Observable features of avalanching systems

Report: M. Gedalin

The team "Observable features of avalanching systems" was awarded ISSI 2003 grant and started to work in late January 2004. The work was finished in February 2005. The team included M. Gedalin (BGU, Beer-Sheva, Israel, team leader), M. Balikhin (ACSE, Sheffield University, Sheffield, UK), D. Coca (ACSE, Sheffield University, Sheffield, UK), G. Consolini (Ist. Fisica Spazio Interplanetario, Istituto Nazionale di Astrofisica, Rome, Italy), and R. Treumann (Max-Planck-Institute for Extraterrestrial Physics, Garching, Germany). During the work of the team one more participant, M. Bregman (BGU, M. Sci. student of M. Gedalin) joined the team and contributed significantly to the results, but did not visit ISSI.

The objectives of the research were formulated as follows. Avalanching systems are very ubiquitous in nature. They are often related to self-organized criticality (SOC), although the avalanching feature is more general. SOC has been proposed as a universal mechanism for the behaviour of a wide class of statistical systems and phenomena (magnetic substorms, solar flares, earthquakes, rainfall, forest fires, etc.). Research in this area mainly concentrates on what is considered to be the basic features of avalanching systems and SOC in particular: statistics of avalanches, self-similarity, and large correlation length. Despite substantial efforts, no physical system with firmly established SOC behaviour has been observed: existence of a critical state without tuning parameter in avalanching observed avalanching systems has not been proven. Universal features of avalanching models have been extensively studied. Nevertheless, applicability of this studies to real physical systems in still under question. This is partly because of the lack of studies of what and how should be measured in real systems to identify manifestations of SOC and to relate the internal (not directly observable) processes to measurable parameters. The objective of the proposed research is to properly establish what physical variables (output) should be studied in real physical systems (like magnetosphere or earthquakes) in order to make firm conclusions about presence or absence of SOC and study the relation between the driving (input) and microprocesses in the avalanching systems and the output. As a result of the hopefully successful research we will have appropriate tools to distinguish SOC systems from non-SOC ones and will be able to conclude about the microprocesses in avalanching systems from observations of some macroscopic variables.

During the research (ISSI grant) period substantial progress has been achieved, although we were not able to answer all the questions above. In particular, a novel burning model was proposed as a prototype model for reconnecting systems. The new avalanching model is characterized by a) a local threshold in the transition from passive to active states, b) finite life time of active sites, and c) is dissipative. This model seems to be more appropriate for the description of a continuous system where localized reconnection plays a crucial role. The model allowed for an analytical treatment. We established the shape of the distribution of cluster sizes and the relation of the observables to the model parameters. The results were illustrated with numerical simulations which supported the analytical results. The results are published in M. Gedalin, M. Bregman, M. Balikhin, D. Coca, G. Consolini, R. Treumann, Dynamics of the burning model, *Nonl. Proc. Geophys.,* 2005 (in press).

Within the proposed study of the relevance of the remote observations to the identification of self-organized criticality of the observed system or the relation of observables to internal dynamics, an extensive comparison was performed of two externally similar but internally very different models. We performed a statistical analysis of two one-dimensional avalanching models: the bi-directional sandpile and the burning model. Such a comparison helped understand whether very limited measurements done by a remote observer may provide sufficient information to distinguish between the two physically different avalanching systems. We showed that the passive phase duration reflects the avalanching nature of the system. The cluster size analysis may provide some clues. The distribution of the active phase durations showed a clear difference between the two models, reflecting the dependence on the internal dynamics. Deeper insight into the active phase duration distribution even provided information about the system parameters. The results of the analysis are published in M. Gedalin, M. Bregman, M. Balikhin, D. Coca, G. Consolini, R. Treumann, Avalanches in bi-directional sandpile and burning models: A comparative study, *Nonl. Proc. Geophys.,* 2005 (in press).

We have also proposed a novel approach to the theoretical analysis of avalanching systems based on the kinetic equation for cluster growth. The results were used for the analysis of the burning model in the first NPG paper. The basics of the proposed approach appear on the web-archive: M. Gedalin, M. Balikhin, D. Coca, G. Consolini, R. Treumann,, Kinetic description of avalanching systems, http://arxiv.org/abs/cond-mat/0501567, and is also submitted for publication.