Self-Organized Criticality and Turbulence

Coordinator: Markus Aschwanden

ISSI Team Meeting - 2012 Oct 15-19 - Hallerstr. 6, 3012 Bern, Switzerland

Program :

Time	Monday Oct 15	Tuesday Oct 16	Wednesday Oct 17	Thursday Oct 18	Friday Oct 19
0830-0930	Welcome and Introduction	Chapman[1]	Jensen	Nishizuka	Discussion[2] Leader: Watkins
0930-1030	Pruessner	Aschwanden[1]	Morales[1]	Morales[2]	Discussion[3]
Coffee break					
1100-1200	Watkins[1]	Sharma	Watkins [2]	Dimitropoulou	Conclusions Future Plans
Lunch break					End
1330-1430	Georgoulis	Mineshige	Splinter Groups	Chapman[2]	
1430-1530	Milovanov	Crosby	or	Aschwanden[2]	
Coffee break			Excursion		
1600-1700	Hergarten	Sanchez		Discussion[1] (Leader: Jensen)	
1700-1730	ISSI Apero				

MONDAY

Welcome and Introduction

Markus Aschwanden - Ruedi von Steiger

Introduction, overview, and scope of meeting (Aschwanden, LMSAL).
ISSI Introduction (Ruedi von Steiger, ISSI)

Any answers? Self Organised Criticality in the third decade after BTW

Gunnar Pruessner, Imperial College London, UK

Self Organised Criticality, for more than a decade the most popular subject within Complexity, or even within Statistical Mechanics, was expected to be found everywhere, explaining not only earthquakes and forest fires, but hospital waiting times, wars and consciousness.

Taking stock more than twenty years later, what are the core findings on the basis of numerical models and analytical tools? I will attempt to give a fair assessment of the status quo, highlighting in particular the point of view of growth phenonmena and field theory. A few robust models have been identified and studied in detail, some even solved analytically. A number of puzzling phenomena and tempting problems remain, which I will try to highlight. In particular, I will discuss recent progress made using the language of second quantisation.

Why is it useful to treat the magnetosphere as a complex system ? [Talk 1]

Nicholas Watkins (British Antarctic Survey, Cambridge, UK)

The magnetosphere is quite clearly "complex" as the word is used in everyday speech. However, in the last 15 to 20 years there has been a growing thread in magnetospheric physics which uses, and develops, an emerging set of concepts and techniques which are maturing to form a science of complex systems. Here "complexity" has a more specific meaning, usually implying system properties which cannot simply be deduced from the properties of the component parts. A particularly well-studied set of system properties has been derived from those used in the study of critical phenomena in condensed matter physics, notably correlation functions, power spectra, burst distributions and so on. I will talk about what these measurements are, why they have been made, how they have been adapted to the magnetospheric context, what they are telling us and what I think the current issues are in their interpretation. I will also sketch some future directions.

My work has been done with many colleagues but I would particularly like to acknowledge Tom Chang, Sandra Chapman, Richard Dendy, Christian Franzke, Mervyn Freeman, Tim Graves, and Martin Rypdal.

Self-Organized Criticality in the Solar Atmosphere: a Universal Property of Solar Magnetism, or Merely One of Eruptive Active Regions?

Manolis K. Georgoulis (Acad. Athens, Greece)

Twenty five years after its introduction, efforts to formulate the Self-Organized Criticality (SOC) concept into a fully-fledged theory are still ongoing. In spite of this, a growing number of physicists seem to endorse the notion that SOC is at work in the solar atmosphere. SOC-related evidence in solar magnetism is indeed mounting, but almost exclusively for the case of solar flares, or solar eruptions in general. What remains unclear is whether SOC is a significant (dominant or not) underlying agent in the non-eruptive evolution of solar magnetic fields, or whether it manifests itself only in the few, privileged active regions that host major solar eruptions (or major flares, in particular). To facilitate this open question, we review some of the evidence favoring non-critical self-organization (but not SOC) in solar magnetic structures, as well as some SOC-favoring evidence for solar eruptions. Of particular interest are the relation between SOC and turbulence, with the latter being wide-spread in the solar magnetized atmosphere, the properties of solar-flare waiting-times and their relation to SOC, the relation between SOC and the loss-of-equilibrium class of solar-eruption mechanisms, and the SOC ramifications for flare forecasting. We further examine how SOC models could be further generalized or refined to better account for the observed properties of solar magnetic fields, in general, or of flaring/eruptive active regions, in particular. Our overarching goal is to stimulate critical discussion - or, ideally, work toward a consensus - on the extent of SOC validity in solar magnetic structures.

The challenge of "complex" systems, with implications for self-organized critical behavior

Alexander V. Milovanov (EURATOM-ENEA, Rome, Italy)

In this report I will summarize the current state of some investigations in the fields of complexity and self-organized criticality, by looking back at what has been accomplished in the past, and trying to identify future research opportunities. Topics are selective, with a focus on original research, and a margin for informal discussion. The presentation is divided between theoretical methods involving fractional-derivative equations of the diffusion, relaxation, and Ginzburg-Landau type and prospective cross-disciplinary applications. In particular, aspects of complex behavior in geo-space and fusion plasma systems will be addressed on an equal footing with some implications for Earth's climate as complex system. Time permitting, the flavor of some emerging projects in geo-space and fusion plasma research, respectively the Russian multi-satellite "ROY" project and Italy's Fusion Advanced Studies Torus (FAST) proposal for an European Union satellite for ITER, International Thermonuclear Experimental Reactor, will be given in connection with the mainstream of this talk.

SOC in natural hazards

Stefan Hergarten (Univ.Graz, Univ.Freiburg, Germany)

The event-sizes of several natural hazards obey heavy-tailed distributions which are more or less clear power laws over some orders of magnitude.

Earthquakes are the most widely studied phenomenon in this context. Their size distribution follows a rather clear power law over several orders of magnitude, known as the Gutenberg-Richter law. So it is not surprising that earthquakes have been considered in the context of SOC for more than 20 years. Spring-block models and their representations as cellular automata turned out to be able the reproduce the power-law distribution and even some more distinct statistical properties of earthquakes such as foreshocks and aftershocks and the almost periodic occurrence of large earthquakes qualitatively. However, it seems that none of these models reproduces all important statistical properties of earthquakes simultaneously.

Wildfires obey power-law distributions with a rather small scaling exponent. It seems that even the simple Drossel-Schwabl forest-fire model is much more realistic than it was thought for a long time, although its acceptance in forest ecology is still not very high. However, wildfires do apparently not provide such a wealth of statistical properties as earthquakes beyond the size distribution. It is therefore difficult to assess whether a model captures the important parts of real wildfire dynamics or whether a well-predicted scaling exponent of the fire-size distribution is just a coincidence.

Landslides exhibit power-law size statistics over a limited range of scales, too. There seems to be a strong difference between mass movements in rock (rockfalls, rockslides) and regolith landslides occurring in a rather soft soil layer. Relating these two classes of mass movements to SOC with the help of models is still a problem, although a recently published approach seems to be promising with respect to rockfalls and rockslides.

Finally, volcanic eruptions may be power-law distributed, too. However, available statistics are insufficient, and the activity of individual volcanoes seems to be rather periodic over considerable time spans. So the relationship of volcanic eruptions to SOC is rather unclear.

At least 3 kinds of scaling in the solar wind (including turbulence) [Talk 1]

Sandra Chapman (Univ. Warwick, UK)

The solar wind has long been proposed as a laboratory for MHD turbulence. However, the sun is also a source of scaling, as in power law distributions of flares. The background solar wind, on scales longer than that of the turbulence, is scaling. In addition, the solar wind is populated by discontinuities. Finally, we also see turbulent-like scaling on ion kinetic scales. This talk aims to prompt a discussion on what all these mechanisms are and how we can distinguish them observationally within a single signal.

A Statistical Fractal-Diffusive Avalanche Model of a Slowly-Driven Self-Organized Criticality System [Talk 1]

Markus Aschwanden (Lockheed Martin Solar and Astrophysics Lab.)

We develop a statistical analytical model that predicts the occurrence frequency distributions and parameter correlations of avalanches in nonlinear dissipative systems in the state of a slowly-driven self-organized criticality (SOC) system.

This model, called the fractal-diffusive SOC model, is based on the following four assumptions: (i) The avalanche size L grows as a diffusive random walk with time T, following $L \propto T^{1/2}$; (ii) The energy dissipation rate $f(t)$ occupies a fractal volume with dimension D_S, (iii) The mean fractal dimension of avalanches in Euclidean space $S = 1, 2, 3$ is $D_S \approx (1 + S)/2$; and (iv) The occurrence frequency distributions $N(x) \propto x^{-\alpha_x}$ based on spatially uniform probabilities in a SOC system are given by $N(L) \propto L^{-S}$, with S being the Eudlidean dimension. We perform cellular automaton simulations in three dimensions ($S = 1, 2, 3$) to test the theoretical model.

The analytical model predicts the following statistical correlations: $F \propto L^{D_S} \propto T^{D_S/2}$ for the flux, $P \propto L^S \propto T^{S/2}$ for the peak energy dissipation rate, and $E \propto FT \propto T^{1+D_S/2}$ for the total dissipated energy; The model predicts powerlaw distributions for all parameters, with the slopes $\alpha_T = (1 + S)/2$, $\alpha_F = 1+(S-1)/D_S$, $\alpha_P = 2-1/S$, and $\alpha_E = 1+(S-1)/(D_S+2)$. The cellular automaton simulations reproduce the predicted fractal dimensions, occurrence frequency distributions, and correlations within a satisfactory agreement within $\approx 10\%$ in all three dimensions.

One profound prediction of this universal SOC model is that the energy distribution has a powerlaw slope in the range of $\alpha_E = 1.40 - 1.67$, and the peak energy distribution has a slope of $\alpha_P = 1.67$ (for any fractal dimension $D_S = 1, ..., 3$ in Euclidean space $S = 3$), and thus predicts that the bulk energy is always contained in the largest events, which rules out significant nanoflare heating in the case of solar flares.

Reference: Aschwanden,M.J. (2012), Astron.Astrophysics 539, A2.
URL="http://www.lmsal.com/~aschwand/eprints/2010_fractal.pdf"

Long-range Correlations and Extreme Events

Surja Sharma (Univ. Maryland, College Park, USA)

The modeling of extreme events in complex driven systems rely heavily on available data. The presence of long-range correlations is among the main origins of extreme events and have been studied using data, from the perspective of complexity science. A combination of dynamical and statistical techniques enables characterizations of extreme events, and their scaling features that can be used for predictions. The studies using extensive data of the coupled solar wind-magnetosphere system will be presented.

SOC in Black Hole Accretion Flow

Shin Mineshige (Kyoto Univ., Japan)

The most well-known features commonly observed in black hole objects is short-term X-ray fluctuations. The X-ray light curves are not periodic nor random fluctuations, but, they seem to comprise numerous peaks (or shots) with different amplitudes and durations. These fluctuations are most likely to be produced by magnetic turbulence and flares, similarly to the cases of the Solar atmosphere. Here we present our attempts to understand such X-ray variations based on the notion of the SOC both from the observational and theoretical points of view. We also wish to discuss similarities and differences from other cases.

Modelling the outer radiation belt as a complex system in a self-organised critical state

Norma Crosby (Belgian Inst. Space Aeronomy, Brussels, Belgium)

The dynamic behaviour of Earth's outer electron radiation belt makes this area of geo-space a candidate for the concept of self-organized criticality. It is shown that frequency distributions of measured outer electron radiation belt data are well-represented by power-laws over two decades. Results suggest that the entire outer radiation belt appears to be affected as the sum of its individual parts.

Self-organized criticality and magnetically confined fusion plasmas

Raul Sanchez (Univ. Carlos III, Madrid, Spain) and D.E. Newman

A review will be given on the status of the application of SOC models and concepts to the understanding of radial turbulent transport in fusion plasmas, such as those magnetically confined in certain regimes in a tokamak or stellarator. Specially, we will discuss relevant experimental findings that support the importance of SOC-like hypothesis. We will also review the abundant numerical evidence from simulations that help to identify the conditions and regimes in which SOC dynamics seem to be dominant. Identification of the physical elements that enable the appearance of SOC dynamics in the context of these plasmas will be stressed. Another important part of the talk will be devoted to the description of old and novel numerical/experimental diagnostics that can be used to characterize SOC-like behaviour in these plasmas, in spite of the fact that a definitive test for SOC-ness is still lacking. Finally, we will discuss the construction of mean-field models to quantify transport in these regimes in terms of fractional transport equations and similar mathematical constructs.

Connecting the Micro-dynamics to the Emergent Macro-variables: Self-Organized Criticality and Absorbing Phase Transitions in the Deterministic Lattice Gas

Henrik Jensen, Imperial College London, UK

We reinvestigate the Deterministic Lattice Gas introduced as a paradigmatic model of the 1/f spectra (Phys. Rev. Lett. 64, 3103 (1990)) arising according to the Self-Organized Criticality scenario. We demonstrate that the density fluctuations exhibit an unexpected dependence on systems size and relate the finding to effective Langevin equations. The low-density behaviour is controlled by the critical properties of the gas at the absorbing state phase transition. We also show that the Deterministic Lattice Gas is in the Manna universality class of absorbing state phase transitions. This is in contrast to expectations in the literature, which suggested that the entirely deterministic nature of the dynamics would put the model in a different universality class. To our knowledge this is the first fully deterministic member of the Manna universality class.

Reference: A. Giometto and H.J. Jensen, Connecting the Micro-dynamics to the Emergent Macro-variables: Self-Organized Criticality and Absorbing Phase Transitions in the Deterministic Lattice Gas, Phy. Rev. E. 85, 011128 (2012).

A self organized critical model of a highly correlated flow-driven turbulent magnetosphere [Talk 1]

Laura Morales (Universite de Montreal, Quebec, Canada), W.W., Liu, P., Charbonneau, V. Uritsky and J. Manuel

The magnetosphere is a large scale natural system where different kind of multiscale structures are generated, essentially, by the driving of the solar wind. The fact that some magnetospheric phenomena, such as: auroral emissions, magnetic field fluctuations, AE and PC indexes, exhibit power law statistical relations, contributed to the idea that the magnetosphere could behave like a self-organized critical (SOC) system. In a recent work (W. W. Liu. et al. (2011), J. Geophys. Res., 116, A03213) we developed a new framework in which the magnetosphere is in a state of weak turbulence and shuffles the magnetic field frozen to it effectively changing the current distribution. Numerically, we implemented this by means of a simple 2D cellular automaton (CA). The model assumes that the central plasma sheet can be thought as a collection of discrete straight flux tubes that is driven by a weak and completely uncorrelated turbulent flow. Simulations performed with that CA yielded highly filamentary current distributions from the primordial uniformity and produced spatially and temporally intermittent, avalanche-like energy release. The frequency distributions of energy release, peak energy and the duration of avalanches were found to be scale free. In this work we added a more realistic driving to the system. We replaced the uncorrelated perturbation with a turbulent velocity field with arbitrary correlation in time and length. We performed several numerical simulations and investigated extensively the effect that increasing correlation of the driving imposes over the system. We found that under this modification the system is able to reach a stationary state with avalanche-like energy release that exhibit scale-free energy distributions. In addition, we studied the statistical properties of the inter-avalanche waiting times and the structure of the current distributions.

Anomalous Diffusion, Anomalous Time Series, and the models that describe them [Talk 2]

Nicholas Watkins (British Antarctic Survey, Cambridge, UK)

I will first talk briefly about why we need to use stochastic (or partly stochastic) models in physics and the geosciences, particularly in time series analysis. The motivation is not only classic problems but also the new importance of topics like extremes and large deviations. I will review how our intuition tends to have been formed by the simplest textbook stochastic time series model: white, Gaussian, iid, stationary noise, for which, following Fisher and others, a highly developed theory of statistical inference exists. Such noise has a short tailed amplitude distribution, it is delta-correlated in time, and has constant finite moments, so its range does not grow.

I will then describe how, in stark contrast, Mandelbrot's classic work in the 1960s and early 1970s focused particularly on 3 effects seen in time series drawn from the natural and economic sciences, each of which represented a strong departure from one of the above properties. These were the Noah effect" (heavy tails in amplitude); the "Joseph effect" (long range serial dependence in time) ; and volatility clustering" (correlations between the absolute value of the time series). Mandelbrot's work has been highly influential, and played a key role in motivating Bak et als postulate of self-organised criticality (SOC). SOC was introduced as a mechanism to explain, and unify, the Noah and Joseph effects through self-similar space-time avalanches with no intrinsic cutoff scale.

I will then discuss three resulting issues which have been of personal interest to me and my co-workers [1,2,3,4]. We were initially motivated by our interest in extreme fluctuations in space and laboratory physics , and the need to compare paradigms like SOC with experimental data. One issue arises from the fact that a measured fluctuating quantity need not always be stationary and noise-like. Instead natural fluctuations may have been integrated or multiplied by the system's physics to create random walk-like observed variable(s). Aggregated fluctuations already have rather different properties when compared to noise, some of which can be traps for the unwary. For example, the first passage time of even an ordinary Brownian random walk is already a heavy tailed random variable with infinite expectation value. A second problem arises from the fact that some popular diagnostics are constructed to measure self-similarity exponents, while others in fact measure long-range dependence, so some confusion can arise when interpreting their outputs [2].

Finally I will discuss the models which modify the Brownian random walk, including those for anomalous diffusion. I will build on, and where necessary correct, the classification we presented in [1], and which I have recently developed in [4]. Particularly important classes of such models are: 1. additive and undamped, including fractional stable models, the fractional CTRW, and generalised shot noises; 2. additive but mean reverting (damped) models like the Ornstein-Uhlenbeck process; and 3. multiplicative processes, and combinations (e.g. the recent work of Rypdal and Rypdal that combines 2 and 3). I will try and dispel the common misconception that such models are "just statistics", as many embody a close correspondence with a physical scenario, which can be used as a guide when trying to choose the most suitable one to use.

References: [1] Watkins, N. W., Credgington, D., Sanchez, R., Rosenberg, S., and Chapman, S. C. Kinetic equation of linear fractional stable motion and applications to modeling the scaling of intermittent bursts. PRE (2009).

[2] C. L. E. Franzke, T. Graves, N. W. Watkins, R. B. Gramacy and C. Hughes. Robustness of estimators of long-range dependence and self-similarity under non-Gaussianity. Phil. Trans. Roy. Soc. A (2012).

[3] N. W. Watkins, B. Hnat and S. C. Chapman. On selfsimilar and multifractal models for the scaling of extreme bursty fluctuations in space plasmas. AGU Monograph on Complexity and Extreme Events in Geoscience (2012).

[4] N. W. Watkins, Bunched black swans in complex geosystems, in preparation for GRL Frontiers (2012).

Power-law distributions of flare brightenings and Fractal Reconnection in a Solar Flare

Naoto Nishizuka (ISAS/JAXA)

The fundamental puzzle inherent to solar reconnection is that the microscopic plasma scale such as ion Larmor radius or ion inertial length are 10-100 cm in the solar corona, and are much smaller than the macroscopic plasma scale such as the size of flare loops, which are of order of $10^9 - 10^10$ cm. Hence even if the micro-scale plasma physics has been solved, there still remains the fundamental puzzle how to connect micro and macro scale plasma physics to explain solar flares (and astrophysical flares as well).

In order to solve this question on scale-gap in solar flares, we analyzed the images and light curves of hard X-rays, H, and C iv emissions of the GOES X2.5-class solar flare occurred on 10 November 2004, which were observed by RHESSI, TRACE 1600A and Sartorius H telescope in Kwasan observatory of Kyoto University. We found many C iv kernels brightened successively during the evolution of the flare ribbon, and that the majority of them were well correlated with the H kernels in both space and time, while some of them were associated with the HXR emission. These kernels were thought to be caused by the precipitation of nonthermal particles at the footpoints of the reconnecting flare loops. The time profiles of the C iv kernels showed intermittent bursts, whose peak intensity, duration, and time interval were well described by power-law distribution functions. This result may be evidence of particle acceleration in an impulsive reconnection associated with plasmoid ejections with various sizes (i.e., fractal current sheet).

We also performed 3D MHD simulation of a solar flare with anomalous resistivity model. The simulation reproduced a turbulent (fractal) curent sheet, in which large numbers of small-scale plasmoids are generated and ejected upward and downward. This dynamics makes a current sheet turbulent and also have a role in storing energy in the current sheet and enhancing the energy release rate and reconnection rate once a plasmoid is ejected out of the current sheet. These processes may be observed as power-law distributions of footpoint flare brightenings and related to self-organized criticality in a solar flare. In this presentation, we will also review recent progress of the studies of plasmoid-induced-reconnection and fractal reconnection in solar flares, including application to particle acceleration.

Anisotropic braiding avalanche model for solar flares: a new 2D interpretation [Talk 2]

Laura Morales (Universite de Montreal, Quebec, Canada), Paul Charbonneau and Markus Aschwanden

There is widespread agreement on the fact that solar flares ca be explained by a mechanism of storage and release of magnetic energy in the solar corona: magnetic reconnection. In 1988 E.N. Parker included this mechanism in a more elaborated physical scenario that may lead to the dissipation of huge amounts of energy, the so called nanoflares. Parkers idea is that stochastic photospheric fluid motions shuffle the footpoints of magnetic coronal loops and the high electrical conductivity of the coronal plasma allows the generation of current sheets. Whenever the current exceeds some threshold magnetic reconnection occurs. Parkers model include all the ingredients necessary to produce a self-regulated state (SOC state, Bak et al. 1987, Phys. Rev. Lett. 59, 381): a dissipative system subject to a local instability requiring a triggering condition (magnetic reconnection), a slowly driven open system, and an external forcing mechanism on a long time scale compared to the dynamical time scales.

Recently, we have produced a new generation of SOC model for solar flares (Morales and Charbonneau, ApJ. 682 (1), 654). This model is based on a 2D cellular automaton with anisotropic connectivity, where linear ensembles of interconnected nodes define the individual strands collectively defining a coronal loop and $B = 0$ is met by design. Driving was introduced by random deformation of the strands distributed uniformly through the lattice. This system produced avalanches of reconnection events characterized by scale-free size distributions that compared favorably with the corresponding size distribution of solar flares, as inferred observationally.

In this work we performed large series of simulations of the new SOC model for solar flares for lattices of several sizes and instability thresholds and calculate the various quantities characterizing the avalanching regions. In all cases the model produced robust results that compare well with observations, and, at the same time, solved some of the discrepancies and interpretative ambiguities presented by earlier SOC models. Additionaly, we assumed that the lattice can be mapped onto a near-vertical current sheet extending from the coronal reconnection regions to the photospheric flare ribbons and tested the simulations results by calculating the temperature and density temporal evolution of avalanches. Thus we were able to compute the resulting peak flux and durations for a given wavelenght to produce the frequency distribution functions od energy, duration and peak flux.

Reference: Morales and Charbonneau, ApJ. 682 (1), 654.

A Dynamic, Data-Driven, Integrated Flare Model Relying on Self-Organized Criticality

Michaila Dimitropoulou (Univ. Athens, Athens, Greece), H. Isliker, L. Vlahos, and M. K. Georgoulis

We interpret solar flares as events originating in active regions having reached the self-organized critical state, by using a dynamic integrated flare model with initial conditions as well as the driving mechanism derived from observations. We investigate whether well-known scaling laws observed in the distribution functions of characteristic flare parameters are reproduced after the self-organized critical state has been reached. To investigate whether the distribution functions of total energy, peak energy and event duration follow the expected scaling laws, we first apply the static cellular automaton model (Dimitropoulou et al. 2011) to 7 consecutive solar vector magnetograms recorded by the Imaging Vector Magnetograph on May 1 1998 between 18:59 UT and 23:16 UT until the self-organized critical state is reached. The target is NOAA active region 8210.We then evolve the magnetic field in-between these processed snapshots through spline interpolation, acting as a natural driver in our dynamic model.We identify magnetic discontinuities exceeding a threshold in the Laplacian of the magnetic field after each interpolation step. These discontinuities are relaxed in local diion events, implemented in the form of cellular automaton evolution rules. Subsequent interpolation and relaxation steps cover all transitions until the end of the sequence. To achieve subsectioncient statistics, we further advance each SOC magnetic configuration by the static model until 50 more avalanches are triggered. Then we run the dynamic model again for the new timeseries of magnetic configurations. This is repeated for 16250 cycles, resulting in 90791 recorded avalanche events. Physical requirements, such as the divergence-free condition for the magnetic field vector, are approximately imposed. We obtain robust power laws in the distribution functions of the modeled flaring events with scaling indices in good agreement with observations. Peak and total flare energy obey single power laws with indices 1:65 Σ 0:11 and 1:47 Σ 0:13, while flare duration is best fitted by a double power law (2:15 Σ 0:15 and 3:60 Σ 0:09 for the flatter and steeper parts, respectively). We therefore conclude that well-known statistical properties of flares are reproduced after active regions reach self organized criticality. A significant enhancement of our refined cellular automaton model is that it initiates and further drives the simulation from observed, evolving vector magnetograms, thus facilitating energy calculation in physical units, whereas a separation between MHD and kinetic timescales is possible by assigning distinct MHD timestamps to each interpolation step.

Similarity and scaling - What the principle of similitude can tell us about turbulence, SOC, and ecosystems [Talk 2]

Sandra Chapman (Univ. Warwick, UK)

Similarity analysis can be used to reveal control and order parameters for systems, even where their functional dependence cannon be obtained often the case in strongly nonlinear multiscale systems. This talk will look at the principle of similitude in operation in systems that show scaling turbulence and SOC- and in a wider class of systems- using a bottom-up analysis of an ecosystem as an example.

SOC Systems in Astrophysics [Talk 2]

Markus Aschwanden (Lockheed Martin Solar and Astrophysics Lab.

The universe is full of nonlinear energy dissipation processes, which occur intermittently, triggered by local instabilities, and can be understood in terms of the self-organized criticality (SOC) concept. A number of cosmic processes exhibit SOC behavior. On the largest scale, galaxy formation may be triggered by gravitational collapses (at least in the top-down scenario), which form concentrations of stars in spiral-like structures due the conservation of the angular momentum. Similarly, stars and planets form randomly by local gravitational collapses of interstellar molecular clouds. Blazars (blazing quasi-stellar objects) are active galactic nuclei that have a special geometry with their relativistic jets pointed towards the Earth, producing erratic bursts of synchrotron radiation in radio and X-rays. Soft gamma repeaters are strongly magnetized neutron stars that produce crust quakes (in analogy to earthquakes) caused by magnetic stresses and star crust fractures. Similarly, pulsars emit giant pulses of radio and hard X-ray bursts during time glitches of their otherwise very periodic pulsar signal. Blackhole objects are believed to emit erratic pulses by magnetic instabilities created in the accretion disk due to rotational shear motion. Cosmic ray particles are the result of a long-lasting series of particle acceleration processes accumulated inside and outside of our galaxy, which is manifested in a powerlaw-like energy spectrum extending over more than 10 orders of magnitude. Solar and stellar flares are produced by magnetic reconnection processes, which are observed as impulsive bursts in many wavelengths. Also phenomena in our solar system exhibit powerlaw-like size distributions, such as Saturn ring particles, asteroids, or lunar craters, which are believed to be generated by collisional fragmentation processes or their consequences (in form of meteroid impacts). The magnetosphere of planets spawns magnetic reconnection processes also, giving rise to substorms and auroras. We discuss how such diverse physical processes share the same nonlinear statistics that is common to SOC systems.

Discussion [1]: When and why does nature self-organize to the VICINITY of a critical state rather than to a critical state

Discussion Leader: Henrik Jensen

We kick off the discussion by showing some data from brain and from rain and discuss this in relation to forest fire phenomenology.

FRIDAY

Discussion [2]: Physics of Fractals: one ring or many ?

Discussion Leader: Nicholas Watkins

We will have a discussion about how the existing paradigms of Bak, Mandelbrot et al have stimulated us all greatly, but have also tended to condition what we see in data, and what needs to come next.

Discussion [3]: Open Discussion

Moderator: TDB

The forum is open for discussion of various SOC topics, such as statistical and physical aspects of SOC processes, all the way to alternative concepts to SOC, and how we can discriminate or define what is SOC, or what is only SOC-like, or even non-SOC processes. The attendants are invided to voice their wide range of viewpoints and backgrounds on all SOC aspects discussed or left out during this week.

Conclusions and Future Plans

The main benefits of an ISSI team project are: (1) A well-balanced, interdisciplinary, international team from fields as diverse as astrophysics, magnetospheric physics, geophysics, and biophysics can jointly tackle a common problem in nonlinear physics and complexity; (2) Each participant has access to unprecedented rich and large state-of-art databases in space physics and laboratories; (3) The joint discussions enforces that we use a common scientific vocabulary that is important to understand each others progress in any field of science; (4) Young scientists are trained during these meetings and they bring new thinking to our problems; and (5) Observational/phenomenological, numerical computer simulations, and analytical/theoretical/modeling approaches are combined to reach a deeper physical understanding of SOC and related non-SOC processes.

What new aspects did we learn during this ISSI meeting? What goals did we accomplish, and what next steps do we want to take for the future?

Discussion of Publications and next ISSI Team Meeting in 2013.

Adjourn.