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Local energy transfers in MHD turbulence: from numerical to spacecraft data

Denis Kuzzay (1), Olga Alexandrova (1), Lorenzo Matteini (1), and Luca Sorriso-Valvo (2)

(1) Paris Sciences et Lettres, CNRS - Observatoire de Paris, Lesia, Meudon, France (denis.kuzzay@obspm.fr), (2) Departamento de Física, Escuela Politécnica Nacional, Ladron de Guevera E11-253, Quito, ECUADOR

We present a local (in space and time) approach to the study of scale-to-scale energy transfers in magnetohydrodynamic (MHD) turbulence. This approach is based on performing local averages of the physical fields, which amounts to filtering scales smaller than some parameter ℓ. A key step in this work is the derivation of a local Kármán-Howarth-Monin relation which can be interpreted as a coarse-grained energy balance. This provides a local form of Politano and Pouquet's 4/3-law without any assumption of homogeneity or isotropy, which is exact, non-random, and connects well to the usual statistical notions of turbulence [1].

After a brief presentation of this approach, we first apply it to turbulent data obtained via a three dimensional direct numerical simulation of the forced, incompressible MHD equations from the John Hopkins turbulent database. The local Kármán-Howarth-Monin relation holds well. The space statistics of local cross-scale transfers is studied, their means and standard deviations being maximum at inertial scales, and their probability density functions (PDFs) displaying very wide tails. Events constituting the tails of the PDFs are shown to form structures of strong transfers, either positive or negative, which can be observed over the whole available range of scales. As ℓ is decreased, these structures become more and more localized in space while contributing to an increasing fraction of the mean energy cascade rate. Second, we show how the same approach can be applied to spacecraft data where the main difficulty lies in the fact that measurements are restricted to few points, in one small region of space at a time, and a single scale. We compare our approach to results obtained from Cluster and MMS data using the LET proxy [2,3], and highlight its importance to the understanding of solar wind turbulence and solar wind heating.

References

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