Fractality of MHD shell model for turbulent plasma driven by solar wind

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An interesting manifestation of complexity in nonlinear systems is the emergence of fractal features. It is then not surprising that fractality has also been seen as a tool to study plasma systems, in contexts such as the Sun's surface, the solar wind and the Earth's magnetosphere.

In a series of works, we have applied the fractal approach to the problem of magnetospheric turbulence, as described by the Gledzer-Yamada-Ohkitani MHD shell model [1,2]. Shell models are low dimensional dynamical models, based on a finite number of coupled equations, originally derived to mimic the spectral Navier-Stokes equation. They have been proposed to describe turbulence in magnetized fluids, having the main statistical properties of MHD turbulence, even for very high Reynolds numbers [3].

We show a series of results for the fractal properties of the GOY shell model, and how the fractal dimension of its forcing may affect its dissipation activity. These studies were motivated by the findings in Ref. [4], which suggest that any model which intends to represent the behavior of the Earth's magnetosphere driven by the solar wind, should not only reproduce the distribution of events, but also the fractal properties of the time series. Then, in Ref. [5], a careful study of the GOY shell model was carried out, for a wide range of parameter values, showing that the fractal dimension of the dissipated magnetic energy time series during active states is lower than during quiet states, and that this result is nontrivial, as it depends on the timescale observed, and the region of parameter space explored.

This suggests that shell models are not only able to describe some statistical features of solar and geomagnetic activity (*e.g.* power-law distribution of events), but they can also qualitatively reproduce its fractal properties, which may expand the use of these models in the context of space plasmas.

Later, we have analyzed the activity of the magnetic energy dissipation rate given by a shell model under various forcing time series, instead of the solution of a Langevin equation as used in Ref. [5], as a very simplified model of turbulence in the Earth's magnetosphere under various stages of forcing by the solar wind along the solar cycle. This is done by using magnetic field and flow speed data for the solar wind during the full 23rd solar cycle to build the forcing terms of the shell model, either by replacing the Langevin time series [6], or modifying its stochastic term [7].

We find that the activity level for dissipative events in the GOY shell model responds to varying levels of fractality, showing correlations with the solar cycle [8]. Thus, the box counting dimension used here, although it is a very simple measure of complexity in a time series, is able to describe varying levels of solar activity.

We believe that the series of works that we have described here, represent an interesting step to understand how complexity in the solar wind data may drive varying levels of geomagnetic activity.

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