

**106th Statistical Mechanics Conference
Program of Short talks**

SESSION A

A1: Ricky Chachra, Cornell University

“Parameter sensitivities and coarse-graining in the 2D Ising model: Is Ising sloppy?”

Coauthors: B. Machta, James P. Sethna

Abstract: We show that a generalized, multiparameter Ising Hamiltonian is an example of a "sloppy model" (i.e., where only a few important parameter combinations significantly affect the behavior). The dependence of the spin configuration probabilities on the values of various long-range spin-spin interactions is studied using the Kullback-Leibler divergence. Two stiff eigenvalues are found, with eigendirections corresponding to the relevant fields t and h of the Ising model. In addition, the analytic corrections to scaling appear to mask the irrelevant and marginal RG eigenvalues, which are revealed upon coarse-graining to yield many orders of magnitude of sloppy eigenvalues corresponding to Ising perturbations that are irrelevant on long length scales.

A2: Suriyanarayanan Vaikuntanathan, Lawrence Berkeley National Lab

“Investigating the adsorption of ions to liquid vapor interfaces: Insights from lattice gas models”

Coauthors: Patrick Shaffer and Phillip Geissler

Abstract: Some aqueous ions prefer residing at the liquid vapor interface to residing in the bulk solution. Recent experiments and computer simulations investigating this adsorption of ions to the liquid vapor interface suggest that process is (generally) favored energetically and not favored entropically. Furthermore, it has been speculated that the loss of entropy associated with the migration of the ion to the interface is mainly due to the suppression of interfacial capillary wave fluctuations. To investigate these trends, we considered a two dimensional lattice gas model at coexistence. Working in the low temperature limit and ignoring any bulk inhomogeneities in the liquid or vapor phase - the configuration of the system can now be specified by just specifying the configuration of the interface -, we were able to analytically compute profiles of the free energy, energy, entropy of the system as a function of the distance of a solute from the mean interface position. The profiles are qualitatively similar to those observed in molecular simulations. These results support the speculation that the entropy loss accompanying the adsorption of ions to the interface is due to the pinning of capillary waves.

A3: Kirill Korolev, Massachusetts Institute of Technology

“Drift, draft, waves, and ratcheting: evolutionary models of cancer progression”

Coauthors: Christopher McFarland and Leonid A. Mirny

Abstract: Recently many mutations in cancerous cells have been found to be detrimental to tumor growth. These mutations, called passenger mutations, are distinguished from the better known cancer-causing driver mutations, which increase a tumor cell's proliferative capacity. The quantitative description of simultaneous accumulation of passenger and driver mutations remains a challenge. Here, we extend population genetics theory to better understand the evolutionary dynamics in precancerous tumors. We find that passengers alter and can even avert progression to cancer. The probability of cancer depended heavily, and non-monotonically, on both the deleteriousness of passengers and overall mutation rate. Counter intuitively, high mutation rates decrease the likelihood of cancer--a finding recently corroborated by clinical data. Our models suggest that therapies exploiting deleterious passengers can avert cancer and may be more effective than targeting driver mutations. Joint work with Leonid A. Mirny and Christopher McFarland.

A4: Benjamin Machta, Cornell University

“Critical Casimir forces in cellular membranes”

Coauthors: S. L. Veatch and J. P. Sethna

Abstract: Recent experiments suggest that membranes of living cells are tuned close to a miscibility critical point in the 2D Ising universality class. We propose that one role for this proximity to criticality in live cells is to provide a conduit for relatively long-ranged critical Casimir forces. Using techniques from conformal field theory we calculate potentials of mean force between membrane bound proteins mediated by their local interactions with the composition order parameter. We verify these calculations using Monte-Carlo and a simple perturbative approximation where we can compare critical and off-critical results. We argue that these results give some quantification of the benefit cells derive by proximity to criticality.

A5: Vladyslav Golyk, Massachusetts Institute of Technology

"Non-equilibrium Casimir forces between conducting nanowires"

Coauthors: M. Kruger and M. Kardar

Abstract: We discuss Casimir forces between two parallel nanowires in thermal non-equilibrium, with the nanowires as well as the environment held at different temperatures. We concentrate on the case of conducting wires because this yields very strong non-equilibrium corrections. The non-equilibrium forces can be orders of magnitudes larger than the weight of the wires or forces due to electric currents. Additionally, we demonstrate a rich phenomenology in which forces can be either attractive or repulsive and also admit stable zero force points.

A6: Hsiang-Ku Lin, University of California at Riverside

"The Casimir force between inclusions in a fluid membrane under tension"

Coauthors: H.-K. Lin, R. Zandi, U. Mohideen, and L. P. Pryadko

Abstract: We present a method to study fluctuation-induced force between inclusions embedded in a stretchable fluid membrane, which is a finite temperature analogue to the Casimir force in vacuum. Starting from Green's functions, we demonstrate that the interaction between the inclusions can be related to multiple scattering processes of thermal fluctuation fields, similar to quantum Casimir effect. The Casimir energies are fully characterized by the objects' "scattering" matrices, which encode their shapes and mechanical properties. With this method, we calculate interactions of a wide range of circumstances, not only in the separate presence of either surface tension or bending rigidities but also when both terms are present. For two circular inclusions in a fluid membrane, the Casimir energy scales as the inverse power law of the separation and is greatly reduced beyond the characteristic length related to the square root of the ratio between the bending rigidity to the surface tension of the fluid membrane.

A7: Matthias Kruger, Massachusetts Institute of Technology

"Casimir levitation in thermal non-equilibrium"

Coauthor: T. Emig, G. Bimonte and M. Kardar

Abstract: We show that a hot nanosphere can levitate in vacuum above a substrate in certain conditions due to a repulsive Casimir force. We discuss the reason for this repulsion, as well as the motion of the sphere in the emerging potential minimum.

A8: Mohammad F. Maghrebi, Massachusetts Institute of Technology

"Entropic force of polymer on a tip cone"

Coauthors: Y. Kantor and M. Kardar

Abstract: We consider polymers attached to the tip of a cone, and the resulting force due to entropy loss on approaching a plate (or another cone). At separations shorter than the polymer radius of gyration R_g , the only relevant length scale is the tip-plate (or tip-tip) separation h , and the entropic force is given by $F = Ak_B T/h$. The universal amplitude A can be related to (geometry-dependent) correlation exponents of long polymers. For the purpose of this talk, we compute A for phantom polymers in three dimensions.

A9 Sebastian Deffner, University of Maryland

"Information, Entropy, and Heat Far From Equilibrium"

Coauthor: C. Jarzynski

Abstract: For equilibrium states, the Shannon entropy H coincides with the thermodynamic entropy. It has lately been recognized that for systems in nonequilibrium steady states a thermodynamic description based on H becomes feasible, as well. In the present work we derive various generalizations of the second law for nonequilibrium processes with additional information supplied from an external or an internal memory. We will show that the irreversible entropy production is bounded from below by the information transferred from the memory to the system.

A10: Andrew Mugler, FOM Institute AMOLF

"Membrane clustering and the role of rebinding in biochemical signaling"

Coauthors: A. G. Bailey, K. Takahashi and P. Rein ten Wolde

Abstract: While it is clear that some membrane-bound proteins form clusters, it is less clear what effect clustering has on downstream signaling within a cell. We find that clustering reduces the response of a covalent modification network by

presenting a smaller target to a molecule in the bulk. However, clustering can enhance the response of a double-modification network by promoting the rapid rebinding of singly modified molecules. The rebinding process exhibits several interesting diffusive regimes, as revealed by the distribution of first-passage times.

A11: Yan Xu, C. N. Yang Institute for Theoretical - Physics, Stony Brook University

"Exact Results on Potts/Tutte and Chromatic Polynomials"

Coauthors: R. Shrock

Abstract: It is of interest to investigate the q -state Potts model on various families of graphs G in a generalized external field that favors or disfavors spin values in a subset of the total set of possible spin values. Exact results are also given for the special case of the zero-temperature Potts antiferromagnet, corresponding to a set-weighted chromatic polynomial that counts the number of proper colorings of the vertices of G with a weighting that favors or disfavors colors in a subset of all choices of colors.

A12: Emre Esenturk, Brown University

"Interfacial free energy of equilibrium systems via phase field method"

Abstract: We will use a non local phase field model and non-local phase field model to calculate the surface tension of Argon at the triple point. We will also introduce a discrete phase field model and general framework to calculate the anisotropy of the solid-vapor interfacial free energy. Application to Lennard-Jones systems is discussed.

A13: Anna Vershynina, University of California, Davis

"Non-equilibrium state of leaking photon cavity pumped by a random atomic beam"

Coauthor: B. Nachtergaele

Abstract: We show the existence of the limiting state of a leaking photon cavity pumped by a random atomic beam. The limiting state is proved to be a non-equilibrium state.

A14: Sateesh Mane, Convergent Computing Inc

"Radiative spin polarization in electron-positron storage rings"

Abstract: Synchrotron radiation is normally visualized as a classical phenomenon, but at higher orders the electron spin operator couples to the radiation field, and electrons and positrons in high-energy accelerators become spontaneously polarized via photon emission. I describe this process, and Michael Fisher's enthusiasm for the application of statistical mechanics to a subject beyond his immediate expertise.

A15: Jacob Oppenheim, Rockefeller University

"A Topological Phase Transition in Models of River Networks"

Coauthor: M. Magnasco

Abstract: The classical Scheidegger model of river network formation is investigated on non-Euclidean geometries, which model the effects of regions of convergent and divergent flows - as seen around lakes and drainage off mountains, respectively. These new models may be differentiated by the number of basins formed. Using the divergence as an order parameter, we see a phase transition in the number of distinct basins at the point of a flat landscape. This is a surprising property of the statistics of river networks and suggests significantly different properties for riverine networks in uneven topography and vascular networks of arteries versus those of veins among others.

A16: Adam Hopkins, Princeton University

"Phase diagram and structural diversity of the densest binary sphere packings"

Abstract: The densest binary sphere packings have historically been very difficult to determine. The only rigorously known packings in the α - x plane of sphere radius ratio α and relative concentration x are at the Kepler limit $\alpha \rightarrow 1$, where packings are monodisperse. Utilizing an implementation of the Torquato-Jiao linear programming algorithm, a sphere-packing algorithm that through this work we show to be particularly versatile and efficient, we find many distinct novel densest binary packings and construct a phase diagram for all known densest packings over the α - x plane.

A17: Lan Gong, New York University

"Noisy Classical Field Theories with Two Coupled Fields and its Application to Monovalent Metallic Nanowires"

Coauthor: D. Stein

Abstract: We introduced and analyzed a system of two coupled partial differential equations with external noise. The equations are constructed to model transitions of monovalent metallic nanowires with non-axisymmetric intermediate or end states, but also have more general applicability. They provide a rare example of a system for which an exact solution of nonuniform stationary states can be found. We have also explored the escape dynamics numerically, using the String Method, a

relaxational technique. We find two kinds of transitions in activation behavior as we tune different parameters in our model, such as the interval length on which the fields are defined, and the bending coefficients of the fields. We discuss how these results apply to real nanowires.

A18: Brooks Harris, University of Pennsylvania

"Landau theory of octahedral tilting in perovskites"

A19: Fereydoon Family, Emory University

"The Effect of Social Cues on Marketing Decisions"

Coauthors: G. Hentschel, Z. Zhang, J. Pan and Y. Song

Abstract: We address the question as to what extent individuals, when given information in marketing polls on the decisions made by the previous N_T individuals questioned, are likely to change their original choices. The processes can be formulated in terms of a Cost function equivalent to a Hamiltonian, which depends on the original likelihood of an individual making a positive decision in the absence of social cues p_0 ; the strength of the social cue J ; and memory size N_T . We find both positive and negative herding effects are significant. Specifically, if $p_0 > \frac{1}{2}$ social cues enhance positive decisions, while for $p_0 < \frac{1}{2}$ social cues reduce the likelihood of a positive decision.

A20: Christopher Henley, Cornell University

"Possible origins of macroscopic chiral asymmetry in animals and plants"

Abstract: During development, chiral or left/right asymmetry at the organism level is somehow generated from the microscopic handedness of proteins. The usual pattern-formation mechanisms of diffusion plus regulation cannot implement such a "right-hand rule"; on the cell level, it tends to involve membrane-bound cytoskeletal molecules, often in dynamic collective states. I outline a possible scenario in the case of snail embryos, involving actin/myosin layers, and mention another one involving microtubule arrays in plant cells.

A21: Christopher Jarzynski, University of Maryland, College Park

Coauthor: D. Mandal

"Minimal model of a stochastic Maxwell Demon"

Abstract: We describe an exactly solvable model that operates as a mechanical (as opposed to intelligent) Maxwell Demon. Our "demon" is a three-state system that interacts stochastically with: a thermal reservoir, a stream of bits, and a mass that can be lifted or lowered. We obtain an exact solution for the steady-state behavior of this system, and we use this solution to map out the nonequilibrium phase diagram as a function of the model parameters. In one region of this diagram the demon acts as an engine, converting heat to work (lifting the mass) while writing information to the stream of bits. In another region it acts as an eraser, using the energy of the falling mass to erase information in the bit stream.

A22: Daniel Lathrop, University of Maryland

"Reconnection of Quantized Vortices in Superfluid Helium"

Abstract: Turbulence in superfluid 4-Helium is dominated by reconnection and ring collapse. We utilize micron and nano-scale ice particles to visualize the dynamics of quantized vortices and the normal component. After briefly reviewing our observations of these phenomena, I will discuss reconnection dynamics at large and small scales. Those dynamics can be understood using scaling solutions and some ideas from dynamical systems. There is one underlying question we work to address: is there a single universal reconnection dynamics, do we need to consider a one or two parameter family of reconnection events?

SESSION B

B1: Sungchul Ji, Rutgers University

"A Category-theoretical framework for integrating physics, biology and informatics based on complementarity and supplementarity principles"

Abstract: N. Bohr [1] introduced into physics the principles of complementarity and supplementarity in the early decades of the 20th century, which can be characterized as follows [2]: Supplementarity is an additive principle, i.e. $A + B = C$; complementarity is non-additive, i.e., $A \wedge B = C$, where the symbol \wedge indicates that A and B are mutually exclusive but complementary manifestations or properties of C. [Click here](#) for full abstract.

B2: Vadim Tkachenko, Ben-Gurion University of the Negev, Israel

"On Hill operators with complex-valued potentials"

Abstract: It is well-known that the spectrum of a Hill operator with real-valued periodic potential in the space $L^2(\mathbb{R}; dx)$ has a band structure and that such an operator generates a representation of functions on finite intervals of the real axis by a Fourier-like series and of functions on the entire real axis by a Fourier-like integral. In the present communication we report on conditions which are necessary and sufficient for a Hill operator with a complex-valued periodic potential to have the same properties. This is the joint work with Fritz Gesztesy.

B3: Xiaming Mao, University of Pennsylvania

"Rigidity percolation and mixed first-order-second-order transition in the square lattice"

Coauthor: W. Ellenbroek

Abstract: The square lattice with central forces between nearest neighbors is isostatic with a subextensive number of floppy modes. It can be made rigid by the random addition of next-nearest neighbor bonds. This constitutes a rigidity percolation transition which we study analytically by mapping it to a connectivity problem of two-colored random graphs. We derive an exact recurrence equation for the probability of having a rigid percolating cluster as a function of system size, and obtained a solution that is exact in the infinite volume limit. We find that, in the thermodynamic limit, the rigidity percolation at the isostatic point is a mixed first-order and second-order transition exhibiting both a discontinuous change in the order parameter and a diverging length scale.

B4: Robin Underwood, Cornell University

"Exploring a Closed Loop Solubility Curve"

Coauthors: K. Koga and B. Widom

We investigate a two component Lennard-Jones fluid which exhibits both an upper and a lower critical solution temperature using molecular dynamics simulations. Of particular interest are the radial distribution functions of these fluids along the closed loop solubility curve.

B5: Trent Brunson, Emory University

"Phase Transitions of the Ising Model on Small-world Hierarchical Hanoi Networks"

Coauthor: S. Boettcher

Abstract: The Hanoi networks are a variety of one-dimensional Ising chains with small-world bonds that are self-similar and hierarchical. Applying an exact renormalization group shows non-universal critical behavior that can be separated into three categories, including the inverted Kosterlitz-Thouless-type transition. If these results can be extended to a larger set of networks, the Hanoi networks may provide a generalized RG classification of criticality in complex networks.

B6: Dibyendu Mandal, University of Maryland

"A proof by graphical construction of the no-pumping theorem of stochastic pumps"

Coauthor: C. Jarzynski

Abstract: A stochastic pump is a Markov model of a mesoscopic system evolving under the control of externally varied parameters. In the model, the system makes random transitions among a network of states. For such models, a 'no-pumping theorem' has been obtained, which identifies minimal conditions for generating directed motion or currents. We provide a derivation of this result using a simple graphical construction on the network of states.

B7: Haitao Quan, University of Maryland

"On the validity of Jarzynski equality for the rapidly expanding quantum piston"

Abstract: Recent work by Teifel and Mahler [Eur. Phys. J. B 75, 275 (2010)] suggests that quantum Jarzynski equality might generally be violated in processes involving moving hard walls. We study this issue in the context of the rapidly expanding one-dimensional quantum piston. Utilizing exact solutions of the time-dependent Schrodinger equation, we find that the evolution of the wave function can be decomposed into static and dynamic components, which have simple semiclassical interpretations in terms of particle-piston collisions. We show that Jarzynski equality remains valid at any finite piston speed, provided both components are included.

B8: S. Jamal Rahi, Rockefeller University

"Biochemical "FM radio" receivers"

Abstract: Many biochemical signaling pathways adapt to continuous input. Some, for example, in developmental or hormonal signaling, produce maximal average output when a stimulus appears periodically. Motivated by this, we investigate the response of the simplest adaptive biochemical circuits to periodic square pulses analytically and computationally. These elementary adaptive systems contain two chemical species and at most two non-dimensional kinetic parameters which are set by the cell. We vary the period between stimulus pulses and the fraction of the period that a pulse takes up. We find that the dependence of the optimal stimulation period on the duration of the pulses differs depending on the architecture but is similar

for different parameters. Our results suggest relatively simple experiments that would elucidate network topology, which has been difficult to probe through biochemistry.

B9: Shamik Gupta, Ecole Normale Supérieure de Lyon, France

"Linear response theory for quasistationary states in long-range interacting systems"

Coauthors: A. Pateli, C. Nardini, and S. Ruffo

Abstract: Systems with long range interactions are nonadditive, whereby thermodynamic quantities scale superlinearly with the system size. Nonadditivity leads to unusual equilibrium features like negative microcanonical specific heat, inequivalence of statistical ensembles, etc. As regards dynamics, these systems while relaxing to equilibrium often get trapped in non-Boltzmann quasi-stationary states (QSS) whose relaxation to equilibrium occurs very slowly over timescales that diverge with the system size. For mean-field models, such states may be explained as stable stationary solutions of the Vlasov equation for the time evolution of the single-particle phase space distribution. Here, we study the response of such states to weak external perturbation by employing the Vlasov framework. We show that to linear order in the external field, the system relaxes to nearby QSS whose properties may be explicitly computed by employing the Vlasov approach.

B10: Bruce Miller, Texas Christian University

"Chaos in the Wedge Billiard: Recent Developments"

Coauthors: A. Hartl, A. Mazzoleni and J. Olafsen

Abstract: The seminal physical model for investigating formulations of nonlinear dynamics is the billiard. Gravitational billiards provide an experimentally accessible arena for their investigation. In the 1980's Halim Lehtihet and I introduced a simple model of a gravitational billiard that exhibits nearly every type of Hamiltonian chaos, depending on a single parameter. Named the wedge billiard, the vertex angle solely determines the type of motion observed. The system was studied rigorously by the mathematician Maciej Wojtkowski and experimentally with cold atoms in Mark Raizen's group at the University of Texas, where the essential behavior was confirmed. In short order versions with curved boundaries (parabolic and hyperbolic) were investigated with computer simulation by Matt Ferguson and me. More recently, in order to overcome frictional damping and other forms of dissipation, a driven version of the wedge billiard was investigated experimentally by Sarah Feldt and Jeff Olafsen at the University at Kansas. This work is being continued at Baylor. In the last few years, a mathematical model of the driven system was formulated by Alex Hartl, Andre Mazzoleni, and myself that includes rotational friction and air drag. It captures the main features observed in the experiments. In my talk I will explain the origin of the Hamiltonian model, describe the Austin and Baylor experiments and show how the results of the recent dissipative model compare with the current experiments at Baylor.

B11: Eric DeGiuli, University of British Columbia

"Statistical Mechanics of Granular Materials"

Abstract: Connecting the macroscopic behavior of disordered materials with the microstructure remains a great challenge. Granular materials, like sand, provide a central example as they undergo a jamming transition from fluid to solid. Using a discrete calculus, we derive, from first-principles and in a mean-field approximation, the entropy of frictional force configurations in the Force Network Ensemble for 2D granular solids. As a result of the concentration of stress along linear force chains, we predict a non-trivial scaling of the entropy with system size. In addition, as a macroscopic consequence of the Coulomb friction condition at contacts, we predict shear failure at a critical shear stress, in accordance with the Mohr-Coulomb failure condition well known in engineering.

B12: Ashivni Shekhawat, Cornell University

"Statistics of Fracture: Renormalization Group And Universality versus Nucleation Theory"

Coauthors: C. Manzano, Phani K. V. V. Nukala, M. Alava, S. Zapperi, and J. Sethna

Abstract: We use renormalization-group methods, nucleation theory and simulations of fuse-networks to re-evaluate the traditional approaches to statistical distributions of fracture strengths. It is believed that the distributions of fracture strengths are universal, and the universal Weibull distribution is used almost exclusively to fit data. The universal aspects of these distributions have been studied in the mathematical theory of extreme value statistics as well as . Recently these distributions have been interpreted as fixed points of a renormalization group flow. It is standard engineering practice to fit fracture data to Weibull forms and extrapolate the fit beyond the range of the available data in order to estimate the probability of rare events such as unlikely collapse of structures etc. Our recent studies of the random fuse network model raises doubts about most of these practices. We find that the emergent distribution of fracture strengths is the Gumbel distribution. However, the extremely slow convergence to the universal Gumbel form renders it unusable at least in this case. On the other hand, we show that a non-universal distribution derived by using a Griffiths type nucleation theory (due to Duxbury et al.) converges rapidly even for moderate system sizes. We find that while extrapolating the RG based universal Gumbel distribution is perilous and gives wildly incorrect predictions, the nucleation based non-universal results can be extrapolated with confidence. It is entertaining

that fracture provides wonderful examples of the statistical mechanics tools developed to study both continuous as well as abrupt phase transitions.

B13: Braden Brinkman, University of Illinois at Urbana-Champaign

"Do tidal stresses trigger large earthquakes early?"

Coauthors: M. LeBlanc, J. T. Uhl, Y. Ben-Zion, K. A. Dahmen

Abstract: The effect of tidal or other periodic stresses on the timing of large earthquakes is a hotly debated topic in geophysics and rock-friction or granular physics communities. I discuss a simple probabilistic model which captures the main qualitative features of several rock-friction or granular experiments and may resolve some outstanding discrepancies between different experimental results. With sufficiently accurate measurements, quantitative predictions for real experiments are possible, including the number of measured events needed to detect correlations between periodic stresses and large slip events for given amplitudes and frequencies.

B14: Navin Singh, Birla Institute of Technology & Science, India

"The Probability Analysis of Opening of dsDNA"

Coauthor: S. Srivastava

Abstract: We have investigated the separation of a double stranded DNA (dsDNA), which is driven either by the temperature or force. By calculating the probability of dissociation of entire base pairs along the chain, we show that the opening of a dsDNA depends not only on the sequence but also on the constrain imposed by the experimental set ups. We have shown that the force induced melting of dsDNA, whose one of the ends is constrained, is significantly different than the thermal melting, whose both ends free.

B15: Wolfgang Losert, University of Maryland

"Cell Shape Dynamics: From Waves to Migration"

Coauthors: M. Driscoll and J. Fourkas

Abstract: The focus of our work is on the dynamics of cell migration, both the center of mass of the cell, and dynamic cell shapes. Though protrusions at the leading edge of migrating cells are guided by chemical signals, the frequency and directional persistence of protrusions appears rather independent of signal strength for a wide range of chemo attractant signals. Indeed, analysis of cell shapes indicates that protrusions exhibit wave-like dynamics. Cells develop protrusions near the leading edge that propagate from the leading edge toward the back, usually along alternating sides of the cell until they contact a surface. Such protrusion waves are particularly visible in cells at the edge of cliffs or in suspended cells. The wave-like character of protrusions provides a plausible mechanism for the observed zig-zagging of the leading edge of cells and for the ability of cells both to swim in viscous fluids and to navigate complex three dimensional topography.

B16: Andrej Kosmrlj Harvard University

"Elastic free energy of deformations for warped membranes"

Coauthor: D. Nelson

Abstract: The local elastic free energy density of deformations for a membrane with a shear modulus, whose minimum free energy configuration is flat, can be decomposed into the free energies of bending and stretching, which then interact via nonlinear couplings. The relevant free energies for bending and stretching are well known, and can be expressed in terms of the curvature tensor, and a strain matrix proportional to the change of the metric due to deformations. However, less is known about "warped membranes", i.e. membranes which are already deformed in their ground state, and characterized by a nontrivial background metric. Using a Landau-type expansion in the tangents to a warped surface, we find that the elastic free energy density can still be decomposed at low temperatures into free energies of bending and stretching. However, the strain tensor and the change in the curvature tensor describing in-plane and perpendicular phonon modes now depend on a "preferred" curvature tensor, an effect not present for flat membranes. If the membrane ground state configuration is nearly flat, this intrinsic background curvature tensor couples only to out-of-plane deformations and breaks the local "up-down" symmetry. As an application of the theory, we show how the macroscopic elastic constants are renormalized due to a frozen background metric at $T=0$. The bending rigidity is increased while the shear modulus is reduced. The change in the bulk modulus can be of either sign.

B17: Étienne Marcotte, Princeton University

"Exploring collective coordinates in high dimensions"

Coauthors: S. Torquato and F. H. Stillinger

Abstract: Disordered "stealthy" ground states are readily obtainable through numerical calculations using a collective coordinates approach. In high dimensions, it is interesting to explore how these ground-states fare as solutions to the covering and quantizer problems.

B18: Maxim Lavrentovich, Harvard University

“Directed percolation with inflation and range expansions with curved fronts”

Coauthors: K. S. Korolev and D. R. Nelson

Abstract: We compare the population genetics of range expansions with flat and circular fronts. When individuals experiencing deleterious mutations divide along a flat, thin, and uniform population front, the evolutionary dynamics fall into the directed percolation (DP) universality class. At the DP phase transition, the mutation rate is just large enough to induce a mutational meltdown where fit individuals are lost to deleterious mutants. In circular expansions, population inflation causally disconnects genetic sectors of the population (DP clusters) after a cross-over time proportional to the initial population radius. We use a generalization of the Domany-Kinzel model to simulate circular range expansions on a disordered lattice. We calculate various scaling functions that characterize the effects of inflation at criticality. We find that the cross-over time behaves like a finite size cut-off of the DP critical dynamics. After the cross-over, the survival probability of clusters generated from single fit individuals approaches a constant value and the surviving cluster spread is enhanced.

B19: Evgeniy Khain, Oakland University

"Clustering of brain tumor cells: theory and experiment"

Coauthors: C. M. Schneider-Mizell, M. O. Nowicki, E. A. Chiocca, S. E. Lawler and L. M. Sander

Abstract: Glioblastoma tumors are highly invasive; therefore the overall prognosis of patients remains poor, despite major improvements in treatment techniques. Cancer cells detach from the inner tumor core and actively migrate away [1]; eventually these invasive cells might form clusters, which can develop to recurrent tumors. In vitro experiments in collagen gel [1] followed the clustering dynamics of different glioma cell lines. Based on the experimental data, we formulated a stochastic model for cell dynamics, which identified two mechanisms of clustering. First, there is a critical value of the strength of adhesion; above the threshold, large clusters grow from a homogeneous suspension of cells; below it, the system remains homogeneous, similarly to the ordinary phase separation. Second, when cells form a cluster, there is evidence that their proliferation rate increases. We confirmed the theoretical predictions in a separate cell migration experiment on a substrate and found that both mechanisms are crucial for cluster formation and growth [2]. In addition to their medical importance, these phenomena present exciting examples of pattern formation and collective cell behavior in intrinsically non-equilibrium systems[3].

1. A. M. Stein et al, Biophys. J., 92, 356 (2007).
2. E. Khain et al, EPL 88, 28006 (2009).
3. E. Khain et al, Phys. Rev. E. 83, 031920 (2011).

B20: Andrew Ferguson, Massachusetts Institute of Technology

"Spin Glass Models of HIV Fitness Landscapes"

Coauthor: A. K. Chakraborty

Abstract: The infinite range Ising spin glass is the least structured (maximum entropy) model able to reproduce the one and two-body mutational probabilities observed in HIV viral sequence databases. Using an efficient algorithm to parametrize the Ising Hamiltonian, we have developed in silico sequence space fitness landscapes of four HIV gag proteins. Comparison to clinical data demonstrates the ability of these models to robustly predict known viral escape mutations, compensatory mutational patterns and immunologically vulnerable regions. We illustrate the value of such quantitative descriptions in the design of Pareto optimal vaccine candidates.

B21: Robert Ziff, University of Michigan

“Retention of water poured on random surfaces”

Coauthors: C. Knecht, W. Trump, and D. ben-Avraham

Abstract: I introduce a "water retention" model for liquids captured on a random surface with open boundaries, for both continuous and discrete surface heights $0, 1, \dots, n-1$, on a square lattice with a square boundary. The model has several intriguing features, including a non-monotonic dependence of the retention on the number of levels in the discrete case: for many n , the retention is counter intuitively greater than that of an $n+1$ -level system. The behavior is explained using percolation theory, by mapping it to a 2-level system with variable occupation probability.

B22: Yang Jiao, Princeton University

"A Dense Packing of Truncated Tetrahedra that Nearly Fills All Space"

Coauthors: S. Torquato

Abstract: Dense polyhedron packings are useful models of a variety of condensed matter and biological systems and have intrigued scientists and mathematicians for centuries. Here, we analytically construct the densest known packing of truncated tetrahedra with a remarkably high packing fraction $207/208=0.995192$, which is amazingly close to unity and strongly implies

its optimality. This construction is based on a generalized organizing principle for polyhedra that lack central symmetry that we introduce here. The packing characteristics and equilibrium melting properties of the putative optimal packing as the system undergoes decompression will be discussed.

B23: Thomas Butler, Massachusetts Institute of Technology

"Random energy models of T cell receptor interactions"

Coauthors: A. Chakraborty

Abstract: T cell receptors respond to peptides in a manner that is both specific and degenerate. This means that while a single T cell receptor can respond to many unrelated peptides, small changes in a peptide can abrogate response. Here we show that these properties can be explained by a precise analogy between T cell development and the random energy model. The qualitative predictions of the model are testable and consistent with known experimental results. The results have implications for autoimmunity and for self-non self discrimination.

B24: Andre Toom, Federal University of Pernambuco

"Phase transitions in the dynamics of slow random Monads"

Coauthor: A.D. Ramos

SESSION C

C1: Steve Abel, Massachusetts Institute of Technology

"Coarsening dynamics of molecularly tethered membranes"

Coauthors: A. K. Chakraborty

Abstract: We study the dynamics of a fluctuating membrane that is tethered to a supported membrane by laterally mobile molecules. The shape of the fluctuating membrane is governed by a time-dependent Ginzburg-Landau model, and the concentrations of molecules evolve in time according to reaction-diffusion equations. The free energy of the system accounts for surface tension, bending rigidity, and molecular elasticity. When two or more molecular species with different natural lengths are present, the species segregate into distinct spatial regions, with the local membrane separation accommodating the natural length of the molecules. This model gives insight into recent experiments using short DNA sequences to tether lipid bilayers.

C2: Nicolas Giovambattista, CUNY, Brooklyn College

"Interplay of the Glass Transition and the Liquid-Liquid Transition in Water"

Coauthors: T. Loerting, B. Lukanov and F. Starr

Abstract: Water is a polyamorphic substance that exhibits an apparent first-order phase transition between low-density (LDA) and high-density (HDA) amorphous solids. It has been argued that such a polyamorphism extends above the glass transition temperature T_g , resulting in a first-order liquid-liquid phase transition (LLPT). In this work, we explore the implications of an LLPT on the pressure dependence of T_g for different amorphous ices using computer simulations. By studying two models for water -- one with an accessible LLPT (the ST2 model), and one without it (the SPC/E model) -- we are able to show how the presence of an LLPT changes the behavior of $T_g(P)$ of various glasses. In the absence of an accessible transition, all amorphous ices exhibit a nearly identical $T_g(P)$, even though they have significantly different properties at T .

C3: Micah Hawkins, University of Maryland, College Park

"Simulations of Steps on a Vicinal (001) Surface With and Without Step Touching: Going Beyond Spinless Fermions"

Coauthor: T.L. Einstein

Abstract: Configurations of steps on vicinal surfaces are long known to be analogous to world lines of spinless fermions. Free (non-interacting) fermions correspond to steps with no energetic interactions (just entropic repulsions) and no multi-height steps, i.e. steps which can touch but do not cross. Physically, multi-height steps can exist; they produce an effective attraction between steps. We discuss these issues with respect to published terrace-step-kink model Metropolis Monte Carlo simulations and solid-on-solid model kinetic Monte Carlo simulations of equilibrium distributions. Of particular interest is how the asymptotic value of the step-position autocorrelation function $g_{\text{sub}_x}(y)$ reflects the effective interaction between steps. This work was supported by NSF-MRSEC at University of Maryland, DMR 0520471.

C4: Qiang Zhang, City University of Hong Kong

"Will particles fall through a steeper funnel faster?"

Abstract: We present several surprising phenomena that occur in an extremely simple granular system of a single inelastic,

spherical particle falling under gravity and colliding with walls of a symmetric funnel. One might naively expect that, on average, particles would fall through funnels with steeper sides more quickly, exert a smaller total impulse on the funnel walls, and lose less energy. However, we show that there are special ranges of angles of the funnel walls for which exactly the opposite occurs. Typically, the particle will experience a sequence of collisions that is highly sensitive to the location at which it enters the funnel and nearby particle trajectories become widely dispersed. However, in the special angular ranges this is not the case and the particle can experience sequences of collisions that have a highly coherent structure. We provide a theoretical analysis that can predict and explain this surprising behavior. We also show that such anomalous phenomena occur in both frictionless and frictional particle systems and the frictional force dramatically enhances the anomalous phenomena. This is due to the stability of the highly coherent structure in these granular systems.

C5: Paata Kakashvili, Rutgers University

"Integrability in anyonic quantum spin chains via a composite height mode"

Coauthor: E. Ardonne

Abstract: Recently, properties of collective states of interacting non-abelian anyons have attracted a considerable attention. We study an extension of the 'golden chain model', a model of interacting Fibonacci anyons, where two- and three-body interactions are competing. Upon fine-tuning the interaction, the model is integrable. This provides an additional integrable point of the model, on top of the integrable point, when the three-body interaction is absent. To solve the model, we construct a new, integrable height model, in the spirit of the restricted solid-on-solid model solved by Andrews, Baxter and Forrester. The model is solved by means of the corner transfer matrix method. We find a connection between local height probabilities and characters of a conformal field theory governing the critical properties at the integrable point. In the antiferromagnetic regime, the criticality is described by the Z_k parafermion conformal field theory, while the $su(2)_1 \tilde{\times} su(2)_1 \tilde{\times} su(2)_{k-2}/su(2)_k$ coset conformal field theory describes the ferromagnetic regime.

C6: Weronika Szafran, Rutgers University

"Three levels of metabolic control in living cells: A category-theoretical representation"

Coauthors: K. Bailoor and S. Ji

Abstract: The microarray technique invented in the mid-1990's allows biologists to measure thousands of RNA levels (or transcript levels, TLs) and transcription rates (TRs) in living cells simultaneously. Garcia-Martinez et al. [1] and Castells-Roca et al. [2] measured TLs and TRs in budding yeast at 6 time points after switching the nutrient from glucose to galactose (the nutritional stress) or after increasing temperature from 25 to 37 degrees C (the temperature stress). Budding yeast cells contain about 6,300 genes (each gene coding for one RNA) and 200 metabolic pathways, each pathway catalyzed by a system of 10-50 coupled enzymes (or mRNAs). The kinetics of individual RNA levels inside the cell is determined by the balance of two opposing processes: $\text{mRNA}_i \xrightarrow{\text{D}_i} \text{mRNA}_i \xrightarrow{\text{T}_i}$, the first arrow indicates the synthesis of the i^{th} mRNA molecule from nucleotides catalyzed by transcriptosome (T_i) and the second arrow indicates the degradation of the i^{th} mRNA molecule back to nucleotides catalyzed by degradosome (D_i). [Click here](#) for full abstract.

C7: Shivani Patel, Rutgers University

"Pathway-specific responses to environmental stresses: Evidence for SOWAWN machines in living cells"

Coauthors: K. Carmona, K. Bailoor and S. Ji

Abstract: The budding yeast cell (or *Saccharomyces cerevisiae*), the atom of cell biology, has about 6,300 genes, each encoding an mRNA molecule and the associated protein. Since the yeast cell possesses approximately 200 metabolic pathways, on average about 30 mRNA molecules are involved in encoding one metabolic pathway. The purpose of this short talk is to present a brief summary of the recent experimental evidence indicating that the metabolic pathways in budding yeast act as what was previously referred to as the SOWAWN (Self-Organizing-Whenever-And-Wherever-Needed) machines when subjected to environmental stresses [1].

Using the microarray technique, Garcia-Martinez et al. [2] and Castells-Roca et al. [3] measured ~ 6000 mRNA levels (also called transcript levels, TLs) and transcription rates (TRs) in budding yeast at 6 time points after switching the nutrient from glucose to galactose (the nutritional stress) or after increasing temperature from 25 to 37 degrees C (the temperature stress). The kinetics of individual RNA levels inside the cell is determined by the balance of the two opposing processes – transcription catalyzed by transcriptosomes and transcript degradation catalyzed by degradosome. Since both the transcription step and transcript degradation step individually can increase, decrease or remain unchanged upon applying an environmental stress, there are a total of 9 distinct mechanism of coupling between these two processes which are labeled 1 through 9. [Click here](#) for full abstract.

C8: John Barton, Rutgers University

"Phase diagram of a generalized ABC model on the interval"

Abstract: We study the equilibrium phase diagram of a generalized ABC model on the interval of the one-dimensional lattice. This is a model of three particle species which interact via a mean field non-reflection-symmetric pair interaction, which need

not be invariant under cyclic permutation of the particle species as in the standard ABC model studied earlier. We prove in some cases and conjecture in others that the scaled infinite system has a unique density profile except for some special values of the particle densities when the system undergoes a second order phase transition at a certain critical temperature.

C9: Sagar Dave, Rutgers University

Coauthor: S. Ji

“Mechanism-based identification of cancer-associated and anticancer drug-responding RNA molecules in human breast tissues”

Abstract: The human genome contains about 23,000 genes but, due to alternative splicing leading to multiple RNA molecules from one gene, the total number of different kinds of RNA molecules in human cells can reach hundreds of thousands, each RNA molecule in turn existing in 0 to hundreds of copies, depending on environmental conditions. When a normal cell is transformed into a cancer cell, the RNA molecules in it can be divided into three groups, namely, the +, 0 and – groups, depending on whether the copy number of the RNA molecules increases, remains constant, or decreases. Also when a cell is treated with an anticancer drug such as doxorubicin, the effect of the treatment can be divided into three groups, i.e., the +, 0, and – effects, depending on whether the drug increases, leaves unaffected or decreases the levels of RNA molecules in the cell. Therefore, there are $3 \times 3 = 9$ distinct mechanisms underlying the interactions between cancer formation (carcinogenesis) and cancer destruction (cancer therapy), and these 9 mechanisms can be mapped onto the 9 directions defined by the unit vector located at the origin of what may be referred to as the “cancer mechanisms circle” drawn on the x-y plane with the x-axis encoding the cancer effect and the y-axis encoding the drug effect on the copy number of RNA molecules in a cell. A similar ‘mechanism circle’ was found very useful in analyzing the budding yeast microarray data reported elsewhere in this Conference [1, 2]. Of these 9 mechanisms, Mechanisms IV and VIII are of particular interest for possible discovery of anticancer drug targets, since Mechanism IV represents those RNA molecules whose levels are decreased by carcinogenesis and increased by anticancer drug treatment and Mechanism VIII represents those RNA molecules whose levels are increased by carcinogenesis and decreased by anticancer drug therapy.

By applying the “cancer mechanism circle” approach (described here for the first time) to the microarrays data measured by Perou et al. [3, 4] from 65 surgical specimens of human breast tumors, we have identified, out of 18 RNA molecules Perou et al. [3, 4] deemed cancer associated, 9 RNA (encoded by GADD34, GADD45A, GAS6, GDF10, GFI1, GRB134, GRB2, GRB7, GFER genes) exhibiting Mechanisms IV and 8 RNA molecules (encoded by GADD45A, GADD45G, GAS2, GAP43, GRB10, GRB14, GRB7, and SST genes) exhibiting Mechanism VIII. Together these RNA molecules represent about 50% of the growth-related and cancer-associated genes studied by Perou et al. [3,4]. These preliminary results suggest that extending the application of the “cancer mechanisms circle” approach to larger sets of RNA data measured from cancer tissues may be worthwhile.

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