



Direct Measurement of Anisotropic and Asymmetric Wave Vector Spectrum and the three dimensional structure in Ion-scale Solar Wind Turbulence

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This analysis represents the first time that a simultaneous measurement of parallel and perpendicular spectral indices at both inertial and kinetic scales has been made directly in wave vector space, using a single interval of solar wind plasma. An interferometric wave vector analysis method is applied to four-point magnetometer data from the Cluster spacecraft to study for the first time the anisotropic and axially asymmetric energy spectrum directly in the three-dimensional wave vector space in the solar wind on spatial scales for the fluid picture (at about 6000 km) down to the ion kinetic regime (at about 400 km) without invoking Taylor's frozen-in flow hypothesis. At fluid scales, the spectral index is found to transition from -2 along the large-scale magnetic field direction to a spectral index approaching $-5/3$ in the perpendicular direction. The wave number for the spectral break between ion inertial and kinetic scales occurs at larger scales in the parallel projection, compared to the perpendicular. At ion kinetic scales, the spectrum in the parallel direction is difficult to measure, while the two perpendicular directions are also anisotropic and vary between $-8/3$ and $-1/3$. This suggests that a single anisotropic process where symmetry is broken in a single direction cannot account for the results. The three dimensional structure of incompressible and compressible plasma turbulence are also discussed.