Geophysical Research Abstracts
Vol. 19, EGU2017-11155, 2017
EGU General Assembly 2017

Small-scale flow structures in the solar wind turbulence

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Small-scale flow structures play a key role in balancing and dissipating turbulent kinetic energy. Significant progress has been made towards understanding the flow patterns in hydrodynamic (HD) turbulence. However, the geometry/topology of the turbulent, magnetized plasma flow remains not fully understood. By virtue of the multi-point plasma moments measured by the Magnetospheric Multiscale (MMS) mission, quantification of the velocity gradient, which carries geometrical information of the fluid elements, becomes available. Through analyzing the geometric invariants of the coarse-grained velocity gradient (R and Q), we have investigated the small-scale structure of the turbulent flow in the solar wind. Three main results that agree with theoretical/numerical and experimental results of homogeneous HD turbulence are reported: (1) The joint probability density function of the (R, Q) phase map exhibit a ‘teardrop’ shape; (2) The vorticity is aligned with the positive intermediate principal of the strain tensor; (3) The ratios of the mean eigenvalues of the stains tensor are around 3: 1: -4, implying sheet-like structures with viscous dissipation and dissipation production. Interestingly, dissimilarities from HD flows are found, featuring a population whose enstrophy is correlated with dissipation. Further investigation of the magnetic field patterns shows a dominance of quasi-2D structures, which is different from the velocity field. Implications of our work are discussed.