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Numerical simulations of kinetic turbulence in the low beta regime: interpreting MMS observations in the Earth's magnetosheath and predicting PSP observations in the solar corona

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We present numerical results from high-resolution hybrid and fully kinetic simulations of plasma turbulence, following the development of the energy cascade from large magnetohydrodynamic scales down to electron characteristic scales. We explore a regime of plasma turbulence where the electron plasma beta is low, so that there is a clear separation between the electron inertial length and the electron gyroradius. This is typical of environments where the ions are much hotter than the electrons, e.g., the Earth's magnetosheath and the solar corona, as well as regions downstream of collisionless shocks. In such range of scales, recent theoretical models predict a different behaviour in the nonlinear interaction of dispersive wave modes with respect to what is typically observed in the solar wind (e.g., polarization characteristic of inertial kinetic Alfvén waves). We also extend our analysis to scales around and smaller than the electron gyroradius, where hints of a further steepening of the magnetic and electric field spectra have been recently observed by the NASA's Magnetospheric Multiscale mission, although not yet supported by theoretical models.

Our numerical simulations exhibit a remarkable quantitative agreement with recent observations by MMS in the magnetosheath, allowing us to investigate simultaneously the spectral break around ion scales and the two spectral breaks at electron scales, the magnetic compressibility, and the nature of fluctuations at kinetic scales, by employing a new kind of analysis which takes into account the local plasma properties. Moreover, they allow us to provide predictions for observations by NASA's Parker Solar Probe mission in the solar corona.