MULTISCALE MULTIFRACTAL INTERMITTENT TURBULENCE IN SPACE PLASMAS*

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Multifractality is commonly related to a probability measure that may have different fractal dimensions on different parts of the support of this measure. In this case the measure is multifractal. Here we propose a notion of multifractality based on an extended self-similarity that depends on scale. We consider the concept of the multiscale multifractality in the context of scaling properties of intermittent turbulence in astrophysical and space plasmas. To quantify scaling of this turbulence, we use a generalized weighted Cantor set with two different scales describing with various probabilities nonuniform intermittent multiplicative process of distribution of the kinetic energy between cascading eddies of various sizes[1].

We examine the spectrum of generalized dimensions and the corresponding multifractal singularity spectrum depending on two scaling parameters and one probability measure parameter demonstrating that the multifractal scaling is often asymmetric[2]. In particular, we analyze time series of plasma parameters of the slow and fast speed streams of the solar wind plasma measured in situ by Helios, Advanced Composition Explorer, and Voyager spacecraft. We show that the universal shape of the multifractal spectrum results not only from the nonuniform probability of the energy transfer rate but rather from the multiscale nature of the cascade. It is worth noting that intermittent pulses are stronger for the model with two different scaling parameters and a much better agreement with the solar wind data is obtained. Only in the case of the multiscale cascade one can reproduce the entire multifractal spectrum, especially for the negative index of the generalized dimensions. Therefore we argue that there is a need to use the multi-scale cascade model. Hence we propose this new more general model as a useful tool for analysis of intermittent turbulence in various environments.

1. W. M. Macek, “Multifractality and intermittency in the solar wind”, Nonlin. Processes Geophys., 14, 695-700, 2007.
2. W. M. Macek and A. Szczepaniak, “Generalized two-scale weighted Cantor set model for solar wind turbulence”, Geophys. Res. Lett., 35, L02108, doi:10.1029/2007GL03263, 2008.