Abstract

I will describe the first three-dimensional (3-D) dispersion relations and wavenumber spectra of magnetic turbulence in the solar wind at sub-proton scales. The analysis takes advantage of the short separations of the Cluster spacecraft ($d/\sim 200$ km) to apply the $\it k$-filtering technique to the frequency range where the transition to sub-proton scales occurs. The dispersion diagrams show unambiguously that the cascade is carried by highly oblique Kinetic Alfvén Wave with $\omega \leq 0.1 \omega_{ci}$ in the plasma rest frame down to $k_{\perp} \rho_i \sim 2$. The wavenumber spectra in the direction perpendicular to the mean magnetic field consists of two ranges of scales separated by a breakpoint in the interval $[0.4,1] k_{\perp} \rho_i$. Above the breakpoint, the spectra follow the Kolmogorov scaling $k_{\perp}^{-1.7}$, consistent with existing theoretical predictions. Below the breakpoint, the spectra steepen to $\sim k_{\perp}^{-4.5}$. We conjecture that the turbulence undergoes a transition-range, where part of energy is dissipated into proton heating via Landau damping, and the remaining energy cascades down to electron scales where electron Landau damping may predominate.