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Thesis

The role of randomness in avalanche statistics and synchronization of spring-block models

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Abstract

Self-organized criticality is a collective behaviour whose main feature is that the dynamical system we are considering moves towards its critical point, without any tuning of adjustable external parameters. The most famous example of SOC is the sandpile model, introduced in 1987 by Bak, Tang and Wiesenfeld. Other examples are variants of this first model, like the forest fire model, a model for front propagation, evolution models for species, and so on. SOC raised interest also in geophysics, as a possible explanation for the scale invariant behaviour of earthquakes, whose empirical distributions in magnitude (Gutenberg Richter Law) and in time (Omori Law) are power laws.

A classical model of earthquakes is the Burridge-Knopoff spring-block model, where the fault between two tectonic plates is described as a lattice of rigid blocks elastically connected among them and to one surface of the fault. Due to the relative movement of the tectonic plates, the stresses on all the blocks increase until the stress of some block reaches an upper threshold and relaxes, causing the slipping of the block and a rearrangement of the constraints on the neighboring blocks. This can possibly push other blocks to relax and trigger an avalanche of slippings, i.e., an earthquake. Spring-block models are the most simple description of a seismic fault reproducing at qualitative level experimental observations as the Gutenberg-Richter law. In the cellular automata version, the so-called OFC model, randomness is present only in the initial condition and avalanche sizes follow a power law distribution with an exponent depending on the dissipation parameter.

It has been proposed that the critical behavior of this model is related to the tendency to synchronization in such systems (Middleton, Tang). In fact, this model presents critical behavior when disomogeneities from the boundaries (open boundary conditions) propagates into the bulk of the system, leading to a partially but non tototally synchronized state. Temporal and spatial correlation of real earthquakes, though, are not correctly described by this model in its original form.

The OFC model can be mapped in the evolution of a driven elastic inter-

face in a disordered medium after adding randomness in the level of friction instability. In this case the avalanche size distribution is still a power law but with a stable exponent independent of the dissipation parameter. A very good agreement with GR law exponent and with spatial correlations of the aftershocks was obtained in a recent work (Jagla, Rosso, Landes) on the depinning of viscoelastic interfaces. The introduction of a *relaxation* mechanism, in a time scale in between the small one of the avalanches and the big one of the drive, leads to a periodic stick-slip dynamics of the big avalanches, and that time scale is the one involved in the aftershocks phenomenon.

In the Thesis I study the mechanism responsible for the observed differences between the pure and the random OFC model, focusing on the role of synchronization leading to quasi-periodic behavior.

In order to achieve a better understanding of synchronization and dissipation in the system we also study simplified models including mean-field models up to two-block systems. The role of relaxation is also discussed in these simplified systems.