Geophysical Research Abstracts
Vol. 14, EGU2012-3024-1, 2012
EGU General Assembly 2012

The solar wind as a turbulence laboratory- some new quantitative points of contact between theory, simulation and solar wind observations

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The solar wind flow has a Reynolds number of order 10^5. Single point observations suitable for the study of turbulence are on timescales from below ion kinetic scales up to days. Central to the concept of using the solar wind as a test laboratory for plasma turbulence are methods that allow direct quantitative comparison between the predictions of theory and simulation, and the observations. Critically, theoretical predictions, and data analysis methods, must come together in a manner in which uncertainties can be well understood, and thus different theoretical scenarios be distinguished unambiguously.

Scaling is a key prediction of theories of infinite range turbulence. Its full characterization requires the scaling exponents of all the moments of the probability density of fluctuations as a function of scale. In practice, only the first few moments are accessible. Most comparisons with theory focus on the second moment scaling, that is, the exponent of the power spectral density (PSD). Solar wind plasma turbulence is anisotropic due to the presence of a background field, so that in general the power spectral density (or correlation) tensor is needed to characterise the turbulence.

We focus on the ratios of the PSD tensor terms which are sensitive to the scaling exponent, providing a method for direct observational tests of theories. The reduced PSD tensor accessed by single spacecraft measurements yields ratios of perpendicular terms which we show are robust to uncertainties. These can clearly distinguish turbulence theories as we show for the Goldreich-Sridhar model of MHD turbulence, and the 'slab-2D' solar wind model, which we compare with ULYSSES observations. The comparison between solar wind observations, and 'fly throughs' of DNS of MHD turbulence, is also an informative tool to understand the reduced PSD tensor. We will use this alongside Cluster observations to propose an origin of the observed non-axisymmetry of solar wind turbulence. Properties of the PSD tensor thus provide a useful diagnostic to test theories of turbulence, both in DNS, and in the data.

References: Turner et al, PRL, 107, 095002, (2011); Turner et al, PRL, in press (2012)