Complexity Week 1 Abstracts

Speaker: Miles Stoudenmire
Titles: Part 1: Quantum Dynamics in 2D and 3D Using Tensor Belief Propagation and Part 2: New Approaches for Quantum Dynamics: Complex and Imaginary Time
Abstract: This mini-course will introduce new methods for quantum dynamics simulations based on tensor networks. Until recently, tensor network simulations of dynamics have been primarily limited to one-dimensional systems and short times. However, recent algorithmic developments are rapidly changing this picture.

The first family of algorithms discussed will be the belief propagation (BP) framework. BP is well-established in the classical statistical mechanics and spin glass fields, but was only recently adapted for quantum tensor network states. Building on the notion of "tree-like" structure, BP gives offers an affordable and complementary perspective for evolving 2D and even 3D wave functions in real and imaginary time. I will end by discussing recent applications to dynamics and thermal properties of spin systems.

The second family of algorithms revolves around the energy content of quantum states. Imaginary time evolution is known to be efficient for tensor networks, due to the rapid damping of high-energy states. One can leverage these benefits for real-time evolution by introducing "complex time" dynamics, which balance benefits of imaginary and real time, in particular controlling the growth of entanglement. Despite the dynamics being fictitious, there are controlled reconstruction techniques to extract real-time correlation functions. I will discuss the philosophy and promise of these methods and possible implications for the future of dynamics simulations.

Speaker: Anatoly Dymarsky
Title: Holographic Krylov complexity
Abstract: I will discuss how the Krylov space method can be formulated for holographic theories, and how it can help to define a dual holographic description for non-holographic systems.

Speaker: Mohammad Maghrebi
Title: Exact stochastic approach to dissipative spin-boson models
Abstract: Spin-boson models involving many interacting spins and bosons are ubiquitous in quantum simulation platforms. At the same time, characterizing the dynamics of these quantum systems represents a significant challenge. In this talk, I introduce general spin-boson models where bosons are subject to Markovian dissipation (e.g., due to cavity loss). I present an exact stochastic approach where the solution of a classical stochastic equation—mimicking the bosonic modes—is input into a quantum stochastic equation for individual spins, thereby effectively decoupling spins. Each stochastic realization may be unphysical, but upon averaging over trajectories, the exact, physical quantum state is recovered, including its nontrivial correlations and entanglement. Finally, I show that Markovian dissipation renders the dynamics classically simulable even for highly entangled states.

Speaker: Hosho Katsura
Title: Integrable SYK-like models
Abstract: In this talk, we introduce two disorder-free variants of the Sachdev–Ye–Kitaev (SYK) model, both built from Majorana fermions with all-to-all interactions: (i) the clean Majorana SYK model and (ii) its N=1 supersymmetric extension. Unlike the original disordered SYK model, which is maximally chaotic, these models are integrable, in the sense that their Hamiltonians commute with a quadratic Hamiltonian.

This integrability allows us to study the static and dynamical properties of Model (i) with 4-body interactions in detail. We find that the out-of-time-order correlators (OTOCs) exhibit early-time exponential growth, resembling that of the disordered SYK model. We also discuss the effect of dissipation on this 4-body clean SYK model. Time permitting, I will briefly touch on a disorder-free version of the quantum breakdown model with all-to-all interactions.