i.e. the displacement current in the Ampere equation. The zero-noise eulerian algorithm used to integrate the Vlasov equation [2] allows for the first time a systematic analysis of kinetic effects along the turbulent cascade from large magnetohydrodynamics (MHD) scales towards small wavelengths (of the order of the electron skin depth), for which the energy level of the fluctuations is typically very low and where previous Lagrangian-like algorithms, such as Particle In Cell (PIC) algorithms, could fail.

Nonlinear three-wave coupling process at large wavelengths produces a MHD turbulent cascade; in the range of wavenumbers close to the Hall wavenumber, proton cyclotron resonance with left-handed cyclotron waves [3] self-consistently generates perpendicular temperature anisotropy ($T_\perp > T_\parallel$) in the ion distribution function that is a possible source of free energy for many instabilities. For the case of hot electrons, electrostatic activity is observed and ion-acoustic waves propagating parallel to the

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ambient magnetic field are produced as the result of the nonlinear cascade of energy.

Electrostatic turbulence and in particular ion-acoustic waves have been experimentally detected ubiquitous in solar wind plasmas [4]. These waves propagate in the direction of the background magnetic field and their intensity shows a strong correlation with the electron to ion temperature ratio and with the production of proton-beam distributions; moreover, the maximum intensity of this electrostatic activity is observed in regions of slow solar wind. Our numerical results show that taking into account kinetic effects on the turbulent cascade is the key ingredient for reproducing the complex phenomenology observed in solar wind plasmas.

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