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The distinct character of anisotropy and intermittency in inertial and kinetic range solar wind plasma turbulence

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The anisotropic nature of the scaling properties of solar wind magnetic turbulence fluctuations is investigated scale by scale using high cadence in situ magnetic field measurements from the Cluster, ACE and STEREO spacecraft missions in both fast and slow quiet solar wind conditions. The data span five decades in scales from the inertial range to the electron Larmor radius. We find a clear transition in scaling behaviour between the inertial and kinetic range of scales, which provides a direct, quantitative constraint on the physical processes that mediate the cascade of energy through these scales.

In the inertial (magnetohydrodynamic) range the statistical nature of turbulent fluctuations are known to be anisotropic, both in the vector components of the magnetic field fluctuations (variance anisotropy) and in the spatial scales of these fluctuations (wavevector or k-anisotropy). We show for the first time that, when measuring parallel to the local magnetic field direction, the full statistical signature of the magnetic and Elsasser field fluctuations is that of a non-Gaussian globally scale-invariant process. This is distinct from the classic multi-exponent statistics observed when the local magnetic field is perpendicular to the flow direction. These observations suggest the weakness, or absence, of a parallel magnetofluid turbulence energy cascade.

In contrast to the inertial range, there is a successive increase toward isotropy between parallel and transverse power at scales below the ion Larmor radius, with isotropy being achieved at the electron Larmor radius. Computing higher-order statistics, we show that the full statistical signature of both parallel, and perpendicular fluctuations at scales below the ion Larmor radius are that of an isotropic globally scale-invariant non-Gaussian process.

Lastly, we perform a survey of multiple intervals of quiet solar wind sampled under different plasma conditions (fast, slow wind; plasma beta etc.) and find that the above results on the scaling transition between inertial and kinetic range scales are qualitatively robust, and that quantitatively, there is a spread in the values of the scaling exponents.