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Spectral features and energy cascade of kinetic scale plasma turbulence

Giuseppe Arrò[1,2], Francesco Califano[2], and Giovanni Lapenta[1]
[1]Department of Mathematics, KU Leuven, Leuven, Belgium, EU
[2]Dipartimento di Fisica, Università di Pisa, Pisa, Italy, EU

Solar wind (SW) *in situ* observations of plasma turbulence show that the turbulent magnetic field spectrum follows a Kolmogorov-like scaling □$k^{-5/3}$ at large MHD scales and steepens at ion scales where a different power law develops with a scaling exponent varying between -2 and -4, depending on SW conditions. Recent satellite measurements revealed the presence of a second spectral break around electron scales where the magnetic field spectrum shows an exponential falloff described by the so called *exp* model □$k^{-8/3}\exp(-\rho_e k)$, where ρ_e is the electron gyroradius. This model was tested on a large number of magnetic spectra at various distances from the Sun (from 0.3 to 1 AU) and appears to be a solid feature of turbulent magnetic field fluctuations at kinetic scales [1].

Using a fully kinetic energy conserving particle-in-cell (PIC) simulation of freely decaying plasma turbulence we study the spectral properties of the turbulent cascade at kinetic scales. Consistently with satellite observations, we find that the magnetic field spectrum follows the $k^{-\alpha}\exp(-\lambda k)$ law at sub-ion scales, with an exponential range developing around $k\rho_e \approx 1$. The same exponential falloff is observed also in the electron velocity spectrum but not in the ion velocity spectrum that drops like a power law without reaching electron scales. We investigate the development of these spectral features by analyzing the high-pass filtered electromagnetic work **J·E** and pressure-strain interaction **-P:□u** of both the ions and the electrons. Our analysis shows that the magnetic field dynamics at kinetic scales is mainly driven by the electrons that are responsible for the formation of the exponential range. In particular, we see that at fully developed turbulence the magnetic field energy is dissipated by a two-stage mechanism lead by the electrons that first subtract energy from the magnetic field and then convert it into internal energy at electron scales through the pressure-strain interaction, that accounts for the electron heating [2].

References

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