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Three dimensional anisotropic k-spectra of turbulence at sub-proton scales in the solar wind

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Large scale solar wind turbulence, where the MHD approximation is valid, has been extensively studied over the past decades. A general consensus exists that turbulence at those scales is dominated by strongly nonlinear Alfven waves, yielding power law spectra with the Kolmogorov scaling k-$5/3$. In contrast, electron scales have been only recently explored using data from the four Cluster satellites. Sahraoui et al., PRL [2009] have indeed shown the first evidence of dissipation range of SW turbulence at electron scales. Here we go further by measuring directly the first three dimensional dispersion relations and k-spectra of magnetic turbulence in the solar wind at the sub-proton scales. Taking advantage of the short separations of the Cluster spacecraft ($d \sim 100$ km) we applied the k-filtering technique to the frequency range where the transition to sub-proton scales occurs. We analyzed several data sets and obtained the 3D $\omega - k$ diagrams of the turbulence in the SW rest frame and the resulting 3D wavenumber spectra. These results will be discussed within existing theoretical predictions and recent work on the linear properties of the plasma modes in the high β_i limit from the Maxwell-Vlasov theory. Implications of the results on the mechanisms of energy dissipation and its consequences on the heating problem of the SW will be discussed.