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Spectra of Dissipation and Dispersion Measures in Space Plasma Turbulence at Kinetic Scales

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Turbulence at kinetic scales involves a wealth of kinetic physics, e.g., diffusion of magnetic flux and fluid element, dispersion of wave propagation, dissipation of turbulent fluctuation. How does turbulence behave at kinetic scales in terms of diffusion, dispersion, and dissipation is the main issue to be addressed in this study. Plasma and electromagnetic field measurements from MMS in the magnetosheath is adopted for study. The concept of ion and electron diffusion ranges (IDRs and EDRs) are proposed and identified practically based on the scale-dependent ratio of electric field power spectral densities between different reference frames: PSD(δ $\mathbf{E'}_{\mathrm{IonFrame}}$)/PSD(δ $\mathbf{E}_{\mathrm{SC\text{-}Frame}}$) and PSD(δ $\mathbf{E'}_{\mathrm{ElectronFrame}}$)/PSD(δ $\mathbf{E}_{\mathrm{SC\text{-}Frame}}$). The outer and inner scales of the IDR seem to be at kd_i~0.2 and kd_i~2, beyond which scales the diffusion between ion-motion and B-flux becomes gradually significant and almost saturated, respectively. The electron diffusion starts to become noticeable at kd_e~0.1, which is termed as the outer scale of EDR. The signature of dispersion is illustrated with flat PSD(δ **E'**) and steep PSD(δ **B**), as well as the bifurcation of PSD(δ **Vi**) and PSD(δ **Ve**). Dissipation rate spectra as a function of wavenumber k are calculated, which clearly show the commencement of dissipation around kd_i~1. It is also found that the dissipation in this case is mainly converted to electron parallel kinetic energy, responsible for the phenomena of frequent occurrence of $T_{e,\parallel}/T_{e,\perp}$. The 3"D" (diffusion, dispersion and dissipation) characteristics of space plasma turbulence is therefore summarized: positive dispersion $\delta E/\delta B(\sim V_{ph})\sim k$ appears in the IDR, while dissipation ($\delta \mathbf{J}\cdot\delta\mathbf{E}\sim\delta\mathbf{J}_{e\parallel}\cdot\delta\mathbf{E}_{\parallel}$) occurs mainly in the EDR.

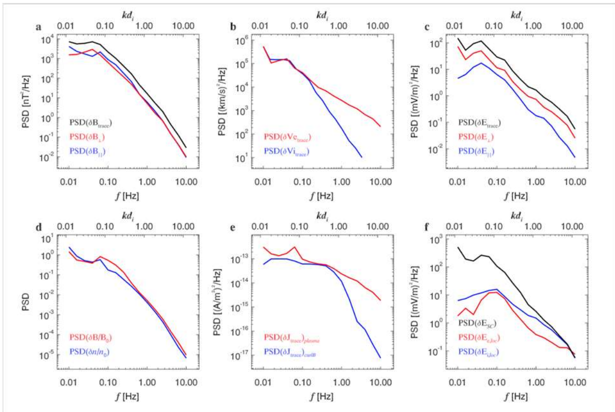

Figure 1. Power spectral densities of different variables: (a) magnetic field, (b) ion and electron bulk velocities, (c) electric field in SC frame, (d) normalized magnetic field and number density, (e) current density, and (f) electric field in ion and electron bulk flow frame.

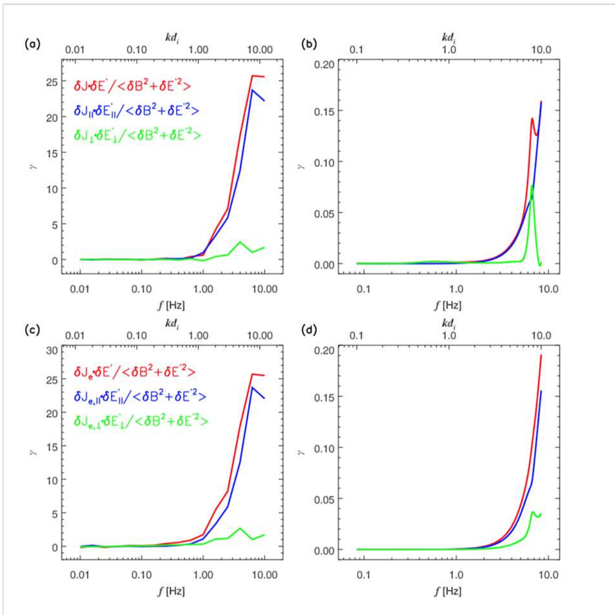

Figure 2. Normalized energy conversion rate spectra (damping and growth rate spectra for positive and negative profiles). Left and right panels for observation and theory, respectively.

Reference:

He, J.-S., Duan, D., Wang, T.-Y., et al., ApJ, in press, 2019.