Geophysical Research Abstracts,
Vol. 11, EGU2009-3349-2, 2009
EGU General Assembly 2009

Evolution of Multiscale Multifractal Turbulence in the Heliosphere

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The aim of this study is to examine the question of scaling properties of intermittent turbulence in the space environment. We analyze time series of velocities of the slow and fast speed streams of the solar wind measured in situ by Helios 2, Advanced Composition Explorer and Voyager 2 spacecraft in the inner and outer heliosphere during solar minimum and maximum at various distances from the Sun. To quantify asymmetric scaling of solar wind turbulence, we consider a generalized two-scale weighted Cantor set with two different scales describing nonuniform distribution of the kinetic energy flux between cascading eddies of various sizes. We investigate the resulting spectrum of generalized dimensions and the corresponding multifractal singularity spectrum depending on one probability measure parameter and two rescaling parameters, demonstrating that the multifractal scaling is often rather asymmetric. In particular, we show that the degree of multifractality for the solar wind during solar minimum is greater for fast streams velocity fluctuations than that for the slow streams; the fast wind during solar minimum may exhibit strong asymmetric scaling. Moreover, we observe the evolution of multifractal scaling of the solar wind in the outer heliosphere. It is worth noting that for the model with two different scaling parameters a much better agreement with the solar wind data is obtained, especially for the negative index of the generalized dimensions. Therefore we argue that there is a need to use a two-scale cascade model. Hence we propose this new more general model as a useful tool for analysis of intermittent turbulence in various environments.

References

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