Kinetic-scale Turbulence in the Inner Heliosphere

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Abstract: The scaling of the turbulent spectra and the nature of the plasma wave modes provide a key measurement that allows to discriminate between different theoretical predictions of turbulence. In the solar wind, this has driven a large number of studies dedicated to this issue using *in-situ* data from various orbiting spacecraft. Using the high-resolution data in the inner heliosphere from Parker Solar Probe (PSP) mission in the inner heliosphere, we find that the sub-ion scales (i.e., at the frequency $f \sim [2, 9]$ Hz) follow a power-law spectrum f^{α} with a spectral index α varying between -3 and -5.7. Our results also show that there is a trend toward and anti-correlation between the spectral slopes and the power amplitudes at the MHD scales, in agreement with previous studies: the higher the power amplitude the steeper the spectrum at sub-ion scales. A similar trend toward an anti-correlation between steep spectra and increasing normalized cross helicity is found, in agreement with previous theoretical predictions about the imbalanced solar wind. In addition, the joint distribution of the normalized reduced magnetic helicity $\sigma_m (\theta_{RB}, \tau)$ is obtained in the in highly Alfvénic slow solar wind at 0.18 AU, where θ_{RB} is the angle between the local mean magnetic field and the radial direction and τ is the temporal scale. Two populations around ion scales are identified: the first population has $\sigma_m (\theta_{RB}, \tau) <0$ for frequencies (in the spacecraft frame) ranging from 2.1 to 26 Hz for $60^o < \theta_{RB} < 130^o$, corresponding to kinetic Alfvén waves (KAWs), and the second population has $\sigma_m (\theta_{RB}, \tau) >0$ in the frequency range [1.4, 4.9] Hz for $\theta_{RB} > 150^o$, corresponding to Alfvén ion Cyclotron Waves (ACWs). This demonstrates for the first time the co-existence of KAWs and ACWs in the slow solar wind in the inner heliosphere, which contrasts with previous observations in the slow solar wind at 1 AU. This discrepancy between 0.18 and 1 AU could be explained, either by i) a dissipation of ACWs via cyclotron resonance during their outward journey, or by ii) the high Alfvénicity of the slow solar wind at 0.18 AU that may be favorable for the excitation of ACWs.