Statistics of dissipative structures in MHD simulated coronal loops: the waiting time problem

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Coronal heating remains one of the main riddles in the solar and space physics community (De Moortel & Browning, 2015). The sudden and concentrated release of energy produced by solar flares cause the heating of the corona with temperatures up to 10^7 K. The fact that the largest flares correlate quite well with magnetic active regions in the solar corona and have a very short onset time, make plausible the hypothesis that magnetic reconnection is the mechanism accountable for the dynamical release of magnetic energy (Priest and Forbes, 2000).

The main idea behind this hypothesis is that magnetic energy liberated during reconnection ends up heating the coronal plasma. Parker (1983) conjectured that the aforementioned energy is stored in the corona: stochastic movements of the photospheric fluid move around the footpoints of magnetic coronal loops. Because the coronal plasma is highly conductive the frozen-in condition for the magnetic field holds up resulting in a complex, entangled magnetic field, force free almost everywhere except in many small electrical currents sheets, which form spontaneously in highly-stressed regions. As the current in these sheets goes beyond some threshold, reconnection takes place and magnetic energy is released.

The power-law energy distributions observed in solar flares in the last forty years (Dennis, 1985; Aschwanden and Parnell, 2002 and Aschwanden, 2021) has been associated either to intermittent turbulence or to self-organized criticality (SOC). But to this day it is still not clear, nor theoretically or observationally if the solar corona is in a turbulent or self organized state and the idea that these two paradigms could be complementary manifestations of the complexity of the system has been on the spot for several years.

In 2020, using a magnetohydrodinamic (MHD) simplified model of the solar corona we have begin addressing this conundrum (Morales et al. 2020).

We numerically integrated the MHD equations to simulate the dynamics of coronal loops (Dmitruk & Gómez, 1997) driven at their bases by foot point motions (as proposed by Parker). After a few photospheric turnover times, a stationary turbulent regime is reached, displaying a broadband power spectrum and a dissipation rate consistent with the cooling rates of the plasma confined in these loops. A statistical analysis of the energy, area, and lifetime of the dissipative structures observed in these simulations displayed robust scaling laws. We calculated the critical exponents characterizing the avalanche dynamics, and the spreading exponents that quantify the growth of these structures over time and found that the result of the simulations could be interpreted in terms of the SOC paradigm (Morales & Charbonneau, 2008).

The behavior of the waiting time statistics for flares have also remained elusive since the study of the data sets and numerical models yielded different interpretations for the probability distributions functions (PDF) observed. In this work we apply three different definitions of waiting time and study the PDFs order to test if the follow a Poisson's statistics or other. The main interest of this analysis is to be able to establish if the intermittent events are randomly distributed or not. The answer to this question is of particular interest since it might strength the case for the actual forecasting of solar flares (Morales & Santos, 2020).

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