Multiscale analysis of Hall-MHD and Hybrid-PIC simulations of plasma turbulence: structures or waves?

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Turbulence in space and astrophysical plasmas is an intrinsically chaotic and multiscale phenomenon that involves nonlinear coupling across different temporal and spatial scales. There is growing evidence that plasma instabilities, such as magnetic reconnection taking place in localized current sheets, enhance the energy dissipation toward small sub-ion scales. However, it is hotly debated whether the dominant contribution to the scale-to-scale energy transfer at kinetic scales is due to non-linear wave interactions or to coherent structures. Here we present the results from a multiscale study of 2D Hall-MHD and hybrid Particle-in-cell (PIC) numerical simulations of decaying turbulence, performed by means of Multidimensional Iterative Filters (MIF), a new technique developed for the spatio-temporal analysis of non-stationary non-linear multidimensional signals. Results show that, at the maximum of turbulent activity, the power spectrum of magnetic fluctuations at sub-ion scales is formed by localized structures and/or perturbations with temporal frequencies smaller than the ion-cyclotron frequency. Going toward smaller kinetic scales, the contribution of low-medium frequency perturbations to the magnetic spectrum becomes important. However, the dispersion relation and polarization properties of such perturbations are not consistent with those of Kinetic Alfvèn Waves (KAW). We conclude that the dynamics of turbulence at sub-ion scales is mainly shaped by localized intermittent structures, with no apparent contribution of KAW-like interactions at small scales.