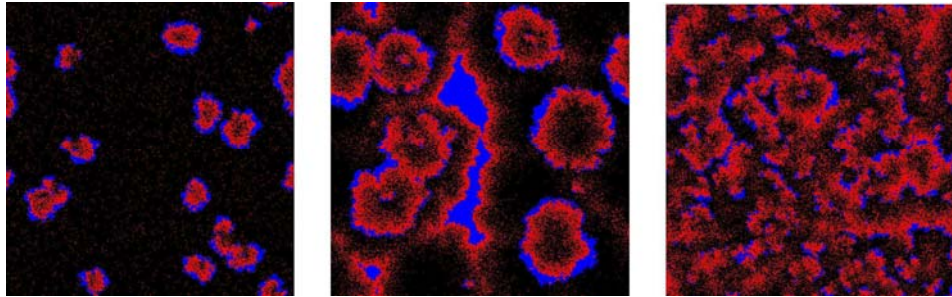


Complexity in Materials far from Equilibrium

an International Symposium

May 14-16, 2008

Virginia Tech



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Mark Sowers

Department of Physics

College of Science

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Schedule of Events

Wednesday, May 14

- | | |
|------------------|---|
| 8:30-9:00 a.m. | Registration |
| 9:00-9:10 a.m. | Welcome |
| 9:10-10:00 a.m. | Maya Paczuski , University of Calgary, Canada
<i>Complexity in living and non-living matter - A physicist looks at life</i> (invited talk) |
| 10:00-10:20 a.m. | Rahul Kulkarni , Virginia Tech, Blacksburg, VA
<i>Modeling of processes governing subcellular protein localization in E. coli</i> |
| 10:20-10:40 a.m. | coffee break |
| 10:40-11:30 a.m. | Mark Novotny , Mississippi State University,
<i>Far from equilibrium processes in magnetic nanoparticles and thin films</i> (invited talk) |
| 11:30-11:50 a.m. | Zhi-Feng Huang , Wayne State University, Detroit
<i>Multiscale modeling of strained film epitaxy: Island formation and dislocation nucleation</i> |
| 11:50-12:10 p.m. | Hill Thompson , FSU, Tallahassee, Florida
<i>Resolution-dependent mechanisms for bimodal switching time distributions in simulated Fe nanopillars</i> |
| 12:10-2:00 p.m. | lunch |
| 2:00-2:50 p.m. | Peter Grassberger , University of Calgary, Canada
<i>Records, causal networks, and earthquakes</i> (invited talk) |
| 2:50-3:10 p.m. | Hang-Hyun Jo , Korea Institute for Advanced Study
<i>Relevance of abelian symmetry and stochasticity in directed sandpile models</i> |

- 3:10-3:30 p.m. coffee break
- 3:30-4:20 p.m. **Leticia Cugliandolo**, Université Pierre et Marie Curie- Paris VI, France
Exact results in curvature driven coarsening
(invited talk)
- 4:20-4:40 p.m. **Hyan Keun Lee**, Korea Institute for Advanced Study
Recurrent character of biased random walk on regular lattice
- 4:40-5:00 p.m. **David Adams**, University of Michigan, Ann Arbor
Signpost method for obtaining the harmonic measure of 2D percolation clusters

Thursday, May 15

- 9:00-9:50 a.m. **Reinhard Lipowsky**, Max Planck Institute of Colloids and Interfaces, Potsdam, Germany
Molecular Motors: Energy Conversion, cargo transport, and traffic phenomena (invited talk)
- 9:50-10:10 a.m. **Creighton Thomas**, Syracuse University, Syracuse, NY
Using patchwork dynamics to simulate glassy systems
- 10:10-10:30 a.m. coffee break
- 10:30-11:20 a.m. **Eva Andrei**, Rutgers University, Piscataway, NJ
Ageing memory and glassiness of driven vortex matter (invited talk)
- 11:20-11:40 a.m. **Gregory G. Kenning**, Indiana University of Pennsylvania, Indiana, PA
The effects of initial conditions on physical aging in spin glasses

- 11:40-12:00 noon **Paolo Sibani**, University of Southern Denmark,
Odense, Denmark
*Intermittent linear response and spontaneous
fluctuations in off-equilibrium aging dynamics*
- 2:00-2:50 p.m. **Greg McKenna**, Texas Tech University,
Lubbock, Texas
*Aging and structural recovery in 'concentration'
glasses: Comparisons with 'temperature' glasses*
(invited talk)
- 2:50-3:10 p.m. **Stephan A. Mackowiak**, Columbia University,
New York, NY
*Single molecule study of dynamics near the
glass transition*
- 3:10-3:30 p.m. coffee break
3:30-4:20 p.m. **Katharina Vollmayr-Lee**, Bucknell University,
Lewisburg, PA
*Self-organized critically below the glass
transition*
(invited talk)
- 4:20-5:10 p.m. **Hervé Marand**, Virginia Tech, Blacksburg, VA
*The physical aging of crystallizable polymers
above the glass transition temperature*
(invited talk)
- 5:10-6:00 p.m. Poster session

Friday, May 16

- 9:00-9:50 a.m. **Hernán Makse**, City College of New York, NY
Statistical mechanics of jammed matter
(invited talk)
- 9:50-10:10 a.m. **Stefan Boettcher**, Emory University,
Atlanta, GA
*Unjamming local search heuristics through
extremal driving*
- 10:10-10:30 a.m. coffee break
10:30-11:20 a.m. **Dragana Popovic**, National High Magnetic
Field Laboratory, Tallahassee, FL
*Glassy dynamics of electrons near the metal-
insulator transition in two dimensions* (invited
talk)
- 11:20-12:10 p.m. **Jeff Olafsen**, Baylor University, Waco, TX
*Recapturing thermostistical behavior in
systems driven far from equilibrium*
(invited talk)
- 12:10-12:30 p.m. **Brian Utter**, James Madison University,
Harrisonburg, VA
*Jamming in granular systems with imposed
Vibrations*
- 12:30-2:30 p.m. lunch
2:30-6:00 p.m. Trip/hike to the Cascades waterfall

Invited Talks

Eva Andrei (Rutgers University)

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Ageing memory and glassiness of driven vortex matter

Much progress was made towards understanding the equilibrium properties of vortex systems including the discovery of a topologically ordered Bragg glass phase that is stable in the limit of weak quenched disorder. By contrast, little is known of the dynamics of vortex phases or of their fate when driven out of equilibrium. I will describe experiments that employed time resolved transport and Hall microscopy to probe the evolution of the vortex lattice in NbSe₂ in response to a driving force. The results are summarized in a dynamic phase diagram consisting of regions with distinctly different response characteristics. In particular, we identified a regime where the moving vortex lattice exhibits the hallmarks of glassy dynamics: memory, aging and stretched exponential response.

Leticia Cugliandolo

(Université Pierre et Marie Curie, Paris, France)

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Glassy dynamics and coarsening

A liquid that is rapidly cooled down becomes increasingly sluggish and enters a glassy regime in which its dynamics is far too slow to allow for equilibration with its environment. Although important theoretical progress has been achieved in recent years a fully satisfying theoretical description of the dynamics of glassy systems is still lacking. In particular, it has become clear that dynamic spatio-temporal fluctuations, either in the supercooled liquid or the glass, are especially important; they should then be included in the existing theory.

The origin of spatio-temporal fluctuations in glassy problems seems too hard to be completely understood at this stage. It then appears useful to revisit simpler macroscopic out of equilibrium systems with this scope in mind. Domain growth phenomena are, possibly, the simplest such example. The well-known ferromagnetic coarsening process and phase separation in immiscible fluids or binary alloys fall into this category. The microscopic dynamic mechanisms have been grasped and the long-time dynamic regime has been successfully described with a scaling theory that postulates that a single length scale, the typical domain radius, is sufficient to characterize the scaling of all macroscopic observables. However, in spite of the great success of the scaling hypothesis, the domain structure is not as simple as one could have imagined and important lessons for glassy physics can be learned from studying these systems at all length-scales.

In this talk I shall summarize recent developments in the study of coarsening phenomena at a mesoscopic scale. In particular I shall present an analytic derivation of the number density of domain areas in two-dimensional clean and dirty ferromagnetic systems. The implications of these results to the physics of glasses will be briefly discussed.

Peter Grassberger (University of Calgary)

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Records, causal networks, and earthquakes

There is an obvious connection between earth quakes and records - it is the record-breaking earth quakes which are of most interest. Although this is undoubtedly true, it is NOT the subject of the talk. Instead, the connection we shall uncover and follow is much less spectacular, more subtle, and more rewarding in the sense that it has the potential of triggering two completely independent developments with many possible applications: A theory of causal networks in space-time, and a general theory of records in continuous time and parameter space. Both are rather simple mathematically. The conventional theory of records is built on the assumption of independent events in continuous continuous parameter space and discrete time. By using continuous time one can make use of reflection symmetry [parameter \leftrightarrow time], that does not exist in the conventional formulation

and that simplifies the treatment. In the second part of the talk, concerned with causal networks applied to earth quakes, we discuss a very simple variant where we essentially neglect earth quake magnitudes - except by excluding earth quakes whose magnitude is below some threshold. In spite of this, our strategy allows at least the unambiguous and rigorous conclusion that earth quakes are not causally independent. Even this seemingly weak conclusion would be hard to obtain from other methods.

**Reinhard Lipowsky (Max Planck Institute of Colloids
and Interfaces, Potsdam-Golm, Germany)**

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Molecular Motors: Energy conversion, cargo transport, and traffic phenomena

The activity of molecular motors leads to several distinct motility regimes that will be addressed in this talk: (i) The network of motor cycles arising from the chemomechanical coupling between ATP hydrolysis and mechanical work. These networks have to satisfy balance conditions that impose constraints on the transition rates between the different motor states [1]. When applied to conventional kinesin, a detailed comparison of theory and experiment reveals that this motor is governed by three distinct chemomechanical cycles [2]; (ii) Cooperative cargo transport by several motor molecules. This process can be modelled via a network of cargo states which differ in the number of actively pulling motors. If all motors belong to the same molecular species, the cooperative action of the motors leads to a strongly increased run lengths and to a characteristic force dependence of the velocity distributions [3]. If two antagonistic species of motors pull on the cargo, they perform a tug-of-war which induces up to seven distinct patterns of bidirectional transport [4]; and (iii) Motor traffic arising from the transport of many cargo particles or filaments. These phenomena include: build-up of traffic jams; active pattern formation leading to steady states with spatially nonuniform density and current patterns; and traffic phase transitions between different steady states far from equilibrium [5]. Nonequilibrium phase transitions also occur in gliding assays in which the motors are immobilized on a substrate surface and pull many filaments across this surface [6].

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- [5] R. Lipowsky et al, Physica A 372, 34–51 (2006).
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Hernán Makse (City College of New York)

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*Statistical mechanics of jammed matter and the
nature of fruit packings*

The problem of finding the most efficient way to pack spheres has an illustrious history, dating back to the crystalline arrays conjectured by Kepler and the random geometries explored by Bernal. This problem is as much of interest to the mathematician's pencil as it is to the granular processing industry all the way to the fruit packing in every corner grocery. There are presently numerous experiments showing that the loosest way to pack spheres gives a density of ~55% (named RLP) while filling all the loose voids results in a maximum density of ~63% (named RCP). While those values seem robustly true, to this date there is no physical interpretation for them.

Here we show that random spheres in 3d cannot pack above ~63.4%. The reason for this limit arises from a statistical picture of jammed states in which the RCP can be interpreted as the ground state of the ensemble of jammed matter. The results presented lead to a phase diagram that provides a common view of the hard sphere packing problem and further shedding light on a diverse spectrum of data. Our results suggest an ensemble definition of RLP and RCP, predict their density values, and establish the concomitant equations of state relating observables such as the coordination number, entropy, and volume fraction. The nature of the disorder of the packings is statistically characterized by the entropy, which is shown to be larger in the random loose case than in the random close case. Within a statistical mechanics framework of jammed matter, this result is a natural consequence.

Hervé Marand (Virginia Tech)

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Physical aging of crystallizable polymers above the glass transition temperature

As a non-crystallizable polymeric material is cooled isobarically at a constant rate from the equilibrium rubbery state, a temperature (the glass transition temperature or T_g) is reached where the material's physical properties (volume, enthalpy, entropy, modulus, etc...) cannot maintain their equilibrium value as the temperature decreases. The material has become glassy and its physical properties are now observed to vary with the cooling rate or with the storage time below T_G . The latter process, known as physical aging, is not unique to polymers and has been observed for a variety of materials. Much of the pioneering work in the polymer area was conducted by Struik and coworkers.

Polymers, which exhibit sufficient chemical regularity to crystallize, do so incompletely, as a result of "kinetic frustration" during the phase transformation process. Hence, crystallization from the melt state results in a non-equilibrium state, known as the semicrystalline state, where a given polymer chain will partition itself between crystalline chain-folded lamellar domains and amorphous interlamellar domains. The (stacked) lamellar morphology is ubiquitous in semicrystalline polymers. The amorphous fraction in semicrystalline polymers exhibits a glass transition temperature and the associated phenomenon of physical aging. A major distinction between semicrystalline and amorphous polymers is the observation of physical aging-like processes in an often broad temperature range **above** the glass transition temperature of the amorphous fraction. Such observations were rationalized by Struik using the concept of lower and upper glass transition temperatures, associated, respectively, with a mobile amorphous fraction (away from the crystal-melt interface) and a constrained amorphous fraction (in the vicinity of the crystal-melt interface).

In this presentation, we report results of differential scanning calorimetry and atomic force microscopy studies carried out on a variety of semicrystalline polymers and show some universality in their temporal evolution above T_G . In disagreement with Struik, we suggest that the physical aging behavior is associated with a specific type of secondary crystallization. Our results also suggest the existence of an upper temperature T_{co} above which physical aging-like behavior is no longer observed and where rejuvenation takes place.

Evidence will be given to associate T_{co} with the onset of sliding diffusion within the crystal phase. When the aging temperature T is expressed on the dimensionless scale $\square = (T_{co} - T)/(T_{co} - T_G)$ defined by T_{co} and T_G , the calorimetric rate of aging becomes independent of chemical composition and structure. We speculate that for temperatures below T_{co} , secondary crystallization leads to an increase in conformational constraints in the remaining amorphous fraction. The rate at which these constraints are released (i.e. the rate at which the amorphous fraction approaches a metastable equilibrium), would then depend on the level of segmental activity within the crystal phase (i.e. on $T_{co} - T_x$). In contrast, at temperatures above T_{co} , constraints can be relieved “instantaneously” because of exceedingly fast dynamics in the crystal fraction.

This model, although outrageously speculative, provides an explanation for the observation of physical aging-like effects in semicrystalline polymers between T_G and T_{co} and rejuvenation effects at higher temperatures.

Greg McKenna (Texas Tech University)

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Aging and structural recovery in 'concentration' glasses: Comparisons with 'temperature' glasses

The behavior of glass-forming systems in the equilibrium state above the glass temperature is still a heavily investigated field. Surprisingly, the behavior of the glass itself is less widely investigated. Even less investigated is the behavior of glass-forming materials in which composition is changed. Here we look at the behavior of glasses after temperature jumps and compare that behavior with that of glasses subjected to concentration jumps. [1,2] Moisture and carbon dioxide are used as the plasticizing environments. Surprisingly, the glass created by jumping (down) to a given final condition via a change in concentration is more stable than that formed by a change in temperature—this in spite of the external condition of temperature and chemical activity (RH or carbon dioxide pressure) being the same. Furthermore, the concentration glass has a higher excess volume than the temperature glass and its response does not “merge” with that of the temperature glass, hence, the concentration glass is not the same as a temperature hyperquenched glass. We suggest that the two routes to glass formation result in inherent structures that populate the energy landscape differently.

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- [2] Y. Zheng and G.B. McKenna, *Macromolecules*, **36**, 2387-2396 (2003).

Mark A. Novotny (Mississippi State University)
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Far from equilibrium processes in magnetic nanoparticles and thin films

Magnetic materials have had technological applications, from the lodestones of antiquity to magnetic storage today, precisely because of their non-equilibrium properties such as metastability and hysteresis. First, an overview of metastability and hysteresis will be discussed, with particular attention to the additional complexity that finite-temperature effects require for the understanding of these properties in magnetic nanoparticles and magnetic thin films. Two recent investigations will then be discussed. One is the reversal mechanisms for magnetic nanopillars, in particular finite-temperature micromagnetic simulations that show that in certain parameter regimes there are both slow-mode and fast-mode escapes from the metastable state. The second is investigation of the dynamic phase transition (DPT) that occurs in thin magnetic films that have strong perpendicular anisotropy. From the theoretical side, we illustrate using finite-size scaling that the DPT has critical exponents that are the same as of the underlying $d=2$ Ising phase transition. This includes the critical isotherm exponent δ associated with the conjugate field of the associated dynamic order parameter. From the experimental side, we provide strong evidence for the observation of the DPT in $[\text{Co}(4 \text{ \AA})/\text{Pt}(7 \text{ \AA})]_3$ multilayer systems. Open questions, including the possibility of first-order DPT transitions and tricritical points, fluctuation-dissipation type relations for the DPT, and further experimental investigations of these effects in magnetic nanopillars and thin films will be discussed.

Jeff Olafsen (Baylor University)

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*Recapturing thermostistical behavior in systems
driven far from equilibrium*

Thermodynamics and statistical mechanics of equilibrium systems is one of the most beautiful successes of physics in the 20th Century, connecting both classical and quantum mechanical pictures of multi-particle systems in a coherent and complementary fashion. The current challenge in thermostistical systems is to extend our fundamental understanding to processes that occur outside of the conditions of equilibrium. In such non-equilibrium systems, fundamental assumptions such as ergodicity and the central limit theorem must be carefully re-examined before trying to extend the framework of equilibrium thermodynamics to non-equilibrium conditions. Results from several experiments (and a few simulations) of dissipative, driven non-equilibrium systems will be discussed to highlight this challenge.

Maya Paczuski (University of Calgary)

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*Complexity in living and non-living matter -
A physicist looks at life*

This talk will discuss several problems that fall into the general category of bioinformatics or, more specifically, the physics of biological information. Indeed, traditional methods of mathematical statistics are often no longer sufficient to analyze these data, and must be complemented by methods from statistical physics such as Monte Carlo simulations, statistical inference and large deviation methods, fractals, dynamical systems, scaling laws, complex networks, and others. I will discuss several algorithms and methods of analysis developed in my group recently to analyze and understand high throughput biological data. This includes the graph animal algorithm, twinness in protein interaction network, and mutual information as a robust, quantitative measure of sequence similarity.

Dragana Popovic
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Glassy dynamics of electrons near the metal-insulator transition in two dimensions

This talk will review several recent studies of the electron dynamics in the vicinity of the metal-insulator transition in two dimensions (2D). The dynamics of a 2D electron system in Si was probed in two ways: by using resistance noise spectroscopy and by investigating the relaxations of conductivity in response to a large perturbation, in particular to a change in the carrier density. The system exhibits various manifestations of glassiness, including dramatic slowing down of the dynamics, nonexponential relaxations, aging and memory. The data strongly suggest that the 2D metal-insulator transition can be described as the melting of a Coulomb (charge) glass, with the transition to a glassy phase occurring as $T \rightarrow 0$. The observed complex dynamics of the electronic transport is strikingly similar to that of a variety of glasses (e.g. structural and spin glasses) and other systems that are far from equilibrium.

Katharina Vollmayr-Lee (Bucknell University)
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Self-organized criticality below the glass transition

We study a binary Lennard-Jones mixture below the glass transition via molecular dynamics simulations. To investigate the dynamics of the system we define single particle jumps via their single particle trajectories. We present as a function of temperature the number of jumps, jumps size and waiting time between jumps. To study how the single particle jumps are correlated in time and space we identify clusters of cooperatively jumping particles [1]. We find string-like clusters whose size is power-law distributed not only close to T_c but for *all* temperatures below T_c , indicating self-organized criticality which is suggestive of a freezing in of critical behavior.

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Contributed Talks

David Adams (University of Michigan)

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Signpost method for obtaining the harmonic measure of 2D percolation clusters

The harmonic measure is the probability for a random walker to attach to an absorbing surface such as the surface of a fractal. It can also be thought of as the distribution of electric field on a charged conductor. It is of both practical and theoretical interest. In the case of Diffusion-Limited Aggregation (DLA) the harmonic measure is also the growth probability, but it is defined for any surface, for example the hull of a percolation cluster. The most interesting part of the measure is that which involves very small probabilities, e.g., deep in the fjords for DLA. In order to test scaling theories it is necessary to measure probabilities of the order of 10^{-30} . There are few numerical methods that allow an efficient computation of this quantity. Direct approaches -- simply throwing many random walkers at a surface cannot measure such small numbers. We have devised a method of enriched sampling which will allow small numbers to be measured (we can go down to 10^{-300}). Our preliminary results on percolation clusters reveal structure that is not understood in current theory. We hope to resolve controversies about the measure for DLA clusters.

Stefan Boettcher (Emory University)
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*Unjamming local search heuristics through
extremal driving*

I will introduce Extremal Optimization, a recently proposed meta-heuristic for optimization with local search. Obtained results will allow me to make a number of predictions, in particular, for low-temperature properties of spin glasses. Finally, I will demonstrated theoretically and through numerical studies how extremal optimization manages to project itself widely through complex energy landscapes to probe many low-energy states without getting jammed.

**Zhi-Feng Huang (Wayne State University) and
Ken Elder (Oakland University)**
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*Multiscale modeling of strained film epitaxy: Island
formation and dislocation nucleation*

It has been well established that a variety of nanostructures such as quantum dots and nanowires can self-assemble through the process of strained film epitaxy on predefined substrates. However, the fundamental mechanisms that control the precise morphologies remain unclear, despite recent intensive studies. In this work we focus on a new approach at the mesoscopic level, combining continuum feature and crystalline symmetry. It is based on the phase field crystal (PFC) model which incorporates fast length scale of crystalline structures and diffusive time scales, and also on the amplitude equation formalism for slowly varying film surface profile. Analytic and numerical results are presented to described the formation and evolution of strained islands, with particular attention paid to the scaling of island size. Our results are consistent with recent experiments on SiGe, but not with the predictions of classic continuum elasticity theory (or the Asaro-Tiller-Grinfeld instability). We will also discuss the nucleation and climb of misfit

dislocations at late stage of film evolution, as well as the important effects of growth temperature on film structural properties.

Hang-Hyun Jo (Korea Institute for Advanced Study)

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Relevance of abelian symmetry and stochasticity in directed sandpile models

We consider three directed sandpile models without Abelian symmetry on (1+1)-dimensional space, where the topping rule is deterministic. Based on our numerical results, we revisit the debatable issue of the universality class in directed sandpile models, and discuss the scaling properties of avalanches and the formation of a spatial structure at the self-organized critical (metastable) state with the power-law decaying grain density along the transverse direction. We argue the scaling exponents characterizing the avalanche distributions as well as the scaling relations in terms of the exponents of the underlying particle dynamics.

Gregory G. Kenning (Indiana University of Pennsylvania)

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The effects of initial conditions on physical aging in spin glasses

The measurement of dynamic response in the Spin Glass state has provided both fascinating insights into the nature of the Spin Glass phase while at the same time providing an experimental challenge which is still not fully explored or understood. One of the most interesting dynamic effects in these materials is Physical Aging which has been extensively probed with the Thermoremanent Magnetization (TRM). We have performed a series of TRM experiments with various cooling protocols over a range of temperatures within the spin glass state. The various protocols set up a variety of initial conditions as a prelude to the aging experiment. These experiments show that the initial conditions have a much greater role than previously

thought. Full Aging, an End to Aging and the role of the initial conditions are some of the insights gained. This analysis opens the way for a better understanding of the spin glass phase and aging in general, as well as potentially leading to new and interesting physics.

Rahul Kulkarni (Virginia Tech)

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*Modeling of processes governing subcellular protein localization in *E. coli**

Recent research has highlighted several examples wherein bacterial cell fate is determined by precise subcellular localization of proteins. A prominent example is the polar localization and oscillation of the Min proteins which is necessary for accurate cell division in *Escherichia coli*. Several computational models have been proposed which reproduce the oscillatory behavior and observed phenotypes. However, these models use varying assumptions to do so leading to different mechanisms for precise polar localization of MinD zones. To gain further insight, we present a simplified model which focuses on some key processes to explain the observed length scale for MinD zone formation. Using analytical approaches and numerical simulations, we explore cellular MinD distributions produced by these processes and propose a mechanism for precise polar localization of MinD.

Hyun Keun Lee (Korea Institute for Advanced Study)

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Recurrent character of biased random walk on regular lattice

We study the return-to-the-origin problem of the random walk biased to the origin on regular lattice. It is shown that the walker eventually visits the origin with probability one, i.e. becomes recurrent, irrespective of bias strength, lattice structure, and spatial dimension. For this, we decompose the lattice walk into the patched walks on spanning trees which are designed to make

the problem tractable. This decomposition method is applied to the hypercube lattice, and then we show that it is applicable to any type of regular lattice.

**Stephan A Mackowiak and Tobias K Herman
(Columbia University)**

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*Single molecule study of dynamics near the
glass transition*

We are investigating the rotational dynamics of single fluorescent molecules in supercooled liquids near the glass transition to elucidate the presumed heterogeneous dynamics in these systems. We have collected preliminary data on the behavior of rubrene, and of Nile red, in glycerol. These data show a broad range of diffusion times, demonstrating that these probes experience at least a subset of the heterogeneities in supercooled glycerol. Furthermore, a subset of molecules appear to exhibit changes in dynamics, possibly related to exchange of local environment.

Paolo Sibani (University of Southern Denmark)

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*Intermittent linear response and spontaneous
fluctuations in off-equilibrium aging dynamics*

Physical observables, e.g. energy and magnetization, undergo qualitatively different types of fluctuations during an aging process. Reversible Gaussian fluctuations of zero average characterize dynamical processes within a metastable state of the system. Rare intermittent events, possibly with non-zero average, signal a transition from one metastable configuration to another. In particular, since the linear response of aging systems has an intermittent component, the interpretation of linear response data crucially depends on the relation between spontaneous and induced fluctuations.

In the talk, I argue that the intermittent linear response of aging systems is statistically subordinated to intermittent out-bursts of energy, so called quakes, which release the internal strains of the initial configuration. The description includes general analytical expressions for the average linear response which flow from the subordination hypothesis. These expressions cover isothermal aging as well as the effect of small temperature shifts applied to the aging system.

References

1. Linear response subordination to intermittent energy release in off-equilibrium aging dynamics, Simon Christiansen and Paolo Sibani, New J. Phys. 10 No 3 (March 2008) 033013.
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Creighton Thomas (Syracuse University)

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Using patchwork dynamics to simulate glassy systems

Glassy materials have slow dynamics which prohibit direct simulation of their rich nonequilibrium behavior. We use "patchwork dynamics" to mimic relaxation over a broad range of time scales by directly equilibrating or optimizing on successive length scales.

Hill Thompson (Florida State University)

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Resolution-dependent mechanisms for bimodal switching time distributions in simulated Fe nanopillars

Numerical simulations of magnetization reversals of iron nanopillars in off-axis applied fields at different lattice resolutions reveal bimodal distributions in the switching times (first-passage times through 0 of the longitudinal magnetization, M_z). We show that the mechanisms responsible for these distributions are resolution-dependent. The highest-resolution model, in which the computational cell is smaller than the exchange length, is three-dimensional. Here, the bimodal distribution results from a reversal process in which the pillar sometimes avoids a metastable free-energy well. At medium resolution, the pillar is modeled as a 1-D stack of spins. The bimodal distribution then reflects whether the reversal starts from one or both pillar ends. Finally, for a low-resolution model in the form of a single spin with an anisotropic potential, the bimodal distribution is an artifact of the definition of a switching event: the result of the spin precessing close to $M_z=0$. While the zero- and one-dimensional models display bimodal switching-time distributions, the mechanisms are different than for the three-dimensional model. Only the latter captures the mechanism that is most interesting from an experimental and device-application point of view.

Brian Utter (James Madison University)

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Jamming in granular systems with imposed vibrations

The behavior of dense granular materials can be characterized by the continuous forming and breaking of a strong force network resisting flow. This jamming/unjamming behavior is typical of a variety of systems, including granular flows, and is influenced by factors such as grain packing fraction, applied shear stress, and the random kinetic energy of the particles. We present experiments on quasi-static shear and free-surface granular flows under the influence of external vibrations. By using photoelastic grains, we are able to measure particle trajectories and the local force network in these 2D flows. We find that during shear, sufficient shaking weakens the strong force network and reduces the amount of flow driven by sidewalls. We vibrate either the driving wall (sidewall forcing) or the entire shearing zone (bulk forcing). For sidewall forcing, flow behavior is controlled by vibration amplitude in particular and slipping of force chains at the boundary. In a rotating drum geometry, we find that small vibration leads to strengthening of the pile while larger vibrations induce failure as might be expected. Preliminary data suggests that history dependence might be important in the initial failure of the slope.

Posters

Sven Dorosz (Virginia Tech)

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Nonequilibrium relations in reaction diffusion systems

We investigate the behavior of reaction diffusion models that are driven out of their stationary state (either equilibrium state or non equilibrium stationary state) in a finite amount of time due to a time dependent reaction rate. Motivated by the Jarzynski and the Hatano-Sasa relations, we study the validity of different definitions for work and heat as well as the spontaneous creation of entropy in these systems. Our work is mainly based on numerically exact calculations for small systems and on numerical simulations for larger system sizes. An interesting question addresses the validity of the existing derivations of detailed fluctuation theorems in cases where the microscopic reversibility of the elementary transitions does not hold.

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Aging processes in reversible reaction-diffusion systems

Reversible reaction-diffusion systems display anomalous dynamics characterized by a power-law relaxation toward stationarity. In this paper we study in the aging regime the nonequilibrium dynamical properties of some model systems with reversible reactions. Starting from the exact Langevin equations describing these models, we derive expressions for two-time correlation and autoresponse functions and obtain a simple aging behavior for these quantities. The autoresponse function is thereby found to depend on the specific nature of the chosen perturbation of the system.

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Structural properties of generalized small-world networks

We explore generalized small-world networks (SWNs) in which an additional parameter (r) sets the length scale over which shortcuts are uniformly distributed. When $r=0$ we have an ordered network whereas $r=1$ corresponds to the original SWN model. We observe the small-world phenomenon for $r \ll 1$ indicating that global shortcuts are not necessary for the small-world effect. For short-range SWNs, the average path length changes non-monotonically with system size, whereas for the original SWN model it increases monotonically. We propose an expression for the average path length for short-range SWNs based on numerical simulations and analytical approximations.

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Dynamics of driven vortices in type-II superconductors in the strong point or columnar pinning centers

We investigate the nonequilibrium steady state of driven magnetic flux lines in type-II superconductors subject to strong point or columnar pinning centers. We employ a three-dimensional elastic line model and Metropolis Monte Carlo simulations. We characterize the system by means of the force-velocity / current-voltage curve, static structure factor, mean vortex gyration radius, number of double-kink and half-loop excitations, and velocity / voltage noise features. We use different annealing methods to minimize numerical artifacts originating from long-lived metastable states. We compare the results for the above quantities for randomly distributed point and columnar defects.



**Special thanks to all of the people
who made this symposium happen!**

We hope you have enjoyed your stay.