Geophysical Research Abstracts
Vol. 17, EGU2015-12636, 2015
EGU General Assembly 2015

Turbulent fluctuations at kinetic scales: from coherent structures to quasi-parallel whistler waves

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The nature of the magnetic field fluctuations in the solar wind between the ion and electron scales is still under debate. Using the Cluster/STAFF instrument, we make a survey of the power spectral density and of the polarization of these fluctuations at frequencies $f \in [1, 400]$ Hz, during five years (2001–2005) when Cluster was in the free solar wind. In most of the analyzed time intervals, the fluctuations have quasi-random polarization and they have a general spectral shape between the ion scales and a fraction of electron scales. The intensity of these spectra is well correlated to the ion thermal pressure. These fluctuations seem to have a negligible frequency in the solar wind frame, and a wavevector anisotropy $k_\perp \gg k_\parallel$. Such time intervals are dominated by coherent structures, propagating with a finit velocity in the plasma frame, in the plane perpendicular to the mean magnetic field. In the rest $\sim 10\%$ of the selected data, we observe narrow-band, right-handed, circularly polarized fluctuations, with wave vectors quasi-parallel to the mean magnetic field, superimposed on the spectrum of the permanent background turbulence. We interpret these coherent fluctuations as whistler mode waves. The life time of such waves varies between a few seconds and several hours. We analyze in details the long-lived whistler waves, i.e. with a life time longer than five minutes. When the electron parallel beta factor $\beta_{e\parallel}$ is larger than 3, the whistler waves are seen along the heat flux threshold of the whistler heat flux instability.