Adhesives

the force-induced cis-trans isomerization of prolines, which are repeated every fifth residue in the main chain of ELPs. We present evidence for this mechanism

combination with our analysis procedure can be used to study the subtleties of polypeptide-water interactions on the single molecule level. We also report on

length can be used to interpret the hydrophobic hydration behavior of elastin-like polypeptides (ELPs).Our results are intriguing as they suggest that SMFS in

changes in molecular architecture on molecular-elasticity of individual (bio)macromolecules. Specifically, we show how changes in the effective Kuhn segment

force-extension data obtained by single molecule force spectroscopy (SMFS). This approach allows, for the first time, to infer effects of solvent quality and minor

, STEFAN ZAUSCHER, Duke University — We present a new procedure to reduce and analyze

cryogenic to the glass transition temperature. Challenges facing characterization and the establishment of structure-property correlations will be discussed.

8:36AM A4.00002 Hydrophobic Hydration of Stimulus-Responsive Polyproteins Measured by

Single Molecule Force Spectroscopy . STEFAN ZAUSCHER, Duke University — We present a new procedure to reduce and analyze

force-extension data obtained by single molecule force spectroscopy (SMFS). This approach allows, for the first time, to infer effects of solvent quality and minor

changes in molecular architecture on molecular-elasticity of individual (bio)macromolecules. Specifically, we show how changes in the effective Kuhn segment

length can be used to interpret the hydrophobic hydration behavior of elastin-like polypeptides (ELPs).Our results are intriguing as they suggest that SMFS in

combination with our analysis procedure can be used to study the subtleties of polypeptide-water interactions on the single molecule level. We also report on

the force-induced cis-trans isomerization of prolines, which are repeated every fifth residue in the main chain of ELPs. We present evidence for this mechanism

by Monte Carlo simulations of the force-extension curves using an elastically coupled two-state system. Our results suggest that SMFS could be used to assay

proline cis-trans isomerization in proteins and may thus have significant potential diagnostic utility.

9:12AM A4.00003 Nature’s Mechanisms for Tough, Self-healing Polymers and Polymer

Adhesives1 , PAUL HANSMA, University of California — Spider silk2 and the natural polymer adhesives in abalone shells3 and bone4,5 can give

us insights into nature’s mechanisms for tough, self-healing polymers and polymer adhesives. The natural polymer adhesives in biomaterials have been

optimized by evolution. An optimized polymer adhesive has five characteristics. 1) It holds together the strong elements of the composite. 2) It yields

just before the strong elements would otherwise break. 3) It dissipates large amounts of energy as it yields. 4) It self heals after it yields. 5) It takes just

a few percent by weight. Both natural polymer adhesives and silk rely on sacrificial bonds and hidden length for toughness and self-healing.6 A relatively

large energy, of order 100eV, is required to stretch a polymer molecule after a weak bond, a sacrificial bond, breaks and liberates hidden length, which was

previously hidden, typically in a loop or folded domain, from whatever was stretching the polymer. The bond is called sacrificial if it breaks at forces well

below the forces that could otherwise break the polymer backbone, typically greater than 1nN. In many biological cases, the breaking of sacrificial bonds has

been found to be reversible, thereby also providing a “self-healing” property to the material.2-4 Individual polymer adhesive molecules based on sacrificial

bonds and hidden length can supply forces of order 300pN over distances of 100s of nanometers. Model calculations show that a few percent by weight of

adhesives based on these principles could be optimized adhesives for high performance composite materials including nanotube and graphene sheet composites.

9:48AM A4.00004 Cell micromechology in health and disease” be suitable for your session . DENIS

WIRTZ, Johns Hopkins University — No abstract available.

10:24AM A4.00005 Is experimental heteropolymer sequence design practical, or does it belong
to the realm of science fiction? , ALEXANDER GROSBERG, Physics Department University of Minnesota — In the protein folding context,
thorists consider various methods of sequence design, which turns out a very useful way to look at various heteropolymer properties. Simultaneously and largely

independently, there is a rather old idea to find an experimental counterpart of computational and theoretical sequence design algorithms. Here, we review

some of the experiments in this direction along with some of the more recent theoretical advances and come to the guarded conclusion that full experimental

realization of sequence design is possible but probably remote.
8:12AM A22.00002 Counting solutions for the CDMA multiuser MAP demodulator, JUN-ICHI INOUE, Hokkaido University, J.P.L. HATCHETT, Hymans Robertson — We evaluate the average number of locally minimal solutions for maximum-a-posteriori (MAP) demodulation in code-division multiple-access (CDMA) systems [1]. For this purpose, we use a sophisticated method to investigate the ground state properties for the Sherrington-Kirkpatrick-type (i.e., fully connected) spin glasses established by Tanaka and Edwards [2] in 1980. We derive the number of locally minimal solutions as a function of several parameters which specify the CDMA multiuser MAP demodulator. We also calculate the distribution function of the energies for the locally minimum states. We find that for a small number of chip intervals (or equivalently a large number of users) and large noise level, the number of local minimum solutions becomes larger than that of the SK model [3]. This provides us with useful information about the computational complexity of the MAP demodulator [4].


8:24AM A22.00003 A Weibull distribution with power-law tails that describes the first passage time processes of foreign currency exchanges, NAOYA SAZUKA, Sony Corporation, JUN-ICHI INOUE, Hokkaido University — A Weibull distribution with power-law tails is confirmed as a good candidate to describe the first passage time process of foreign currency exchange rates. The Lorentz curve and the corresponding Gini coefficient for a Weibull distribution are derived analytically. We show that the coefficient is in good agreement with the same quantity calculated from the empirical data. We also calculate the average waiting time which is an important measure to estimate the time for customers to wait until the next price change after they login to their computer systems. By assuming that the first passage time distribution might change its shape from the Weibull to the power-law at some critical time, we evaluate the averaged waiting time by means of the renewal-reward theorem. We find that our correction of tails of the distribution makes the averaged waiting time much closer to the value obtained from empirical data analysis. We also discuss the deviation from the estimated average waiting time by deriving the waiting time distribution directly. These results make us conclude that the first passage process of the foreign currency exchange rates is well described by a Weibull distribution with power-law tails.

8:36AM A22.00004 A new perspective on Quantum Finance using the Black-Scholes pricing model, LAMINE DIENG, Rutgers University — Options are known to be divided into two types, the first type is called a call option and the second type is called a put option and these options are offered to stock holders in order to hedge their positions against risky fluctuations of the stock price. It is important to mention that due to fluctuations of the stock price, options can be found sometimes deep in the money, at the money and out of the money. A deep in the money option is described when the option’s holder has a positive expected payoff, at the money option is when the option’s holder has a zero expected payoff and an out of the money option is when the payoff is negative. In this work, we will assume the stock price to be described by the well known Black-Scholes model or sometimes called the multiplicative model. Using Ito calculus, Martingale and supermartingale theories, we investigated the Black-Scholes pricing equation at the money (\(X(\text{stock price}) = K \) (strike price)) when the expected payoff of the options holder is zero. We also hedged the Black-Scholes pricing equation in the limit when delta is zero to obtain the non-relativistic time independent Schroedinger equation in quantum mechanics. We compared the two equations and found the diffusion constant to be a function of the stock price in contrast to the Bachelier model we have worked on earlier. We solved the Schroedinger equation and found a dependence between interest rate, volatility and strike price at the money.

8:48AM A22.00005 Evolution of Trading strategies, JAVIER VICENTE, Universidad Carlos III Madrid, Spain and Santa Fe Institute, N.M., USA — We attempt to classify the trading strategies of agents in the London Stock Exchange into broad categories. Our study is based on that that identifies the member of the exchange associated with each transaction. Based on the evolution of the inventory (holdings of the stock) as a function of time, we use clustering methods to classify the strategies into several groups. We study how these groups evolve in time and attempt to correlate the membership of the groups with other market properties, such as price volatility.

9:00AM A22.00006 The Product Space and its Consequences for Economic Growth, CESAR HIDALGO, CCNR and Dept. of Physics, University of Notre Dame, BAILEY KLINGER, CID, Kennedy School of Government, Harvard University, ALBERT-LASZLO BARABASI, CCNR and Dept. of Physics, University of Notre Dame, RICARDO HAUSMANN, CID, Kennedy School of Government, Harvard University — In this paper, we test the assumption underlying the foundational models of trade that there always exist products through which countries can express their endowments and technology. We map the ‘space’ of products in the world, and find it to be quite heterogeneous, with a central core and outer periphery. Moreover, we show that the way countries develop comparative advantage is far from random, and that the empirical rules observed here predict, together with the structure of the product space, explain the lack of convergence in international income levels. Some developing countries produce in the periphery of the product space with few opportunities for diversification, whereas others have developed capabilities easily deployable in a wide range of products creating a path to convergence.

1 We acknowledge funding from the NetWork Bench NSF (IIS-0513650) and the Kellogg Institute

9:12AM A22.00007 Stochastic volatility of financial markets as the fluctuating rate of trading: an empirical study, CHRISTIAN SILVA, Eqa Inc., VICTOR YAKOVENKO, University of Maryland — We present an empirical study of the subordination hypothesis for a stochastic time series of a stock price. The fluctuating rate of trading is identified with the stochastic variance of the stock price, as in the continuous-time random walk (CTRW) framework. The probability distribution of the stock price changes (log-returns) for a given number of trades \( N \) is found to be approximately Gaussian. The probability distribution of \( N \) for a given time interval \( \Delta t \) is non-Poissonian and has an exponential tail for large \( N \) and a sharp cutoff for small \( N \). Combining these two distributions produces a nontrivial distribution of log-returns for a given time interval \( \Delta t \), which has exponential tails and a Gaussian central part, in agreement with empirical observations.

Reference: physics/0608299.
9:24AM A22.0008 Using behavioral statistical physics to understand supply and demand1, DOYNE FARMER, Santa Fe Institute — We construct a quantitative theory for a proxy for supply and demand curves using methods that look and feel a lot like physics. Neoclassical economics postulates that supply and demand curves can be explained as the result of rational agents selfishly maximizing their utility, but this approach has had very limited empirical success. We take quite a different approach, building supply and demand curves out of impulsive responses to not-quite-random trading fluctuations. Because of reasons of empirical measurability, as a good proxy for changes in supply and demand we study the aggregate price impact function \( R(V) \), giving the average logarithmic price change \( R \) as a function of the signed trading volume \( V \). (If a trade \( v_i \) is initiated by a buyer, it has a plus sign, and vice versa for sellers; the signed trading volume for a series of \( N \) successive trades is \( V_N(t) = \sum_{i=t}^{t+N} v_i \).) We develop a “zero-intelligence” null hypothesis that each trade \( v_i \) gives an impulsive kick \( f(v_i) \) to the price, so that the average return \( R_i(t) = \sum_{i=t}^{t+N} f(v_i) \). Under the assumption that \( v_i \) is IID, \( R(V_N) \) has a characteristic concave shape, becoming linear in the limit as \( N \to \infty \). Under some circumstances this is universal for large \( N \), in the sense that it is independent of the functional form of \( f \). While this null hypothesis gives useful qualitative intuition, to make it quantitatively correct, one must add two additional elements: (1) The signs of \( v_i \) are a long-memory process and (2) the return \( R \) is efficient, in the sense that it is not possible to make profits with a linear prediction of the signs of \( v_i \). Using data from the London Stock Exchange we demonstrate that this theory works well, predicting both the magnitude and shape of \( R(V_N) \). We show that the fluctuations in \( R \) are very large and for some purposes more important than the average behavior. A computer model for the fluctuations suggests the existence of an equation of state relating the diffusion rate of prices to the flow of trading orders.

1In collaboration with Austin Gerig and Fabrizio Lillo. Work supported by Barclays Bank.

10:00AM A22.0009 Modelling Limit Order Execution Times from Market Data , ADLAR KIM, Massachusetts Institute of Technology, MA / Santa Fe Institute, NM, DOYNE FARMER, Santa Fe Institute, NM, ANDREW LO, Massachusetts Institute of Technology — Although the term “liquidity” is widely used in finance literature, its meaning is very loosely defined and there is no quantitative measure for it. Generally, “liquidity” means an ability to quickly trade stocks without causing a significant impact on the stock price. From this definition, we identified two facets of liquidity – 1 execution time of limit orders, and 2 price impact of market orders. The limit order is an order to transact a prespecified number of shares at a prespecified price, which will not cause an immediate execution. On the other hand, the market order is an order to transact a prespecified number of shares at a market price, which will cause an immediate execution, but are subject to price impact. Therefore, when the stock is liquid, market participants will experience quick limit order executions and small market order impacts. As a first step to understand market liquidity, we studied the facet of liquidity related to limit order executions – execution times. In this talk, we propose a novel approach of modeling limit order execution times and show how they are affected by size and price of orders. We used q-Weibull distribution, which is a generalized form of Weibull distribution that can control the fatness of tail to model limit order execution times.

10:12AM A22.0010 The Influence of Signed Order Volume on Stock Prices , AUSTIN GERIG, University of Illinois at Urbana-Champaign, DOYNE FARMER, Santa Fe Institute, FABRIZIO LILLO, Unità di Palermo, SZABOLCS MIKE, Budapest University of Technology and Economics. Using data from the London Stock Exchange we investigate the influence of signed transaction order volume on current and future price changes. (Buy orders are given a positive sign, sell orders a negative sign). Empirical studies have shown that transaction order signs display long memory. Because buying tends to move the price up and selling tends to move the price down, this creates a puzzle regarding efficiency – if transaction order signs are highly predictable, why aren’t prices predictable? We show that efficiency is maintained by correlated fluctuations in the response of prices to orders. We also study whether or not this is an important effect causing clustered volatility in price changes, i.e. the tendency of the magnitude of price changes to be temporally correlated.

10:24AM A22.0011 Is clustered volatility essential to understand heavy tails in financial markets? , ANUJ PURWAR, Santa Fe Institute and Los Alamos National Laboratory, J. DOYNE FARMER, Santa Fe Institute — Heavy tails are observed in the returns of stocks even for transaction by transaction data. We study the tail exponents and quantiles of the heavy tails for stock returns: first for transaction by transaction data, second after aggregating over \( n \) transactions. In order to separate out the effect of clustered volatility, we repeat our analysis after shuffling the transaction sequence and look for variation in tail exponents and quantiles for shuffled vs. original (unshuffled) data.

10:36AM A22.0012 Persistent Patterns in Trading Firms’ Actions , NEDA ZAMANI, University of Sydney, Australia / Santa Fe Institute, N.M., USA, J. DOYNE FARMER, Santa Fe Institute, N.M., USA — To understand the dynamics of price formation in financial markets, we take the approach of investigating the actions of market participants. We examine the impact of the participating firms on the price and find that different firms have different patterns of impact. Each firm can be representative of many traders with different trading habits and strategies but nevertheless we observe statistically significant differences in the firms’ market impacts. We also investigate a method of clustering the firms based on a simplified conception of strategies. We find consistent clusters and patterns in firm strategies and show that these relations are statistically significant.

10:48AM A22.0013 Universality of Tail Exponents of Price Changes? , LUWEN HUANG, DOYNE FARMER, Santa Fe Institute — We study the tail exponents of the distribution of logarithmic price changes in financial markets, and investigate the conjecture that they are universal with an exponent near three. Using data from the London Stock Exchange, we construct the empirical distributions of price returns on several different time scales and study their variation as a function of parameters such as trading volume and tick size (the minimal unit of price variation).

Monday, March 5, 2007 11:15AM - 2:15PM
Session B6 GSNP DPOLY: Control and Architecture in Directed Macromolecular Self-Assembly
Colorado Convention Center 207

11:15AM B6.00001 Geometry and universality in self-assembly1, MARK BOWICK, Syracuse University — I will discuss the use of ideas from geometry and topology in combination with the statistical mechanics of self-assembly to classify the possible types of mesoatoms that can constitute a library of raw materials for making mesomolecules and bulk materials. I will concentrate on mesoatoms made up of an ordered two-dimensional monolayer of particles on the surface of a liquid droplet. Both the shape and the topology of the two-dimensional surface can be varied as well as the architecture of the ordering particles. The topology of the surface and the symmetries of the two-dimensional order severely restrict the possible defect structure of the mesoatom, which in turn fixes its valency. Defective regions are natural places for biological activity, chemical linking, unusual elastic response and aggregation of disorder. Specific examples include crystalline and hexatic order of point particles on the sphere, paraboloid, torus and Gaussian bump, nematic order of nematogens on the sphere and torus, and vector order of polar units on the sphere. The Gaussian curvature of the underlying surface may also lead to new features in the ground state, such as extended defect arrays of various kinds and curvature-driven defect unbinding, all of which may be exploited via engineered or spontaneous self-assembly.

1Work supported by NSF grant ITR-DMR-0219292
11:51AM B6.00002 Colloidal atoms and molecules¹. DAVID PINE, Center for Soft Matter Research, Department of Physics, New York University, 4 Washington Place, New York, NY 10003 — We describe two new types of colloidal particles that greatly expand the kinds of colloids and nanoparticles that are available for self-assembly. The first type, called colloidal molecules, consists of clusters of microspheres and/or nanospheres that take on well-defined geometries such as dumbbells, triangles, tetrahedra, octahedral, etc. With these, we explore new two and three-dimensional phases, including dumbbells at a planar interface, and three-dimensional assemblies of tetrahedra. The second type, called colloidal atoms, consists of nearly spherical particles with a specific number of symmetrically-placed patches on their surface. These patches have symmetries similar to the colloidal molecules described above. The patches can be functionalized with single-stranded DNA that interacts specifically with complementary strands on other particles forming a network or crystal of colloidal particles.

¹Various aspects of this work involve collaborations with V. N. Manoharan, M. T. Elsesser, D. R. Breed, Xiaochao Xu, P. V. Schwartz, G. R. Yi, Y. S. Cho, and S. M. Yang.

12:27PM B6.00003 Colloidal Armor. HOWARD STONE, DEAS, Harvard University — Assembly of colloidal particles on fluid-fluid interfaces is a promising technique for synthesizing two-dimensional structured materials. We describe a microfluidic method that allows direct visualization and understanding of the dynamics of the growth of colloidal crystals on a curved interface. We show how this approach allows control over composition and size of the colloidal armor, including making janus shells. The two-dimensional granular shells have mechanical properties similar to other elastic-plastic materials. These features will be described and the influence of surfactants on the shells will be presented. Finally, gas bubbles covered with colloidal particles show unusual stability against gas dissolution, and we will explore this stability using experiments and numerical simulations.

1:03PM B6.00004 Recent Advances in Solution-state Assembly of Synthetic Polymers into Well-defined Nanostructures. KAREN WOOLEY, Washington University — The solution-state assembly of synthetic amphiphilic block copolymers has emerged as a powerful tool to conveniently and rapidly afford discrete, well-defined nanoscale materials for study and application to advance nanoscience and nanotechnology. One of the key challenges has been to identify the appropriate polymer components and conditions to control the assembly mechanisms and produce complex materials of uniform size, narrow size distribution and having interesting morphologies. In addition, developing systems that are capable of undergoing assembly directly from aqueous solution and also those that contain complex internal phase segregated domains (i.e., multicompartment micelles) are significant interests. This presentation will provide an update on our work to control the micelle morphologies and will describe recent di- and tri-block copolymer designs that allow for pH-triggered self assembly into amphiphilic core-shell micelles, without the use of organic solvents. Moreover, the aqueous solution-state assembly of novel amphiphilic hyperbranched copolymers will be discussed.

1:39PM B6.00005 Non-ionic micelles and encapsulation. PASCHALIS ALEXANDRIDIS, University at Buffalo - The State University of New York — The development of self-assembly as a useful approach to the synthesis and manufacturing of complex systems and materials is a central theme in our research. Amphiphilic block copolymers of the poly(ethylene oxide)-poly(propylene oxide) (PEO-PPO) family (commercially available as Poloxamers) are well-known for self-assembling into (core-shell spherical) micelles and (cubic, hexagonal, and lamellar) lyotropic liquid crystals in water. We are interested on how the aqueous phase behavior and structure of these non-ionic polymeric amphiphiles can be modulated by the addition of organic solvents or solutes. Our studies (i) probe the amphiphile organization in both micellar solutions and lyotropic liquid crystals, (ii) combine macroscopic observations (e.g., concentration-temperature micellization phase boundaries, ternary isothermal amphiphile-water-cosolvent phase diagrams) with microscopic measurements (from small-angle neutron and X-ray scattering), and (iii) aim to relate the type of structure formed and its properties to the relative swelling of the polymer blocks and to the location of the solvent/solute in the amphiphile assembly. These studies address the following practical questions: What are the “right” components and conditions for self-assembly? What if the conditions are no longer “right”? How can we “help” self-assembly? Modulation of structure-property relationships in amphiphile-containing media is central to formulation of pharmaceutics and personal care products.

Monday, March 5, 2007 11:15AM - 2:15PM —
Session B22 GSNP: Systems Far from Equilibrium Colorado Convention Center 108

11:15AM B22.00001 Aging in disordered magnets and local scale-invariance¹. MICHEL PLEIMLING, Department of Physics, Virginia Tech, MALTE HENKEL, Universite Henri Poincare Nancy I, France — The aging of the bond-disordered two-dimensional Ising model quenched to below its critical point is studied through the two-time autocorrelator and thermoremanent magnetization (TRM). The corresponding aging exponents are determined. The form of the scaling function of the TRM is well described by the theory of local scale-invariance.

¹Supported by the Deutsche Forschungsgemeinschaft (grant no. PL 323/2).

11:27AM B22.00002 Minimal Modeling of Driven Dissipative Systems. YAIR SHOKEF, Department of Physics & Astronomy, University of Pennsylvania, Philadelphia, PA, USA, DOV LEVINE, Department of Physics, Technion, Haifa, Israel — By simple modeling of dissipative interactions we resolve fundamental questions related to systems far from thermal equilibrium, such as granular materials, foams and colloidal suspensions. We solve the non-Boltzmann energy distribution, demonstrate the violation of time-dependent fluctuation-dissipation relations, show that different measures of effective temperatures generally differ, and address further issues such as ergodicity breaking and detailed balance violation.

11:39AM B22.00003 Work Distributions far from Equilibrium in Quantum Spin Chains¹. SVEN DORORSZ, Virginia Polytechnic Institute and State University — We are investigating the non equilibrium steady state for different quantum spin chains by an exact numerical calculation. The systems, initially in a canonical state, are driven out of equilibrium by a periodic external force which couples to each site. Motivated by the Jarzynski relation and the fluctuation theorem for quantum systems we analyze in detail the probability distribution P(W). Both finite and infinite temperatures are discussed. General properties independent of the nature of the interaction are identified and we observe two dynamic regimes in the limit of small and large frequencies. The intermediate regime is characterized by resonance peaks in the distribution. The moments of the distribution can be exploited to discuss the possible definitions of a Jarzynski-operator for quantum systems.

¹in cooperation with University Henri Poincare Nancy I
11:51AM B22.00004 Conjugate Field and Fluctuation-Dissipation Relation for the Dynamic Phase Transition in the Two-dimensional Kinetic Ising Model, D.T. ROBB, Clarkson University, P.A. RIKVOLD, Florida State University, A. BERGER, Hitachi Global Storage Technologies, M.A. NOVOTNY, Mississippi State University — The two-dimensional kinetic Ising model, when exposed to an oscillating magnetic field with zero time-average, has been shown to exhibit a nonequilibrium, second-order dynamic phase transition (DPT), whose order parameter \( Q \) is the period-averaged magnetization. It has been established that this DPT falls in the same universality class as the equilibrium phase transition in the two-dimensional Ising model in zero applied field. Here we apply a square-wave field with (for the first time) a non-zero period-averaged magnetic field, \( H_s \), and study the scaling of the dynamic order parameter with respect to \( H_s \). We find evidence that the field scaling exponent, \( \Delta_H \), at the critical period of the DPT is equal to the exponent for the critical isotherm, \( \Delta_c \), in the equilibrium Ising model. A finite-size scaling analysis of the dynamic order parameter in the critical region provides further support for this result. We also demonstrate numerically that a fluctuation-dissipation relation (FDR), with an effective temperature \( T_{eff} \) depending on the period, and possibly the temperature and field amplitude, holds for the dynamic order parameter and its conjugate field. This FDR justifies our use of the scaled variance of \( Q \) as a proxy for the nonequilibrium susceptibility, \( \partial \langle Q \rangle / \partial H_s \).

12:03PM B22.00005 A possible classification of nonequilibrium steady states.1, ROYCE K.P. ZIA, BEATE SCHMITTANN, Virginia Tech — We propose a general classification of nonequilibrium steady states in terms of their stationary probability distribution and the associated probability currents. The stationary probabilities can be represented graph-theoretically as directed Cayley trees; closing a single loop in such a graph leads to a representation of probability currents. This classification allows us to identify all choices of transition rates, based on a master equation, which generate the same nonequilibrium steady state. We explore the implications of this freedom, e.g., for entropy production, and provide a number of examples.

1Supported by NSF DMR-0414122

12:15PM B22.00006 Noise induced chaos in optically driven colloidal rings. YAELE ROICHMAN, GEORGE ZASLAVSKY, DAVID G. GRIER, New York University — Given a constant flux of energy, many driven dissipative systems rapidly organize themselves into configurations that support steady state motion. Examples include swarming of bacterial colonies, convection in shaken sandpiles, and synchronization in flowing traffic. How simple objects interacting in simple ways self-organize generally is not understood, mainly because so few of the available experimental systems afford the necessary access to their microscopic degrees of freedom. This talk introduces a new class of model driven dissipative systems typified by three colloidal spheres circulating around a ring-like optical trap known as an optical vortex. By controlling the interplay between hydrodynamic interactions and fixed disorder we are able to drive a transition from a previously predicted periodic steady state to fully developed chaos. In addition, by tracking both microscopic trajectories and macroscopic collective fluctuations the relation between the onset of microscopic weak chaos and the evolution of space-time self-similarity in macroscopic transport properties is revealed. In a broader scope, several optical vortices can be coupled to create a large dissipative system where each building block has internal degrees of freedom. In such systems the little understood dynamics of processes like frustration and jamming, fluctuation-dissipation relations and the propagation of collective motion can be tracked macroscopically.

12:27PM B22.00007 Fluctuation-dissipation relations in driven dissipative systems, GUY BUNIN, Technion, YAIR SHOKEF, University of Pennsylvania, DOV LEVINE, Technion — Exact theoretical results for the violation of time dependent fluctuation-dissipation relations in driven dissipative systems are presented. The ratio of correlation to delayed response in the stochastic model introduced in [Phys. Rev. Lett. 93, 240601 (2004)] is shown to depend on measurement time. The fluctuation temperature defined by this ratio differs both from the temperature of the environment performing the driving, and from other effective temperatures of the system, such as the average energy (or “granular temperature”). General explanations are given for the time independence of fluctuation temperature for simple measurements or long measurement times.

12:39PM B22.00008 Time Correlations on the Ziff-Gulari-Barshad Model with Random Defects, C.S. DIAS, A. CADILHE, GCEP-Centro de Fisica da Universidade do Minho, 4710-057 Braga, Portugal — We studied a generalized version of the Ziff, Gulari, and Barshad model (1986), i.e., of the \( A + B \rightarrow A \) reaction, in order to accommodate the presence of a given fraction of inert sites present on the substrate. Specifically, we show their impact on the kinetics of the catalysis, particularly on the time correlation of the reactants distribution on the surface, to monitor the evolution, in time, of a list of reactants of both species. We also characterize the reactant cluster structure in the presence of impurities by resorting to the Hosen-Kopelman algorithm. We have found two different regimes of the time correlation, namely, an initial exponential decay at short times, and a second regime given by a stretched exponential decay at late times of the number of surviving particles.

12:51PM B22.00009 Renormalization Group Treatment of the Trapping Reaction, JACK HANSON, Rutgers University, SCOTT MCISAAC, Rice University, BENJAMIN VOLLMAYR-LEE, Bucknell University — We consider the trapping reaction \( A + B \rightarrow A \), with diffusing traps (A), and particles (B), where the traps additionally undergo either an annihilation \( (A + A \rightarrow \emptyset) \) or coalescence \( (A + A \rightarrow A) \) reaction. This two-species reaction-diffusion system exhibits asymptotic power law decays in both the trap and particle densities, and simple scaling in the trap-trap (\( A+A \)) and particle-trap (\( AB \)) correlation functions. However, simulations indicate the induced particle-particle correlations scale as \( C_{BB}(x,t) = t^{\phi} f(x/t^{1/2}) \) with an anomalous dimension \( \phi \) [B.P. V-L and R.C. Rhoades]. We perform a one-loop renormalization group calculation of this exponent for \( d < 2 \) — which involves 59 diagrams — and demonstrate that the anomalous dimension is universal and is due to a renormalization of the initial particle density. Our results are compared to the simulation data.

1:03PM B22.00010 Comparing Extremal and Hysteric Optimization in Spin Glasses1, BRUNO GONCALVES, STEFAN BOETTCHER, Emory University — We compare the capabilities of the \( HC \) and the \( EC \) heuristic in finding spin glass ground states. Using a one-parameter model recently discussed by Katzgraber and Young that interpolates between the mean-field, infinite-dimensional SK spin glass and the finite-dimensional EA lattice spin glass, we evaluate the heuristics as a function of that parameter. Our results show interesting variations in algorithmic behavior that elucidates their properties. It may also indicate a transition in the physics between high and low-dimensional spin glasses.

1This work has been supported by grant 0312510 from the Division of Materials Research at the National Science Foundation.

2PRL 89, 150201

3PRL 86, 5211

4PRB 67, 134410
1:15PM B22.00011 Shock-induced crystalline instabilities. RAMON RAVELO, University of Texas-El Paso, BRAD LEE HOLIAN, TIMOTHY C. GERMANN, Los Alamos National Laboratory — Uniaxial deformations of single crystals such as those produced under planar shock loading can produce structural instabilities which compete with defect nucleation mechanisms. In fcc single crystals under (110) shock loading, the resulting body-centered orthorhombic crystal structure develops a long-wavelength dynamical instability associated with tetragonal shear distortions, which occurs at lower strains (pressures) than those predicted by the vanishing of the elastic constants at finite pressure (stiffness coefficients). The criterion for these instabilities is derived and verified by equilibrium and non-equilibrium molecular dynamics simulations.

1:27PM B22.00012 Hydrodynamic solutions of spatially-varying 1D exclusion processes. GREG LAKATOS, Harvard University, TOM CHOU, UCLA — We analyze the open boundary partially asymmetric exclusion process with smoothly varying internal hopping rates in the infinite-size, mean field limit. The mean field equations for particle densities are written in terms of Ricatti equations with the steady-state current $J$ as a parameter. These equations are solved both analytically and numerically. Upon imposing the boundary conditions set by the injection and extraction rates, the currents $J$ are found self-consistently. We find a number of cases where analytic solutions can be found exactly or approximated. Results for $J$ from asymptotic analyses for slowly varying hopping rates agree extremely well with those from extensive Monte Carlo simulations, suggesting that mean field currents are exact as long as the hopping rates vary slowly over the lattice. If the forward hopping rate is greater than or less than the backward hopping rate throughout the entire chain, the three standard steady-state phases are preserved. Our analysis reveals the sensitivity of the current to the relative phase between the forward and backward hopping rate functions.

1:39PM B22.00013 Off-Lattice 3D Eden Cluster Growth Model. ERIC KUENNEK. University of Wisconsin Oshkosh — The Eden model for 2D clusters is understood to be in a large universality class of models and phenomena which have 1D surfaces with growth dynamics as predicted by the KPZ equation. However, the growth behavior of 3D Eden clusters, and that of the KPZ equation for 2D surfaces, is less well understood and a matter of some controversy. Determining which growth phenomena belong to the KPZ universality class in 3D is an important unsolved problem in statistical physics. Previous studies of the Eden model in 3D have all used an underlying lattice and grew clusters vertically from a flat substrate. Since Eden clusters grown on a lattice exhibit significant anisotropies, and in many natural phenomena growth occurs radially from a seed, in this paper, I propose a 3D Eden model for off-lattice clusters grown radially from a seed. With large-scale computer simulations, I investigate the kinetic roughening of the surface by estimating the surface-width growth exponent, in order to determine whether 3D Eden growth indeed belongs to the KPZ universality class. Noise-reduction techniques are used, and for validation the model is applied to a flat substrate geometry, which makes it possible to estimate the roughness exponent as well.

1:51PM B22.00014 Nucleation and growth of islands during submonolayer deposition on Ag/Ag(100). NUNO ARAUJO, ANTONIO CADILHE, GCEP - Centro de Fisica - Universidade do Minho — The growth of multilayer thin films is strongly influenced by the formation of the first layer. We introduce a kinetic Monte Carlo model to study the nucleation and growth of the first layer in the regime of high values of the incoming flux. We simulate the deposition of Ag adatoms on the Ag(100) substrate at a temperature of 200 K for values of the incident flux of particles ranging between 0.01 ML/s and 1.00 ML/s. To characterize the nucleation process we studied the dependence of the mean island density during growth and the island size distribution on the incident flux of particles. Varying the flux of incident adatoms allows us to tune the relevance of the different elemental processes taking place during the deposition stage. In the limit of high fluxes, we show that scaling functions do not match and the island size distribution function does not have a maximum value coincidental with the mean island size.

2:03PM B22.00015 Surface Growth Modeling of Load Balancing in Parallel Discrete Event Simulations (PDES). POONAM VERMA, MARK NOVOTNY, Mississippi State University — We study a non-equilibrium surface growth model of load balancing for conservative Parallel Discrete Event Simulations (PDES) [Korniss et al., Science 299, 677 (2003); Guclu et al., Phys. Rev. E 73, 066115 (2006)]. Load balancing improves the performance of the parallel simulations by distributing the work load over all processors evenly. These models for static load balancing are in the Kardar-Parisi-Zhang (KPZ) universality class, with the KPZ process often mixed with a Random Deposition (RD) process [Kolakowska et al., Phys. Rev. E 73, 011603 (2006)]. We study how the utilization and the desynchronization behave when the load changes randomly during the simulation. We compare the static and dynamic load balancing results for the models of PDES. The underlying framework proposed in [L. N. Shchur and M. A. Novotny Phys. Rev. E 70, 026703 (2004)], is that the Local Simulated time (LST) is associated with the nodes and not with the processing elements.

Monday, March 5, 2007 2:30PM - 5:30PM –
Session D22 GSNP DMP: Focus Session: Fracture Colorado Convention Center 108

2:30PM D22.00001 Failure of heterogeneous materials: Scaling properties of fracture surfaces and implications on models of cracks in disordered media. DANIEL BONAMY, Groupe Fracture DMS/DRECAM/SPCSI CEA Saclay — While there exists a unified theoretical framework - Linear Elastic Fracture Mechanics (LEFM) - to describe the failure of homogeneous materials, understanding and modelling the mechanical properties of heterogeneous media continue to raise significant fundamental challenges. These mechanical properties, observed at the macroscopic scale, result from microscopic processes occurring at the scale of the material. To include these local processes into a statistical description constitutes then a crucial step toward the setup of predictive macroscopic models. Crack surface roughness is a consequence of these local processes. Consequently, many fractography experiments have focussed on their analysis. In this context, it was recently evidenced that, in many materials, fracture surfaces exhibit anisotropic scaling properties reminiscent to interface growth problems, fully characterized by two couples of parameters: The roughness exponents and the characteristic length-scales measured along and perpendicular to the direction of crack growth respectively. While the characteristic length-scales do depend on the considered material, the exponents are surprisingly universal: Two distinct sets of critical exponents are observed whether the surfaces are examined at scales below or above the size of the damaged zone at the crack front. Models of crack growth in disordered media are discussed at the light of these experimental observations. In particular, one can derive a model from LEFM which describe the development of crack roughness as an “elastic” manifold creeping in a random media. This approach captures quantitatively the experimental observations performed at length-scales above the size of the process zone. In this approach, the onset of crack propagation can be interpreted as a dynamic phase transition while sub-critical crack growth can be assimilated to thermally-assisted depinning.

1: Membership Pending

3Supported by NSF grant DMR-0426488

1:27PM B22.00011 Shock-induced crystalline instabilities. RAMON RAVELO, University of Texas-El Paso, BRAD LEE HOLIAN, TIMOTHY C. GERMANN, Los Alamos National Laboratory — Uniaxial deformations of single crystals such as those produced under planar shock loading can produce structural instabilities which compete with defect nucleation mechanisms. In fcc single crystals under (110) shock loading, the resulting body-centered orthorhombic crystal structure develops a long-wavelength dynamical instability associated with tetragonal shear distortions, which occurs at lower strains (pressures) than those predicted by the vanishing of the elastic constants at finite pressure (stiffness coefficients). The criterion for these instabilities is derived and verified by equilibrium and non-equilibrium molecular dynamics simulations.

3:06PM D22.00002 Low self-affine exponents of fractured glass ceramics surfaces, LAURENT PONSON, Federal University of Rio de Janeiro, HAROLD AURADOU, FAST-Universite Paris-Sud, DANIEL BONAMY, ELISABETH BOUCHAUD. SPCSI-Commissariat à l’Energie Atomique, JEAN-PIERRE HULIN, FAST- Universite Paris-Sud, FRACTURE GROUP TEAM, MELANGE ET MILIEUX DISPERSES TEAM — The morphology of fracture surfaces encodes the various complex damage and fracture processes occurring at the microstructure scale during crack propagation. It is now well established that fracture surfaces are self-affine characterized by a roughness exponent usually found close to \( \zeta \approx 0.75 \) for a wide range of materials. Recently, fracture surfaces of sandstone were found to be also self-affine but with a lower roughness exponent \( \zeta \approx 0.4-0.5 \). To investigate its origin, we studied fracture surfaces of glassy ceramics which are obtained by sintering glass beads. Such a material mimics the structure of sandstone with the advantage that their porosity may be tuned. They are also found to be self-affine, characterized by a roughness exponent \( \zeta \approx 0.40 \pm 0.04 \) significantly lower than the “universal” roughness exponent \( \zeta \approx 0.75 \) widely reported in the literature. Its value is found to depend very slightly on the crack growth velocity and the microstructure (grain diameter, porosity) in the range studied. This suggests the existence of a second universality class in failure problems. Its physical origin is then discussed and a model proposed.

3:18PM D22.00003 Rapid and slow self-affine fracture in glass, MOISES HINOJOSA, FIME-UANL, CLAUDIA GUERRA, DSM/DRECAM/SPCSI, France, LEONARDO CHAVEZ, EDGAR REYES-MELO, VIRGILIO GONZALEZ, FIME-UANL, PROGRAMA DOCTORAL EN INGENIERIA DE MATERIALES, FIME-UANL, MEXICO. TEAM — We discuss the self-affine properties of the fracture surfaces of soda-lime glass obtained in conditions of both rapid and slow fracture in bending. The fracture surfaces were studied by SEM and AFM. The analysis of the mirror and mist-hackle zones for the two conditions suggest the existence of two well defined self-affine regimes governed by universal or attractor values. At low-speed/line-scales the roughness exponent \( \zeta \approx 0.5 \). \( \zeta \) dominates whereas the value \( \zeta \approx 0.8 \) is recovered for high-speed/large scales regimes. These values are subjected to significant deviations that give rise to a possible transitional regime at intermediate scales and speeds, where both attractor values may coexist, particularly in the case of slow fracture. In this context the transitional regime can thus be regarded as the result of the competition of these attractors at intermediate scales and velocities.

3:30PM D22.00004 Roughness Exponent Measurements for the Central Force Model, JAN Ø. H. BAKKE, ALEX HANSEN, Department of Physics, NTNU, Trondheim, Norway — We study the roughness properties of fracture profiles from the two-dimensional central force lattice model for a wide range of disorders. The intrinsic and the extrinsic roughness exponent have been measured together with the step size distribution \( p(\Delta h) \) and the height difference distribution \( p(\Delta h, l) \). We find that the profiles are self-affine for systems with narrow disorders and that broader disorders introduces overhangs in the fracture surface leading to deviation from self-affinity for small length scales and to non-trivial finite size scaling.

3:42PM D22.00005 Local waiting time fluctuations along a randomly pinned crack front, STEPHANE SANTUCCI, KNUT JORGEN MALOY, RENAUD TOUSSAINT, JEAN SCHMITTBULH, University of Oslo — The propagation of an interfacial crack along a heterogeneous weak plane of a transparent Plexiglas block is followed using a high resolution fast camera. We show that the fracture front dynamics is governed by local and irregular avalanches with very large size and velocity fluctuations. We characterize the intermittent dynamics observed, i.e. the local pinnings and depinnings of the crack front which trigger a rich burst activity, by measuring the local waiting time fluctuations along the crack front during its propagation. The local front line velocity distribution deduced from the waiting time analysis exhibits a power law behavior, \( P(v) \propto v^{-\gamma} \) with \( \gamma = 2.55 \pm 0.15 \), for velocities \( v \) larger than the average front speed \( \langle v \rangle \). The burst size distribution is also a power law, \( P(S) \propto S^{-\gamma} \) with \( \gamma = 1.7 \pm 0.1 \). Above a characteristic length scale of disorder \( L_d \sim 20 \mu m \), the avalanche clusters become anisotropic, and the scaling of the anisotropy ratio provides an estimate of a local roughness exponent, \( H = 0.6 \).

3:54PM D22.00006 A Dissipative Particle Dynamics Model of Fracture, DA GAO, PAUL MEAKIN, Center for Advanced Modeling and Simulation, Idaho National Laboratory, Idaho Falls, ID 83415 — The role of thermal fluctuations and dissipative physical processes in fracture initiation and propagation has not been systematically studied due to the absence of appropriate simulation models. In order to investigate this issue, we have developed a dissipative particle dynamics (DPD) model, in which the elastic interactions between adjacent nodes in a two-dimensional spring network model are supplemented by dissipative interactions and random forces related through the fluctuation-dissipation theorem. With this newly developed model, we have simulated two different scenarios: One is self-initiated spontaneous fracturing and the other is externally forced fracturing. Our preliminary results show that the fluctuating and dissipative forces have an important influence on the propagation mode, and propagation path. Both qualitative analysis and quantitative results will be presented and discussed.

4:06PM D22.00007 Sub-critical crack growth in a sheet of paper, L. VANEL, S. SANTUCCI, N. MALLICK, P.-P. CORTET, S.G. ROUX, S. CILIBERTO, Laboratoire de Physique, ENS Lyon, France — We present experiments on the slow growth of a single crack in a fast paper sheet submitted to a constant force \( F \). The non-averaged crack growth curves present a stepwise growth dynamics. Modelling the material as a lattice where the crack is pinned by elastic traps and grows due to thermal noise, we find that, in agreement with experiments, the distribution of step sizes follows a power law (exponent 3/2) and a stress-dependent exponential cutoff diverging at the critical rupture threshold [1]. Taking into account the microstructure of cellulose fibers, the model is able to reproduce the shape of the statistically averaged crack growth curves, the dependence of the characteristic growth length on \( F \) as well as the effect of the average front speed on the rupture time. Finally, roughness of the crack interface is shown to depend on whether the crack grows in the subcritical regime, or in the rapid regime, over the critical rupture threshold. We analyze this roughness difference using a new approach based on the cumulants of the statistical distribution of the crack front height variations.


4:18PM D22.00008 Stability and roughness of crack paths in 2D heterogeneous brittle materials, EYTAN KATZAV, MOHKTAR ADDA-BEDIA, BERNARD DERRIDA, LPS - Ecole Normale Superieure, Paris — We present a recent study on the stability of propagating cracks in heterogeneous two-dimensional brittle materials and on the roughness of the surfaces created by this irreversible process. We introduce a stochastic model describing the propagation of the crack tip based on an elastostatic description of crack growth in the framework of linear elastic fracture mechanics. The model recovers the stability of straight cracks and allows for the study of the roughening of fracture surfaces. We show that in a certain limit, the problem becomes exactly solvable and yields analytic predictions for the power spectrum of the paths. This result suggests a surprising alternative to the conventional power law analysis often used in the analysis of experimental data and thus calls for a revised interpretation of the experimental results.
5:06PM D22.00012 Mechanisms for Fragment Formation in Brittle Solids, ARTEM LEVANDOVSKY, ANNA BALAZS, University of Pittsburgh — The fracture process is usually analyzed in terms the fractal dimension of a crack, the crack surface roughness, or fragment size distributions. It is established that relatively simple scaling laws exist for the crack surface roughness in mode I fracture and for the power law distribution for fragment sizes in fracture by impact. These two types of fracture are usually studied separately. Consequently, much less is known about the relationship between crack roughness and fragment size distribution. In this work, we study this relationship by developing a simple model of mode I fracture, which nevertheless produces sufficiently rich behavior in terms of crack roughness and fragment formation. Using this model, we show that different roughness in local regions of the crack path leads to different mechanisms for the subsequent fracture of those regions. We observe two robust power laws for the size distribution of smaller and larger fragments. We connect measurements in fragment size distribution with the local fractal dimension of cracks in the region of fragment formation.

5:18PM D22.00013 Competition between Diffusion and Fragmentation: Evolution of polycrystalline materials under stress, JOACHIM MATHIESEN, Physics of Geological Processes, University of Oslo, Norway, JESPER FERKINGHOFF-BORG, MOGENS H. JENSEN, Niels Bohr Institute, Copenhagen, Denmark, POUL OLESEN — We propose a dynamical model for the grain fragmentation process, which is based on the competition of the common physical processes diffusion and fragmentation. Specifically, we formulate a rate equation in terms of the distribution $N(x, t)$ of grains or crystallites of linear size $x$ at time $t$. The grains either grow by boundary diffusion or shrink by deformation and subsequent fragmentation. The equation leads to a third order differential equation which we solve exactly in terms of Bessel functions. The stationary state is a universal Bessel distribution described by one parameter. Our model perfectly fits experimental data on grain evolution in polycrystalline materials. The model is based on the examination of side surfaces of fracture mechanics specimens, at the point where the crack intersects the free surface. Such measurements were carried out with an atomic force microscope, which demonstrated finite depressions in the regions around and in front of crack tips in silicate glasses. The height profile around crack tips supposedly differed from that obtained from a simple linear elastic fracture mechanics analysis; while, in front of the crack tip small depressions were observed which were interpreted as cavities. We used a three-dimensional finite element analysis to show that the calculated depression around the crack tip is in excellent agreement with that obtained by atomic force microscopy. In addition, we used AFM measurements on the fracture surfaces themselves to demonstrate the absence of the kind of residual damage that should be present on fracture surfaces if cavitation occurred at crack tips in glass. Our results are proof that cracks in glass propagate by brittle fracture; glass is elastic and bond snapping is the dominant feature of crack growth.

5:42PM D22.00010 Do Plastic Zones form at Crack Tips in Silicate Glasses?, STEPHANIE DESCHANEL, GERARD VIGIER, NATHALIE GODIN, GEMPPM, INSA Lyon, France, LOIC VANEL, SERGIO CILIBERTO, Laboratoire de Physique, ENS Lyon, France — For some heterogeneous materials fracture can be described as a clustering of microcracks: global rupture being not controlled by a single event. We focus on polycrystalline foams whose heterogeneities (pores) constitute the starting points where microcracks can stop. We record both the spatial and time distributions of acoustic emission emitted by a sample during mechanical tests: each microcrack nucleation corresponds to a burst of energy that can be localized on the widest face of the specimen. The probability distributions of the energy released is power-law distributed, independently of the material density, the loading mode or the mechanical behavior. On the other hand, the agreement of a power law for the time intervals between two damaging events seems to require a quasi constant strain during damaging. Moreover, we notice a behavior difference of the cumulative number of events and the cumulative energy of the localized events with temperature in the case of tensile tests and not any more for creep tests. The occurrence of a unique behavior and a power law in a restricted time interval for the cumulative number of events and the cumulative energy in creep allow us to apprehend interesting later studies of materials’ lifetime prediction.

4:54PM D22.00011 Fragmentation in brittle rods, NICOLAS VANDENBERGHE, ROMAIN VERMOREL, EMMANUEL VILLERMAUX1, IRPHE, Aix-Marseille Université — When a rod made of brittle material is axially impacted it breaks into fragments of various sizes. Before the first breaking event, an axial compression wave propagates along the rod, triggering a buckling instability. The instability selects a transverse mode with a well defined wavelength. Recently, Gladden et al. have shown that the fragment size distribution exhibits two peaks corresponding to the length selected by the buckling instability. In the present work we explore in more details the dynamics of elastic waves in the rod and the different phenomena that may explain the broad distribution of fragment sizes. In particular, we will discuss the coupling between the longitudinal and the transverse displacement in the post buckling dynamics.

4:30PM D22.00009 Statistical properties of microcracking in polyurethane foams under tensile and creep tests: influence of temperature and density, STEPHANIE DESCHANEL, GERARD VIGIER, NATHALIE GODIN, GEMPPM, INSA Lyon, France, LOIC VANEL, SERGIO CILIBERTO, Laboratoire de Physique, ENS Lyon, France — For some heterogeneous materials fracture can be described as a clustering of microcracks: global rupture being not controlled by a single event. We focus on polycrystalline foams whose heterogeneities (pores) constitute the starting points where microcracks can stop. We record both the spatial and time distributions of acoustic emission emitted by a sample during mechanical tests: each microcrack nucleation corresponds to a burst of energy that can be localized on the widest face of the specimen. The probability distributions of the energy released is power-law distributed, independently of the material density, the loading mode or the mechanical behavior. On the other hand, the agreement of a power law for the time intervals between two damaging events seems to require a quasi constant strain during damaging. Moreover, we notice a behavior difference of the cumulative number of events and the cumulative energy of the localized events with temperature in the case of tensile tests and not any more for creep tests. The occurrence of a unique behavior and a power law in a restricted time interval for the cumulative number of events and the cumulative energy in creep allow us to apprehend interesting later studies of materials’ lifetime prediction.

We will mention about an explicit form of this star product. Our formula has the following merits.


The simplest model for interacting anyons in one dimension is closely related to the Fibonacci topological quantum field theory. The Hamiltonian favors neighboring anyons to fuse into the trivial channel, similar to the quantum Heisenberg spin chain favoring neighboring spins to form spin singlets. Numerical simulations show that the model is critical with a dynamical critical exponent z=1. It is described by a conformal field theory with central charge c=7/10. An exact solution of each system are independent of the interaction parameter, and a system with discrete degrees of freedom (i.e. the p-state clock model) behaves (from the point of view of all thermodynamic observables) exactly as if these degrees of freedom were continuous (i.e. the planar rotor or XY model). To the best of our knowledge there is only one comparable case where a similar sharp switchover between a discrete and a continuum description of a system is observed: this is in the area of telecommunications; digital signal processing, and information theory: the Nyquist-Shannon sampling theorem [2]. In this talk we will give an interpretation of the extended universality in terms of the Nyquist-Shannon sampling theorem. [1] Universality away from critical points in two-dimensional phase transitions, C.M. Lapilli, P. Pfeifer, and C. Wexler, Phys. Rev. Lett. 96, 140603 (2006). [2] H. Nyquist, Trans. AIEE 47, 617 (1928); [3] C.E. Shannon, Proc. Inst. of Radio Engineers 37, 10 (1949).

10:00AM H22.00011 Interacting anyons in one dimension: The Fibonacci chain, ANDREAS LUDWIG, UC Santa Barbara, ADRIAN FEIGUIN, SIMON TRESTB, Microsoft Research, Station Q, MATTHIAS TROYER, ETH Zurich, ALEXEI KITAENV, ZHENGHAN WANG, MICHAEL FREEDMAN, Microsoft Research, Station Q — We discuss generalizations of quantum spin chains using anyonic degrees of freedom. The simplest model for interacting anyons in one dimension is closely related to the Fibonacci topological quantum field theory. The Hamiltonian favors neighboring anyons to fuse into the trivial channel, similar to the quantum Heisenberg spin chain favoring neighboring spins to form spin singlets. Numerical simulations show that the model is critical with a dynamical critical exponent $z=1$. It is described by a conformal field theory with central charge $c=7/10$. An exact solution of each system are independent of the interaction parameter, and a system with discrete degrees of freedom (i.e. the p-state clock model) behaves (from the point of view of all thermodynamic observables) exactly as if these degrees of freedom were continuous (i.e. the planar rotor or XY model). To the best of our knowledge there is only one comparable case where a similar sharp switchover between a discrete and a continuum description of a system is observed: this is in the area of telecommunications; digital signal processing, and information theory: the Nyquist-Shannon sampling theorem [2]. In this talk we will give an interpretation of the extended universality in terms of the Nyquist-Shannon sampling theorem. [1] Universality away from critical points in two-dimensional phase transitions, C.M. Lapilli, P. Pfeifer, and C. Wexler, Phys. Rev. Lett. 96, 140603 (2006). [2] H. Nyquist, Trans. AIEE 47, 617 (1928); [3] C.E. Shannon, Proc. Inst. of Radio Engineers 37, 10 (1949).

10:12AM H22.00012 Zeros of the dispersion relation of the elementary excitation and the correlation length of strongly correlated quantum systems, YUICHI NAKAMURA, Dept. of Phys, the Univ. of Tokyo — We argue that the imaginary part of a zero of the dispersion relation of the elementary excitation of quantum systems is equal to the inverse correlation length. We confirm the relation for the Hubbard model[1] in the half-filled case; it has been confirmed only for the S=1/2 antiferromagnetic XXZ chain[2]. In order to search zeros of the dispersion relation in the complex momentum space efficiently, we introduce a non-Hermitian generalization of quantum systems by adding an imaginary vector potential $i\mathbf{g}$ to the momentum operator[3]. We also show for the half-filled Hubbard model the reason why the non-Hermitian critical point[4] is equal to the inverse correlation length[5] by noting the dispersion relation of the charge excitation.

10:24AM H22.00013 Gauge covariant Keldysh formulation of Wigner representation through deformational quantization, NAOYUKI SUGIMOTO, Department of Applied Physics, University of Tokyo, SHIGEKI ONODA, NAO TO NAGAOSA, CREST, Department of Applied Physics, University of Tokyo — Non-linear responses such as nonlinear optical effects are of great current interests from the fundamental physics and application viewpoints. Therefore a microscopic quantum theory for these non-linear processes in non-equilibrium state is called for. The extension of the Kubo formula or the Keldysh formula to the nonlinear response preserving gauge-covariance is not straightforward. We developed a gauge-covariant Keldysh formulation with a general electromagnetic field[1]. Such a formulation is realized by replacing the Moyal product in the Wigner space by the star product which is given by deformational quantization. We derived the explicit form of this star product. Our formula has the following merits. (1) The star product facilitates an order-by-order calculation of an observable in terms of the electromagnetic field. (2) The gauge-invariance of the formula is clearly seen, contrary to the usual situation for any abelian gauge theory by the usual Wigner space. We will mention about an application of this method to Zener tunneling problem in the presence of dissipation. [1] N. Sugimoto, S. Onoda and N. Nagaosa, cond-mat/0611142.
Combining the density matrix renormalization group and truncated spectrum approach for two-dimensional strongly correlated systems, YURY ADAMOV, Texas A&M University, ROBERT KONIK, Brookhaven National Laboratory — We propose a combined numerical and analytical approach to two-dimensional strongly correlated systems which are representable as arrays of one-dimensional exactly solvable systems. In our approach the exact solution provides us a compact representation of one-dimensional subsystems that makes it numerically feasible to treat the interactions between subsystems using a DMRG algorithm. This compact representation comes about through a simple truncation of the spectrum. To illustrate our approach, we consider an array of interacting quantum Ising chains. The results are then compared with an analytical RPA treatment of the same system.

Tuesday, March 6, 2007 11:15AM - 2:15PM –
Session J2 DCP DCOMP GSNP: Prize Session (DCP, DCOMP, GSNP) Colorado Convention Center
Four Seasons 4

11:15AM J2.00001 Frontiers of Surface Science. Structure, Bonding and Dynamics on the Nanoscale at High Pressures and at the Buried (solid-liquid and solid-solid) Interfaces, GABOR A. SOMORJAI, Department of Chemistry and Lawrence Berkeley National Laboratory, University of California, Berkeley — Model surfaces from single crystals to monodispersed nanoparticles are investigated at high pressures and at liquid interfaces by sum frequency generation (SFG) vibrational spectroscopy and high pressure scanning tunneling microscopy. The phenomena discovered by surface studies at low pressures in the past, adsorbate-induced restructuring, the chemical activity of surface defects, surface mobility of adsorbates and coadsorption-induced ordering are detected at high pressures as well. Newly discovered surface phenomena include the low melting point of nanoparticles, the coadsorption of water and hydrogen at polymer and metal surfaces, respectively, and hot electron flow during exothermic processes across oxide-metal interfaces (nanodiodes). Applications of surface science expanded into nanosciences, catalysis, tribology, polymers, biointerfaces, microelectronics, energy conversion and environmental chemistry will be discussed.

11:51AM J2.00002 Aneesur Rahman Prize Talk, DAAN FRENKEL, FOM Institute for Atomic and Molecular Physics — During the past decade there has been a unique synergy between theory, experiment and simulation in Soft Matter Physics. In colloid science, computer simulations that started out as studies of highly simplified model systems, have acquired direct experimental relevance because experimental realizations of these simple models can now be synthesized. Whilst many numerical predictions concerning the phase behavior of colloidal systems have been vindicated by experiments, the jury is still out on others. In my talk I will discuss some of the recent technical developments, new findings and open questions in computational soft-matter science.

12:27PM J2.00003 Conformation-specific spectroscopy and dynamics in the complexity gap, TIMOTHY ZWIER, Purdue University — Studies of the spectroscopy and conformational isomerization dynamics of flexible molecules typically fall into one of two size regimes. (i) small-molecule studies in which the molecule possesses two minima and a single barrier (e.g., cis-trans isomerization about a double bond) or (ii) large macromolecules for which it is impossible to describe the potential energy surface in exhaustive detail (e.g., protein folding). Between them is a ‘complexity gap’ of considerable proportions. This talk will describe our group’s contributions to studies of molecules that are in that complexity gap in the sense that they have potential energy surfaces containing tens to hundreds of minima, and many times that number of transition states. By employing double resonance laser spectroscopy of isolated molecules cooled in a supersonic expansion, it is possible to obtain the ultraviolet and infrared spectral signatures of the individual conformational isomers of these molecules free from interference from others present in the sample. This foundation of spectroscopic data also serves as the basis for conformation-specific studies of the dynamics of conformational isomerization. In these studies, either infrared excitation or stimulated emission pumping (SEP) is used to excite a single conformation with a well-defined internal energy, thereby initiating conformational isomerization. By re-cooling the products prior to interrogation downstream, the energy thresholds for isomerization between individual X→Y reactant-product pairs can be determined. Several examples from our recent work will be given to illustrate the kinds of insight that can be drawn from these studies regarding the conformational preferences, spectral signatures, barrier heights and relative energies of minima, fractional abundances, isomerization pathways, and internal energy flow accompanying isomerization.

1Supported by the National Science Foundation and the Department of Energy Basic Energy Sciences.

1:03PM J2.00004 Nicholson Medal - Award Talk, SHLOMO HAVLIN, Bar Ilan University — No abstract available.

1:39PM J2.00005 Nicholas Metropolis Award Talk: Quasi-static Modeling of Plasma and Laser Wakefield Acceleration, CHENGKUN HUANG, UCLA — Plasma wakefields driven by intense ultrashort charged particle or laser beams can sustain acceleration gradients three orders of magnitude larger than conventional RF accelerators. These wakefields are promising for accelerating charged particles in short distances for applications such as an energy booster of a linear collider and as a ultra-compact accelerator. In the Plasma Wakefield Accelerator (PWFA) or Laser Wakefield Accelerator (LWFA), the space charge force of an electron beam or the ponderomotive force of a laser beam expels plasma electrons away from its path, forming a bubble-like structure where the longitudinal electric field inside of it provides accelerating and the transverse Lorentz force provides focusing forces on electrons. Recently, quasi-monoenergetic beams from self-trapped plasma electrons in wakefields driven by intense laser beam have been observed in experiments in many laboratories around the world, and a PWFA experiment performed at Stanford Linear Accelerator Center (SLAC) successfully demonstrated that the energy of particles at the tail of the driving electron can be doubled from ~40 GeV to ~80 GeV in just 80 cm. However, to fully understand these experiments requires a particle-based computer model because the interaction between the plasma and the driver is highly nonlinear. We have developed a highly efficient, fully parallelized, fully relativistic, three dimensional particle-in-cell code, QuickPIC, for simulating plasma wakefield acceleration. The model is based on what is called the quasi-static or frozen field approximation, which assumes that the driver does not evolve during the time it takes for it to pass a plasma particle and reduces a fully three-dimensional electromagnetic field calculation and particle push into a two-dimensional electrostatic field solve and particle push. This algorithm reduces the computational time by at least 2 to 3 orders of magnitude. Comparison with a fully explicit PIC model (OSIRIS) shows excellent agreement for problems of interest. QuickPIC simulations of the SLAC PWFA experiment have revealed important physics and achieved good agreement with experiment measurement. Theoretical analysis of the stability of acceleration can now be guided and verified by QuickPIC simulations.

1Work supported by DOE

Tuesday, March 6, 2007 11:15AM - 1:51PM –
Session J22 GSNP DFD: Focus Session: Collective Dynamics of Self-Driven Particles Colorado Convention Center 108
11:15AM J22.00001 From cell extracts to fish schools to granular layers: the universal hydrodynamics of self-driven systems1, SRIRAM RAMASWAMY, Centre for Condensed Matter Theory, Department of Physics, Indian Institute of Science, Bangalore 560 012 India — Collections of self-driven or “active” particles are now recognised as a distinct kind of nonequilibrium matter, and an understanding of their phases, hydrodynamics, mechanical response, and correlations is a vital and rapidly developing part of the statistical physics of soft-matter systems far from equilibrium. My talk will review our recent results, from theory, simulation and experiment, on order, fluctuations, and flow instabilities in collections of active particles, in suspension or on a solid surface. Our work, which began by adapting theories of flocking to include the hydrodynamics of the ambient fluid, provides the theoretical framework for understanding active matter in all its diversity: contractile filaments in cell extracts, crawling or dividing cells, collectively swimming bacteria, fish schools, and agitated monolayers of orientable granular particles.

1Support: DST (through the CCMT) and IFCPAR Project 3504-2.

11:51AM J22.00002 Simulations of Interacting Magnetic Micro-swimmers, ERIC KEAVENY, MARTIN MAXEY, Division of Applied Mathematics, Brown University — Following a recent realization of artificial micro-swimming (Dreyfus et. al., Nature, 437, 862-865), we conduct simulations of a swimmer whose mechanism of propulsion is the magnetically driven undulation of a flagellum-like tail composed of chemically linked paramagnetic beads. In our model, the tail is treated as a series of spheres tied together by inextensible, bendable links. The spheres interact magnetically through mutual dipole interactions, and hydrodynamic interactions are achieved by the force-coupling method. Building on our previous results, we examine the interactions between multiple swimmers employing a flagellum beating strategy as well as those using a rotary propulsion scheme. In addition to swimmer-swimmer interactions, the effects of a nearby surface on the behavior of a micro-swimmer will be discussed.

12:03PM J22.00003 Response and Fluctuations in an Active Bacterial Suspension, ANDY W.C. LAU, Florida Atlantic University, DANIEL T. CHEN, ARJUN G. YODH, TOM C. LUBENSKY, UPenn — An active bacterial bath consists of a population of rod-like motile or self-propelled bacteria suspended in a fluid environment. In this talk, we present a two-fluid model for the dynamics of a bacterial bath, and show, in particular, that the non-equilibrium contribution to the stress arising from the swimming of the bacteria and the non-equilibrium couplings between the alignment tensor and bacterial density, lead to i) a \(1/\sqrt{\omega}\) scaling in the power spectrum of the active stress fluctuations, and ii) anomalous density fluctuations in the bacteria themselves. These predictions are observed in a recent experiment.

12:15PM J22.00004 Collective dynamics of concentrated swimming micro-organisms1, JOHN O. KESSLER, Physics Dept, University of Arizona, Tucson, Az 85721, LUIS CISNEROS, Physics, Univ. of AZ, RAYMOND E. GOLDSTEIN, DAMTP, University of Cambridge, UK, CHRISTOPHER DOMBROWSKI, Physics, Univ. of AZ — Approximately close packed populations of the cylindrical self-propelled bacteria Bacillus subtilis intermittently form domains of aligned, co-directionally swimming organisms. The velocities of these phalanxes are often “high” compared to the speed of individual swimmers. They vary with the depth of the suspension of organisms. Although the Reynolds number is < 1, this collective dynamic phase, the “Zooming BioNematic” (ZBN), appears turbulent. Remarkable spatial and temporal correlations of velocity and vorticity, associated with the spontaneous appearance and decay of these surging phalanxes, were measured using appropriately modified Particle Imaging Velocimetry (PIV). These new data, together with measurements of the trajectories of individual cells, provide ingredients for a rational bio-fluid-dynamical theory of the ZBN.

1Work supported by DOE W31-109-ENG38 & NSF PHY 0517142

12:27PM J22.00005 Large scale flows and density fluctuation in ensembles of swimming bacteria1, ANDREY SOKOLOV, IGOR ARONSON, Argonne Natl Lab, JOHN KESSLER COLLABORATION, RAYMOND GOLDSTEIN COLLABORATION, RAYMOND GOLDSTEIN, DAMTP, University of Cambridge, UK, CHRISTOPHER DOMBROWSKI, Physics, Univ. of AZ — We study experimentally self-organization of concentrated ensembles of swimming bacteria Bacillus Subtilis. Experiments are performed in a very thin (of the order of 1 bacteria diameter) fluid film spanned between four supporting fibers. Small amplitude electric field is used to adjust dynamically the density of bacteria inside the experimental cell. Our experiments revealed only gradual increase of the large scale flow correlation length with the increase in number density of bacteria, and no sharp transition. The fluctuation of density of bacteria as a function of thickness of the film was explored.

1This work was supported by U. S. DOE grants DE-AC02-06CH11357 (IA) and DE-FG02-04ER46135

12:39PM J22.00006 Chemotaxis and Target Finding using Chemical Echolocation1, TOM CHOU, Department of Biomathematics and Mathematics, University of California, Los Angeles, AJAY GOPINATHAN, School of Natural Sciences, University of California, Merced — Chemotaxis is usually modeled by cellular responses to an imposed, exogenous chemoattractant gradient. Here, we consider a scenario in which a single agent releases a chemical that diffuses and is converted to, or signals the production of another chemical upon contact with a target. This secondary chemical can diffuse back to the agent, which uses it as a chemotacticant. We show that this mechanism has interesting features depending on how the probe chemical is produced, and how the product chemotacticant is sensed. Although involving more steps than conventional chemotaxis that relies on a single chemotacticant, we show that this chemical “pinging” mechanism can provide cells with flexibility in regulating behavior and finding different targets.

1Supported by the NSF and NIH.

12:51PM J22.00007 Dynamics of Gas-Fluidized Bipolar Rods, L. DANIELS, D. DURIAN, U. Penn — We study a driven, non-equilibrium two-dimensional system consisting of bipolar rods in a gas-fluidized bed. The rods have an aspect ratio of 4 and occupy an area fraction of 42%, chosen both to minimize the effects of ordering as well as to ensure a uniform density of particles across the system. We are able to track the position and orientation of the particles as a function of time. From this, we measure the dynamics of the system with the advantage that our temporal resolution allows us to observe ballistic motion at the shortest time scales. We calculate the mean squared displacement (MSD) in both the lab frame and the particle’s frame in which displacements are measured as either perpendicular or parallel to the rod’s long axis. In contrast to a comparable system of isotropic particles in which the dynamics are thermal, our system exhibits distinctly athermal behavior. Specifically, the effective temperature along the parallel direction is greater than that along the perpendicular direction. Furthermore, the parallel MSD remains superdiffusive at the longest time scales we are able to measure before the particles have reached the wall whereas the perpendicular component experiences cross-over to diffusive motion. This is emphasized by the power law decay of the velocity autocorrelation function (VAF). In comparison to a thermal fluid, the parallel VAF decays much more slowly whereas the perpendicular VAF decays more rapidly. With these characteristics in mind, ours is a simple experimental system that could be used to compare to biological models of active particles as well as to generalize the framework of statistical mechanics to non-equilibrium, athermal systems.
The force impulse exerted on the target during the collision and relate it to the granular ripples formed on the thin ejected granular sheet. [1] C. Clanet, J. Fluid

The results can all be explained by a stopping force consisting of the sum of two terms: an inertial drag, proportional to velocity squared and independent

As a result, traffic jams emerge in the stationary density profiles, their location can be controlled by the particle fluxes at the boundaries. We obtain analytical results on the shape of the density profiles as well as resulting phase diagrams by a mean-field approximation and a continuum limit. [1] T. Reichenbach, T. Franosch, E. Frey, Phys. Rev. Lett. 97, 050603 (2006)

Tuesday, March 6, 2007 11:15AM - 2:15PM —
Session J29 DFD GSNP: Focus Session: Granular Flows I Colorado Convention Center 303

11:15AM J29.00001 Lateral stripe state in rapid granular flow on an inclined plane, ROBERT ECKE, Los Alamos National Laboratory, TAMAS BORZSONYI, Hungarian Academy of Sciences — Recently longitudinal vortices were reported in a rapid, dilute flow of sand down a rough inclined plane [1]. We present experimental results, showing that a robust stripe state develops at moderate plane inclinations in denser flows, with a structure substantially different from the one observed in dilute flows. We characterize this new type of stripes by measuring velocity profiles, height profiles, light transmission, and average density of the flow. As opposed to the stripes observed in the dilute regime, here the fast moving region corresponds to the maximum of the height profile. The stripe state is detected in the flow of various materials such as sand of different sizes, glass beads of different sizes, and copper particles of various shapes. We show that by increasing plane inclination we get back the dilute regime and the previously reported stripe structure. For sand particles with the diameter of d=0.4 mm the flow properties were extensively measured at six downstream locations. For this case we find an explicit correspondence between the accelerating nature of the flow and the formation of stripes in the dense regime.


11:27AM J29.00002 Universality of granular impact dynamics, HIROAKI KATSURAGI, DOUGLAS DURIAN, University of Pennsylvania — We dropped projectiles into granular media from various heights, and measured the dynamics by an optical method with 100 nanometer and 20 microsecond resolution. Data were obtained for 11 different projectiles (including cylinder as well as spheres) and 4 different granular media. The results can all be explained by a stopping force consisting of the sum of two terms: an inertial drag, proportional to velocity squared and independent of depth, and a frictional drag, proportional to depth and independent of speed. The latter scales as the square-root of projectile density and hence is not simply Coulomb friction. We also demonstrate that this stopping force law can explain seemingly-contradictory penetration and dynamics data reported by other researchers.

11:39AM J29.00003 The Liquid Nature of a Granular Jet Hitting a Fixed Target, XIANG CHENG, GERMAN VARAS, DANIEL CITRON, HEINRICH JAEGGER, SIDNEY NAGEL, James Franck Institute and Department of Physics, University of Chicago — We perform the granular analog to the ‘water bell’ experiment [1]. A column of dry spherical glass beads is accelerated by pressurized air through a glass tube to form a high-speed granular jet. When this jet collides with a stationary target disc, we observe the formation of granular sheets and cones enveloping the target similar to those seen when water jets hit a target and subsequently form water balls. The opening angle of the cones is measured as a function of the speed and diameter of the initial granular column and the diameter of the target disc. Under these conditions, dry granular material behaves similarly to a fluid with zero surface tension, i.e., a fluid with infinite Weber number. By decreasing the flux and increasing the size of the granular particles, we observe that the structure formed by the jet becomes more diffuse and the dynamics changes as the particulate nature of the material becomes more apparent. Furthermore, we measure the force impulse exerted on the target during the collision and relate it to the granular ripples formed on the thin ejected granular sheet. [1] C. Clanet, J. Fluid Mech. 430, 111 (2001).
11:51 AM J29.00004 Rapid Granular Flows: From Kinetic Theory to Hydrodynamics. V. KUMARAN, Indian Institute of Science — Rapid granular flows are defined as flows in which the time scales for the particle interactions are small compared to the inverse of the strain rate, so that the particle interactions can be treated as instantaneous collisions. We first show, using Discrete Element simulations, that even very dense fluids of sand or glass beads with volume fraction between 0.5 and 0.6 are rapid granular flows. Since collisions are instantaneous, a kinetic theory approach for the constitutive relations is most appropriate. We present kinetic theory results for different microscopic models for particle interaction. The significant difference between granular flows and normal fluids is that energy conservation is not conserved in a granular flow. The differences in the hydrodynamic modes caused by the non-conserved nature of energy are discussed. Going beyond Boltzmann's equation, the effect of correlations is studied using the ring kinetic approximation, and it is shown that the divergences in the viscometric coefficients are present for elastic fluids, and are not present for granular flows because energy conservation is not conserved. The hydrodynamic model is applied to the flow down an inclined plane. Since energy is not a conserved variable, the hydrodynamic fields in the bulk of a granular flow are obtained from the mass and momentum conservation equations alone. Energy becomes a relevant variable only in the boundary layers at the boundaries of the flow where there is a balance between the rates of conduction and dissipation. We show that such a hydrodynamic model can predict the salient features of a chute flow, including the flow initiation when the angle of inclination is increased above the 'friction angle', the striking lack of observable variation of the volume fraction with height, the observation of a steady flow only for certain restitution coefficients, and the density variations in the boundary layers.

12:27 PM J29.00005 Kinetic theory of hydrodynamic response functions for a dense granular fluid. JAMES DUFFY, Department of Physics, University of Florida, APARNA BASKARAN, Physics Department, Syracuse University, JAVIER BREY, Fisica Teorica, Universidad de Sevilla, Sevilla, Spain — The general response functions characterizing the response of a homogeneous isolated granular fluid to small spatial perturbations in the hydrodynamic fields have been described recently [1]. These response functions are time correlation functions for the Homogeneous Cooling State. Special cases of this class of time correlation functions are the Green - Kubo expressions for the hydrodynamic transport coefficients. In this work, these functions are expressed in terms of reduced single particle functions that are expected to obey a linear kinetic equation. The functional assumption required to obtain such a kinetic equation and its relationship to the well studied Boltzmann and Enskog kinetic theories of a granular fluid are illustrated in the particular context of the shear viscosity of this fluid. [1] J. W. Duffy, A. Baskaran and J. J. Brey, J. Stat. Mech. 08002 (2006).

12:39 PM J29.00006 Velocity correlations in dense granular flows observed with internal imaging. ARSHAD KUDROLLI, ASHISH ORPE, Clark University — We measure the velocity fluctuations in uniform dense granular flows inside a silo using a fluorescent refractive index matched interstitial fluid. The measurements are made in the uniform plug flow region where the flow is dominated by grains in enduring contacts and fluctuations scale with the distance traveled, independent of flow rate. The distributions of the horizontal and vertical displacements are computed. The measurements show fat tails compared to a Gaussian indicating large fluctuations in particle displacements and possible cage breaking. The mean square displacements show an inflection point supporting the presence of caging dynamics. The velocity autocorrelation function of the grains in the bulk shows a negative correlation at short time and slow oscillatory decay to zero similar to simple dense liquids. Weak spatial velocity correlations are observed in the bulk over several grain diameters. The observed correlations are qualitatively different at the boundaries where significant structural ordering in the flowing granular layer is observed.

1 Supported by the National Science Foundation under grant number CTS-0334587, and by the donors of the Petroleum Research Fund.

12:51 PM J29.00007 Lubrication forces in dense granular flow with interstitial fluid: A simulation study with Discrete Element Method. OLEH BARAN, DENIZ ERTAS, THOMAS HALSEY, FUPING ZHOU, ExxonMobil Research and Eng. — Using three-dimensional molecular dynamics simulations, we study steady gravity-driven flows of frictional inelastic spheres of diameter $d$ and density $\rho_p$ down an incline, interacting through two-body lubrication forces in addition to granular contact forces. Scaling arguments suggest that, in 3D, these forces constitute the dominant perturbation of an interstitial fluid for small Reynolds number $Re$ and low fluid density $\rho_f$. Two important parameters that characterize the strength of the lubrication forces are fluid viscosity and grain roughness. We observe that incline flows with lubrication forces exhibit a packing density that increases with decreasing distance from the surface. As the incline angle is increased, this results in a severely dilated basal layer that looks like 'hydroplaning' similar to that observed in geological subaqueous debris flows. This is surprising since the model explicitly disallows any buildup of fluid pressure in the base of the flow, and suggests that hydroplaning might have other contributing factors besides this traditional explanation. The local packing density is still determined by the dimensionless strain rate $\dot{\gamma} \equiv \frac{1}{d} \sqrt{\frac{\rho_p}{\rho_f}}$, where $\rho_f$ is the average normal stress, obeying a "dilatancy law" similar to dry granular flows.

1:03 PM J29.00008 Geometrical Mechanism for Solid-Fluid transition in a Granular system. ROHIT INGALE, MARK SHATTUCK, Levich Institute, CCNY — We report an experimental investigation of the geometrical mechanism for solid-fluid transition in a quasi-two dimensional granular system. We demonstrate the presence of geometrical structures resembling plane tilings composed of squares and equilateral triangles in our quasi-2D granular fluid. We further show that this tiling structure manifests itself in unique features in the bond-length and bond-angle distribution functions. These experimental observations coupled with a number of previously reported theoretical and simulation studies strongly support the proposed square-triangle tiling mechanism for 2D melting. These findings present a possible way to explain the observed phase transitions in non-equilibrium granular systems using entropic-like arguments similar to those used for equilibrium hard-sphere/disk systems.

1:15 PM J29.00009 Swirling Motion in the System of Vibrated Elongated Particles. IGOR ARANSON, Argonne National Laboratory, DMITRII VOLFSON, LEV TSMIRING, University of California, San Diego — We study large-scale collective motion emerging in a monolayer of vertically vibrated elongated particles. The motion is characterized by recurring swirls with the characteristic scale exceeding several times the size of an individual particle. Our experiments identified small horizontal component of the oscillatory acceleration of the vibrating plate in a combination with the mass and momentum conservation equations alone. Energy becomes a relevant variable only in the boundary layers at the boundaries of the flow where there is a balance between the rates of conduction and dissipation. We show that such a hydrodynamic model can predict the salient features of a chute flow, including the flow initiation when the angle of inclination is increased above the 'friction angle', the striking lack of observable variation of the volume fraction with height, the observation of a steady flow only for certain restitution coefficients, and the density variations in the boundary layers.

1 This work was supported by U. S. DOE grants DE-AC02-06CH11357 (IA) and DE-FG02-04ER46135 (DV,LT).

1:27 PM J29.00010 Angle of Repose of Small, Conducting and Non-Conducting Plates. PAUL J. DOLAN, JR., DENISA S. MELICHIAN, Northeastern Illinois University, ALAN FEINERMAN, University of Illinois at Chicago, REBECCA J. CARLTON, Illinois Wesleyan University, KATHY AUGUSTYN, Evergreen Park Community High School, JUSTIN JOHNSON, Illinois Math and Science Academy — We have investigated the behavior of granular collections consisting of laser-cut shapes from conducting and non-conducting paper, with various cross-sectional shapes (square, rectangular, triangular, circular) and in several sizes and aspect ratios. In particular we have measured the Angle of Repose of piles consisting of large numbers of these particles. While the shape of these particles would suggest that these should behave as thin plates, making quite shallow piles, instead we find that the piles are not shallow, and that the piling is remarkably robust to external disturbances. We will compare our results for various types of materials in various shapes, and also compare these results with what we have observed for larger, symmetric particles.
We extend our previous work on shock mitigation in tapered chains to look at energy sharing among spheres and how the system approaches a so-called quasi-equilibrium in 1d lattices is interesting for granular media since temperature is not well-defined and various authors have reported a violation of equipartition.


1Acknowledgements to Pfizer, Inc. for funding

1:39PM J29.00011 Large scale surface flow generation in driven suspensions of magnetic microparticles: Experiment, theoretical model and simulations , MAXIM BELKIN, ALEXEY SNEZHKO, IGOR ARANSON, Materials Science Division, Argonne National Laboratory — Nontrivially ordered dynamic self-assembled snake-like structures are formed in an ensemble of magnetic microparticles suspended over a fluid surface and energized by an external alternating magnetic field. Formation and existence of such structures is always accompanied by flows which form vortices. These large-scale vortices can be very fast and are crucial for snake formation/destruction. We introduce theoretical model based on Ginzburg-Landau equation for parametrically excited surface waves coupled to conservation law for particle density and Navier-Stokes equation for water flows. The developed model successfully describes snake generation, accounts for flows and reproduces most experimental results observed.

1:51PM J29.00012 The Behavior of Ultradefine Particles in the Absence and Presence of External Fields1 MEENAKSHI DUTT, University of Cambridge, BRUNO HANCOCK, CRAIG BENTHAM, Pfizer Global R & D, JAMES ELLIOTT, University of Cambridge — Length scale of particles and their surrounding medium strongly determines the nature of their interactions with one another and their responses to external fields. We are interested in systems of ultradispersed particles (0.1 - 1.0 micron) such as volcanic ash and aerogels, or fine powders for pharmaceutical inhalation applications. We develop a numerical model for these systems using the Derjaguin-Muller-Toporov (DMT) adhesion theory along with the van der Waals attraction between the particles and their contact mechanical interactions. We study the dynamics of these systems in the absence and presence of gravity by controlling the particle size, and thereby, the surface properties of the particles. Finally, we explore the response of these systems to external fields by studying the evolution of the internal microstructure under constant load and shear strain.

1:39PM J29.00111 Large scale surface flow generation in driven suspensions of magnetic micro- particles: Experiment, theoretical model and simulations , MAXIM BELKIN, ALEXEY SNEZHKO, IGOR ARANSON, Materials Science Division, Argonne National Laboratory — Nontrivially ordered dynamic self-assembled snake-like structures are formed in an ensemble of magnetic microparticles suspended over a fluid surface and energized by an external alternating magnetic field. Formation and existence of such structures is always accompanied by flows which form vortices. These large-scale vortices can be very fast and are crucial for snake formation/destruction. We introduce theoretical model based on Ginzburg-Landau equation for parametrically excited surface waves coupled to conservation law for particle density and Navier-Stokes equation for water flows. The developed model successfully describes snake generation, accounts for flows and reproduces most experimental results observed.

2:03PM J29.00113 Quasi-equilibrium in tapered chains , ROBERT DONEY, Department of Physics, State University of New York at Buffalo and U.S. Army Research Laboratory, SURAJIT SEN, Department of Physics, State University of New York at Buffalo — The approach to equilibrium in 1d lattices is interesting for granular media since temperature is not well-defined and various authors have reported a violation of equipartition. We extend our previous work on shock mitigation in tapered chains to look at energy sharing among spheres and how the system approaches a so-called quasi-equilibrium. An overlap potential of adjacent particles is used to model the elastic response of spheres under loading and has the form, V ∝ δn. For spheres, n = 5/2 and is known as the Hertz potential. We can also compare results when n = 2 which resembles spring-like behavior. It should be noted however, that in both cases the potential has no restoration term and vanishes when adjacent spheres lose contact. We present the velocity statistics for a variety of Hertzian chain configurations as well as fluctuations for the system’s total kinetic energy for both n = 2 and n = 2.5. We find that most particles in these systems exhibit Gaussian velocity distributions and that the kinetic energy fluctuations of the system depend strongly on system size and weakly on tapering of the spheres. Fluctuations do not damp out over long time however, indicating that the steady-state is a type of quasi-equilibrium. Mathematical fits of the mean fluctuations are further provided as functions of system size, tapering, and n.

Tuesday, March 6, 2007 2:30PM - 5:30PM – Session L22 GSNP: Focus Session: Structure and Dynamics of Complex Networks Colorado Convention Center 108

2:30PM L22.00001 Functional Aspects of Biological Networks , KIM SNEPPEN, Niels Bohr Institute, Copenhagen University — We discuss biological networks with respect to 1) relative positioning and importance of high degree nodes, 2) function and signaling, 3) logic and dynamics of regulation. Visually the soft modularity of many real world networks can be characterized in terms of number of high and low degrees nodes positioned relative to each other in a landscape analogue with mountains (high-degree nodes) and valleys (low-degree nodes). In these terms biological networks looks like rugged landscapes with separated peaks, hub proteins, which each are roughly as essential as any of the individual proteins on the periphery of the hub. Within each sup-domain of a molecular network one can often identify dynamical feedback mechanisms that falls into combinations of positive and negative feedback circuits. We will illustrate this with examples taken from phage regulation and bacterial uptake and regulation of small molecules. In particular we find that a double negative regulation often are replaced by a single positive link in unrelated organisms with same functional requirements. Overall we argue that network topology primarily reflects functional constraints. References: S. Maslov and K. Sneppen. “Computational architecture of the yeast regulatory network.” Phys. Biol. 2:94 (2005) A. Trusina et al. “Functional alignment of regulatory networks: A study of temerate phages”. Plos Computational Biology 1:7 (2005). J.B. Axelsen et al. “Degree Landscapes in Scale-Free Networks” physics/0512075 (2005). A. Trusina et al. “Hierarchy and Anti-Hierarchy in Real and Scale Free networks.” PRL 92:178702 (2004) S. Semsey et al. “Genetic Regulation of Fluxes: Iron Homeostasis of Escherichia coli”. (2006) q-bio.MN/0609042

3:06PM L22.00002 Optimal transport on complex networks1 BOGDAN DANILA, YONG YU, The University of Houston, JOHN MARSH, Assured Information Security, KEVIN BASSLER, The University of Houston — Transport optimization is a problem encountered in connection to many different types of complex networks, including biological networks, social networks, and a variety of natural and human-made transport and communication networks. We present results for transport optimization on random, scale-free, as well as geometric networks, obtained using a novel heuristic algorithm. Some of the results have been published in Phys.Rev. E 74, 046106 (2006). Our algorithm balances transport by adjusting traffic routing at every iteration to minimize the betweenness of the busiest node on the network. This is done with the least possible lengthening of the paths passing through that node. Our results are compared with those obtained using classical shortest path routing, as well as previously proposed network transport optimization algorithms. We show that routing produced by our algorithm enables networks to sustain significantly higher traffic without jamming than in the case of any previously proposed routing optimization algorithm. Furthermore, we show that, in spite of unavoidable lengthening of the average path, the small-world character of network routing is preserved.

3:18PM L22.00003 ABSTRACT WITHDRAWN –

3:30PM L22.00004 Model framework for describing the dynamics of evolving networks JAN TOBOCHNIK, Kalamazoo College, KATHERINE STRANDBURG, DePaul University College of Law, GABOR CSARDI, Department of Biophysics, KFKI Research Institute, PETER ERDI, Kalamazoo College — We present a model framework for describing the dynamics of evolving networks. In this framework the addition of edges is stochastically governed by some important intrinsic and structural properties of network vertices through an attractiveness function. We discuss the solution of the inverse problem: determining the attractiveness function from the network evolution data. We also present a number of example applications: the description of the US patent citation network using vertex degree, patent age and patent category variables, and we show how the time-dependent version of the method can be used to find and describe important changes in the internal dynamics. We also compare our results to scientific citation networks.
3:42PM L22.00005 Sampling of Complex Networks: A Datamining Approach, MARKUS LOECHER, DataInsight, LLC, JAKOB DOHRMANN, Doehrmann Consulting, GMBH, GERNOT BAUER, University of Applied Sciences, Muenster, Germany, PRINCETON-MUENSTER-ALLIANCE COLLABORATION — Efficient and accurate sampling of big complex networks is still an unsolved problem. As the degree distribution is one of the most commonly used attributes to characterize a network, there have been many attempts in recent papers to derive the original degree distribution from the data obtained during a traceroute-like sampling process. This talk describes a strategy for predicting the original degree of a node using the data obtained from a network by traceroute-like sampling making use of datamining techniques. Only local quantities (the sampled degree k, the redundancy of node detection r, the time of the first discovery of a node t and the distance to the sampling source d) are used as input for the datamining models. Global properties like the betweenness centrality are ignored. These local quantities are examined theoretically and in simulations to increase their value for the predictions. The accuracy of the models is discussed as a function of the number of sources used in the sampling process and the underlying topology of the network. The purpose of this work is to introduce the techniques of the relatively young field of datamining to the discussion on network sampling.

3:54PM L22.00006 Transport on weighted Networks: when correlations are independent of degree, JOSE JAVIER RAMASCO, ISI Foundation, BRUNO GONCALVES, Physics Department, Emory University — Most real-world networks are weighted graphs with the weight of the edges reflecting the relative importance of the connections. In this work, we study non degree dependent correlations between edge weights, generalizing thus the correlations beyond the degree dependent case. We find that two measures, the disparity and the range, defined below, are able to discriminate between the different types of correlated networks. We also study the effect of weight correlations on the transport properties of the graphs. We find that positive correlations dramatically improve transport. The classic case of degree dependent weight correlations relates to our graphs with positive weight correlations.

4:06PM L22.00007 Limited Percolation on Complex Networks, EDUARDO LOPEZ, Los Alamos National Laboratory, RONI PARSHANI, Bar-Ilan University, REUVEN COHEN1, New England Complex Systems Institute, SHLOMO HAVLIN, Bar-Ilan University — We study the stability of network communication under removal of q = 1 − p links when communication between nodes is possible only through a subset of the paths connecting them. We find a new percolation transition p below which only a fractal fraction of nodes Nγ can communicate, where γ is a function of the accepted communication paths. Above p, order N nodes can communicate. The results may be useful for the design of communication networks and immunization strategies.

4:18PM L22.00008 Criticality in finite dynamical networks, THIMO ROHLF, Santa Fe Institute, NATALI GULBAHCHE, CHRISTOF TEUSCHER, Los Alamos National Laboratory — It has been shown analytically and experimentally that both random boolean and random threshold networks show a transition from ordered to chaotic dynamics at a critical average connectivity Kc in the thermodynamical limit [1]. By looking at the statistical distributions of damage spreading (damage sizes), we go beyond this extensively studied mean-field approximation. We study the scaling property of damage size distributions as a function of system size N and initial perturbation size Δ(t = 0). We present numerical evidence that another characteristic point, Kc exists for finite system sizes, where the expectation value of damage spreading in the network is independent of the system size N. Further, the probability to obtain critical networks is investigated for a given system size and average connectivity k. Our results suggest that, for finite size dynamical networks, phase space structure is very complex and may not exhibit a sharp order-disorder transition. Finally, we discuss the implications of our findings for evolutionary processes and learning applied to networks which solve specific computational tasks. [1] Derrida, B. and Pomeau, Y. (1986), Europhys. Lett., 1, 45-49

4:30PM L22.00009 Rich-club ordering in complex networks, ALESSANDRO FLAMMINI, VITTORIA COLIZZA, MARIANGELES SERRANO, ALESSANDRO VESPIGNANI, Indiana University, CX GROUP TEAM — Uncovering the hidden regularities and organizational principles of networks arising in physical systems ranging from the molecular level to the scale of large communication infrastructures is the key issue for the understanding of their fabric and dynamical properties. The “rich-club” phenomenon refers to the tendency of nodes with high centrality, the dominant elements of the system, to form tightly interconnected communities and it is one of the crucial properties accounting for the formation of dominant communities in both computer and social sciences. The talk will provide the analytical expression and the correct null models for the measurement of the rich-club ordering and its relation with the function and dynamics of networks in examples drawn from the biological, social and technological domains.

4:42PM L22.00010 Scaling properties of critical random Boolean networks, BARBARA DROSEL, Institute of Condensed Matter Physics, TU Darmstadt — Until a few years ago, it was believed that random Boolean networks at the critical point (i.e., Kauffman networks) have a square-root relationship between the mean number of length of attractors and the system size N (i.e. the number of nodes). In the meantime, it became known that in fact the mean number and the mean length of attractors increase faster than any power law with increasing N. This talk gives an intuitive understanding of why this is the case. We investigate mainly analytically the scaling behavior of the number of nodes that are not frozen on all attractors, and of the number of relevant nodes, i.e. the nodes that determine the number and length of attractors. From the results it becomes clear that the relevant nodes form of the order of log(N) components, most of which have the form of simple loops. From this in turn attractor numbers and lengths follow. References: V. Kaufman, T. Mihalev, B. Droessel, PRE 72, 046124 (2005). B. Droessel, T. Mihalev, F. Greil, PRL94, 088701 (2005). B. Droessel, PRE72, 016110 (2005).

4:54PM L22.00011 Exhaustive percolation in binary avalanches, BJÖRN SAMUELSSON, JOSHUA SOCOLAR, Physics Department and Center for Nonlinear and Complex Systems, Duke University — We introduce the concept of binary avalanches as a generalization of commonly investigated site or bond percolation processes. Binary avalanches are capable of displaying a behavior that we call exhaustive percolation, where the fraction of nodes that are not affected by an avalanche approaches zero in the large system limit. We present a numerical example of exhaustive percolation on a directed lattice and analytical results for directed random networks. For random networks, the transition to exhaustive percolation is second order with scaling properties different from ordinary percolation. Our numerical calculations indicate that the exhaustive percolation transition on the directed lattice is also second order. Our analytic results for random networks improve the understanding of dynamical properties in random Boolean networks.

5:06PM L22.00012 Heterogeneity in community structure and renormalization in scale-free networks, BYUNGNAM KAHNG, JIN KIM, DOOCHUL KIM, Seoul National University — While many real-world networks contain community structures within them, their structural feature has not been fully understood yet. Here we study heterogeneities of community structures such as their sizes, cohesiveness, modularity, and renormalized degree, finding that there exist nontrivial power-law relationships between them, based on real-world networks. We show that such obtained relationships provide the condition of scale invariance of the degree distribution under renormalization. Also we show that the load or betweenness centrality of communities depends on such structural properties of communities.

3:00PM L22.00003 Rich-club ordering in complex networks, ALESSANDRO FLAMMINI, VITTORIA COLIZZA, MARIANGELES SERRANO, ALESSANDRO VESPIGNANI, Indiana University, CX GROUP TEAM — Uncovering the hidden regularities and organizational principles of networks arising in physical systems ranging from the molecular level to the scale of large communication infrastructures is the key issue for the understanding of their fabric and dynamical properties. The “rich-club” phenomenon refers to the tendency of nodes with high centrality, the dominant elements of the system, to form tightly interconnected communities and it is one of the crucial properties accounting for the formation of dominant communities in both computer and social sciences. The talk will provide the analytical expression and the correct null models for the measurement of the rich-club ordering and its relation with the function and dynamics of networks in examples drawn from the biological, social and technological domains.

3:12PM L22.00004 Structural Properties of Complex Networks, JHONGDA HUANG, ROBERT J. M. ZIEGLER, Simon Fraser University, RONI PARSHANI, Bar-Ilan University, REUVEN COHEN — We study structural properties of complex networks, focusing on rich-club and connectivity. We analyze the degree distribution, degree-degree correlations, and the rich-club ordering. We find that the degree distribution is well described by a power law, and that the rich-club effect is significant. We also investigate the connectivity of the network, finding that the connectivity is also well described by a power law. Our results provide insights into the structure of complex networks and their potential applications in real-world systems.
5:18PM L22.00013 Price of Anarchy on Complex Networks, HYE-JIN YOUN, HAWOONG JEONG, Department of Physics, Korea Advanced Institute of Science and Technology, Daejeon 305-711, Korea — We present an optimization problem of decentralized transportation networks, where latency depends linearly on congestion of a link. The system shows that a collection of individual optimization of the flow does not always meet the most optimized outcome that is conventionally assumed. We suggest that the Price of Anarchy, the ratio of two optimums, can quantify such discrepancy and accordingly regarded as an index of inefficiency of the system. We also measure the Price of Anarchy of model networks with various underlying structures, and a simplified Boston road network. Our numerical result confirms the existence of the Price of Anarchy in the networks. Finally, we find Braess’s paradox is not just a pedagogical example, but inefficiency that can counterintuitively take place in real.

Tuesday, March 6, 2007 5:45PM - 6:45PM —
Session M22 GSNP: GSNP Business Meeting Colorado Convention Center 108

5:45PM M22.00001 GSNP Business Meeting —

Wednesday, March 7, 2007 8:00AM - 10:48AM —
Session N22 GSNP: Focus Session: Jamming I Colorado Convention Center 108

8:00AM N22.00001 Discontinuous jamming transition in driven foam1, MICHAEL DENNIN, UC Irvine Department of Physics and Astronomy — Aqueous foam (gas bubbles with liquid walls) is a surprising substance. Every molecule in foam is in a fluid state, either liquid or gas. Yet, the entire foam holds its shape as a solid would. In fact, when subjected to an applied strain at a slow enough strain rate, the initial response of the foam is the same as an elastic solid. On the other hand, under sufficiently large stress or strain, the foam can flow in a fashion similar to a fluid. This is similar to plastic flow that occurs in many “molecular” solids. In this talk, we will focus on experimental studies of the transition from solid behavior to flowing behavior, with an emphasis on to what degree this “jamming” transition is analogous to a “real” phase transition. We will focus on recent results using a model, two-dimensional foam: bubble rafts. Bubble rafts are a single layer of bubbles on the surface of water. By focusing on a two-dimensional system, it is relatively easy to track individual bubbles and gain insight into the connection between bubble dynamics (the mesoscopic scale) and the response of the entire foam (macroscopic scale). We will focus on recent measurements of a discontinuous transition from solid to fluid like behavior in the bubble raft.

1Supported by DOE grant DE-FG02-03ER46071

8:36AM N22.00002 Dynamical heterogeneity at the jamming transition, LUCA CIPPELLETTI, Universite Montpellier 2 — We investigate the dynamics of a variety of soft materials close to the jamming transition, including strongly attractive colloidal gels, concentrated surfactant phases, and charged platelets (Laponite). By using novel time- and space-resolved light scattering techniques, we show that, quite generally, the dynamics of these systems are strongly heterogeneous both in time and space, suggesting that they relax through discrete rearrangement events. Surprisingly, we find that each event affects a volume much larger that the size of the system’s constituent (particles or clusters). This finding is in stark contrast with simulations and experiments on supercooled fluids, where spatial correlations of the dynamics extend over a few particles at most.

9:12AM N22.00003 ABSTRACT WITHDRAWN —

9:24AM N22.00004 A Statistical Ensemble for Soft Granular Matter, SILKE HENKES, Brandeis University, COREY O’HERN, Yale University, BULBUL CHAKRABORTY, Brandeis University — Work on packings of soft spheres (PRE 68, 011306 (2003)) has shown the existence of a Jamming transition and has highlighted the need for a general statistical framework to describe granular packings. This work presents an extension of the formalism proposed by Edwards (Physica A 157, 1080 (1989)) to packings of soft particles. We base our analysis on a height formalism developed in two dimensions (PREL 78, 115505 (2002)) to extract a topological invariant \(\Gamma\), the trace of the global stress tensor, which is conserved under internal rearrangements of the system. Upon assuming a flat measure in \(\Gamma\)-space, we can derive a canonical distribution of the local \(\Gamma\)-values in a grain packing. We then check the predictions of this ensemble against distributions of mechanically stable packings of frictionless disks obtained from computer simulations. Work supported by NSF-DMR 0549762.

9:36AM N22.00005 Some Packings Are More Equal Than Others, LEO SILBERT, Southern Illinois University — Computer simulations of packings of frictionless and frictional monodisperse spheres are discussed in the context of the jamming transition. Power-law scalings in several quantities characterising the packings are identified with distance from the jamming transition point, over several orders of magnitude in the particle friction coefficient. It is also noted that the 'critical' values of the coordination number and packing fraction scale with the friction coefficient. How friction modifies the structural and dynamical properties of the packings are also discussed.

9:48AM N22.00006 Isostatic Frictional Packings: Topology and Response Functions, DAVID WU, Colorado School of Mines — Frictionless disks and spheres are known to spontaneously organize into isostatic contact networks with minimal coordination number under common loadings such as gravity or compression. The isostatic character of such networks has been associated with the force-chain character and constitutive properties of the macroscopic assembly. However, for non-spherical or frictional grains, the conditions for an isostatic network are no longer spontaneously satisfied, most notably due to the indeterminacy associated with frictional contacts. Here I show the existence of a general isostatic limit of frictional packings for general shape grains similar to the case of frictionless disks. I discuss the consequences for force response functions and relationship to experiments showing the onset of network failure at low coordination numbers.

10:00AM N22.00007 Growing length scale for dynamical heterogeneity in an air-driven granular system near jamming, AARON KEYS, SHARON GLOTZER, Department of Chemical Engineering, University of Michigan, ADAM ABATE, DOUGLAS DURIAN, Department of Physics, University of Pennsylvania — Anomalous behaviour known as “spatially heterogeneous dynamics” (SHD) has been observed in supercooled liquids, dense colloids, and, more recently, in confined granular packings. Dynamics in these systems may be governed by proximity to a generic “jamming transition,” beyond which rearrangements cease and the viscosity diverges. However, the universality of this jamming hypothesis has not yet been tested in terms of variation in the hallmark dynamical heterogeneities as a function of control parameter. Here, we report measurement of SHD in systems of air-driven granular beads, as a simultaneous function of both density and effective temperature. On approach to jamming, the dynamics are found to become progressively slower and more heterogeneous. The measured dynamical time and length scales appear to diverge, and can be modeled both by mode-coupling theory and by the Vogel Tammann-Fulcher (VFT) equation, in quantitative analogy with glass-forming liquids. The Vogel temperature arising from the VFT fit, which corresponds to an ideal glass transition temperature in liquids, coincides with point-J, the volume fraction corresponding to a random close-packed structure. Our findings provide a significant step forward in the quest for a unified theory of “jamming” in disparate systems.
10:12AM N22.00008 Jamming with attractive interactions1 , COREY O’HERN, GREGG LOIS, Departments of Mechanical Engineering and Physics, Yale University, JERZY BLAWZDZIEJWICZ, Department of Mechanical Engineering, Yale University — We numerically study the effects of cohesion on granular solids using a minimal model relevant to various experimental settings. The inclusion of a small amount of attraction between contacting grains is shown to significantly alter even the qualitative features of both the attainable mechanically stable packings and their material response. The structure of the jammed packings formed using energy minimization techniques varies from dilute and heterogeneous gel-like states with large void spaces to dense and homogeneous packings reminiscent of the random close packed state. The mechanical response exhibits stability under tension and a much greater sensitivity to plastic events produced by non-affine grain motion. In elastic regions the values of the moduli depend on geometric features of the packing.

1NSF-DMR-0448838 and NSF-CTS-0625149.

10:24AM N22.00009 Shear-Induced crystallization in jammed systems , DANIEL LACKS, NATHAN DUFF, Case Western Reserve University — Simulations are used to address the effects of oscillating shear strain on jammed systems composed of spherical particles. The simulations show that shear oscillations with amplitudes of more than a few percent lead to substantial crystallization of the system. To ensure that the conclusions are independent of the simulation methodology, a range of simulations are carried out that use both molecular dynamics and athermal dynamics methods, soft and hard potentials, potentials with and without attractive forces, and systems with and without surrounding walls. The extent of crystallization is monitored primarily by the Q6 order parameter, but also in some simulations by the potential energy and the radial distribution function, and by direct visual inspection. A mechanism is proposed for shear-induced crystallization of jammed systems, based on fold catastrophes of the free energy landscape.

10:36AM N22.00010 Heterogeneity of the structural relaxation of jammed state in particle-filled elastomers , XIAORONG WANG, Bridgestone Americas, Center for Research and Technology, CHRISTOPHER ROBERTSON — The Payne effect is a low-strain hysteresis softening in particle-filled elastomers which we recognize as part of jamming physics [1-2]. We find that in particle-filled elastomers aging at a fixed oscillatory strain $\gamma_1$ produces a spectral hole in the loss modulus vs strain spectrum which is localized near the aging strain [3]. Sequential aging at two strains reveals that when $\gamma_1 > \gamma_2$ the resulting dynamic spectra appear to be a combination of that aged at $\gamma_1$ and $\gamma_2$; whereas for $\gamma_1 < \gamma_2$, the resulting dynamic spectra only reflect the characteristic hole burning of the second strain after holding at $\gamma_2$. This remarkable behavior of particle-filled elastomers suggests that structural relaxations in jammed state are heterogeneous and aging at a fixed strain $\gamma_0$ only affects part of the relaxation spectra.


11:15AM P22.00001 The impact of social network complexity: from collaboration teams to epidemics1 , ALESSANDRO VESPIGNANI, Indiana University — Recent years have witnessed a tremendous progress in the gathering of large scale social networks thanks to the development of new informatics tools and the increase in computational power. Networks which trace the activities and interactions of individuals, social patterns, transportation fluxes and population movements on a local and global scale have been analyzed and found to exhibit complex features encoded in large scale heterogeneity, self-organization and other properties typical of complex systems. We will review the complex features characterizing many of these networks and their impact on dynamical processes ranging from the establishment of collaboration teams and the emergence of consensus to the geographical behavior of large scale epidemics.

1Supported in part by the NSF IIS-0513650 award.

11:51AM P22.00002 Modeling self-organization of communication and topology in Social Networks , KIM SNEPPEN, Niels Bohr Institute — We introduce a model of self-organization of communication and topology in social networks with a feedback between different communication habits and the topology. To study this feedback, we let agents communicate to build a perception of a network and use this information to create strategic links. We observe a narrow distribution of links when the communication is low and a system with a broad distribution of links when the communication is high. We also analyze the outcome of chatting, cheating, and lying, as strategies to get better access to information in the network. Chatting, although only adopted by a few agents, gives a global gain in the system. Contrary, in a system with too many liars a global loss is inevitable. References: M. Rosvall and K. Sneppen. “Modeling self-organization of communication and topology in social networks.” Phys. Rev. E 74:16108 (2006)

12:03PM P22.00003 ABSTRACT WITHDRAWN —

12:15PM P22.00004 Large-scale Individual-based Models of Pandemic Influenza Mitigation Strategies , KAI KADAU, TIMOTHY GERMANN, Los Alamos National Laboratory, IRA LONGINI, University of Washington and Hutchinson Cancer Research Center, CATHERINE MACKEN, Los Alamos National Laboratory — We have developed a large-scale stochastic simulation model to investigate the spread of a pandemic strain of influenza virus through the U.S. population of 281 million people, to assess the likely effectiveness of various potential intervention strategies including antiviral agents, vaccines, and modified social mobility (including school closure and travel restrictions) [1]. The heterogeneous population structure and mobility is based on available Census and Department of Transportation data where available. Our simulations demonstrate that, in a highly mobile population, restricting travel after an outbreak is detected is likely to delay slightly the time course of the outbreak without impacting the eventual number ill. For large basic reproductive numbers $R_0$, we predict that multiple strategies in combination (including both social and medical interventions) will be required to achieve a substantial reduction in illness rates. [1] T. C. Germann, K. Kadau, I. M. Longini, and C. A. Macken, Proc. Natl. Acad. Sci. (USA) 103, 5935-5940 (2006).
12:27PM P22.00005 Dynamics of epidemics outbreaks in heterogeneous populations, DIRK BROCK-MANN, ALEJANDRO MORALES-GALLARDO, THEO GEISEL, MPI for Dynamics and Self-Organization — The dynamics of epidemic outbreaks have been investigated in recent years within two alternative theoretical paradigms. The key parameter of mean field type of models such as the SIR model is the basic reproduction number $R_0$, the average number of secondary infections caused by one infected individual. Recently, scale free network models have received much attention as they account for the high variability in the number of social contacts involved. These models predict an infinite basic reproduction number in some cases. We investigate the impact of heterogeneities of contact rates in a generic model for epidemic outbreaks. We present a system in which both time periods of being infectious and the time periods between transmissions are Poissonian processes. The heterogeneities are introduced by means of strongly variable contact rates. In contrast to scale free network models we observe a finite basic reproduction number and, counterintuitively a smaller overall epidemic outbreak as compared to the homogeneous system. Our study thus reveals that heterogeneities in contact rates do not necessarily facilitate the spread to infectious disease but may well attenuate it.

12:39PM P22.00006 The effect of heterogeneity in infectivity and susceptibility on epidemic spread, JOEL MILLER, Los Alamos National Laboratory — We consider the spread of an epidemic on a network with few short cycles. We develop analytical tools to determine the probability and final size of an epidemic when the infectiousness and/or susceptibility of individuals is heterogeneous. Using these tools, we find the distributions of infectiousness or susceptibility which maximize or minimize the size or probability of an epidemic.

12:51PM P22.00007 Phase diagram of the diffusive epidemic process, RONALD DICKMAN, DANIEL SOUZA MAIA, Universidade Federal de Minas Gerais — We study the absorbing-state phase transition in the one-dimensional diffusive epidemic process via mean-field theory and Monte Carlo simulation. In this model, particles of two species (A and B) hop on a lattice and undergo reactions $B \rightarrow A$ and $A + B \rightarrow 2B$; the total particle number is conserved. A phase transition between the absorbing B-free state and an active state is observed as the parameters (reaction and diffusion rates, and total particle density) are varied. Mean-field theory reveals a surprising, nonmonotonic dependence of the critical recovery rate on the diffusion rate of B particles. A computational realization of the process faithful to the master equation the model is devised. Using the quasi-stationary simulation method we determine the order parameter and the survival time in systems of up to 4000 sites. Due to strong finite-size effects, the results converge only for large system sizes. Rapidly increasing evidence for a discontinuous transition and the existence of three distinct universality classes, depending on whether A particles diffuse more rapidly, less rapidly, or at the same rate as B particles. We also perform quasi-stationary simulations of the triplet creation model, which yield consistent results with a discontinuous transition at high diffusion rates.

1 CNPq and Fapemig, Brazil

1:03PM P22.00008 Epidemics on dynamic networks with spatial structure, LEAH SHAW, IRA SCHWARTZ, Naval Research Lab — When a population is faced with an epidemic outbreak, individuals are likely to modify their social behavior to avoid exposure to the disease. Epidemic models that assume a fixed network of contacts do not address this phenomenon. We consider an extension of the model of Gross et al (PRL 96: 208701, 2006), in which the contact network is rewired dynamically so that susceptibles avoid contact with infectives. We add a spatial structure to the network and explore both the network geometry and the dynamics of the infection.

1:15PM P22.00009 Proximity Networks and Epidemics, HASAN GUCLU, Los Alamos National Laboratory, ZOLTÁN TORÓCZKAI, University of Notre Dame — We presented the basis of a framework to account for the dynamics of contacts in epidemic processes, through the notion of dynamic proximity graphs. By varying the integration time parameter $T$, which is the period of infectivity one can give a simple account for some of the differences in the observed contact networks for different diseases, such as smallpox, or AIDS. Our simplistic model also seems to shed some light on the shape of the degree distribution of the measured people-people contact network from the EPISIM data. We certainly do not claim that the simplistic graph integration model above is a good model for dynamic contact graphs. It only contains the essential ingredients for such processes to produce a qualitative agreement with some observations. We expect that further refinements and extensions to this picture, in particular deriving the link-probabilities in the dynamic proximity graph from more realistic contact dynamics should improve the agreement between models and data.

1 The authors thank for support DOE W-7405-ENG-36.

1:27PM P22.00010 Adaptive networks: the example of consensus formation, BALAZS KOZMA, ALAIN BARRAT, LPT, Universite de Paris-Sud 11, Orsay, FRANCE — It is well known that the structure of a network can significantly influence the properties of the dynamical processes on them. Though, the interplay between a process and the network topology on adaptive networks is still an open question. Adaptive rewiring of links can happen in real life systems such as acquaintance networks where two people are more likely to maintain a social connection if their views and values are similar. Similar adaptation also should be observed in biological and ecological networks. In our study, we consider various systems modeling the consensus formation of people and try to identify the quantities that are relevant in determining the behavior of adaptive networks.

1:39PM P22.00011 Social network analysis based on WWW search engine, SANG HOON LEE, PAN-JUN KIM, YONG-YEOL AHN, HAWOONG JEONG, KAIST, Daejeon 305-701, Korea — Recently, massive digital records have made it possible to analyze a huge amount of data in social sciences, one of which is social network theory. We investigate social networks between people by extracting information on the World Wide Web. Using famous search engines such as Google, we construct weighted social networks where the nodes are the names of people and the weight of each link is assigned as the number of web pages including both of the names attached to the link. The weight distribution is found to be quite broad with heavy-tail. The strength of a node, defined as the sum of weights over the node, is strongly correlated with the number of web pages including the single node. We compare networks constructed by this method with real networks to test the reliability of the method. Furthermore, we suggest the quantity, called the effective degree, characterizing the homogeneity (or heterogeneity) of weight distribution for each node in the weighted network. Another way to quantify the importance of each node, based on the effective degree, is also introduced.

1:51PM P22.00012 The voter model on an adaptive network, BEATE SCHMITTMANN, IZABELLA BENCZIK, ROYCE K.P. ZIA, SANDOR BENCZIK, Virginia Tech — In social networks, friendships emerge and fade, as individuals change their opinions. We discuss a simple model of such a network, in which the individuals are modeled by Ising spins (taking just two values: up or down) on the nodes of the network, while their connections are modeled by the presence or absence of edges. Nodes and edges evolve simultaneously. The spins are updated according to a simple majority rule (the voter model). Then, any pair of spins is then connected by an edge with probability $p (q)$ if they are in the same (different) state. Thus, the edges also become dynamic variables, correlated with the state of the nodes, and the network is termed “adaptive.” Using simulations and exact solutions, we find four phases in the thermodynamic limit. There are two absorbing states in which all nodes are in the same state (all up or down). Then, there is a disordered phase in which the nodes take random values, and a phase in which the system remembers its initial magnetization. For finite systems, only the two absorbing states survive in the long-time limit. Consequences for social networks will be discussed.

1Supported by NSF DMR-0414122.
2:03PM P22.00013 Resolution limit in community detection, MARC BARTHELEMY, CEA, SANTO FORTUNATO, Indiana University — Understanding the relation between structure and function in a complex network is a fundamental issue for practical applications in many disciplines such as biology or sociology. An important step in this direction has been made with the identification of communities through a now widely used method relying on the optimization of a quantity called modularity. However, we will show here that modularity optimization fail to identify modules smaller than a scale which depends on the total size of the network and on the degree of interconnectedness of the modules, even in cases where modules are unambiguously defined. We will illustrate this with simple examples taken both in artificial and in real social, biological and technological networks for which we show that modularity optimization indeed does not resolve a large number of modules. Reference: S. Fortunato and M. Barthelemy, PNAS, in press.

Wednesday, March 7, 2007 11:15AM - 2:15PM –
Session P34 DBP GSNP DPOLY: Focus Session: Cytoskeletal Dynamics and Cell Migration 1
Colorado Convention Center 404

11:15AM P34.00001 Integration of actin dynamics and adhesion in cell migration, CLARE WATERMAN-STORER, Scripps Research Institute — Cell migration requires transmission of motion generated in the actin cytoskeleton to the extracellular environment through a complex assembly of proteins in focal adhesions. We developed Correlational Fluorescent Speckle Microscopy to measure the coupling of focal adhesion proteins to actin filaments. Different classes of focal adhesion structural and regulatory molecules exhibited varying degrees of correlated motions with actin filaments, indicating hierarchical transmission of actin motion through focal adhesions. Interactions between vinculin, talin and actin filaments appear to constitute a stiffness interface between the cytoskeleton and integrins, generating a molecular clutch that is regulated during the morphodynamic transitions of cell migration.

1NIH Director's Pioneer Award Program, DP1-OD000435

11:51AM P34.00002 The Translation of Actin Dynamics into Traction Force via Focal Adhesions in Migrating Cells, MARGARET GARDEL, The Scripps Research Institute, BENEDIKT SABASS, Heidelberg University, LIN JI, The Scripps Research Institute, ULRICH SCHWARZ, Heidelberg University, CLARE WATERMAN, The Scripps Research Institute — Forces are generated in the actin cytoskeleton by myosin-II motors and transmitted to the extracellular matrix (ECM) via dynamic macromolecular assemblies called focal adhesions (FA). To explore how forces are transmitted from the contractile actomyosin network to the ECM, we combine traction force microscopy and fluorescent speckle microscopy (FSM) of FAs and actin cytoskeleton in PtK1 epithelial cells. We find that the relationship between intracellular actin flow and traction force is spatially segregated within individual focal adhesions. Near the leading edge, actin flow is inversely related to force, while towards the cell center, there is a positive correlation. This change is regulated by small GTPase signal transduction pathways and myosin II motor based contraction. Thus, the FA is a molecular clutch that exhibits regulatory switching between different coupling mechanisms.

12:03PM P34.00003 Modeling and imaging the topography of nascent adhesions, ERDINC ALTIGAN, DAVID ENTENBERG, BEN OVRYN, Department of Anatomy and Structural Biology, Albert Einstein College of Medicine — We have developed a model to explain the initiation of adhesions on the ventral surface of a cell. An analysis of the energetics of membrane bending and the effects of a composite system of freely diffusing repellers and receptors and a fixed network of ligands on the extracellular matrix demonstrates that a small bundle of actin filaments is able to push the membrane down to the extracellular matrix and nucleate a nascent adhesion. This model is consistent with experiments which demonstrate that cell motility requires cycles of actin polymerization and depolymerization at the leading edge of cell protrusions; the leading lamella adheres to the extracellular matrix and stable focal contacts form which can resist strong contractile forces. Although several of the mechanisms responsible for focal contact formation have been elucidated, the detailed processes leading to the formation of the earliest adhesions have remained elusive. Based upon the energetics of adhesion formation, our model predicts the shape of the membrane at the nucleated adhesion. We have developed a novel form of confocal interference microscopy to measure the distance between the ventral surface of a cell and the substratum with several nanometer precision and we have measured the topography of focal adhesions.

12:15PM P34.00004 Actin-Filament Networks and Cell Mechanics, KAREN KASZA, Harvard University, FU-MIHKO NAKAMURA, THOMAS STOSSEL, Brigham and Women’s Hospital, NING WANG, University of Illinois at Urbana-Champaign, DAVID WEITZ, Harvard University — We seek to elucidate the mechanisms underlying stress dependent stiffening of the cellular cytoskeleton. Filamin A (FLNa) is a protein that cross-links and bundles actin filaments into soft gels that stiffen dramatically with applied mechanical stress. Living cells show similar stiffening behavior, but the underlying physical mechanism is poorly understood. While it is known that FLNa plays an important biological role in some very mechanical cellular processes, it is still unclear whether FLNa plays such a dominant mechanical role in the cell as it does in simple reconstituted actin networks. Here, we work with a human melanoma cell line deficient in FLNa and a transfected subline expressing FLNa. For both cell lines, we probe cell stiffness measured by magnetic twisting cytometry as we increase the stress supported by the actin cytoskeleton to determine the contribution of FLNa to both the linear and nonlinear material properties of the cell cytoskeleton.

12:27PM P34.00005 Critical state enhances cross-linker denaturation under stress in biopolymer networks, BRIAN DIDONNA, ALEX J. LEVINE, University of California, Los Angeles — We report on the statistical behavior of cross-linker molecules containing numerous unfolding domains when they are used to bind a random semiflexible polymer network. Cross-linkers with unfolding domains are ubiquitous in the F-actin component of the cytoskeleton - examples include filamin and a-actinin. We show, through mean field calculations and simulations, that under tension the cross-links naturally organize into a critical state which greatly enhances their propensity to unfold. Unfolding of cross-links could play a role in stress-regulation and mechanotransduction. The critical state is characterized by an exponential or faster growth in the population of cross-links as a function of tension up to a characteristic unfolding tension. This critical state should occur at physiologically relevant stress levels in any open random network built with such cross-linkers.

12:39PM P34.00006 Molecular motor-induced instabilities and crosslinkers determine biopolymer organization, DAVID SMITH, University of Leipzig, Institute for Soft Matter Physics, FALKO ZIEBERT, Universitaet Bayreuth, DAVID HUMPHREY, CYNTHIA DUGGAN, University of Texas at Austin, CNLD, WALTER ZIMMERMANN, Universitaet Bayreuth, JOSEF KAES, University of Leipzig, Institute for Soft Matter Physics — All eukaryotic cells rely on the active self-organization of protein filaments to form a responsive intracellular cytoskeleton. The need for motility and reaction to stimuli additionally requires pathways that quickly and reversibly change cytoskeletal organization. While thermally-driven order-disorder transitions are, from the viewpoint of physics, the most obvious method for controlling such organization, the timescales necessary for effective cellular dynamics would require temperatures exceeding the physiologically viable temperature range. We report a mechanism whereby myosin II can cause near-instantaneous order-disorder transitions in reconstituted cytoskeletal actin solutions. When motor-induced filament sliding diminishes, the actin network structure rapidly and reversibly self-organizes into various assemblies. Addition of stable crosslinkers was found to alter the architecture of ordered assemblies. These isothermal transitions between dynamic disorder and self-assembled ordered states illustrate that the interplay between passive crosslinking and molecular motor activity plays a substantial role in dynamic cellular organization.
12:51PM P34.00007 Instabilities in filament-motor solutions with crosslinkers.1, FALKO ZIEBERT, Materials Science Division, Argonne National Laboratory, 9700 South Cass Avenue, Argonne, IL 60439, RONNY PETER, WALTER ZIMMERMANN, Theoretical Physics 1a, University of Bayreuth, D-95440 Bayreuth, Germany — Filament-motor systems are in nonequilibrium due to the energy consumption during motor movement (via ATP hydrolysis), and thus display pattern and structure formation. We report on simple mesoscopic modeling based on conservation laws with active filament currents. We discuss instabilities in a recent experiment on actomyosin, where ATP is depleted in the presence of a small amount of crosslinker proteins. In the limit of high density of crosslinkers, we propose a model where transported filaments are coupled to an elastic crosslinked network, leading to oscillatory behavior.

References:

1Supported by the U.S. Department of Energy, grant W-31-109-ENG-38 (IA)

1:03PM P34.00008 Interaction of Semi-flexible Filaments and Molecular Motors1, DMITRY KARPEEV, IGOR ARONSON, Argonne National Laboratory, LEV TSMIRING, University of California at San Diego, HANS KAPER, Argonne National Laboratory/National Science Foundation — We consider effects of finite flexibility on interaction of two microtubules with molecular motor. On the basis of numerical solution to nonlinear elasticity equation we show that the flexibility enhances tendency of microtubules to align, which, in turn, favors formation of large-scale structures in the multi-tubules system. Moreover, for much softer filaments, like actin, we observed that the action of the motors may result in formation of multiple loops due to buckling of the filaments.

1This work was supported by U.S. DOE grants DE-AC02-06CH11357 (DK,IA,HK) and DE-FG02-04ER46135 (LT)

1:15PM P34.00009 Effective medium theory of semiflexible filamentous networks1, MOUMITA DAS7, Dept. of Chemistry and Biochemistry, University of California, Los Angeles, ALEX J. LEVINE, Dept. of Chemistry and Biochemistry, University of California, Los Angeles, F.C. MACKINTOSH, Dept. of Physics, Vrije Universiteit, Amsterdam, The Netherlands. — We develop an effective medium approach to the mechanics of disordered, semiflexible polymer networks such as those forming the cytoktoskeleton and study their response to both spatially uniform and nonuniform strain. We identify distinct elastic regimes in which the effective filament bending stiffness or stretch modulus vanishes. We also show that our effective medium theory predicts a crossover between affine and non-affine strain, consistent with both prior numerical studies and scaling theory.

7Affiliation from Jan 2007: Dept. of Physics, Vrije Universiteit, Amsterdam, The Netherlands.

1:27PM P34.00010 Forced shape deformations of interfaces and biopolymer networks, WOLFGANG LOSERT, ANDREW POMERANCE, CORY POOLE, ERIN RERICA, University of Maryland — What sets the characteristic length and timescale of shape deformations of motile cells? To investigate possible contributions to these scales, we investigate shape deformations of biopolymer networks and lipid bilayers, two key components of motile cells. Controlled deformations are generated with holographic optical tweezers and detected optically. We observe that small deformation lengths of to about 4 microns (for cage sizes less than one micron) and short time deformations of order seconds, actin networks respond mostly elastically. We see evidence of coupling between two nearby deformation fields in an actin network. Relaxations of directly forced giant unilamellar vesicles reveal that –during free relaxation- apparent membrane stresses remain localized on micron scales.

1:39PM P34.00011 Viscoelasticity and rheology of a suspension of active filaments1, M. CRISTINA MARCHETTI, Syracuse University, TANNIEMOLA B. LIVERPOOL, Leeds University, UK. — We study the viscoelasticity of an active solution of polar biofilaments and motor proteins under an externally imposed stress. Adapting methods from polymer physics, we derive the constitutive equations for the stress tensor in the isotropic phase and in phases with liquid crystalline order (nematic and polarized). The stress relaxation in the various phases is discussed. Activity is responsible for a strong enhancement (a divergence in 2d) of the viscosity at the isotropic-nematic transition. This behavior is reminiscent of an equilibrium liquid-solid transition rather than a liquid-liquid transition, and is a direct consequence of contractile bundling. A second signature of activity is found in the nematic phase, where the stress tensor acquires a nonequilibrium contribution proportional to ATP (Adenosine Tri-Phosphate) consumption rate that remains finite in the absence of imposed mechanical deformation. The role of boundaries on these phenomena will also be discussed.

1Work supported by the NSF grant No. DMR-0305407 and by the Royal Society

1:51PM P34.00012 Dynamics and statistical mechanics of semiflexible polymer bundles. CLAUS HEUSSINGER, MARK BATHE, ERWIN FREY, Arnold-Sommerfeld Center for theoretical physics, University of Munich — Bundles formed from semiflexible polymers are ubiquitous in nature (e.g. filopodia) and many areas of technology (e.g. carbon nanotube bundles). Despite their simple structure, their mechanical and dynamical properties are only poorly understood. We set up an elastic energy functional that allows characterizing the dynamical and statistical mechanical properties of polymer bundles, in much the same way as the standard worm-like chain model (WLC) does for single polymers. The key result of our analysis is that bundles must be characterized by a wave-number dependent persistence length $\ell_p(q)$ instead of just a single $q$-independent value. This finding is shown to have dramatic consequences not only on the static and dynamic fluctuation spectrum of an isolated bundle but also on the scaling behaviour of their entangled solutions as well as their cross-linked networks.

2:03PM P34.00013 Dynamic Control of F-actin Polymerization Using Electrical Interfaces. IAN Y. WONG, Materials Science and Engineering, Stanford University, MATTHEW J. FOOTER, Biochemistry, Stanford University, NICHOLAS A. MELOSH, Materials Science and Engineering, Stanford University — The cytoskeletal biopolymer F-actin plays a crucial role in the mechanics and motility of eukaryotic cells and is also a model system for the investigation of the physics of semiflexible polymers. Historically, the polymerization of reconstituted F-actin has been initiated in vitro by increasing the bulk ion concentration from reduced to physiological levels. In this work, nanoscale electrodes are used to achieve spatial and temporal control of F-actin polymerization. The application of a low-frequency AC voltage alternately concentrates divalent cations and negatively charged G-actin monomers at the electrode surface, promoting highly localized polymerization. Unlike bulk polymerization, the kinetics of this electronically activated polymerization are governed by two competing mechanisms: ionic activation through Mg$^{2+}$ binding and nucleation of actin trimers. Additional control can be achieved through the superposition of a high-frequency AC signal to align and trap filaments through dielectrophoresis. This combination of low and high frequency AC voltages may allow for the dynamic assembly of nanostructures with precisely controlled size and registry.

Wednesday, March 7, 2007 2:30PM - 5:30PM – Session S7 GSNP: Percolation Colorado Convention Center Korbel 4A-4B
We next consider the probability of crossing between various points for percolation in the upper half-plane. For two points, with the point \( x \) also occur in epidemic spreading and diffusion-limited chemical reactions. Transition. Observables involving dynamical correlations display nonclassical scaling behavior that can nonetheless be determined exactly in two dimensions. Subtle. In diluted quantum magnets with and without dissipation, this leads to novel universality classes for the zero-temperature percolation quantum phase transition which, in turn, implies the absence of an epidemic threshold. Clustering can strongly affect the size and the resilience of the giant connected component, neither weak nor strong transitivity can restore a finite percolation threshold which, in turn, implies the absence of an epidemic threshold.

This work was supported in part by the National Science Foundation Grants Nos. DMR-0536927 and DMS-0244419.

### S7:00002 2d Turbulence, percolation and SLE

GREGORY FALKOVICH, Weizmann Institute of Science — We analyze isolines of scalar fields (vorticity, temperature) in different cases of 2d turbulence and found that they belong to the SLE class, i.e. to curves that can be mapped to 1d Brownian motion. Such curves have conformal invariant statistics. We find that vorticity isolines in 2d turbulence are equivalent (within our 5% accuracy) to SLE\(_{6}\) i.e. to percolation despite the fact that the vorticity field is long-correlated and does not satisfy Harris criterium. We find that the temperature isolines in surface quasi-geostrophic turbulence belong to SLE\(_{6}\) i.e. statistically equivalent to isolines of a Gaussian free field despite the fact that the temperature is non-Gaussian. Link with SLE allows one to obtain a variety of quantitative results going well beyond all we knew about turbulence before and hints about some deep analogy between turbulence and critical phenomena.

### S7:00003 Percolation properties of complex networks with weak and strong clustering

M. ANGELES SERRANO, School of Informatics, Indiana University — A diversity of systems in the real world can be analyzed as complex networks. This makes any theoretical development in the field potentially applicable to many different areas. As a germane example, percolation has helped us to understand, for instance, the high resilience of scale-free networks in front of the random removal of a fraction of their constituents, with important implications for communication or biological systems among others. In addition to its high theoretical interest, it serves as a conceptual approach to treat more factual problems on networks, such as the dynamics of epidemic spreading. On the other hand, when large systems of interactions are mapped into comprehensible graphs, just vertices and edges are usually recognized as the primary building blocks. However, transitive relations, represented by triangles and referred to as clustering, should also be taken into account as a basic structure whose presence and self-organization can drastically impact network structure and properties. In this framework, the introduction of clustering in the percolation analysis of complex networks represents a theoretical challenge. Previous approaches were based on the idea of branching process, which works well when the network is locally tree-like and thus the clustering coefficient is very small. Real networks, however, are shown to have a significant level of clustering. They can be classified in networks with strong transitivity, where edges are forced to share many triangles. The class a network belongs to changes its percolation properties. For networks with weak clustering, we find analytically the critical point for the onset of the giant component and its size. By means of numerical simulations, we also prove that, when comparing with the unclustered counterpart, weak clustering hinders the onset of the giant connected component whereas it is favored by strong clustering. This is a direct consequence of the differences in the k-core structure for the two types of networks. In the particular case of scale-free networks, and although clustering can strongly affect the size and the resilience of the giant connected component, neither weak nor strong transitivity can restore a finite percolation threshold which, in turn, implies the absence of an epidemic threshold.

### S7:00004 Critical 2-D Percolation: Crossing Probabilities, Modular Forms and Factorization

PETER KLEBAN, University of Maine — We first consider crossing probabilities in critical 2-D percolation in rectangular geometries, derived via conformal field theory. These quantities are shown to exhibit interesting modular behavior [1], although the physical meaning of modular transformations in this context is not clear. We show that in many cases these functions are completely characterized by very simple transformation properties. In particular, Cardy’s function for the percolation crossing probability (including the conformal dimension 1/3), follows from a simple modular argument.

We next consider the probability of crossing between various points for percolation in the upper half-plane. For two points, with the point \( x \) an edge of the system, the probability is

\[
P(x, z) = \lim_{m \to \infty} \frac{1}{m} P(x, z)^{1/3}
\]

where \( \Phi \) is the potential at \( z \) of a 2-D dipole located at \( x \), and \( k \) is a non-universal constant. For three points, one finds the exact and universal factorization [2,3]

\[
P(x_1, x_2, z) = C \sqrt{P(x_1, z)P(x_2, z)P(x_1, x_2)}
\]

with

\[
C = \frac{8\sqrt{2}}{3\sqrt{3}} \frac{\pi^{5/2}}{\Gamma(1/3)^{3/2}}.
\]

These results are calculated by use of conformal field theory. Computer simulations verify them very precisely. Furthermore, simulations show that the same factorization holds asymptotically, with the same value of \( C \), when one or both of the points \( x_i \) are moved from the edge into the bulk. 1.) Peter Kleban and Don Zagier, Crossing probabilities and modular forms, J. Stat. Phys. 113, 431-454 (2003) [arXiv: math-ph/0209023]. 2.) Peter Kleban, Jacob J. H. Simmons, and Robert M. Ziff, Anchored critical percolation clusters and 2-d electrostatics, Phys. Rev. Letters 97,115702 (2006) [arXiv: cond-mat/0605120]. 3.) Jacob J. H. Simmons and Peter Kleban, in preparation.

This work was supported in part by the National Science Foundation Grants Nos. DMR-0536927 and DMS-0244419.

### S7:00005 Quantum phase transitions on percolating lattices

THOMAS VOJTA, University of Missouri-Rolla — When a quantum many-particle system exists on a randomly diluted lattice, its intrinsic thermal and quantum fluctuations coexist with geometric fluctuations due to percolation. In this talk, we explore how the interplay of these fluctuations influences the phase transition at the percolation threshold. While it is well known that thermal fluctuations generically destroy long-range order on the critical percolation cluster, the effects of quantum fluctuations are more subtle. In diluted quantum magnets and without dissipation, this leads to novel universality classes for the zero-temperature percolation quantum phase transition. Observables involving dynamical correlations display nonclassical scaling behavior that can nonetheless be determined exactly in two dimensions. Moreover, by exploring a relation between quantum Hamiltonians and classical nonequilibrium processes, we demonstrate that exotic percolation transitions can also occur in epidemic spreading and diffusion-limited chemical reactions.

Wednesday, March 7, 2007 2:30PM - 5:06PM – Session S22 GSNP: Nonlinear Dynamics and Applications Colorado Convention Center 108
2:30PM S22.00001 Stochastic “Time”. TORU OHIRA, Sony Computer Science Laboratories, Inc. — We present a simple dynamical model which uses “non-locality” and “noise” on time axis. The model is a delayed dynamical map model with a stochasticity on the variable corresponding to “time” steps. The analogy is made with a tape recorder whose recording devise can move back on a tape as it records the values of the dynamical variable. With a tuned probability of “moving backward” with a given delay, the dynamics of the model shows an oscillatory behavior, similar to the one found in the models of stochastic resonance. We discuss implications of this model and whether it provides any reasonable approach to considering “non-locality” and “noise” on time axis.

References:

2:42PM S22.00002 Towards a RMT Scattering-matrix with universal frequency correlations1 RICHARD L WEaver, University of Illinois — We concern ourselves with the prediction of mesoscopic wave phenomena from statistical knowledge of classical trajectories. A diffusing particle picture for the flow of mean probability in chaotic systems is used to estimate dynamical features of mean square time-domain S-matrices for waves coupled in and out through perfectly open channel. The additional constraint of unitarity and minimum phase, then leads to a unique and plausible S-matrix that exhibits familiar mesoscopic wave dynamics. These include enhanced backscatter, quantum echo, power law tails, level repulsion and spectral rigidity. We conjecture that a generalization to $n \times n$ S matrices would exhibit behavior identical to that of the GOE or GUE depending on its symmetries.

2:54PM S22.00003 Synthesizing Chaos. JONATHAN BLAKELY, NED CORRON, SCOTT HAYES, SHAWN PETHEL, US Army RDECOM — Chaos is usually attributed only to nonlinear systems. Yet it was recently shown that chaotic waveforms can be synthesized by linear superposition of randomly polarized basis functions. The basis function contains a growing oscillation that terminates in a large pulse. We show that this function is easily realized when viewed backward in time as a pulse followed by ringing decay. Consequently, a linear filter driven by random pulses outputs a waveform that, when viewed backward in time, exhibits essential qualities of chaos, i.e. deterministic and a positive Lyapunov exponent. This phenomenon suggests that chaos may be connected to physical theories whose framework is not that of a deterministic dynamical system. We demonstrate that synthesizing chaos requires a balance between the topological entropy of the random source and the dissipation in the filter. Surprisingly, using different encodings of the random source, the same filter can produce both Lorenz-like and Rössler-like waveforms. The different encodings can be viewed as grammar restrictions on a more general encoding that produces a chaotic superset encompassing the Lorenz and Rössler paradigms of nonlinear dynamics. Thus, the language of deterministic chaos provides a useful description for a class of signals not generated by a deterministic system.

3:06PM S22.00004 Eigenvalues of the time evolution operator governing nuclear spin behavior in solids2 STEVEN W. MORGAN, BRIAN SAAM, University of Utah Physics Department — The decay of nuclear magnetic resonance (NMR) signals in solids is an extremely difficult many-body problem with no complete solution. Utilizing frozen xenon polarized by spin-exchange optical pumping, we have observed the long-time behavior of the transverse NMR signal for both free-induction decay and spin (solid) echoes. The hyperpolarized signal can be observed for up to $\sim 10$ decay constants, allowing us to characterize the long-time behavior, which is predicted to have one of two forms: $S(t) \sim e^{-\gamma t}$ or $S(t) \sim e^{-\gamma t} \cos(\omega t + \phi)$, where the constants $\omega$ and $\gamma$ are the same for the FID as for the solid echo. Our data agree well with this prediction, which follows from considering the evolution of the density matrix under the action of its time evolution operator, with the corresponding eigenvalues determining the evolution of the spin system. Not only is this decay an example of Markovian behavior on non-Markovian timescales but these eigenvalues should be a deep fundamental property of many-body quantum systems. The eigenvalues are also expected to be analogous to Pollicott-Ruelle resonances in classical chaotic systems. *B.V. Fine, Phys. Rev. Lett. 94, 247601 (2005).

3:18PM S22.00005 Dynamics of semiclassical wave packets in closed and open chaotic billiards1 ARSENI GOUSSEV, KLAUS RICHTER, Institute for Theoretical Physics, University of Regensburg — We investigate the sensitivity of the time evolution of semiclassical wave packets in two dimensional chaotic billiards with respect to local perturbations of their boundaries. For this purpose, we address, analytically and numerically, the time decay of fidelity, also known as the Loschmidt echo. We find the fidelity to decay exponentially in time, with the rate equal to the classical escape rate from an open billiard obtained from the original one by removing the perturbation-affected region of its boundary. In addition to that, we propose a principle scheme for the experimental observation of the fidelity decay. Finally, we analyze semiclassical corrections to the classical formula describing particle escape from open chaotic billiards.

3:30PM S22.00006 Bayesian Inference and the Symbolic Dynamics of Deterministic Chaos CHRISTOPHER C. STRELIOFF, Center for Complex Systems Research and Department of Physics, University of Illinois at Urbana-Champaign, JAMES CRUTCHFIELD, Computational Science and Engineering Center and Department of Physics, University of California at Davis, ALFRED HUBLER, Center for Complex Systems Research and Department of Physics, University of Illinois at Urbana-Champaign — Symbolic dynamics has proven to be an invaluable tool in analyzing the mechanisms that lead to unpredictability and random behavior in nonlinear dynamical systems. Surprisingly, a discrete partition of continuous phase space can produce a coarse-grained description of the behavior that accurately describes the invariant properties of an underlying chaotic attractor. In particular, measures of the rate of information production—the topological and metric entropy rates—can be estimated from the outputs of Markov or generating partitions. Here we develop Bayesian inference for k-th order Markov chains as a method for finding generating partitions and estimating entropy rates from finite samples of discretized data produced by coarse-grained dynamical systems.

3:42PM S22.00007 Nonlinear Dynamics of Nanomechanical Resonators SUBRAMANIAN RAMAKRISHNAN, YUIRY GULAK, Rutgers University, BALA SUNDARAM, University of Massachusetts — Boston, HAYM BENAROYA, Rutgers University — Nano-electromechanical systems (NEMS) offer great promise for many applications including motion and mass sensing. Recent experimental results suggest the importance of nonlinear effects in NEMS, an issue which has not been addressed fully in theory. We report on a nonlinear extension of a recent analytical model by Armour et al [1] for the dynamics of a single-electron transistor (SET) coupled to a nanomechanical resonator. We consider the nonlinear resonator motion in both (a) the Duffing and (b) nonlinear pendulum regimes. The corresponding master equations are derived and solved numerically and we consider moment approximations as well. In the Duffing case with hardening stiffness, we observe that the resonator is damped by the SET at a significantly higher rate. In the cases of softening stiffness and the pendulum, there exist regimes where the SET adds energy to the resonator. To our knowledge, this is the first instance of a single model displaying both negative and positive resonator damping in different dynamical regimes. The implications of the results for SET sensitivity as well as for, as yet unexplained, experimental results will be discussed. 1. Armour et al. Phys.Rev.B (69) 125313 (2004).
The system synchronizes to a common value of the time averaged frequency which depends on the initial phases of the oscillators at the ends of the chain. The time-averaged frequency decays as the coupling strength increases. Near the transition to the frozen state, the maximum Lyapunov exponent indicates quasiperiodicity. Time with this power law, there is an increase in phases of each oscillator with specific jumps with a scaling law of the elapsed time between the jumps. During the transition to macroscopic synchrony. In the mean-field limit, the model exhibits a supercritical Hopf bifurcation and global oscillatory behavior as coupling strength changes. The analytical theory based on topological model is in a reasonable agreement with the numerical results for mutual information between the input and output signal.

### S22.00008 Interference of fractals - a method to control the deterministic stochastic multiresonance

**Sawomir MATY.JASKIEWICZ**, Department of Physics, King’s College London, Strand, London, WC2R 2LS, UK — We present a new method to control the deterministic stochastic multiresonance in dynamical systems, which can be considered as a threshold-crossing systems, in the vicinity of chaotic crises. As an example we choose a two-dimensional chaotic map, where the threshold-crossing probability follows the overlap of the fractal structures of chaotic saddles and the basins of escape. Using a small periodic perturbation we induce interference like behaviour in fractal structure leading to significant changes of the information transmission through the system. The analytical theory based on topological model is in a reasonable agreement with the numerical results for mutual information between the input and output signal.

4:06PM S22.00009 Arnold Tongue Mixed Reality States in an Interreality System

**Vadas Gintautas**, Alfred Hubler, University of Illinois at Urbana-Champaign — We present experimental data on the limiting behavior of an interreality system comprising a virtual horizontally driven pendulum coupled to its real-world counterpart, where the interaction time scale is much shorter than the time scale of the dynamical system. We present experimental evidence that if the physical parameters of the virtual system match those of the real system within a certain tolerance, there is a transition from an uncorrelated dual reality state to a mixed reality state of the system in which the motion of the two pendula is highly correlated. The region in parameter space for stable solutions has an Arnold tongue structure for both the experimental data and for a numerical simulation. As virtual systems better approximate real ones, even weak coupling in other interreality systems may produce sudden changes to mixed reality states. This work was supported by the National Science Foundation Grant No. NSF PHY 01-40179, NSF DMS 03-25939 ITR, and NSF DGE 03-38215.

4:18PM S22.00010 Complex Dynamics in Systems of Interacting Bosons

**Moritz Hiller**, MPI for Dynamics and Self-Organization, Goettingen-Germany and Fakultaat fuer Physik, University of Goettingen, Joshua Bodenfelt, Department of Physics, Wesleyan University, Middletown CT-USA, and **Dynamic and Self-Organization, Goettingen-Germany and Theo Geisel**, MPI for Dynamics and Self-Organization, Goettingen-Germany and Fakultaat fuer Physik, University of Goettingen — We consider interacting bosons described by a Bose-Hubbard Hamiltonian (BHH) and analyze the evolving energy distribution as an experimentally controllable parameter, the coupling strength k between neighboring sites, is changed. Three driving schemes of k are considered: (a) the sudden limit (LDOS analysis), (b) the one-pulse scheme (wavepacket dynamics), and (c) the time-reversal scheme (fidelity). We find in all cases two distinct regimes: the Linear Response (LRT) regime where we can trust the Fermi-Golden Rule picture, and what we call the non-perturbative regime where the perturbation k is quantum mechanically large. In the former regime, the evolving distribution can be described by an improved Random Matrix Theory (RMT) which takes into account the structured energy landscape of the perturbation. Instead, in the latter regime, non-universal features of the underlying classical dynamics dictate the energy spreading thus leading to a clash with the predictions of RMT.

4:30PM S22.00011 Synchronization in a chain of nearest neighbors coupled oscillators with fixed ends

**Yinka FUWAVE**, Federal University of Technology, Akure, Nigeria — A system of coupled phase oscillators with nearest neighbors coupling in a chain with fixed ends is investigated. The system synchronizes to a common value of the time averaged frequency which depends on the initial phases of the oscillators at the ends of the chain. The time-averaged frequency decays as the coupling strength increases. Near the transition to the frozen state, the time-averaged frequency has a power law behavior as a function of the coupling strength with synchronized time averaged frequency equal to zero. Associated with this power law, there is an increase in phases of each oscillator with specific jumps with a scaling law of the elapsed time between the jumps. During the interval between the full frequency synchronization and the transition to the frozen state, the maximum Lyapunov exponent indicates quasiperiodicity. Time series analysis of the oscillators frequency shows this quasiperiodicity as the coupling strength increases.

4:42PM S22.00012 Stationary and traveling solitons in one-dimensional quartic lattices

**San-Hamitra Neogi**, Gerald D. Mahan, Department of Physics, The Pennsylvania State University — We discuss the solutions to classical vibrations of a monatomic one-dimensional lattice. The interaction potential between the nearest neighbor atoms in the lattice contains nonlinear quartic terms. We found a total of N normal modes, that are symmetric and antisymmetric with respect to the center of the chain consisting of N atoms. Also, there exist stationary soliton solutions that are neither symmetric nor antisymmetric suggesting the total number of solutions exceeds the number of atoms in the chain. We generated traveling solitons by giving an impulse to the atoms at the end of the chain which has free ends. However, if the end of the chain is bound to a wall, we could not find any solitary waves to sustain more than few atoms.

4:54PM S22.00013 Universality of Synchrony

**Kevin Wood**, Dept Physics, Dept Chemistry and Biochem, University of California, San Diego, Christian Van Den Broeck, Hasselt University, Ryoichi Kawai, Dept Physics, University of Alabama, Birmingham, Katja Lindenberg, Dept Chemistry and Biochem, INLS, University of California, San Diego — We present a discrete model of stochastic, phase-coupled oscillators that is sufficiently simple to be characterized in complete detail, lending insight into the universal critical behavior of the corresponding nonequilibrium phase transition to macroscopic synchrony. In the mean-field limit, the model exhibits a supercritical Hopf bifurcation and global oscillatory behavior as coupling strength increases. The simplicity of our model allows us to perform the first detailed characterization of stochastic phase coupled oscillators in the locally coupled regime, where the model undergoes a continuous phase transition which remarkably displays signatures of the XY equilibrium universality class, verifying the analytical predictions of Risler et al. (1). Finally, we study the model under the influence of spatial disorder and provide analytical and numerical evidence that such disorder does not destroy the capacity for synchronization. 1. T. Risler, J. Prost, F. Julicher. Phys Rev. Letters, 93 (17), (2004); Phys Rev E, 72, 016130 (2005).

---

**Thursday, March 8, 2007 8:00AM - 11:00AM**

**Session U7 CSNP FE: Teaching Nonequilibrium Statistical Mechanics for the Needs of 21st Century Physicists**

**Colorado Convention Center Korbel 4A-4B**

8:00AM U7.00001 Nonequilibrium Statistical Mechanics for Today’s Graduate Students

**JAMES DUFTY**, University of Florida — The notion of nonequilibrium statistical mechanics as a tool for analysis of many body systems is emphasized to support its value to graduate students in general. Evolution across a wide range of fields within and beyond physics over the past half century is recalled. Much of the earlier focus on detailed and systematic applications to simple systems has been replaced by more qualitative analysis of complex systems. A case is made for the utility of a carefully-crafted course in nonequilibrium statistical mechanics as a means of thinking about problems in condensed matter physics, materials sciences, chemical physics, and particle physics.

---

8:00AM U7.00008 Interference of fractals - a method to control the deterministic stochastic multiresonance

**Sawomir MATY.JASKIEWICZ**, Department of Physics, King’s College London, Strand, London, WC2R 2LS, UK — We present a new method to control the deterministic stochastic multiresonance in dynamical systems, which can be considered as a threshold-crossing systems, in the vicinity of chaotic crises. As an example we choose a two-dimensional chaotic map, where the threshold-crossing probability follows the overlap of the fractal structures of chaotic saddles and the basins of escape. Using a small periodic perturbation we induce interference like behaviour in fractal structure leading to significant changes of the information transmission through the system. The analytical theory based on topological model is in a reasonable agreement with the numerical results for mutual information between the input and output signal.
8:36AM U7.00002 Entropy, Order Parameters, and Complexity: Incorporating the last 50 years into the statistical mechanics curriculum

JAMES SETHNA, LASSP, Cornell University — The purview of statistical mechanics has grown rapidly in the past decades, with nonequilibrium extensions and applications to dynamical systems, molecular biology and bioinformatics, complex systems and networks, digital communication and information theory, and econophysics and other social sciences. It is our responsibility to join these new insights to the old wisdom in the field, and to distill the key ideas for the next generation. We should include (a) Shannon entropy, data compression, and reversible computation, (b) chaotic motion, ergodicity and the KAM theorem, and renormalization-group treatments of the onset of chaos, (c) molecular motors and hidden Markov models for analyzing genomic data. We should make statistical mechanics useful and comprehensible to those outside of physics, eschewing applications (Gausius-Clapeyron equations, \( c_p \) vs. \( c_v \)) and methods (quantum mechanics) accessible and interesting only to condensed-matter physicists and physical chemists. See Entropy, Order Parameters, and Complexity (http://www.physics.cornell.edu/sethna/StatMech/), OUP, 2006.

1Support from NSF DMR 0218475

9:12AM U7.00003 Teaching at the edge of knowledge: Non-equilibrium statistical physics

BEATE SCHMITTMANN, Virginia Tech — As physicists become increasingly interested in biological problems, we frequently find ourselves confronted with complex open systems, involving many interacting constituents and characterized by non-vanishing fluxes of mass or energy. Faced with the task of predicting macroscopic behaviors from microscopic information for these non-equilibrium systems, the familiar Gibbs-Boltzmann framework fails. The development of a comprehensive theoretical characterization of non-equilibrium behavior is one of the key challenges of modern condensed matter physics. In its absence, several approaches have been developed, from master equations to thermostatted molecular dynamics, which provide key insights into the rich and often surprising phenomenology of systems far from equilibrium. In my talk, I will address some of these methods, selecting those that are most relevant for a broad range of interdisciplinary problems from biology to traffic, finance, and sociology. The “portability” of these methods makes them valuable for graduate students from a variety of disciplines. To illustrate how different methods can complement each other when probing a problem from, e.g., the life sciences, I will discuss some recent attempts at modeling translation, i.e., the process by which the genetic information encoded on a mRNA is translated into the corresponding protein.


9:48AM U7.00004 Non-equilibrium statistical mechanics in the context of biological physics

MEHRAN KARDAR, Physics Department, MIT — Living systems are inherently out of equilibrium and operate in a fluctuating environment. The current challenges and interests in quantitative biology thus provide a great opportunity to introduce and develop methods from non-equilibrium statistical physics. For example, Master equations for evolution of probability find applications in mutating sequences, molecular motors, and signaling networks.

3Support through NSF grant number DMR-04-26677 is gratefully acknowledged.

10:24AM U7.00005 The Onsager Matrix Reloaded: Teaching Nonequilibrium Statistical Mechanics via Modern Applications

NIGEL GOLDENFELD, University of Illinois at Urbana-Champaign — Traditional texts and courses on nonequilibrium statistical mechanics (NESM) focus on fundamentals and outmoded examples that do not reflect the explosion of applications and developments from recent decades. With the burgeoning interest in multidisciplinary approaches to key problems in science and technology, in which physics and quantitative methods play a central role, NESM emerges as one of the unifying and pivotal techniques that physicists have to offer. I outline an approach to teaching NESM that emphasizes less formal theory and more modern applications, centered around developments in (e.g.) pattern formation, materials science, biology, fluid dynamics and atmospheric science.

Thursday, March 8, 2007 8:00AM - 10:48AM
Session U22 GSNP DMP: Focus Session: Friction Colorado Convention Center 108

8:00AM U22.00001 Fundamental aspects of energy dissipation in friction

MIQUEL SALMERON, Lawrence Berkeley National Laboratory and Materials Science and Engineering Department, University of California, Berkeley — Energy dissipation in friction is mediated by excitation of elementary processes including surface phonons and electronic excitations. These excitations couple through anharmonic interactions or by Frank-Condon nuclear motions to bulk substrate phonons, which ultimately appear as heat. This gives rise to numerous phenomena including friction anisotropy, velocity dependence, and dissipative surface charge motion. Friction anisotropy can appear when phonon modes with specific polarizations are forbidden in particular crystal directions. Electronic excitations have been discussed and investigated but never clearly and definitely identified as primary mechanisms in contact friction. I will discuss these topics using recent experimental results in my laboratory including the large friction anisotropy of Al-Ni-Co decagonal quasicrystals, the role of hydrogen bonding networks in determining the velocity dependence of friction and finally the control of friction by changing the carrier concentration near the surface of p and n semiconductors.

8:36AM U22.00002 A nanotribology study of self-mated vs. unmated interfaces and local packing density effects for octadecyltrichlorosilane monolayers and silicon

ERIN FLATER, Luther College, W. ROBERT ASHURST, Auburn University, ROBERT CARPICK, University of Pennsylvania — We use atomic force microscopy (AFM) to determine the frictional properties of nanoscale single asperity contacts involving octadecyltrichlorosilane (OTS) monolayers and silicon. Quantitative AFM measurements are performed using both uncoated and OTS-coated silicon AFM tips and surfaces. Friction is reduced by the presence of the OTS coating, and the overall shape of the friction vs. load plot strikingly depends on whether or not the substrate is coated with OTS, regardless of tip material. Uncoated substrates exhibit the common sublinear dependence, while coated substrates exhibit an unusual superlinear dependence. These results can be explained qualitatively by invoking molecular plowing as a significant contribution to the frictional behavior of OTS. Direct in-situ comparison of two intrinsic OTS structural phases of otherwise identical molecules on the substrate show that the lower packing density phase exhibits higher friction, decisively observed only here in single, uninterrupted images on the same monolayer for the first time. The lateral stiffness of the two OTS structural phases are indistinguishable, which implies that the packing density directly affects the interface’s intrinsic resistance to shear as opposed to simply modifying the stiffness of the monolayer.

8:48AM U22.00003 Dynamical noise and avalanches in quasi-static plastic flow of amorphous solids

ANAEL LEMAITRE, Institut Navier, CHRISTIANE CAROLI, INSP, Universite Pierre et Marie Curie-Paris 6, Universite Denis Diderot-Paris 7 — We build a mean-field model of plasticity of amorphous solids, based on the dynamics of an ensemble shear transformation zones, interacting via intrinsic dynamical noise generated by the zone flips themselves. We compare the quasi-static, steady-state properties for two types of noise spectrum: (G) Gaussian; (E) broad distribution derived from quadrupolar elastic interactions. We find that the plastic flow proceeds via avalanches whose scaling properties with system size are highly sensitive to noise tails. Comparison with available data suggests that non-affine strain fields might be of paramount importance in the small systems accessible to molecular simulations.
9:00AM U22.00004 Dynamics of Phononic Dissipation at the Atomic Scale¹, HALDUN SEVINCI, SOMA MUKHOPADHAY, R. TUGRUL SENGEG, SALIM CIRACI, Department of Physics, Bilkent University — Dynamics of dissipation of a local phonon distribution to the bulk is a key issue in boundary lubrication and friction between sliding surfaces. We consider a highly excited molecule which interacts weakly with the substrate surface. We study different types of coupling and substrates having different types of dimensionality and phonon densities of states. We propose three different methods to solve the dynamics of the combined system, namely the equation of motion technique, Fano-Anderson method and the Green’s function method. Using this theoretical framework we present an analysis of transient properties of energy dissipation via phonon discharge at the microscopic level. The methods allow the theoretical calculations to be extended to include any density of states for the substrate including experimental ones and any type of molecule that represent the lubricant or the asperity.

¹TUBITAK

9:12AM U22.00005 Friction and Viscous Forces in Sub-Nanometer Water Films¹, TAI-DE LI, ELISA RIEGO, School of Physics, Georgia Tech, SCHOOL OF PHYSICS, GEORGIA INSTITUTE OF TECHNOLOGY TEAM — Water under nano-confinement is ubiquitous, with examples including clay swelling, aquaporines, ion channels, and water menisci in micro-electrical-mechanical-systems. However, the structural and rheological characteristics of nano-confined pure and ionized water continue to be the subject of discussion and debate. Here, we report an experiment in which an atomic force microscope tip approaches a flat solid surface in purified water, while small lateral oscillations are applied to the tip. Direct measurements of the lateral forces encountered by a nano-size tip approaching a solid surface in purified water are reported for tip-surface distances, 0.03 nm < d < 2 nm. We find that, for hydrophilic surfaces, the dynamic viscosity is measured to grow up orders of magnitude in respect to bulk water, whereas no significant increase in the viscosity has been detected when the confining solid surface is hydrophobic. The origin of the observed different behavior is discussed.

¹NSF, ACS Petroleum Foundation, AFOSR, and DOE

9:24AM U22.00006 Friction Reduction Using Self-Assembled Hydrogels, MICHAEL J. MACKEL, JULIA A. KORNFIELD, California Institute of Technology — Friction of agarose-based hydrogels against bare glass is examined as a function of added linear polyelectrolyte using a stress rheometer to measure the angular velocity of a clean glass plate against the hydrogel surface as a function of applied torque and normal force. Incorporating linear dextran sulfate into 2 weight percent agarose hydrogel reduces friction on the hydrogel surface. The reduction of friction is a nonmonotonic function of dextran sulfate concentration: a 2 percent doping of dextran sulfate shows the minimum friction. Lubricity enhancement on the agarose doped with 2 percent dextran sulfate occurs at all normal forces examined (0.5, 1, 1.5, and 2 N) and is more pronounced at larger angular velocities. Rheological studies of agarose hydrogels doped with dextran sulfate suggest that the dextran sulfate does not interfere with the porous structure of the hydrogel when present in concentrations of 2 weight percent or less.

9:36AM U22.00007 High velocity sliding at a compressed Al(111)/Al(100) interface¹, J. E. HAMMERBERG, Los Alamos National Laboratory, R. RAVELO, University of Texas, El Paso, T.C. GERMANN, B.L. HOLIAN, Los Alamos National Laboratory — We discuss high velocity sliding at a compressed Al(111)/Al(100) interface sliding in the 110 direction at a pressure of 15 GPa. Three temperatures are considered, T=232, 464 and 696 K. System sizes are 1.410¹⁰ atoms. We find that for velocities above a critical velocity, vₜ, the frictional force scales as (v/vₜ)⁻² with β ≈ 3/4. We discuss the temperature and size dependence of vₜ. We find that below vₜ the frictional force is an increasing function of velocity with an initial linear dependence. Above vₜ there is a regime of interfacial instability characterized by a (100) transformation front moving into the (111) material. This is followed by a fluid regime for which a Couette flow profile develops at the interface, the thickness of which grows with increasing velocity.

¹This work supported by the Department of Energy under contract W-7405-ENG-36

9:48AM U22.00008 The Dynamics of Precursors to Frictional Sliding, JAY FINEBERG, SHMUEL RUBINSTEIN, GIL COHEN, The Hebrew University of Jerusalem — The dynamics of frictional motion are governed by the nature of the interface separating two sliding materials. We report that the spatial profile of the contact-area along an interface is a dynamic quantity which evolves via a discrete sequence of rapid crack-like precursors to overall motion. These precursors, which are generated at stress levels much lower than the critical stress for sliding, significantly modify the initially uniform contact area profile. Thus, when overall sliding finally occurs, the contact area is highly non-uniform in space. These results suggest a fundamentally new view of the processes leading to frictional motion with ramifications to earthquake dynamics and material failure.

10:00AM U22.00009 ABSTRACT WITHDRAWN —

10:12AM U22.00010 Molecular Dynamics Simulation of Frictional Melting, SHIGENOBU HIROSE, The Earth Simulator Center, JAMSTEC — Frictional melting produces lubricant at the sliding plane and changes the physics of dynamical sliding, which may play a key role on coseismic slipping. In this paper, molecular dynamics simulation is used to study the basic physics of frictional melting. Here, friction between a Lenard-Johns material and a rigid material is considered for simplicity. When the sliding velocity is low enough, there is no melting and the friction coefficient almost does not depend on the sliding velocity. On the other hand, when the sliding velocity is so high that frictional melting occurs, the friction coefficient decreases due to the melting lubricant. A preliminary result shows that the friction coefficient is roughly power-law of the sliding velocity. A discussion will also be given on the themodynamic balance between the frictional heating, cooling by latent heat, and conduction cooling.

10:24AM U22.00011 Molecular Dynamics Simulations of Nanotribology with Accurate Probe Tip Models, MICHAEL CHANDROSS, Sandia National Laboratories, CHRISTIAN LORENZ, Iowa State University, GARY GREST, Sandia National Laboratories — Results for extensive dynamical nanotribological simulations of amorphous silica tips in contact with alkylsilane self-assembled monolayers (SAMs) will be presented. The radius of curvature of the tips match experimental dimensions. Comparison with contact mechanics models indicate that the standard JKR and DMT models do not give the correct dependence of contact area on applied force. The dependence of the tribological response on the chain length of the SAM has been determined. For short chains and for long chains at low loads the SAM presents a disordered sliding surface to the tip and the chain length is irrelevant. This result is in agreement with our previous simulations for SAMs in contact with a flat surface. For longer chains at higher loads the tip penetrates the monolayer and the friction is dominated by a plowing mechanism. Sandia is a multiprogram laboratory operated by Sandia Corp., a Lockheed Martin Company, for the United States Department of Energy’s National Nuclear Security Administration under Contract DE-AC04-94AL85000.
10:36 AM U22.00012 Molecular dynamics studies of friction between bare and oxidized silicon surfaces, WOO KYUN KIM, MICHAEL FALK, The University of Michigan — Using molecular dynamics simulation we examine the friction between a bare silicon tip and a silicon surface under perfect vacuum conditions. The simulations utilize a Stillinger-Weber model for the Si-Si interactions. In the case of bare silicon, the proper surface reconstruction is verified. Silicon-silicon sliding leads to high friction and significant wear due to the strong adhesive force between tip and surface. Repeated adhesion and shearing produces a stick-slip motion. The quantity of material lost during sliding depends on the relative orientation of the dimers between the reconstructed surfaces of the tip and substrate. Little dependence on the temperature or the normal force is observed in this case. The frictional force is shown to be an upward normal force, although the magnitude of lost material depends on the magnitude of upward normal force. The geometry and elasticity dependence of the stick-slip motion has also been analyzed. We have also begun investigations of a similar geometry in which the silicon is coated with a thin oxide layer. A charge transfer potential having 3-body terms as well as pair-wise interactions is being used to model the amorphous silicon interactions. These simulation results will be compared to the recent AFM experiments by Schirmeisen et al. measuring the frictional forces between an oxidized silicon tip and substrate.

Thursday, March 8, 2007 8:00 AM - 11:00 AM — Session U35 DBP GSNP DPOLY Focus Session: Cytoskeletal Dynamics and Cell Migration I Colorado Convention Center 405

8:00 AM U35.00001 Modelling cell motility and pathways that signal to the actin cytoskeleton, LEAH EDELSTEIN-KESHT, Dept of Mathematics, UBC — Gradient sensing, polarization, and motility of rapidly moving cells such as neutrophils involves the actin cytoskeleton, and regulatory modules such as membrane bound phosphoinositides (PIs), kinases/phosphatases, and proteins of the Rho family (RhoGTPases). I describe recent work in my group in which we have modeled components of these modules, their interconversions, interactions, and action in the context of protrusive cell motility. By connecting three modules, we find that Rho GTPases work as a spatial switch, and that PIs filter noise, and define the front vs. back. Relatively fast PI diffusion also leads to selection of a unique pattern of Rho distribution from a collection of possible patterns. We use the model to explore the importance of specific hypothesized interactions, to explore mutant phenotypes, and to study the role of actin polymerization in the maintenance of the PI asymmetry. Collaborators on this work include A.T. Dawes, A. Jilkine, and A.F.M. Maree.

1 We acknowledge a subcontract from NSF (grant # DMS-0240770, to A. Carlsson, Wash U.), NSERC, and MITACS (Canada)

8:36 AM U35.00002 Migration of a Model Lamellipodium by Actin Polymerization: A Molecular Dynamics Simulation Approach, JUNHWAN JEON, Department of Chemical Engineering, Vanderbilt University, Nashville, Tennessee 37235, PETER CUMMINGS, Nanomaterials Theory Institute, Center for Nanophase Materials Sciences, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831 — We performed molecular dynamics simulation of a model lamellipodium with growing F-actin filaments in order to study the effect of stiffness of the F-actin filament, the G-actin monomer concentration, and the number of polymerization sites on lamellipodium motion. The lamellipodium is modeled as a two-end capped cylinder formed by triangulated particles on its surface. It is assumed that F-actin filaments are firmly attached to a lamellipodium surface where polymerization sites are located and actin polymerization takes place by connecting a G-actin monomer to a polymerization site and the first monomer of a growing F-actin filament. It is found that there is an optimal number of polymerization sites for maximum motion. This optimum number of polymerization sites is independent of the number of available G-actin monomers, and the degree of pulling and holding the lamellipodium surface by non-polymerized actin filaments. The model lamellipodium speed distribution is found to be Maxwellian for particles with random motion in two dimensions and is in agreement with experiment.

8:48 AM U35.00003 Intracellular dynamics during directional sensing of chemotactic cells, GABRIEL AMSELEM, EBERHARD BODENSCHATZ, CARSTEN BETA, MPI for Dynamics and Self-Organization, Goettingen — We use an experimental approach based on the photo-chemical release of signaling molecules in microfluidic environments to expose chemotactic cells to well controlled chemotactant stimuli. We apply this technique to study intracellular translocation of fluorescently labeled PH-domain proteins in the social ameba Dictyostelium discoideum. Single chemotactic Dictyostelium cells are exposed to localized, well defined gradients in the chemoattractant CAMP and their translocation response is quantified as a function of the external gradient.

9:00 AM U35.00004 Searching strategies in Dictyostelium, LIANG LI, Department of Physics, Princeton University, EDWARD COX, Department of Molecular Biology, Princeton University — Levy walks are known to be the best strategy for optimizing non-destructive search times, while an intermittent two-state searching process optimizes the destructive case. Here we ask about hunting strategy in Dictyostelium amoebae when they cannot know where their food is. We show that correlated random walks with two typical correlation time scales bias their search, improving the search outcome. Further analysis indicates that cell trajectories consist of runs and turns. Strikingly, amoebae remember the last turn, and have a strong turning preference away from the last turn. Autocorrelation analysis of turn sequences indicates that this tendency does not persist beyond the nth+1 turn. Computer simulations reveal that this bias contributes to the longer of the two correlation times. The search rules are essentially the same when cells are continuously stimulated by CAMP, with different persistence times and lengths. Interestingly, new pseudopods form in an orientation opposite to the following turn. One of the correlation timescales is approximately 30 seconds in all cases, thus indicating a short-lived cellular process, while the other is 9 to 15 minutes suggesting a process sensitive to external signals, perhaps pseudopod extensions during turning.

9:12 AM U35.00005 Perturbing Streaming in Dictyostelium discoideum, COLIN MCCANN, University of Maryland, PAUL KRIEBEL, CAROLE PARENT, National Institutes of Health, ERIN RERICHA, WOLFGANG LOSERT, University of Maryland — Upon starvation the social amoebae Dictyostelium discoideum aggregate to form multicellular organisms. During the transition from single cells to full aggregates, cells relay the chemotactic signal, align in a head-to-tail fashion, and follow each other in streams. To gain more insight into streaming behavior we investigated two-end capped cylinder formed by triangulated particles on its surface. It is assumed that F-actin filaments are firmly attached to a lamellipodium surface where polymerization sites are located and actin polymerization takes place by connecting a G-actin monomer to a polymerization site and the first monomer of a growing F-actin filament. It is found that there is an optimal number of polymerization sites for maximum motion. This optimum number of polymerization sites is independent of the number of available G-actin monomers, and the degree of pulling and holding the lamellipodium surface by non-polymerized actin filaments. The model lamellipodium speed distribution is found to be Maxwellian for particles with random motion in two dimensions and is in agreement with experiment.

9:24 AM U35.00006 Traction cytometry applied to chemotacting Dictyostelium discoideum, ALBERTO ALISEDA, now at University of Washington, BALDOMERO ALONSO-LATORRE, JUAN CARLOS DEL ALALMO, JAVIER RODRIGUEZ-RODRIGUEZ, now at Universidad Carlos III, RUDOLPH MEILL, RICHARD FIRTEL, JUAN C. LASHERAS, University of California, San Diego — The motion of Dictyostelium discoideum cells moving on a elastic substrate has been studied. Joint analysis of time-lapse DIC movies of the cells and UV fluorescence from the beads embedded in the substrate, allows for identification of time scales of the motion and the quantitative description of the crawling cycle. From the measured displacements of the beads, forces can be computed by analytically solving the elasto-static equation in a finite thickness slab. We found that the finite thickness of the substrate and the distance of the beads to its surface have a substantial effect and that the previous traction cytometry techniques based on the Boussinesq solution effectively low-pass-filter the force field, reducing the spatial resolution and damping the range of the measured forces by as much as 50%.

The improved spatial resolution of this method enables us to determine the spatial extent of the regions where the cells apply force on the substrate and, consequently, the magnitude of the elastic energy spent in its deformation. The measured forces, as well as the elastic energy communicated by the cell to the substrate, will be correlated to the different stages of the crawling cycle for various cell strains.

We acknowledge a subcontract from NSF (grant # DMS-0240770, to A. Carlsson, Wash U.), NSERC, and MITACS (Canada)
9:36AM U35.00007 Stem cell cytoskeleton is slaved to active motors , FLORIAN REHFEIDT, ANDRE BROWN, ADAM ENGLER, DENNIS DISCHER, University of Pennsylvania — Cells feel their physical microenvironment through their adhesion and respond to it in various ways. Indeed, matrix elasticity can even guide the differentiation of human adult mesenchymal stem cells (MSCs) [Engler et al. Cell 2006]. Sparse cultures of MSCs on elastic collagen-coated substrates that are respectively soft, stiff, or extremely stiff were shown to induce neurogenesis, myogenesis, and osteogenesis. Lineage commitment was evaluated by morphological analysis, protein expression profiles, and transcription microarrays. Differentiation could be completely blocked with a specific non-muscle myosin II (NMM II) inhibitor, suggesting that contractile motor activity is essential for the cells to sense matrix elasticity. Current studies by AFM and near-field fluorescence imaging show that NMM II inhibition in stem cells on rigid glass surfaces promotes actin-rich dendritic outgrowth resembling neurite extension. Dynamic cell studies have been conducted to elucidate the complex molecular interplay of the contractile apparatus in response to selected physical and biochemical stimuli. Additional insight is being gained by using AFM to investigate the local elasticity of the cell’s cytoskeletal force sensing machinery.

9:48AM U35.00008 The Collective Contractile Dynamics of Confluent Epithelial Cells is Highly Coherent , THOMAS ANGELINI, Harvard University, INEST program, MANUEL MARQUEZ, PMUSA, DAVID WEITZ, Harvard University — We have studied the collective contractile dynamics of confluent Cos-7 epithelial cells in several contexts. We patterned cells in single file lines on confined PDMS ‘rubber bands’, and quantified substrate deformation by tracking embedded fluorescent particles over the course of approximately 10 hours. Deformations confined to one dimension, well over ten microns in magnitude, correlated over distances exceeding the millimeter scale, were observed. On unpatterned PDMS, collective substrate deformations in two dimensions were over ten times smaller, and exhibited a propagating mechanical excitation. Three dimensional matrix deformation was studied by embedding cells at high density in 1mg/ml collagen. Since collective network deformations are difficult to quantify in the microscope, a dynamic small angle light scattering technique was adapted. With this technique, we have spectrally characterized the three dimensional mechanical network deformations, and observed collective behavior similar to the measurements on compliant surfaces.

10:00AM U35.00009 Membrane fluctuations driven by actin and myosin: waves and quantized division , NIR GOV, ROIE SHLOMOVITZ, Weizmann Institute of Science — We present a model which couples the membrane with the protrusive forces of actin polymerization and contractile forces of molecular motors, such as myosin. The actin polymerization at the membrane is activated by freely diffusing membrane proteins, that may have a distinct spontaneous curvature. Molecular motors are recruited to the polymerizing actin filaments, from a constant reservoir, and produce a contractile force. All the forces and variables are treated in the linear limit, which allows us to derive analytic solutions. Our results show that for convex membrane proteins the myosin activity gives rise to propagating membrane waves similar to those observed on different cells. For concave membrane proteins the myosin activity gives rise to an unstable contraction, which yields a length-quantization of the mitosis process.

10:12AM U35.00010 Simulation of Actin-Polymerization-Mediated Propulsion 1, KUN-CHUN LEE, ANDREA LIU, University of Pennsylvania, Department of Physics and Astronomy — An important component of the cellular cytoskeleton is F-actin, a bipolar polymer whose self-assembly is key to the process of cell crawling. The polymerization and branching of F-actin near the cell membrane is known to drive cell crawling, but the precise mechanism by which these processes lead to the generation of a mechanical force is still controversial. We have constructed a Brownian dynamics simulation of F-actin polymerizing near a surface, which includes all known important processes, including polymerization, depolymerization, branching, severing and capping. Using this model, we are able to simulate the cell movement. We measure the speed as function of concentration of different proteins involved in the process. We find the speed to be non-monotonic, consistent with experimental results [Louis et al. Nature 401 613 (1999)].

1 This work is supported by NSF-CHE06-13331 and UPenn MRSEC NSF-DMR05-20020.

10:24AM U35.00011 Symmetry breaking in actin gels - Implications for cellular motility 1, KARIN JOHN, PHILIPPE PEYLA, CHAOQUI MISBAH, UJF Grenoble, Laboratoire de Spectrométrie Physique — The physical origin of cell motility is not fully understood. Recently minimal model systems have shown, that polymerizing actin itself can produce a motile force, without the help of motor proteins. Pathogens like Shigella or Listeria use actin to propel themselves forward in their host cell. The same process can be mimicked with polystyrene beads covered with the activating protein ActA, which are in a solution containing actin monomers. ActA induces the growth of an actin gel at the bead surface. Initially the gel grows symmetrically around the bead until a critical size is reached. Subsequently one observes a symmetry breaking and the gel starts to grow asymmetrically around the bead developing a tail of actin at one side. This symmetry breaking is accompanied by a directed movement of the bead, with the actin tail trailing behind the bead. Force generation relies on the combination of two properties: growth and elasticity of the actin gel. We study this phenomenon theoretically within the framework of a linear elasticity theory and linear flux-force relationships for the evolution of an elastic gel around a hard sphere. Conditions for a parity symmetry breaking are identified analytically and illustrated numerically with the help of a phasefield model.

1 CNES, Humboldt-Foundation

10:36AM U35.00012 A kinematic description of the trajectories of Listeria monocytogenes propelled by actin comet tails , DHANANJAY TAMBE, VIVEK SHENOY, Brown University — The bacterial pathogen Listeria monocytogenes propels itself in the cytoplasm of the infected cells by forming a filamentous comet tail assembled by the polymerization of the cytoskeletal protein, actin. While a great deal is known about the molecular processes that lead to actin based movement, most macroscopic aspects of motion, including the nature of the trajectories traced out by the motile bacteria are not well understood. Listeria moving between a glass-slide and cover slip in a Xenopus frog egg extract motility assay is observed to display a number of geometrically fascinating trajectories including sine curves, serpentine shapes, circles, and a variety of spirals. We have developed a dynamic model that provides a unified description of these seemingly unrelated trajectories. A key ingredient of the model is a torque (not included in any microscopic models to date) that arises from the rotation of the propulsive force about the body-axis of the bacterium. The trajectories of bacteria executing both steady and salutary motion are found to be in excellent agreement with the predictions of our dynamic model. When the constraints that lead to planar motion are removed, our model predicts motion along regular helical trajectories, observed in recent experiments. We discover from the analysis of the trajectories of spherical beads that the comet tail revolves around the bead.

10:48AM U35.00013 Steady-state configurations and dynamics of the MreB helix within bacteria, ANDREW RUTENBERG, JUN ALLARD, Dalhousie University — We present a quantitative model of the actin-like MreB cytoskeleton that is present in many prokaryotes. Individual MreB polymers are bundled into a supra-molecular array to make up helical cables. The cell wall imposes constraint forces on any microscopic models to date) that arises from the rotation of the propulsive force about the body-axis of the bacterium. The trajectories of bacteria executing both steady and salutary motion are found to be in excellent agreement with the predictions of our dynamic model. When the constraints that lead to planar motion are removed, our model predicts motion along regular helical trajectories, observed in recent experiments. We discover from the analysis of the trajectories of spherical beads that the comet tail revolves around the bead.

This work is supported by NSF-CHE06-13331 and UPenn MRSEC NSF-DMR05-20020.
The nonequilibrium thermodynamics of small systems, FELIX RITORT, University of Barcelona — Nonequilibrium behavior is widespread and rich in nature. Yet our understanding of the fundamental principles underlying nonequilibrium behavior is still poor as shown by the fact that non-equilibrium theories tend to be ad-hoc and specific (1). Recently there has been a lot of interest in applying single-molecule techniques to scrutinize nonequilibrium theories (2). The use of new micromanipulation tools in the exploration of the behavior of tiny objects (such as biomolecules and motors) embedded in a thermal environment opens the possibility to investigate how these systems exchange energy with their environment. The study of such questions, nowadays referred to as “Nonequilibrium thermodynamics of small systems,” is becoming quite popular among statistical physicists who recognize there new aspects of thermodynamics where large Brownian fluctuations are of pivotal importance as compared to fluctuations in macroscopic (or large) systems (3). Nonequilibrium small systems are characterized by large deviations in work/heat distributions that satisfy some relations called fluctuation theorems. In this talk I will discuss single-molecule experiments where some of these fluctuation theorems have been tested (4).

REFERENCES:
(1) F. Ritort, Nonequilibrium fluctuations in small systems: From physics to biology, To be published in Advances in Chemical Physics, volume 137;
(3) C. Bustamante, J. Liphardt and F. Ritort, The nonequilibrium thermodynamics of small systems, Physics Today,58 (2005) 43-48;

Activation barrier scaling and crossover for noise-induced switching in a micromechanical parametric oscillator, COREY STAMBAUGH, HO BUN CHAN, University of Florida — We explore fluctuation-induced switching in a parametrically-driven micromechanical torsional oscillator, a system far from thermal equilibrium. Under sufficiently strong parametric modulation of the spring constant, the oscillator possesses one, two or three stable attractors depending on the modulation frequency. Near the bifurcation points where the number of attractors changes, the activation barrier for switching out of a stable state is predicted to display universal, system-independent scaling relationships. We induce the oscillator to switch between the coexisting states by injecting noise in the excitation. By measuring the rate of random transitions as a function of noise intensity, we deduce the activation barrier as a function of frequency. Near both bifurcation points, the activation barriers are found to depend on frequency detuning with critical exponent of 2, consistent with the predicted universal scaling in parametrically driven systems. Away from the immediate vicinity of the bifurcation point, universal scaling relationships for the activation barrier no longer hold. At large detuning, we observe a crossover to a different power law dependence with an exponent that is specific to our device.

Scaling crossovers in activated escape of nonequilibrium systems: a resonantly driven oscillator, OLEG KOGAN, California Institute of Technology, IRA SCHWARTZ, Naval Research Laboratory, MARK DYKMAN, Michigan State University — The rate of metastable decay in nonequilibrium systems is expected to display scaling behavior: i.e., the logarithm of the decay rate should scale as a power of the distance to a bifurcation point where the metastable state disappears. Recently such behavior was observed and some of the earlier predicted exponents were found in experiments on several types of systems described by a model of a modulated oscillator. Here we establish the range where different scaling behavior is displayed and show how the crossover between different types of scaling occurs. The analysis is done for a nonlinear oscillator with two coexisting stable states of forced vibrations. We map out the entire parameter range. We find the regions where the scaling exponents are 1 or 2/3, depending on the damping. We also uncover new scaling behavior which extends, numerically, beyond the close vicinity of the bifurcation point. The results of the numerical calculations based on the instanton method are compared with the results of Monte Carlo simulations.

Spontaneous symmetry breaking in parametrically driven atomic trap and measurement of dynamic critical exponents, WONHO JHE, MYOUNG-SUN HEO, YONGHEE KIM, KIWHAN KIM, Seoul National University, HEUNG-ROYUL NOH, Chonnam National University, SEOUL NATIONAL UNIVERSITY TEAM, CHONNAM NATIONAL UNIVERSITY COLLABORATION — While critical phenomena in equilibrium systems has been well established both in theory and in experiment, experimental studies in non-equilibrium or far-from-equilibrium systems still lack of quantitative investigation and remain as challenging subjects. Here we report on the use of laser cooled and trapped atoms can be a good candidate for such study since one can easily control its temperature and numbers. By parametrically modulating the magneto-optical trap potential we have observed several interesting phenomena such as dynamic double well, Hopf bifurcation and spontaneous symmetry-breaking (SSB). Particularly SSB is identified as the mean-field system exhibiting the Ising-like phase transition. We measured critical exponents relevant to this phase transition, with respect to the control parameter, the size of the system or the total number of atoms. We also have observed the occurrence of SSB as the temperature is changed by illuminating a resonant laser light.

Equilibrium theory for a particle pulled by a moving optical trap, RAYMOND DEAN ASTUMIAN, University of Maine — The viscous drag on a colloidal particle pulled through solution by an optical trap is large enough that on experimentally relevant time scales the mechanical force exerted by the trap is equal and opposite the viscous drag force. The rapid mechanical equilibration allows the system to be modeled using equilibrium theory where the effects of the energy dissipation (thermodynamic disequilibrium) show up only in the coordinate transformations that map the system from the laboratory frame of reference, relative to which the particle is moving, to a frame of reference in which the particle is, on average, stationary and on which the stochastic dynamics is governed by a canonical equilibrium distribution function. The simple equations in the stationary frame can be analyzed using the Onsager-Machlup theory for stochastic systems and provide generalizations of equilibrium and near equilibrium concepts such as detailed balance and fluctuation-dissipation relations applicable to a wide range of systems including molecular motors, pumps, and other nano-scale machines.

Energy and efficiency optimization of a Brownian heat engine, MULUGETA BEKELE, Department of Physics, Addis Ababa University, Addis Ababa, Ethiopia, YENENEH YALEW, Eindhoven University of Technology, Eindhoven, The Netherlands — A simple Brownian heat engine is modeled as a Brownian particle moving in an external sawtooth potential (with or without) load assisted by the thermal kick it gets from alternately placed hot and cold heat reservoirs along its path. We get closed form expression for its current in terms of the thermal kick it gets from alternately placed hot and cold heat reservoirs along its path. We get closed form expression for its current in terms of the

1 We would like to thank the International Programme in Physical Sciences, Uppsala University, Sweden for the support in carrying out the research as well as travel support to this APS March Meeting

Relationships involving spatial transitions for Brownian particles within a potential-well, ROSS BRODY, University of Maine — Using an optical tweezer apparatus we have trapped single latex spheres and analyzed their Brownian motion within a potential well. By considering transitions from various initial and final positions within the well, we experimentally show that the ratio of conditional probabilities, \[ P(x_f, t + \Delta t | x_i, t) / P(x_i, t + \Delta t | x_f, t) \], is independent of \( \Delta t \). We also show the instanton times corresponding to last-touch-first-touch (LTFT) trajectories obey the equality, \( LTFT(x_1 \rightarrow x_f) = LTFT(x_f \rightarrow x_1) \), shown by Bier et al. [Phys. Rev. E 59, 6422 (1999)].
probability distributions of local intermediate scattering functions in the aging regime, the equilibrium regime and the crossover between them, for a simple structural glass with purely repulsive Weeks-Chandler-Anderson interactions. However, we show that these novel properties can in fact be proven for suitably modified models of correlated percolation, with qualitatively different behavior but with diverging time scales and correlation lengths. We show that their proof misidentified the critical point, so that these properties are currently unproven for this model. Atomic force microscopy was used to manipulate and unfold individual molecules of the muscle protein titin. We reconstructed the free energy surface of stretching and unfolding of titin I27 domain using Jarzynski’s equality. An exact formula that relates the nonequilibrium work fluctuations to the molecular free energy was used for the reconstruction. From the free energy surface, the unfolding free energy barrier, i.e. the activation energy, was directly obtained from experimental data for the first time.

JENG, JENNIFER SCHWARZ, Syracuse University — Toninelli, Biroli, and Fisher recently introduced a model of correlated percolation called the Knight model, for which they claimed to prove underwent a dynamical glass transition. This transition had novel properties, with a discontinuous jump in the order parameter, which they associated with small regions. We compare the results for probability distributions in the different regimes, and we show that the nonequilibrium work fluctuations to the molecular free energy was used for the reconstruction. From the free energy surface, the unfolding free energy barrier, i.e. the activation energy, was directly obtained from experimental data for the first time.

Thursday, March 8, 2007 11:15AM - 2:03PM
Session V22 GSNP: Focus Session: Jamming II
Colorado Convention Center 108

11:15AM V22.00001 A Local, Geometrical Probe for Jamming, MARTIN VAN HECKE, Leiden University — When jammed disordered materials such as Lennard-Jones systems, granulates and foams are forced externally, the resulting deformation fields exhibit large scale vortical patterns and are strongly non-affine. Here we introduce the distribution P(\alpha) as a local probe of the non-affine nature of this response. \alpha denotes the angle between the bonds and the local deformations of pairs of particles in contact - hence \alpha = \pi/2 corresponds to particles sliding past each other, while particles squeezed together or moving apart correspond to \alpha = 0 or \pi. We find that near jamming, P(\alpha) becomes strongly peaked around \pi/2, with the width and height of the peak scaling with the distance to the jamming point. Grains then predominantly slide past each other, which signals an increasingly non-affine response of the material caused by the proximity of floppy modes. We relate this local measure to the global, anomalous scaling of the elastic moduli and contact numbers near jamming, and show the first experimental determination of P(\alpha) in sheared, 2D foams.

11:51AM V22.00002 A critical length scale in jammed granular media, WOUTER ELLENBROEK, Leiden University, ELLAK SOMFAI, Oxford University, MARTIN VAN HECKE, WIM VAN SAARLOOS, Leiden University — Granular media consist of macroscopic, anisotropic particles that “jam” into a solid-like state when subjected to a confining pressure. Recent studies of this jamming transition in systems of frictionless particles have shown, quite remarkably, that the jamming point has many features of a critical point, exhibiting power law scalings of various quantities nearby. We study the linear response of these jammed systems to a localized mechanical perturbation. The response fluctuations over a length scale that diverges at the jamming transition, providing a direct numerical observation of a critical length scale in jammed granular media.

12:03PM V22.00003 Critical Scaling at the Jamming Transition for Zero and Finite Applied Shear Stress1, PETER OLSSON, Umeå University, STEPHEN TEITEL, University of Rochester — We carry out numerical simulations to study the jamming transition of a model granular material in two dimensions at zero temperature. Behavior is simulated as a function of particle density and applied shear stress. We find a collapse of our data to scaling curves that provides evidence for a sharp 2nd order jamming transition in non-equilibrium steady states at finite shear, that ends at a critical point (point “J”) as the shear stress vanishes. We estimate the values of the critical exponents at both zero and finite shear stress.

11 supported in part by DOE grant DE-FG02-06ER46298.

12:15PM V22.00004 The fluid-glass transition for hard spheres, JOHN DROZD, COLIN DENNISTON, University of Western Ontario — A gravity-driven hard sphere simulation is used to study the phenomena of disorder-order transitions, or simply the glass transition from a granular hard sphere fluid to a jammed glass. We find a diverging length scale and a diverging viscosity at this transition and compare our simulation to experiment on the connection between local velocity fluctuations and shear rate.

12:27PM V22.00005 Correlated Percolation Models of Jamming and Glass Transitions, MONWHEA JENG, JENNIFER SCHWARZ, Syracuse University — Toninelli, Biroli, and Fisher recently introduced a model of correlated percolation called the Knight model, which they claimed to prove underwent a dynamical glass transition. This transition had novel properties, with a discontinuous jump in the order parameter, but with diverging time scales and correlation lengths. We show that their proof misidentified the critical point, so that these properties are currently unproven for this model. However, we show that these novel properties can in fact be proven for suitably modified models of correlated percolation, with qualitatively different behavior but with diverging time scales and correlation lengths. We show that their proof misidentified the critical point, so that these properties are currently unproven for this model. However, we show that these novel properties can in fact be proven for suitably modified models of correlated percolation, with qualitatively similar culling rules. We discuss the features of the models necessary for a rigorous proof to be possible. We also discuss properties of models such as the force balance model and the original Knight model, which appear to undergo novel transitions despite the lack of a rigorous proof of such a transition.

12:39PM V22.00006 Fluctuations in the crossover from aging to equilibrium of a structural glass, AZITA PARSAYIAN, HORACIO E. CASTILLO, Department of Physics and Astronomy, Ohio University — We investigate the fluctuations in the aging regime, the equilibrium regime and the crossover between them, for a simple structural glass with purely repulsive Weeks-Chandler-Anderson interactions. We characterize how the fluctuations evolve by studying the probability distributions of local observables such as individual particle displacements \Delta x and intermediate scattering functions C_g associated with small regions. We compare the results for probability distributions in the different regimes, and we also compare with results obtained previously for the aging regime of a glass with both repulsive and attractive interactions. We discuss the fitting of the probability distributions of local intermediate scattering functions C_g by generalized Gumbel distributions, and the tails of the probability distributions of particle displacements by non-linear exponential forms.
12:51PM V22.00007 Colloidal Glass Transition Observed in Confinement, KAZEM EDMOND, Emory University, CARRIE NUGENT, HETAL N. PATEL, ERIC R. WEEKS, Emory University — We study a colloidal suspension confined between two parallel walls as a model system for glass transitions in confined geometries. The suspension is a mixture of two particle sizes to prevent wall-induced crystallization. We use confocal microscopy to directly observe the motion of particle clusters. This motion is slower in confinement, thus producing glassy behavior in a sample which is a liquid in an unconfined geometry. We present results from a range of volume fractions. Our results demonstrate that the maximum thickness at which confinement effects still occur defines a length scale for a given particle volume fraction. This length scale increases as the volume fraction increases toward the glass transition.

1:03PM V22.00008 The Manhattan Model: A simple model for glassy dynamics, PRASANTA PAL, Department of Applied Physics, Yale University, COREY O’HERN, Department of Mechanical Engineering, Department of Physics, Yale University, JERZY BLAWZDZIEWICZ, Department of Mechanical Engineering, Yale University, O’HERN GROUP TEAM — We study the dynamics of 1d hard rods undergoing Brownian motion in an array of narrow, multiply intersecting channels. In the current version, the junction size equals the particle size and particles are prevented from making turns at each intersection. This simple model shares many of the important features of glassy systems including kinetic arrest, cooperative and heterogeneous dynamics, and aging behavior in the high packing fraction limit. One of our key results is that the structural relaxation time and other dynamical quantities increase super-exponentially with \( \phi \) and diverge at \( \phi_g < \phi_{cp} \) significantly below the close-packed density.

1:15PM V22.00009 Simultaneous measurements of bulk moduli and particle dynamics in a sheared colloidal glass, MICHAEL V. MASSA, CHRISTOPH EISENMANN, CHANJOONG KIM, DAVID A. WEITZ, DEAS, Harvard University, Cambridge, MA 02138, USA — We present a novel study of glassy colloidal systems, using a stress-controlled rheometer in conjunction with a confocal microscope. This experimental setup combines the measurement of bulk moduli, using conventional rheology, with the ability to track the motion of individual particles, through confocal microscopy techniques. We explore the response of the system to applied shear, by simultaneously monitoring the macroscopic relaxation and microscopic particle dynamics, under conditions from the quiescent glass to a shear-melted liquid.

1:27PM V22.00010 Discontinuous shear thickening, or shear jamming, of dense suspensions of uniform non-spherical particles, RYAN LARSEN, JIN-WOONG KIM, Division of Engineering and Applied Sciences, Harvard University, DAVID WEITZ, Division of Engineering and Applied Sciences and Department of Physics, Harvard University — Discontinuous shear thickening, or shear jamming, occurs when suspensions undergo a shear-induced transition from fluid-like behavior to solid-like behavior. Because jamming is associated with geometrical confinement of the particles, it is reasonable to expect particle shape to have an effect on the jamming of suspensions. To test this dependence, we synthesize uniform polystyrene particles of dumbbell and triangle shape and compare their jamming behavior to that of equivalent spheres. We show that the non-spherical particles display more dramatic viscosity increases during jamming, and they persist in the jammed state for longer periods of time. Moreover, as the spherical particles approach the jamming transition, they oscillate stochastically between the jammed and un-jammed states on milli-second time scales, whereas the non-spherical particles display no such behavior. We rationalize these qualitative differences in jamming behavior in terms of the higher packing efficiency of non-spheres at low shear rates relative to that at high shear rates.

1:51PM V22.00012 Signatures of critical phenomena of a filled elastomer under deformation, MINDAUGAS RACKAITIS, XIAORONG WANG, Bridgestone Center for Research and Technology — Fluctuations and critical phenomena have drawn much attention for many years. But, no report anticipates that an elastomer containing fillers under gentle deformations will show similar effects. In this presentation, we show that a filled rubber system under about 2% strain may display feature fluctuations that could be associated with a transition of the filler from an elastic solid state to a dispersed fluid state and that is reminiscent of critical phenomena. Besides, electrical conductivity fluctuations and their link to the mechanical fluctuations will also be discussed. In addition, we show that the fluctuation of macroscopic parameters can be related to the microscopic fluctuation of filler structures in the rubber compound and in principle it can act as a probe of what is happening physically at the microscopic scale.

Thursday, March 8, 2007 2:30PM - 4:54PM –
Session W22 GSNP: Applications to Networks and Organized Systems Colorado Convention Center 108

2:30PM W22.00001 ABSTRACT WITHDRAWN –

2:42PM W22.00002 Predicting large events in power-law distributed avalanches: implications for earthquake forecast, OSVANNY RAMOS, Physics Department, University of Oslo, Blindern, 0316 Oslo, Norway, ERNESTO ALTSHULER,\footnote{Henri Poincare’ group of Complex Systems, Physics Faculty, University of Havana, 10400 Havana, Cuba, KNU丁 JORGEN MALOY, Physics Department, University of Oslo, Blindern, 0316 Oslo, Norway — It is a common idea that power law distributed avalanches are inherently unpredictable. It mostly comes from the concept of Self-organized criticality. Nevertheless, we have found in classical simulations and experiments where the slowly addition of energy drives the system into a state of power law distributed avalanches, clear signs of both long and short term prediction. The simulations consist of a more realistic modification of the Olami-Feder-Christensen earthquake model where criticality and periodicity coexist. The experiment shows a clear power law behaviour for the system into a state of power law distributed avalanches, clear signs of both long and short term prediction.}

Our work is supported by the NSF (DMR-0602684) and the Harvard MRSEC (DMR-0213805)
2:54PM W22.00003 Space-Time Clustering and Correlations of Earthquakes, JAMES HOLLIDAY, JOHN RUNDLE, Center for Computational Science and Engineering, University of California, Davis, DONALD TURCOTTE, Department of Geology, University of California, Davis, WILLIAM KLEIN, Department of Physics, Boston University, KRISTY TIAMPO, Department of Earth Sciences, University of Western Ontario, ANDREA DONNELLAN, NASA Jet Propulsion Laboratory — Earthquake occurrence in nature is thought to result from correlated elastic stresses, leading to clustering in space and time. We show that occurrence of major earthquakes correlates with time intervals when fluctuations in small earthquakes are suppressed relative to the long term average and estimate a probability of less than 1% that this coincidence is due to random clustering. Furthermore, we show that an order parameter can be defined to characterize these fluctuations and that a generalized Ginzburg criterion can be established to measuring the relative importance of fluctuations in the parameter.

3:06PM W22.00004 Numerical simulations of the 2-dimensional Robin-Hood model, GABRIEL CWILICH, PERRY FOX, FREDY ZYPMAN, SERGEY BULDYREV, Yeshiva University, Physics Department — The Robin Hood, or Zaitsev model [1] has been successfully used to model depinning of interfaces, friction, dislocation motion and flux creep, because it is one of the simplest extremal models for self-organized criticality. Until now, its properties have been well understood theoretically in one dimension and its scaling laws numerically verified. It is important to extend the range of validity of these laws into higher dimensions, to find precise values for the scaling exponents, and to investigate how they depend on the details of the model (like anisotropy). The case of two dimensions is of particular importance when studying surface friction [2]. Here, we numerically evaluate high precision scaling exponents for the avalanche size distribution, the avalanche fractal dimension, and the Levy flight-like distribution of the jumps between extremal active sites. [1] S.I. Zaitsev, Physica A 189, 411 (1992). [2] S. Budyrev, J. Ferrante and F. Zypman Phys. Rev E (accepted)

3:18PM W22.00005 Self-organized criticality of elastic networks, MYKKYA V. CHUBYNSKY, M.-A. BRIÈRE, NORMAND MOUSSEAU, Département de physique and RQCHP, Université de Montréal, Montréal, Québec, Canada — We consider a model of elastic network self-organization inspired by studies of covalent glasses [1,2]. In the model, networks self-organize by avoiding stress whenever possible, but otherwise are random. Instead of a single rigidity percolation transition, with percolation always absent below a certain bond concentration and always present above, we find that the percolation threshold lies somewhere in a range of bond concentrations, the intermediate phase. A power-law distribution of non-percolating cluster sizes, normally observed at a single critical point in percolation transitions, is seen everywhere in the intermediate phase. There is also a finite probability of percolation appearing and disappearing upon the application of a microscopic perturbation (addition or removal of a single bond). These properties indicate that in this phase the network maintains itself in a critical state on the verge of rigidity, a signature of self-organized criticality, but in a system at equilibrium.


3:30PM W22.00006 Transport in Weighted Networks: Partition into Superhighways and Roads, ZHENHUA WU, Center for Polymer Studies, Boston University, Boston, Massachusetts 02215, USA, LIDIA A. BRAUNSTEIN, Departamento de Física, Facultad de Ciencias Exactas y Naturales, Universidad Nacional de Mar del Plata, Funes 3350, 7600 Mar del Plata, Argentina, SHLOMO HAVLIN, Minerva Center of Department of Physics, Bar-Ilan University, Ramat Gan, Israel, H. EUGENE STANLEY, Center for Polymer Studies, Boston University, Boston, Massachusetts 02215, USA — Transport in weighted networks is dominated by the minimum spanning tree (MST), the tree connecting all nodes with the minimum total weight. We find that the MST can be partitioned into two distinct components, having significantly different transport properties, characterized by centralities of node (or link) used by transport paths. One component, superhighways, is the infinite incipient percolation cluster, for which we find that nodes (or links) with high centrality dominate. For the other component, roads, which includes the remaining nodes, low centrality nodes dominate. We find also that the distribution of the centrality for the infinite incipient percolation cluster satisfies a power law, with an exponent smaller than that for the entire MST. The significance of this finding is that one can improve significantly the global transport by improving a tiny fraction of the network, the superhighways.

3:42PM W22.00007 Geometric properties of minimal-cost spanning trees, TOM JACKSON, N. READ, Yale University — The minimal-cost spanning tree (MST) problem is one of the oldest combinatorial optimization problems of computer science: given a graph with a unique cost associated with each edge, the MST is the subset of edges that will connect all vertices of the graph to each other at lowest total cost. While the MST is easy to compute (i.e., of polynomial complexity), it is of interest both intrinsically and as a heuristic approximation to harder questions in optimization, such as the Steiner tree and Traveling Salesmen problems. Using techniques of statistical field theory, we study the random MST where the edge costs are independent, identically distributed, random variables. We develop a mean field theory by solving the MST exactly on the Bethe lattice using the relationship between bond percolation and Kruskal’s greedy algorithm for the MST. These considerations carry over to finite dimensional lattices and the field theory for percolation in $d - \epsilon$ dimensions. From this we find that the critical dimension $d_c = 6$ for the MST problem, contrary to the result $d_c = 8$ previously suggested by Newman and Stein. Finally we calculate to order $\epsilon$ the Hausdorff (fractal) dimension of the unique path on the MST connecting two widely separated points.

3:54PM W22.00008 Ridge Network of Crumpled Paper, CHRISTIAN ANDRESEN, ALEX HANSEN, Norwegian University of Science and Technology, JEAN SCHMITTBUEHL, Ecole et Observatoire des Sciences de la Terre — The work presented has investigated the network formed by the complete sets of ridges from samples of crumpled paper. Sheets of paper were crumpled, and their height profiles measured by a laser profilometer. From these data lines of high curvature were identified as ridges. Intersections between ridges were considered as nodes, and the ridges as links between these nodes. The emerging networks have been investigated using network theory. Properties such as the degree distribution, degree correlation and clustering coefficient are reported. These are compared to comparable random networks and networks formed by the Voronoi diagrams. Spatial properties such as the ridge length, domain area and vertex distributions have also been investigated.

4:06PM W22.00009 Physics of curling ribbons, ANNA M. KLALES, Department of Physics and Astronomy, Haverford College, Haverford, PA 19041, BUDDHAPIRYA CHAKRABARTI, Lyman Laboratory of Physics, Harvard University, Cambridge, MA 02138, VINCENZO VITIELLI, Department of Physics and Astronomy, University of Pennsylvania, Philadelphia, PA 19104, L. MAHADEVAN, Division of Engineering and Applied Sciences, Harvard University, Cambridge, MA 02138, VINOTHAN MANOHARAN, Department of Physics, Harvard University, Cambridge, MA 02138 — Curling decorative ribbons by dragging it past one’s thumb and the blade of a scissor is a well known technique used frequently. However a quantitative understanding of this apparently simple phenomenon is still lacking. We present results from recent experimental and theoretical investigations of this problem. Using the insights gained from this we propose a method of generating novel shapes by differential stretching and subsequent selective stress relief for thin sheets. We discuss the implications of this mechanism for the formation of ribbon like structures in biological systems.
validate, the most surprising prediction. The success of this model illuminates the emergent (network-level) functional robustness of cellular regulatory networks.

perturbations. Although qualitative, the model provides a ranking of disruptions and perturbations in the order of their severity. We experimentally test, and varying process durations and initial conditions and by simulating gene disruptions, and find a remarkable robustness against a significant fraction of possible accords well with previous experimental results at both the pathway and whole cell physiological level. We identify the dynamical repertoire of the network by regulating drought response in plants. We integrate qualitative and indirect relationships into the simplest network consistent with all experimental observations, networks and there is significant robustness to changes in kinetic parameters. This presentation will focus on a Boolean model of the signal transduction network.

1Although high throughput genomics and proteomics. On the other hand, current information about the network is mostly qualitative—while there is a circuit diagram for the spontaneous activity of a neuron. In this model, the firing of the neuron corresponds to the first passage of the process to a constant boundary, or threshold. While the Laplace transform of the first passage time distribution is available, the real density has not been obtained in any tractable form. We address the problem of estimating the parameters of the process when the only available data from a neuron are the interspike intervals, or the times between firings. In particular, we give an algorithm for computing maximum likelihood estimates (MLEs) and their corresponding confidence regions for the model parameters by numerically inverting the Laplace transform. We also provide an analysis on the reliability of the estimates and their confidence regions when simulated data is used to generate the first passage sample.

1Work done in collaboration with F. Li, Y. Lu, M. Zhong, Q. Ouyang.

Friday, March 9, 2007 8:00AM - 11:00AM —
Session X6 GSNP DBP: Networks in Genetic Regulation
Colorado Convention Center 207

8:00AM X6.00001 Check Point as Fixed point: Analysis of a Yeast Cell-Cycle Model1. CHAO TANG, University of California, San Francisco — The cell cycle regulation in the budding yeast Saccharomyces cerevisiae is one of the best studied biological systems. Many major players and their interactions have been identified by decades of work in genetics and biochemistry as well as by the more recent effort in high-throughput genomics and proteomics. On the other hand, current information about the network is mostly qualitative—while there is a circuit diagram (although it may not be complete) of who regulates whom, there is little quantitative information (e.g. kinetic constants) about the regulation. Here we construct a model of yeast cell-cycle regulation from the known circuit diagram using ordinary differential equations and focus our attention on the global dynamic property and structural stability of the system. We found that certain qualitative conclusions about the system’s behavior are very robust to parameter choices. In particular, each checkpoint can be a global attractor—when a checkpoint is on all cell states evolve to the stationary state corresponding to the checkpoint arrest. Furthermore, there is a unique globally attracting trajectory for this dynamic system, which corresponds to the biological pathway of the cell cycle regulation. Substantial changes of certain parameters, especially when several parameters are changed simultaneously, can result in qualitative changes in the system’s behavior. Typically, these not-so-robust parameters are associated with transitions between different cell-cycle phases and the corresponding abnormal behavior is often related to the arrest or bypass of a checkpoint. Our results reveal a robust picture of the yeast cell cycle regulation and the mechanisms under which the robustness can be compromised.

1Work done in collaboration with F. Li, Y. Lu, M. Zhong, Q. Ouyang.

8:36AM X6.00002 Boolean modeling of cellular regulatory networks1. REKA ALBERT, Pennsylvania State University — Interaction between gene products forms the basis of essential processes like signal transduction, cell metabolism or embryonic development. Recent experimental advances helped uncover the structure of many cellular networks, creating a surge of interest in the dynamical description of gene regulation. Traditionally genetic and protein interactions are modeled by differential equations based on reaction kinetics, but these studies are greatly hampered by the sparsity of known kinetic detail. As an alternative, qualitative models assuming a small set of discrete states for gene products, or combinations of discrete and continuous dynamics, are gaining acceptance. Many results also suggest that the interaction topology plays a determining role in the dynamics of regulatory networks and there is significant robustness to changes in kinetic parameters. This presentation will focus on a Boolean model of the signal transduction network regulating drought response in plants. We integrate qualitative and indirect relationships into the simplest network consistent with all experimental observations, and express the regulation of network nodes as logical functions. Our model captures the regulation of more than forty identified network components, and accords well with previous experimental results at both the pathway and whole cell physiological level. We identify the dynamical repertoire of the network by varying process durations and initial conditions and by simulating gene disruptions, and find a remarkable robustness against a significant fraction of possible perturbations. Although qualitative, the model provides a ranking of disruptions and perturbations in the order of their severity. We experimentally test, and validate, the most surprising prediction. The success of this model illuminates the emergent (network-level) functional robustness of cellular regulatory networks.

9:12AM X6.00003 Symmetry and the Self-Organized Evolution of Canalization in Boolean Networks. KEVIN BASSLER, University of Houston — Canalization of genetic regulatory networks have been argued to be favored by evolutionary processes due to the stability that it can confer to phenotype expression. Using an N-K Boolean network model of a genetic regulatory network, we explore whether a significant amount of canalization can arise in purely random networks in the absence of evolutionary pressures. We use a mapping of the Boolean functions in the Kauffman N-K model for genetic regulatory networks onto a k-dimensional Ising hypercube to show that the functions can be divided into different classes strictly due to geometrical constraints. The classes can be counted and their properties determined using results from group theory and isomer theory. We demonstrate that partially canalized functions completely dominate all possible Boolean functions, particularly for higher K. This indicates that partial canalization is extremely common, even in randomly chosen networks, and has implications for how much information can be obtained in experiments on native state genetic regulatory networks. Furthermore, we demonstrate that a highly canalized state evolves spontaneously from a highly canalized state at the terminus of a competition between the different classes strictly due to geometrical constraints. The classes can be counted and their properties determined using results from group theory and isomer theory. We demonstrate that partially canalized functions completely dominate all possible Boolean functions, particularly for higher K. This indicates that partial canalization is extremely common, even in randomly chosen networks, and has implications for how much information can be obtained in experiments on native state genetic regulatory networks. Furthermore, we demonstrate that a highly canalized state evolves spontaneously from a competition between the nodes. Network finite-size effects are found to be important to that evolutionary process.

9:48AM X6.00004 Quantitative aspects of gene regulation by small RNAs. PANKAJ MEHTA, Princeton University — Small, non-coding RNAs (sRNAs) play an important role as genetic regulators in both prokaryotes and eukaryotes. Many sRNAs act through base-pairing interaction with target messenger RNAs (mRNAs) to regulate transcription, translation, and mRNA stability. sRNAs represent a novel form of genetic regulation distinct from more thoroughly studied protein regulators. This talk addresses quantitative aspects of sRNA-mediated genetic regulation, focusing on noise, tunability, and feedback. In particular, we compare and contrast sRNA and protein regulators in an attempt to understand the comparative advantages of each form of regulation.

10:24AM X6.00005 Gene regulatory networks: what is still missing? GÁBOR BALÁZS, University of Texas M. D. Anderson Cancer Center — Gene regulatory networks have evolved to respond to a changing environment, serving the survival of the biological population. The topology of these networks has been investigated with the hope of gaining insight into their function or identifying the factors shaping their evolution. Recent studies have shown that gene regulatory networks have different in-degree and out-degree distribution, contain network motifs, and are organized in a hierarchical set of layers. However, important pieces of information are still needed before the topological features of these networks can be correctly determined and their response to environmental changes can be modeled at increasingly large scales.

Friday, March 9, 2007 8:00AM - 10:36AM — Session X22 GSNP DMP: Focus Session: Deformation and Fracture Colorado Convention Center 108

8:00AM X22.00001 Crystal strength by direct computation. VASILY BULATOV, Lawrence Livermore National Laboratory — The art of making materials stronger goes back to medieval and even ancient times. Swords forged from Damascus steels more than 10 centuries ago possessed a unique combination of hardness and flexibility, two qualities that are difficult to attain simultaneously. The skills of metalworking were based on empirical knowledge and were passed from the master smith to his pupils. The science of physical metallurgy came about only in the XX century bringing with it new methods for finding out why some materials are strong while others are not. Soon it was realized that, when it comes to metal strength, it is all about crystal defects — impurities, dislocations, grain boundaries, etc. — and how they are organized into crystal microstructure. This understanding has since resulted in new effective methods of material processing aiming to modify crystal microstructure in order to affect material's properties, e.g. strength and/or hardness. Remarkably and disappointingly, general understanding that microstructure defines material's response to external loads has not yet resulted in a workable physical theory of metal strength accounting for the realistic complexity of material microstructure. In this presentation I would like to discuss a few tidbits from computational and experimental research in our group at LLNL on crystal defects and their contributions to material strength. My selection of the examples aims to illustrate the major premise of our work that the mechanisms by which the microstructure affects crystal strength are multiple and complex but that there is hope to bring some order to this complexity.

8:36AM X22.00002 Modeling of Self-Healing in Materials Reinforced with Nanoporous Fibers. VLADIMIR PRIVMAN, Clarkson University — We report on our group's progress towards continuum rate equation modeling, as well as numerical simulations, of self-healing of fatigue in composites reinforced with glue carrying nanoporous fibers. We conclude with the proper choice of the material parameters, effects of fatigue can be partially overcome: fracture and degradation of mechanical properties can be delayed.

1Web site: www.clarkson.edu/Privman

8:48AM X22.00003 Effects of grain boundary constraints on properties of polycrystalline materials. KIMBERLY MCGRARRITY, Dept. of Physics & Astronomy, Michigan State University, ERIN MCGRARRITY, Dept. of Chemical Engineering & Materials Science, Michigan State University, PHILLIP DUXBURY, Dept. of Physics & Astronomy, Michigan State University, BRYAN REED, Materials and Technology Division, Lawrence Livermore National Laboratories, ELIZABETH HOLM, Computational Materials Modeling, Sandia National Laboratories — Grain boundary networks are engineered by increasing the fraction of boundaries which have favorable properties. Favorable boundaries have either low grain boundary misorientation or they are special boundaries, such as coincident site lattice boundaries. Significant improvement in properties such as corrosion resistance, critical current in superconductors and mechanical strength and toughness occur, provided percolating grain or grain boundary structures can be engineered. We demonstrate that grain boundary constraints shift percolation thresholds from their uncorrelated values and that the behavior near threshold is also modified. The origin of these behaviors is an enhanced clustering of weak boundaries induced by grain boundary constraints.

9:00AM X22.00004 Evolution of Subsurface Microstructures During Wear of Metal Single Crystals. CORBETT BATTAILE, SOMURI PRASAD, JOSEPH MICHAEL, Sandia National Laboratories — Friction can lead to complex mechanical and microstructural evolution near the worn surface, and these changes can impact the properties of the material. Recent results from tribological experiments on nickel single crystals reveal the formation of microstructural features ranging from nanometers (very near the surface) to microns in size. The formation and mechanical response of these zones is sensitive to crystallography, and can dramatically alter the frictional properties of the material itself. We have modeled these phenomena using a combination of dislocation plasticity, microstructure formation, and grain boundary sliding. The loading conditions are adopted from an analysis of static frictional contact. A phenomenological treatment of wear debris and asperity-mediated contact is included to appropriately describe the mechanical mixing that occurs very near the contact interface. We will provide an overview of the experimental evidence, discuss the wear model in detail, and present results for kilocycle wear on nickel single crystals in different crystallographic orientations.

3Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under contract DE-AC04-94AL85000.
9:12AM X22.00005 Spontaneous shear localization in a model brittle solid1, CRAIG E. MALONEY, MARK O. ROBBINS, Physics and Astronomy, Johns Hopkins — A better understanding of the failure of brittle materials is practically important in situations ranging in scale from nano-indentation to earthquake physics. Recent discrete models of this failure focused on geometries such as uniaxial tension or anti-plane strain where creation of free surfaces dominates. They are not appropriate for modeling the formation of shear zones where frictional sliding of material in intimate contact and plastic deformation are important. We present results on a novel approach which introduces damage directly into particle based simulations. When loaded, the model exhibits a period of bursts of spatially correlated damage accumulation followed by a period of catastrophic weakening during which a geometrically complex through-going fault network forms, strikingly reminiscent of both laboratory experiments and geophysical observations at the field scale. We will discuss: spatial correlations in damage, evolution of the geometry of the fault system, and the dependence on confining pressures.

1This work was supported by NSF Grant DMR-0454947.

9:24AM X22.00006 Simulations of Nanoscale Mechanical Contacts with Intervening Adsorbates1, SHENGFENG CHENG, MARK ROBBINS, Department of Physics and Astronomy, The Johns Hopkins University, Baltimore, MD 21218 — Molecular simulations are used to investigate the role of intervening adsorbed molecules in nanometer scale mechanical contacts between nominally spherical tips and flat elastic substrates. Previous studies show that atomic scale deviations from the sphere that are present on any tip constructed from discrete atoms can have profound effects on contact areas, adhesive energies, and lateral stiffness. We find that including adsorbed molecules in contacts reduces the variation with tip geometry, but introduces new effects. One is that tip geometry affects the number of atoms that are pushed out of the contact and the resulting pressure distribution. The pressure at the center of the contact may be smaller than at the edge. We also find that the presence of adsorbates influences frictional behavior of contacts. For some cases the frictional force is proportional to area for bare tips and proportional to load when adsorbed molecules are present.

9:36AM X22.00007 ABSTRACT WITHDRAWN —

9:48AM X22.00008 Rubber Band Recoil, ROMAIN VERMOREL, NICOLAS VANDENBERGHE, EMMANUEL VILLERMAUX1, IRPHE, Aix - Marseille Universite — When an initially stretched rubber band is suddenly released at one end, an axial stress front propagating at the celerity of sound separates a free and a stretched domain of the elastic material. As soon as it reaches the clamped end, the front rebounds and a compression front propagates backward. When the length of the compressed area exceeds Euler critical length, a dynamic buckling instability develops. The rebound is analysed using Saint-Venant’s theory of impacts and we use a dynamical extension of the Euler-Bernoulli beam equation to obtain a relation between the buckled wavelength, the initial stretching and the rubber band thickness.

1also at Institut Universitaire de France

10:00AM X22.00009 String breaking and the Petersburg Paradox , JAKE FONTANA, PETER PALFFY-MUHORAY, Liquid Crystal Institute, KSU, LIQUID CRYSTAL INSTITUTE TEAM — The Petersburg Paradox(1) provides a simple paradigm for systems that show critical sensitivity to rare events. The breaking strength of filaments, yarns and strings is determined by the presence of defects. In a given sample, the largest defect determines the stress at which failure occurs, and since the defect distribution is a function of sample size, the breaking strength of strings depends on their length. Analogy with the Petersburg paradox suggests that the breaking strength should vary approximately linearly with the logarithm of the length. We have carried out experiments to measure the breaking strength of samples of polyester sewing thread and of monofilament fishing line ranging in length from 1mm to 1km. We describe our experiments, present the results, and, compare fits of our data to Weibull and mean field failure statistics and the predictions from analogy with the Petersburg Paradox. 1. I. Todhunter, A History of Mathematical Theory of Probability, (Chelsea, New York, 1949)

10:12AM X22.00010 Simulations of aging and plastic deformation in polymer glasses , MYA WARREN, JOERG ROTTLER, University of British Columbia — Experiments on a broad class of amorphous glassy materials show that their mechanical behavior strongly depends on the time since vitrification. The slow relaxation of configurational degrees of freedom, or aging, generally increases the material’s resistance to applied stress. In this study, we investigate the interplay between aging and plastic deformation in a simple model for polymer glasses by means of molecular dynamics simulations. We determine the macroscopic creep compliance for different loading conditions and aging times and find excellent qualitative agreement with experiments: compliance curves can be shifted to form a universal master curve, and the applied stress can reduce the effective age of the glass (mechanical rejuvenation). We then measure microscopic, local relaxation times and show that they correlate well with the aging characteristics of the macroscopic creep response. In addition, we explore the evolution of several measures of local order during aging and discuss their role in the mechanical behavior.

10:24AM X22.00011 Deformation mechanism of silver nanowires1, MARCEL LUCAS, School of Physics, Georgia Institute of Technology, AUSTIN LEACH, MATT MCDOWELL, KEN GALL, School of Materials Science and Engineering, Georgia Institute of Technology, SIMONA HUNYADI, CATHERINE MURPHY, Department of Chemistry and Biochemistry, University of South Carolina, ELISA RIEDO, School of Physics, Georgia Institute of Technology — Silver is the metal which exhibits the highest electrical and thermal conductivity, and has potential applications in electronics, photonics and catalysis. Silver nanowires could serve as interconnects between electronic circuits, catalysts in chemical reactions, or substrates for surface-enhanced Raman spectroscopy. Understanding how their mechanical properties are affected by their structure (size, cross-section geometry) is essential for their integration in nanodevices. Recently, silver nanowires have been synthesized in aqueous solution without surfactant or catalyst. These nanowires were characterized by Atomic Force Microscopy (AFM) and have a diameter ranging from 20 to 40 nm. Their deformation mechanism was studied by AFM nanoindentation and the results were correlated with atomistic simulations of silver nanowires with a pentagonal cross section.

1The authors acknowledge the financial support from the Department of Energy under grant No.DE-FG02-06ER46293.
11:15 AM Y5.00001 Nonaffine deformations in random solid media, BRIAN DIDONNA, University of California, Los Angeles — The elastic properties of materials which are inhomogeneous on mesoscopic length scales is a subject of broad interest in soft matter physics. Example systems include stiff polymer or polymer gel, foams, emulsions, grain packs, and microstructured solids. These diverse systems share the common feature that their linear elastic response is highly non-uniform, or "non-affine" at intermediate length-scales. I will present a general theoretical framework for interpreting the non-affine component of the linear elastic response of inhomogeneous materials. I will outline the connection between measured correlation functions and internal quantities such as correlation lengths, internal stress fields, and the degree of local elastic heterogeneity. I will show that the simplest 2-point correlation function gives misleading results in 2 dimensions, and I will propose better functions to measure.

11:51 AM Y5.00002 Incompressibility, fluctuations, and elasticity in random solids, XIANGJUN XING, Syracuse University — Rubbers and elastomers are usually characterized by two common properties: entropic elasticity and incompressibility. At short length-scales, these systems behave as incompressible liquids. Nevertheless, macroscopic shear deformations reduce the entropy of the polymer network, and therefore cost an elastic free energy that is proportional to temperature. In this talk I shall discuss the role of incompressibility in the elasticity of rubbery materials, and its interplay with the long wave-length fluctuations. Rubbers gain shear rigidity through the vulcanization transition, a second-order phase transition driven by cross-link density and closely related to percolation. The scaling of shear modulus as a critical phenomenon sensitively depends on the incompressibility. We have recently discovered that the vulcanization theory naturally exhibits two universality classes: phantom systems and incompressible systems. Each class exhibits distinct scaling exponent for the shear modulus near the transition. Incompressibility also crucially affects the nonlinear elasticity of rubbery materials. As we have shown recently, a subtle interplay between incompressibility and long wave-length fluctuations leads to a qualitative modification of the stress-strain relation predicted by the classical theory. To leading order, this mechanism provides a simple and generic explanation for the peak structure of Mooney-Rivlin stress-strain relation, and shows good agreement with experiments. It also leads to the prediction of a phonon correlation function that depends on the strain deformation. If time permits, I will also address incompressibility and fluctuations in liquid crystalline elastomers.

1 supported by ACS PRF 44689-G7

12:27 PM Y5.00003 Floppy modes and non-affine deformations in biopolymer networks, ERWIN FREY, Ludwig-Maximilians-Universitaet Muenchen — Fibrous materials are ubiquitous in nature. They form the cytoskeleton of cells and are essential components of the extracellular matrix. Its building blocks are stiff protein filaments and a myriad of associated crosslinking proteins. The interplay between the elasticity of the biopolymers and the binding and elastic properties of the crosslinkers lead to a variety of network architectures [1]. We review recent advances in understanding the elastic properties of these networks in terms of “floppy modes” [2], which are the relevant low-energy excitations characterizing non-affine deformations. This approach might very well serve as a novel paradigm to understand the elasticity of microstructured materials. The theoretical concepts are applied to recent experimental studies of F-actin networks crosslinked with fascin. [1] C. Heussinger and E. Frey, Stiff Polymers, Foams and Fiber Networks, Phys. Rev. Lett. 96, 017802 (2006). [2] C. Heussinger and E. Frey, Floppy Modes and Non-Affine Deformations in Random Fiber Networks, Phys. Rev. Lett. 97, 105501 (2006)

1:03 PM Y5.00004 Molecular dynamics studies of rigidity in solids, MICHAEL PLISCHKE, Simon Fraser University — We have used molecular dynamics (MD) to study the elastic properties of systems of particles randomly and permanently crosslinked to each other as function of crosslink density $p$. At zero temperature, such systems generically lose the ability to withstand shear at a rigidity percolation point, $p_r$, that is (at least for particles interacting through central forces) different from the geometric percolation point $p_c$. At finite temperatures there is an entropy-generated component of the shear modulus $G(p,T)$ that remains finite for all $p > p_c$ and which vanishes with a characteristic power law $G(p,T) \sim (p - p_c)^{\gamma}$. Our simulations in both two and three dimensions seem to indicate that $\gamma$ is model-independent and, within our error bars, the same as the exponent that describes the behavior of a disordered network of conductors near its percolation point.