124th STATISTICAL MECHANICS CONFERENCE

SHORT TALK SCHEDULE

SESSION A

A1: Jaeuk Kim, Princeton University

Title: Theoretical Prediction of the Effective Dielectric Constant of Disordered Layered Media Beyond the Long-Wavelength Regime

Abstract: The problem of wave propagation in a two-phase (or multi-phase) layered medium has been extensively studied because of its simplicity and ease of fabrication. A key wave characteristic is the effective dynamic dielectric constant tensor for the incident radiation of the given frequency and wavevector k_1. This complex-valued quantity determines the effective wavenumber and extinction mean free path. While there have been many theoretical/numerical treatments to estimate this effective property, the previous closed-form approximations are applicable to disordered media in the quasistatic (or long-wavelength) regime, i.e., $k_1 xi \ll 1$, where ξ is a characteristic inhomogeneity length scale. Here, we derive, for the first time, a nonlocal approximation for the effective dynamic dielectric constant for disordered dielectric two-phase media that applies well beyond the quasistatic regime. To carry out this task, we utilize general nonlocal strong-contrast expansion for the effective dielectric constant tensor that can be applied to two-phase media with various symmetries [S. Torquato and J. Kim, PRX 11, 021002 (2021)]. We focus on incident waves of transverse electric (TE) polarization. The resulting approximation yields an accurate closed-form formula depending on the spectral density, which is the Fourier transform of the autocovariance function of the phase indicator function. Our theoretical predictions agree very well with finite-difference time-domain (FDTD) simulations.

A2: Peter Morse, Princeton University

Title: Like a crystal at long lengths and a liquid at short lengths: disordered stealthy hyperuniform systems and their novel material properties

Coauthors : Jaeuk Kim, Paul Steinhardt, Sal Torquato

Abstract : Hyperuniform many-particle systems are characterized by a structure factor S(k) that is precisely zero as the wavenumber k goes to zero; and stealthy hyperuniform systems have S(k)=0 for the finite range 0 ir novel properties have shown great promise. However, the size and relative accuracy of previous efforts may not be sufficient to observe certain phenomena. In this short talk, I will present an improved methodology using quad precision calculations on GPUs which produces systems more than an order of magnitude larger and which reduces deviations of S(k) from zero in the exclusion region by a factor greater than 30 orders of magnitude. This ultra-high accuracy is required to draw definitive conclusions about the nature of their energy landscape and to observe certain physical properties, including the presence or absence of Anderson localization.

Comments and Questions : I submitted a talk abstract a few minutes ago which seems to have not copied into the window correctly (thus removing a small section). This version is correct.

A3: Chris Baldwin, University of Maryland

Title: Revisiting the replica trick: Competition between spin glass and conventional order

Coauthors : Brian Swingle

Abstract : There is an ambiguity in how to apply the replica trick to spin glass models which have additional order parameters unrelated to spin glass order --- with respect to which quantities does one minimize vs maximize the action, and in what sequence? We show that the correct procedure is to first maximize with respect to "replica" order parameters, and then minimize with respect to "conventional" order parameters. With this result, we further elucidate the relationship between quenched free energies, annealed free energies, and replica order. Phase transitions in which the quenched and annealed free energies become unequal, which we term "self-averaging transitions", do not necessarily correspond to the appearance of replica order. In fact, the quenched and annealed ensembles can each undergo transitions entirely independently of the other.

A4: Qidong He, Rutgers University
Title: Crystallization phenomenon in a large class of hard-core lattice particle models
Coauthors : Ian Jauslin
Abstract: We study the high-density behavior of systems of identical hard-core particles on a lattice. Such systems are known to crystallize if the particles can perfectly tile the lattice and do not exhibit the sliding phenomenon. Using a local density argument based on discrete Voronoi diagrams, we extend this result to a much larger class of systems, including those that do not satisfy the tiling condition.

A5: Carlo Vanoni, SISSA
Title: Dynamics of interfaces in the two-dimensional quantum Ising model
Coauthors: Federico Balducci, Andrea Gambassi, Alessio Lerose and Antonello Scardicchio
Abstract : In this short talk, I will show how the melting of a sufficiently smooth interface in the 2D quantum Ising model with transverse and longitudinal fields shows signs of localization. This is done by means of a “holographic” mapping to a 1D integrable model of fermions in the large ferromagnetic coupling J limit and after the systematic introduction of 1/J corrections. Based on Phys. Rev. Lett. 129, 120601 (2022) Phys. Rev. B 107, 024306 (2023)

A6: Sriram Ganeshan, CUNY
Title: Ocean waves and Fractional quantum hall effect
Abstract : The fluid dynamics of the ocean subject to earth’s spin gives rise to some fascinating wave phenomena with topological properties. In this talk, I will discuss similarities and differences between fluid dynamical equations resulting in ocean waves to the “hydrodynamics” of quantum Hall (QH) fluids. Following this analogy, I will develop a fluid dynamical framework of the QH state that has certain advantages over the existing state-of-the-art approaches.

A7: Yu Qiao, University of California, San Diego
Title: Intrinsically Nonequilibrium State Caused by a Narrow Energy Barrier
Coauthors: Z. Shang, M Wang
Abstract : The concept of spontaneously nonequilibrium dimension (SND) was investigated. In general, if across an area (often small in at least one dimension) the particle number density distribution inherently cannot reach thermodynamic equilibrium, we refer to this area as a SND. One example of SND is a narrow energy barrier, with the width much less than the particle mean free path. As the local particle trajectories tend to be nonchaotic, the global system state may be nonequilibrium, which has been demonstrated through a computer simulation on a “toy” model in gravity, and an experiment using Coulomb force. While such a phenomenon seems counterintuitive, it is compatible with the basic principle of maximum entropy. What makes the system unique is that the narrow energy barrier interrupts the probability distribution of local microstates, and imposes additional constraints on the global

microstates.

A8: Evgeniy Khain, Oakland University, Michigan
Title: Front propagation in expanding cell monolayer
Coauthors : John Straetmans
Abstract : In a dense monolayer of cells, cells divide, grow, and maintain contacts with their neighbors. During migration, cells display complex behavior, adjusting both their division rate and their growth after division to the local mechanical environment. Experimental observations show that cells near the edge of the expanding monolayer are larger and move faster than cells deep inside the colony. To explain these observations and describe cell migration patterns, we formulate a spatio-temporal theoretical model for multicellular dynamics in terms of the cell area distribution; the model includes cell growth after division and effective pressure. Numerical simulations of the model predict both the speed of invasion and the width of the outer proliferative rim; these predictions are in a good agreement with experimental observations. Theoretical analysis yields the equation for density of cells and reveals a novel type of propagating front with compact support. The velocity of front propagation (monolayer expansion) is derived analytically and its dependence on all the relevant parameters is determined. For details, please see Refs [1,2]. [1]. E. Khain and J. Straetmans, “Dynamics of an expanding cell monolayer”, Journal of Statistical Physics 184, 20 (2021). [2]. J. Straetmans and E. Khain, “Modeling Cell Size Dynamics in a Confined Nonuniform Dense Cell Culture”, Journal of Statistical Physics 176, 299-311, (2019).

A9: Michael Kiessling, Rutgers University
Title: Testing Lennard-Jones clusters for optimality
Coauthors: Annie Wei
Abstract : We will explain a necessary criterion for optimality of Lennard-Jones N-body ground state energies, and report our results of subjecting publicly available data to this criterion.

A10: Benjamin Vollmayr-Lee, Bucknell University
Title: Phase Separation Dynamics with Anistropy
Coauthors : Jaime Wallace (Bucknell University), Ella Carlander (University of Washington)
Abstract : We study the asymptotic late stage of phase separation dynamics, where the characteristic domain size grows as a power of time, and the growth exponent and scaled domain structure are universal, behavior suggestive of a dynamical renormalization group (RG) fixed point. We consider in particular the influence of surface tension anistropy on the resulting growth and structure. Since this RG fixed point is not accessible via a controlled perturbation theory, we resort to simulations of the two-dimensional Cahn-Hilliard equation, modified to include an anisotropic surface tension. We find that anisotropy persists in the asymptotic state, modifying the domain structure but not the growth exponent. The Porod tail of the angle-resolved structure factor S(k,t) provides a sensitive diagnostic, which allows us to quantify the degree of anistropy in the scaled domain structure. Evidently the underlying RG fixed point must depend on the full shape of the surface tension anisotropy.

A11: Michael Winer, Joint Quantum Institute
Title: The Spectral Statistics of Spin Glasses
Coauthors: Richard Barney,Christopher L. Baldwin, Victor Galitski, Brian Swingle
Abstract: It is widely expected that systems which fully thermalize are chaotic in the sense of exhibiting random-matrix statistics of their energy level spacings, whereas integrable systems exhibit Poissonian

statistics. In this paper, we investigate a third class: spin glasses. These systems are partially chaotic but do not achieve full thermalization due to large free energy barriers. We examine the level spacing statistics of a canonical infinite-range quantum spin glass, the quantum p-spherical model, using an analytic path integral approach. We find statistics consistent with a direct sum of independent random matrices, and show that the number of such matrices is equal to the number of distinct metastable configurations — the exponential of the spin glass "complexity" as obtained from the quantum Thouless-Anderson-Palmer equations. Our results show that level spacing statistics can probe the ergodicity-breaking in quantum spin glasses and provide a way to generalize the notion of spin glass complexity beyond models with a semi-classical limit.

A12: A. Nihat Berker, Kadir Has University and MIT
Title: Nematic ordering in the Heisenberg spin-glass system in three dimensions
Coauthors: Egemen Tunca and A. Nihat Berker
Abstract: Nematic ordering, where the spins globally align along a spontaneously chosen axis irrespective of direction, occurs in spin-glass systems of classical Heisenberg spins in d = 3.[1] In this system where the nearest-neighbor interactions are quenched randomly ferromagnetic or antiferromagnetic, instead of the locally randomly ordered spin-glass phase, the system orders globally as a nematic phase. This nematic ordering of the Heisenberg spinglass system is dramatically different from the spin-glass ordering of the Ising spin-glass system. The system is solved exactly on a hierarchical lattice and, equivalently, Migdal-Kadanoff approximately on a cubic lattice. The global phase diagram is calculated, exhibiting this nematic phase, and ferromagnetic, antiferromagnetic, disordered phases. The nematic phase of the classical Heisenberg spin-glass system is also found in other dimensions d > 2: We calculate nematic transition temperatures in 24 dimensions in 2 < d <= 4.
[1] "Renormalization-Group Theory of the Heisenberg Model in d Dimensions", E. Tunca and A.N. Berker, Physica A 608, 128300 (2022); "Nematic Ordering in the Heisenberg Spin-Glass System in d=3 Dimensions" E. Tunca and A.N. Berker, Phys. Rev. E 107, 014116 (2023).

SESSION B

B1: Pradip Kattel, Rutgers University
Title: Exact solution of non-Hermitian PT-symmetric spin chain
Coauthors : Parameshwar R Pasnoor, and Natan Andrei
Abstract : We construct the exact solution of a non-Hermitian $\mathscr{PT}$-symmetric isotropic Heisenberg spin chain with integrable boundary fields. We find that the system exhibits two types of phases named A and B. In the B type phase, the $\mathscr{PT}$ symmetry remains unbroken and it comprises of eigenstates with only real energies, whereas the A type phase exhibits both $\mathscr{PT}$ symmetry broken and unbroken sectors, comprising of eigenstates with only complex and real energies respectively. The $\mathscr{PT}$-symmetry broken sector comprises of pairs of eigenstates whose energies are complex conjugates of each other. The existence of two sectors in the A type phase is associated with the exponentially localized bound states at the edges with complex energies which are described by boundary strings. We find that both A and B type phases can be further divided into sub-phases which exhibit different ground states. We also compute the bound state wavefunction in one magnon sector and find that as the imaginary value of the boundary parameter is increased, the exponentially localized wavefunction broadens thereby protruding more into the bulk,

which indicates that exponentially localized bound states may not be stabilized for large imaginary values of the boundary parameter.

B2: Fedrico Corberi, Salerno University, Italy
Title: Coexistence of coarsening and mean field relaxation in the long-range Ising chain
Coauthors: A. Iannone, M.umar, E. Lippiello, P. Politi
Abstract: We study the kinetics after a low temperature quench of the one-dimensional Ising model with long range interactions between spins at distance r decaying as r^{-a}. For a = 0, i.e. mean field, all spins evolve coherently quickly driving the system towards a magnetised state. In the weak long range regime with $a>1$ there is a coarsening behaviour with competing domains of opposite sign without development of magnetisation. For strong long range, i.e. 0

B3: Kalle Koskinen, University of Helsinki
Title: Metastates of the Random Field Mean-Field
Abstract: The random field mean-field spherical model
The random field mean-field spherical model is obtained by adding a random linear term, corresponding to the coupling of the system with a random external field, to the Hamiltonian associatd with the mean-field spherical model. The finite volume Gibbs states of this model are random probability measures, and their distributions are probability measures on probability measures referred to as metastates. For this particular model, one is able to exactly determine the limiting infinite volume metastates. We will present the model, the limiting metastates, and the procedure by which they are obtained.

B4: Jorge Rosa, Limmer Group, University of California, Berkeley
Title: Non-equillibrium free-energetics
Coauthors: David T. Limmer
Abstract: Title: Non-equilibrium free-energetics of free and confined active filaments from variational time reversal Abstract: The interplay between dynamics, structure and function of active systems is central to inquiries ranging from spontaneous organization inside the cell nucleus to macroscopic collective organization of self-driven agents. In this short talk, we introduce a method to estimate deviations from equilibrium of arbitrary structural properties of a driven system through the solution of a stochastic optimal control problem for non-equilibrium free-energy profiles along order parameters. We find a natural physical interpretation for the optimal control solution as that which achieves a non-dissipative time reversal of the driven system's dynamics, and use this knowledge to design ansätze of the optimal control policy that lead to rapid convergence in an online reinforcement-learning implementation of the method. Applications to coarse-grained models of active semi-flexible filaments swimming freely and under confinement allow us to map out non-equilibrium population enhancements of structural-dynamic motifs as functions of the distribution and intensity of active forces along the filament backbone.

B5: Xingyu Liu
Title : Free long flight in infinite horizon Lorentz Gas
Coauthors : Dr. Peter Nandori
Abstract : In this work, we are interested in the length of a few consecutive long free flights in infinite horizon Lorentz Gas. In dimension D = 2, it is well known that a flight of length $T \gg 1$ is typically followed by a flight of length $C\sqrt{T}$. Here, we extend this result to any dimension D. The main theorem we want to prove is In $D \geq 2$ and under some conditions. There exists a stochastic process X1, X2, ... so that for any finite n and for any sets $Ai \subset R$ with $Leb(\partial Ai) = 0$, limT →∞ν0(τ1 > T, τi ∈ AiT 1/Di−1, i =

1, ..., n)/ν0(τ1 > T) = P(Xi ∈ Ai, i = 1, ..., n). We divide our proof into some parts. For some special cases such that n = 1 or D = 2 with single scatter, the theorem is easy to prove. In higher dimensions, we follow by Marklof-Str¨ombergsson'theory to prove the theorem.

B6: Maxime Van de Moortel, Rutgers University
Title : The scattering of a massive scalar field on a black hole
Coauthors : Federico Pasqualotto (UC Berkeley), Yakov Shlapentokh-Rothman (Toronto)
Abstract : The decay of massive scalar fields obeying a Klein-Gordon equation on a black hole has long remained an outstanding issue in General Relativity. This problem involves the scattering theory with a long-range attractive potential whose far-away asymptotics match that of the hydrogen atom, and thus cannot be studied by perturbative methods. We prove that massive scalar fields on a Schwarzschild black hole admit no bound states (in contrast to the hydrogen atom!), however each fixed spherical harmonic decays at a slow t^{-5/6} rate in a compact region. Our work appears to be the first rigorous decay result for a massive matter model on a black hole. Joint work with Federico Pasqualotto and Yakov Shlapentokh-Rothman.

B7: Ronald Fisch
Title: Spontaneous Symmetry Breaking in a Random Uniaxial Anisotropy Heisenberg Model
Abstract : A 3D random uniaxial anisotropy Heisenberg ferromagnet with a weak uniform cubic anisotropy has been studied on L x L x L simple cubic lattices with periodic boundary conditions and L up to 128. Each spin is restricted to point in one of the [1,1,0] directions. For weak random anisotropy, D/J, there is a ferromagnetic phase, FM, at low temperature, T/J, in which the spins are oriented, on the average, along one of the [1,1,1] directions. A phase with broken time-reversal symmetry, BTR, but no apparent long-range ferromagnetic or average orientational order is found between the FM phase and the paramagnetic phase, PM. At the transition temperature from the PM phase to the BTR phase, T_c, there are sharp peaks in the magnetic susceptibility and the specific heat. The structure factor. S(k), diverges at T_c approximately as |k|^{-2} for small |k|, and this peak diverges more strongly as T is decreased below T_c. It is conjectured that the BTR phase can be described as a set of finite [1,1,1] FM domains having strong energetic constraints between the orientations of neighboring domains. The domain structure becomes coarser as T is reduced. These constraints can then create a type of topological long-range order. It is not clear whether a random anisotropy Heisenberg model without the uniform cubic anisotropy will behave in a similar way, because the pure cubic Heisenberg model is not in the same universality class as the isotropic Heisenberg model in 3D.