Geophysical Research Abstracts
Vol. 18, EGU2016-15326, 2016
EGU General Assembly 2016

Investigating the ion-scale spectral break of solar wind turbulence from low to high plasma beta with high-resolution hybrid simulations

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We investigate the properties of the ion-scale spectral break of solar wind turbulence by means of two-dimensional, large-scale, high-resolution hybrid particle-in-cell simulations. We impose an initial ambient magnetic field perpendicular to the simulation box, and we add a spectrum of in-plane large- scale magnetic and kinetic fluctuations, with energy equipartition and vanishing correlation. We perform a set of ten simulations with different values of the ion plasma beta, β_i. In all cases, we observe the power spectrum of the total magnetic fluctuations following a power law with a spectral index of $-5/3$ in the inertial range, with a smooth break around ion scales and a steeper power law in the sub-ion range. This spectral break always occurs at spatial scales of the order of the proton gyroradius, ρ_i, and the proton inertial length, $d_i = \rho_i/\sqrt{\beta_i}$. When the plasma beta is of the order of 1, the two scales are very close to each other and determining which is directly related to the steepening of the spectra it's not straightforward at all. In order to overcome this limitation, we extended the range of values of β_i over three orders of magnitude, from 0.01 to 10, so that the two ion scales were well separated. This let us observe that the break always seems to occur at the larger of the two scales, i.e., at di for $\beta_i < 1$ and at i for $\beta_i > 1$. The effect of β_i on the spectra of the parallel and perpendicular magnetic components separately and of the density fluctuations is also investigated. We compare all our numerical results with solar wind observations and suggest possible explanations for our findings.