

130th STATISTICAL MECHANICS CONFERENCE SHORT TALK SCHEDULE

SESSION A: Monday May 11, 2026 8:45 am – 9:45 am

A1: Matthew Marko, Marko Motors LLC

Title: Numerical Simulations of the Molecular Behavior and Entropy of Non-Ideal Argon

Abstract: A numerical model is built, simulating the principles of kinetic gas theory, to predict pressures of molecules in a spherical pressure vessel; the model tracks a single particle and multiplies the force on the spherical walls by a mole of molecules to predict the net pressure. An intermolecular attractive force is added for high-density simulations, to replicate a real fluid; the force is chosen to ensure the fluid matches the Peng-Robinson equation of state as it is compressed to a near supercritical density. The standard deviations of the molecule velocity with respect to temperature and density is studied to define the entropy. A parametric study of a Stirling cycle heat engine utilizing near-supercritical densities is modeled, to study how the temperature dependence of the attractive intermolecular Van der Waal forces can affect the net total entropy change to the surrounding environment. A practical, macroscopic-scale piston-cylinder engine was then built and demonstrated, utilizing a novel thermodynamic cycle that closely resembles the Carnot heat engine cycle, utilizing an arrangement of valves and pneumatic air to replicate the isothermal and isentropic compression and expansion of the working fluid. This heat engine cycle could be built without requiring advanced manufacturing, and utilized non-ideal carbon dioxide as the working fluid, to take advantage of the entropy effects of the Van der Waals forces demonstrated in the Argon simulations to boost the thermodynamic efficiency. This engine demonstrated this capability in a practical, macroscopic heat engine, and offers great opportunities to practical energy generation.

<https://arxiv.org/abs/2004.03584> USPTO Publication US-20260078714-A1

A2: Erik Bahnson, Rutgers University

Title: The Simplified Approach to Interacting Bose Gas in Two Dimensions

Coauthors: Erik Bahnson, Ian Jauslin

Abstract : Elliott Lieb's Simplified Approach, first formulated in 1963, offers a novel mathematical framework to analyze an interacting Bose gas. We assume an integrable (soft), non-negative pair potential with finite scattering length. In this framework, a system of many particles is described by a single nonlinear integro-differential equation on $\mathbb{R}^d$. A detailed analysis of this equation and its predictions has been carried out in three dimensions by Eric Carlen, Ian Jauslin, and Elliott Lieb in 2020 and 2021. The 2D Bose gas, however, exhibits unique behavior that distinguishes it from higher dimensions. In particular, the scattering solution exhibits logarithmic divergence, and the relationship between the 2-particle scattering energy and the total ground state energy is different than in 3D. In recent joint work with Ian Jauslin, we computed the low-density expansion of the Simple equation's prediction of the ground state energy, and of the condensate fraction. We found

that the Simple equation reproduces the correct leading order and first correction terms for the energy, agreeing with previous predictions by Michael Schick (1971), and rigorous results by Søren Fournais, Théotime Girardot, Lukas Junge, Léo Morin, and Marco Olivieri (2024). For the condensate fraction, we have found agreement with Bogoliubov theory and the prediction of Schick (1971).

**A3: Ofek Lauber Bonomo, Center for Urban Science and Progress, New York University
Tandon School of Engineering**

Title: Diffusion/Subdiffusion in the Pushy Random Walk

Coauthors: Itamar Shitrit, Shlomi Reuveni, Sidney Redner

Abstract: Random motion in disordered media is sensitive to the presence of obstacles, preventing atoms, molecules, and other particles from moving freely in space. When obstacles are static, a sharp transition between confined motion and free diffusion occurs at a critical obstacle density: the percolation threshold. Recently, Bonomo and Reuveni proposed a new minimalist model for diffusion in disordered media to test if this conventional wisdom continues to hold in the presence of simple tracer-media interactions [1,2]. In the model, a random walker is granted the ability to push away single obstacles that block its path. Surprisingly, the presence of these weak and localized tracer-media interactions leads to the process dynamically confining itself to a finite region, losing the hallmark critical transition. Similar effects of tracer-media interactions on the transport properties of active tracers were observed in recent controlled experimental studies [3]. In contrast to the binary pushing rule in the model, these experimental systems exhibit a graded pushing ability, where tracers can displace multiple obstacles at once. In this talk, I introduce the generalized Pushy Random Walk model, to account for this nonbinary pushing ability. In the model, a simple random walker is allowed to push more than a single obstacle at a time, with a probability that is a function of the number of pushed obstacles M . For the case of a 1D walk with power-law pushing probability, M^{-1} , I solve the model analytically and show that the walk exhibits subdiffusive behavior with exponent $1/3$. For a 2D simple random walk, I study the system numerically, revealing an obstacle-density dependent phase transition. Namely, for low densities, the pushy random walk follows regular diffusion. However, for high densities, the walk is subdiffusive

A4: Ziga Krajnik, NYU

Title: Anomalous fluctuations in many-body systems

Abstract: One-dimensional models are a theoretical playground for the investigation of strongly interacting many-body dynamics that have in recent years become experimentally realizable. While mean-field methods and other standard approaches are not applicable, they can often be investigated with techniques of integrability and generalized hydrodynamics that have revolutionized our understanding of their large-scale behavior. Fluctuations around hydrodynamic values display remarkable robustness and have recently been observed to be anomalous, indicating additional processes besides normal diffusion. We show that linearly degenerate systems support non-Gaussian fluctuations generated by convective diffusion and

derive a one-parameter family of central limit theorem interpolating between a Gaussian and a nested-Gaussian distribution. Hydrodynamics results are in perfect agreement with an exact solution of a microscopic model of ballistically propagating charged particles with stochastic scattering. In the single-file limit hydrodynamic noise is absent and all fluctuations are propagated from the initial conditions. The same anomalous phenomenology of equilibrium spin current fluctuations has been numerically observed in the easy-axis regime of the XXZ spin chain. By relating magnetization dynamics to those of large magnons, we identify the universal underlying hydrodynamic mechanism and give an analytical prediction for the distribution of spin current fluctuations. We also comment on anomalous fluctuations at the Heisenberg point and partial connections to the Parisi-Zhang universality class.

A5: Haoyu Guo, Cornell University

Title: Phonon Induced Energy Relaxation in Quantum Critical Metals

Coauthors: Debanjan Chowdhury

Abstract: Metals at the brink of electronic quantum phase transitions display high-temperature superconductivity, competing orders, and unconventional charge transport, revealing strong departures from conventional Fermi liquid behavior. Investigation of these fascinating intertwined phenomena has been at the center of research across a variety of correlated materials over the past many decades. A ubiquitous experimental observation is the emergence of a universal timescale that governs electrical transport and momentum relaxation. In this Letter, we analyze an equally important theoretical question of how the energy contained in the electronic degrees of freedom near a quantum phase transition relaxes to the environment via their coupling to acoustic phonons. Assuming that the bottleneck for energy dissipation is controlled by the coupling between electronic degrees of freedom and acoustic phonons, we present a universal theory of the temperature dependence of the energy relaxation rate in a marginal Fermi liquid. We find that the energy relaxation rate exhibits a complex set of temperature-dependent crossovers controlled by emergent energy scales in the problem. We place these results in the context of recent measurements of the energy relaxation rate via nonlinear optical spectroscopy in the normal state of hole-doped cuprates.

A6: Stefan Boettcher, Emory University

Title: Domain wall exponents in the dilute Edwards-Anderson spin glass

Coauthors: Xinrui Wang

Abstract: A bond-diluted lattice (sufficiently above the percolation transition) allows to reach larger system sizes to study the asymptotic behavior of ground state (GS) excitations in the Edwards-Anderson spin glass, an NP-hard optimization problem. In this new implementation, the diluted lattice is not only reduced to manageable sizes to determine the GS energies, but it also allows to reconstruct the undiluted spin configuration of each GS to measure the fractal exponent of the domain walls. Initial results for lattices in 3 dimensions are compared with previous studies and the (approximate) strong-disorder renormalization group. These results

suggest that it should be possible to scale up the measurement to well-above the upper critical dimension ($d_u=6$) to compare with mean-field predictions. (Earlier results are summarized in <https://www.frontiersin.org/journals/physics/articles/10.3389/fphy.2024.1466987/full>)

A7: Qidong He, Rutgers University

Title: High-density crystallization of polyomino fluids on the square lattice

Abstract: We consider hard-core lattice gases of congruent polyominoes on the square lattice. We prove that every polyomino with only finitely many tilings, up to translation and rotation, exhibits crystalline order at sufficiently high density, using a recent extension of Pirogov–Sinai theory due to Mazel–Stuhl–Suhov (2024).

A8: Endian Li, Seton Hall University

Title: Mechanical and rheological properties of the ideal glass

Coauthors: Viola Bolton-Lum, Eric Corwin, Peter Morse

Abstract: Recent numerical work has shown the existence of the ideal glass in 2d for hard polydisperse disks. This packing is unique, strictly jammed, rattler-free, triangulated, and hyperuniform and it is in the deepest well of the free-energy landscape. It is furthermore expected that no stable packings will be nearby in that landscape. We test this conjecture by softening the interaction to a contact potential and applying either shear or compression. We find that these packings are remarkably stable and report on the distance to the nearest stable minimum, the size of the first stress drop, and the character of the stress-strain curve.

A9: Peter K. Morse, Seton Hall University

Title: Decimated packings: A greedy approach to the Minkowski sphere packing bound

Coauthors: Daniel Gilliland

Abstract: Dense packings of non-overlapping spheres in d spatial dimensions are of fundamental interest in physics, mathematics, and computer science. Taking inspiration from a new class of greedy removal algorithms, which has raised the lower bound on non-lattice packings, we approach the problem from a simplistic view and deduce the greediest removal algorithm. Starting from a Poisson point process, we find the smallest pair-gap and remove the particle within the pair with the shortest distance to another particle. This removal corresponds to the greatest increase in free volume available to the remaining points, and thus the densest decorated sphere packing. The process is iterated until only a vanishing fraction of the original particles remain. As d increases, these packings approach the Minkowski bound, such that the packing fraction scales as $2^{-(1-d)}$. While the resulting packings are not dense by modern standards, we discuss how they can be used in conjunction with an additive algorithm to build the greediest local packing algorithm.

A10: Carlo Piermarocchi, Michigan State University

Title: From Fixed Points to Cycles: Nonreciprocal Hopfield Models of Cell Fate

Abstract: Standard Hopfield models can be used to represent cell states as attractors of a symmetric interaction matrix in gene regulatory networks. Introducing antisymmetric components breaks detailed balance and leads to non-equilibrium steady states with circulating currents. Building on a two-memory model, I will show how nonreciprocity turns fixed-point attractors into limit cycles. Using single-cell expression and RNA velocity from cells with different phenotypes, we extract effective couplings and test for violations of equilibrium. The result is a data-driven, minimal model of cell-state dynamics beyond the gradient-flow picture of Waddington landscapes.

A11: Mehran Kardar, MIT

Title: Polymer adsorption on phase separating substrate

Coauthors: Rajiv G Pereira, Andriy Goychuk, and Buddhapriya Chakrabarti

Abstract: We investigate polymer adsorption on a surface coated by a phase-separating binary mixture, where the polymer selectively associates with one component. Molecular dynamics simulations observe a non-monotonic variation of the polymer film height with adsorption strength. Using transfer matrix methods and mean-field analysis, we demonstrate that this behavior arises from competition between surface phase separation, adsorption energy, and excluded-volume interactions.