Predicting the probability of solar outbursts: the perspective of complex systems: report and further plans

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Background

Solar outbursts are typical example of extreme events. Complex systems theory [1] offers different approaches to model these, generally large-scale (global) macroscopic events, which are generated from small-scale (local) microscopic interactions. There are two classes of theoretical approaches, self-organized criticality (SOC) [2] and intermittent criticality [3]. They give quite different answers for the question of eventual predictability. The first framework suggests that extreme events are inherently unpredictable, the second implies the possibility to find precursors.

If we see correctly, there are SOC, but not IC models for solar flares. However, based on the discussion we had (Gombosi, personal communication), IC may be realistic for solar flares, too. There are existing models of IC to describe IC related to earthquakes based on the modification of the celebrated sand-pile model of SOC.

Goal

SOC solar flare models should be modified to generate intermittent criticality (IC). The effects of realistic assumptions on the structure and parameters on the statistics of the flares should be evaluated.
Existing SOC models of solar flares generation

Morales and Charbonneau (MC) [4, 5, 6] established a model framework by using 2D lattice model to calculate some geometrical properties of avalanches in a novel avalanche model of solar flares "... closely built on Parker’s physical picture of coronal heating by nanoflares..."

Cellular automata approach to the self-organized criticality in solar mCares was constructed. The anisotropy of the lattice seemed to be an essential feature of the model.

SOC models: comparative studies

What is the relationship between the sand-pile toy model of SOC generation, and the MC model framework. The hope is that the essential assumptions of the two frameworks are in accordance with each other.

Existing IC models related to earthquakes

Precursory phenomena associated with large avalanches in the long-range connective sandpile (LRCS) model [7]. This study proposes an alternative sandpile model. Specifically, some distant connection between two separated cells was introduced. The modified model was able to demonstrate reduction in scaling exponents before large events through adaptable long-range connections. So, as opposed to the SOC models, it can be used for prediction. In a following paper [8] the relation between the (Gutenberg-Richter) $b$-value and the Hurst ($H$) exponent in seismicity were analyzed. The long-range connectivity parameter seems to essential to contribute the decrease of $b$ and increase of $H$ value. Intermittent criticality was demonstrated in the long-range connective sandpile (LRCS) [9].

Simulation results

Basically we reproduced the simulations Fig. 1, Explanation in the caption.

Conclusions

We would build a model by incorporating physically realistic long-range connections, and need more interactions from solar physicists to implement the model.

References

Figure 1: On the first figure (noise like curves) there are plots of the average height of sand pile at different reconnection parameter vs. time. The change in the average height can be interpreted as the total energy released by an avalanche or by the magnetic field. The second figure shows the distribution of the avalanche sizes with a fitted linear suggesting a power law distribution which indicates the difficulty of making a reliable prediction of the size of the events. On the third figure the red plus representing the exponent of the distribution on figure two shown at different long range connectivity probability. This is the so-called exponent "B" , also a candidate precursor for large events. Blue circle is the average "activity" at different reconnection level corresponding to the average level of curves on the first plot. Black star represent the intersection of the distribution of avalanche sizes also indicating the increasing probability of larger events as the reconnection parameter increases. All of the 3 quantity starts from one as they are normalized with the starting value.


