Fluctuations, Entanglements, and Chaos: Exact Results: August 28, 2023- September 1, 2023

Events for:
Monday, August 28th - Friday, September 1st

Monday, August 28th

9:00am **Workshop: Breakfast - SCGP Cafe**

Title: Breakfast

9:30am **Workshop: Frank Pollmann - SCGP 102**

Speaker: Frank Pollmann

Title: Entanglement Transitions in Unitary Circuit Games

Abstract: Repeated projective measurements in unitary circuits can lead to an entanglement phase transition as the measurement rate is tuned. In this work, we consider a different setting in which the projective measurements are replaced by dynamically chosen unitary gates that minimize the entanglement. This can be seen as a one-dimensional unitary circuit game in which two players get to place unitary gates on randomly assigned bonds at different rates: The "entangler" applies a random local unitary gate with the aim of generating extensive (volume law) entanglement. The "disentangler", based on limited knowledge about the state, chooses a unitary gate to reduce the entanglement entropy on the assigned bond with the goal of limiting to only finite (area law) entanglement. In order to elucidate the resulting entanglement dynamics, we consider three different scenarios: (i) a classical discrete height model, (ii) a Clifford circuit, and (iii) a general U(4) unitary circuit. We find that both the classical and Clifford circuit models exhibit phase transitions as a function of the rate that the disentangler places a gate, which have similar properties that can be understood through a connection to the stochastic Fredkin chain. In contrast, the ``entangler" always wins when using Haar random unitary gates and we observe extensive, volume law entanglement for all non-zero rates of entangling.

10:30am **Workshop: Coffee Break - SCGP Cafe**

Title: Coffee Break

11:00am **Workshop: Vir Bulchandani - SCGP 102**

Speaker: Vir Bulchandani

Title: Exact results on monitored all-to-all Haar-random circuits

Abstract: We present exact results for the Lyapunov exponents and Born probabilities in monitored all-to-all Haar-random circuits. We relate such circuits to various known ensembles in random matrix theory and discuss connections with the volume and area law entangled phases that arise in spatially local monitored random circuits.

12:00pm **Workshop: Lunch - SCGP Cafe**

Title: Lunch

1:15pm **Workshop: Jerome Dubail - SCGP 102**

Speaker: Jerome Dubail

Title: Probing the local rapidity distribution of 1D Bose gases

Abstract: I will present our ongoing work with Léa Dubois, Guillaume Thémèze and Isabelle Bouchoule (Institut d'Optique, Palaiseau, France) on the measurement of the local rapidity distribution in 1D Bose gases.1D bosons with point-like interaction, also known as Lieb-Liniger gas, display peculiar dynamical behavior because they are (nearly) integrable. The rapidities of a 1D Bose gas are the asymptotic momenta of the atoms, which can be measured by 1D time of flight. It is now established that the rapidity distribution entirely characterizes these 1D gases after relaxation, and over the past few years the rapidity distribution has become the central concept in the study of their dynamics, both theoretically with the advent of Generalized Hydrodynamics in 2016 and experimentally with first measurements of the global rapidity distribution performed in 2020 by the group of David Weiss. Here I will discuss a new experimental protocol to access the spatially resolved distribution of rapidities in the Palaiseau experiment, which should ultimately allow to experimentally map out the entire state of the gas and measure the phase-space distribution of quasi-particles. I will argue that this can be done by performing a one-dimensional expansion of a selected zone of the gas, and I will discuss some new experimental results.

2:15pm **Workshop: Break - SCGP 102**

Title: Break

2:30pm **Workshop: Ashvin Vishwanath - SCGP 102**

Speaker: Ashvin Vishwanath

Title: From wave-function collapse and Galois solvability to the realization of non-Abelions on a quantum device.

Abstract: I will review our recent set of theoretical works on generating long range quantum entanglement with adaptive quantum circuits. Adaptive circuits combine mid-circuit measurement with unitary gates whose choice is determined by previous measurement outcomes. In particular, we find that certain kinds of non-Abelian topological order can be efficiently prepared with a circuit depth that is independent of system size. Surprisingly, these particular non-Abelian states are closely related to Galois' characterization of solvable polynomial equations. Finally, I will describe our recent collaboration with Quantinuum that leverages these insights to create the D4 quantum double topological order, and demonstrate the non-Abelian statistics of its excitations on a quantum device. In particular, I will discuss the Borromean braiding of excitations, a signature unique to non-Abelian topological order, and its measurement on the Quantinuum platform. In collaboration with Ruben Verresen, Nat Tantivasadakarn, Ryan Thorngren and the team at Quantinuum

3:30pm **Workshop: Tea - SCGP Cafe**

Title: Tea

4:00pm **Workshop: Katja Klobas - SCGP 102**

Speaker: Katja Klobas

Title: Solvable quantum circuits: Insights into interacting integrable dynamics

Abstract: Under very general conditions, a quantum many-body system initialized in a non-equilibrium state exhibits a linear growth of entanglement, followed by its saturation to an extensive value. Recently it was understood that the two regimes can be related to each other through the so-called "space-time duality": the slope of the entanglement growth can be interpreted as the stationary density of the model obtained by formally swapping the roles of space and time. In this talk I will discuss a solvable example, where this mapping can be performed exactly. This allows us to independently test the predictions for the slope of the growth of entanglement entropies and their symmetry-resolved generalisations, such as full counting statistics.

Tuesday, August 29th

9:00am **Workshop: Breakfast - SCGP Cafe**

Title: Breakfast

9:30am **Workshop: Ewan McCulloch - SCGP 102**

Speaker: Ewan McCulloch

Title: Equilibration of fluctuations in chaotic quantum systems

Abstract: In closed chaotic quantum systems, the approach from local to global equilibrium is described by the hydrodynamic transport of conserved quantities. By doing large scale simulations of a hard-core boson ladder (using a quantum gas microscope), we find experimental evidence that classical fluctuating hydrodynamics controls not only transport, but also large scale fluctuations in isolated quantum many body systems. This result is supported in the context of number conserving quantum circuits, where we show that the full counting statistics of charge transfer is controlled by a simple fluctuating hydrodynamic equation of motion.

10:30am **Workshop: Coffee Break - SCGP Cafe**

Title: Coffee Break

11:00am **Workshop: Aditi Mitra - SCGP 102**

Speaker: Aditi Mitra

Title: Topological Defects in Floquet Circuits

Abstract: I will discuss how one may construct Floquet models from a fusion category, and how this formalism is a natural way to construct topological defects: non-local operators that can be deformed in the space and time direction without changing the physics. One of these topological defects is the "duality defect" that implements the Kramers-Wannier duality transformation and is a "non-invertible symmetry" as it projects out states of a given parity. I will highlight the consequence of the duality defect on Floquet time-evolution, first for the exactly solvable Floquet-Ising model, and then by adding integrability breaking perturbations to the model.

12:00pm **Workshop: Lunch - SCGP Cafe**

Title: Lunch

1:15pm **SCGP Weekly Talk & Workshop Speaker: Tomaz Prosen - SCGP 102**

Speaker: Tomaz Prosen

Title: Exactly Solvable Models of Quantum Many-Body Chaos

Abstract: Focusing on quantum lattice systems with local interactions I will discuss the unreasonable effectiveness of random matrix theory for description of their spectral fluctuations. A class of locally interacting spin systems has been recently identified where the spectral form factor is proven to match with random matrix theory, and where spatiotemporal correlation functions of local observables as well as some measures of dynamical complexity can be calculated analytically. These, so-called dual unitary systems, include integrable, non-ergodic, ergodic, and generically, (maximally) chaotic cases. After reviewing the basic properties of dual unitary Floquet circuits, I will argue that dynamical correlation functions of these models are generally perturbatively stable with respect to breaking dual-unitarity, describe a simple result within this framework, and motivate some conjectures

2:15pm **Workshop: Break - SCGP 102**

Title: Break

2:30pm **Workshop: Alexander Abanov - SCGP 102**

Speaker: Alexander Abanov

Title: Limit shape phase transitions

Abstract: A limit shape phenomenon in statistical mechanics is the appearance of a most probable macroscopic state. This state is usually characterized by a well-defined boundary separating frozen and liquid spatial regions. We consider a particular class of topological phase transitions in the limit shape problem of statistical mechanics. The problem considered is generally known as the Arctic circle problem. One can visualize the considered transition as merging two limit shapes (Arctic circles). We establish the mapping, which identifies the transition as the Gross-Witten-Wadia transition known in lattice QCD and random matrix problems. It is a continuous phase transition of the third order. We identify universal features of the limiting shape close to the transition using the free fermion and hydrodynamic description.

3:30pm **Workshop: Tea - SCGP Cafe**

Title: Tea

4:00pm **Workshop: Sagar Vijay - SCGP 102**

Speaker: Sagar Vijay

Title: “Coding” Phases of Open Quantum Dynamics

Abstract: Chaotic, unitary quantum many-body dynamics will rapidly hide local quantum information in distant degrees of freedom, thus acting as an effective quantum error-correcting code. In this talk, I will show how regimes of open quantum many-body evolution can similarly encode and protect quantum information, in spite of the presence of dissipation. Specifically, I will demonstrate that a chaotically-evolving one-dimensional quantum many-body system with dissipation near its spatial boundary can be in one of two dynamical phases: a phase in which initially locally-accessible quantum information in the system is completely lost to the environment, and a “quantum coding” phase in which this information is preserved in the system for a parametrically-long time in system size. The nature of these phases and of the transition out of the quantum coding phase is determined by analytically investigating random quantum circuit evolution.

Wednesday, August 30th

9:00am **Workshop: Breakfast - SCGP Cafe**

Title: Breakfast

9:30am **Workshop: Michael Knap - SCGP 102**

Speaker: Michael Knap

Title: Emergent hydrodynamics in constrained quantum matter

Abstract: The far-from-equilibrium dynamics of generic interacting quantum systems is characterized by a handful of universal guiding principles, among them the diffusive transport of globally conserved quantities. Certain systems with kinetic constraints or constrained interactions, however, defy these expectations and exhibit anomalous transport instead. In this talk, we will discuss some of these exceptions. For example, systems with conserved, and sometimes hidden, spin patterns, including XNOR or tJz models, show anomalously slow spin relaxation dynamics. In these models, spin transport is governed by tracer diffusion, which describes the diffusion of a tagged particle with hard-core constraints. Another example are fracton systems, which conserve the dipole moment (or equivalently the center of mass). Fractons are excitations that are immobile on their own, but they can move when forming a composites. In the ergodic phase of these dipole-conserving, fracton systems transport is anomalously slow and exhibits sub-diffusive scaling. We will discuss relations and differences between the two cases and also draw connections to recent quantum simulation experiments with ultracold atoms.

10:30am **Workshop: Coffee Break - SCGP Cafe**

Title: Coffee Break

11:00am **Workshop: Tianci Zhou - SCGP 102**

Speaker: Tianci Zhou

Title: A physical theory of the two-stage thermalization

Abstract: Thermalization time marks the scale at which the subsystem entanglement of a pure state reaches its thermal value. Recent studies [Phys. Rev. X 11, 031019] on local quantum circuits revealed two exponential stages with rates r1 and r2 in the decay of purity. We use entanglement membrane theory to understand this two-stage thermalization process. In the first stage, the rate r1 is associated with the domain wall free energy. A geometric effect can lead to r1 r2, rendering r1 as a "phantom eigenvalue" inside the transfer matrix's spectrum gap. Moreover, the second stage can host a competition between domain wall and magnon modes. Analytical results from dual unitary circuits and numerics demonstrate that r2 r1 when the magnon wins. Interestingly, when the domain wall prevails, the scenario offers a practical method for measuring Renyi entanglement growth through fluctuations of a local correlation function.

12:00pm **Workshop: Lunch - SCGP Cafe**

Title: Lunch

2:30pm **Workshop: Wojciech de Roeck - SCGP 102**

Speaker: Wojciech de Roeck

Title: Status of many-body localization and related issues

Abstract: I will comment on some ongoing work about many body localization, with the focus being on rigorous results. The precise contents will depend on the situation at the time of the talk.

3:30pm **Workshop: Tea - SCGP Cafe**

Title: Tea

4:00pm **Workshop: Sarang Gopalakrishnan - SCGP 102**

Speaker: Sarang Gopalakrishnan

Title: Defining stable phases of Markovian open systems

Abstract: The steady states of Markovian open systems (whether classical or quantum) are extremal eigenvectors of a certain class of non-Hermitian matrices. Even when these matrices have gapped spectra, the steady states are not perturbatively stable in general. We propose an alternative definition of stability, in terms of the robustness of the steady state against weak local perturbations of the dynamics. We check that our definition recovers many of the properties one would expect in a "phase" of matter, and that it encompasses many known examples of nontrivial steady-state phases [1]. [1] Unpublished work in collaboration with Curt von Keyserlingk and Tibor Rakovszky.

6:00pm **Workshop: Dinner Banquet - SCGP Cafe**

Title: Dinner Banquet

Thursday, August 31st

9:00am **Workshop: Breakfast - SCGP Cafe**

Title: Breakfast

9:30am **Workshop: Robert Konik - SCGP 102**

Speaker: Robert Konik

Title: Multipartite Entanglement Spectroscopy using Single Particle Green’s Functions

Abstract: We propose a protocol for detecting multipartite entanglement in itinerant many-body electronic systems using the quantum Fisher information (QFI). We establish a connection between the QFI and single-particle Green's functions by identifying a set of non-trivial witness operators. To construct these operators, we employ a doubling of the system wherein we introduce two identical copies of the original model. While the witness operator hops electrons between copies, the copies do not interact with one another. We apply this methodology to a finite-sized fermionic systems and showcase its effectiveness in detecting entanglement in spinless and spinful itinerant electron models. We show that the detected entanglement level is sensitive to the wave vector associated with the hopping process. We also demonstrate the important role that symmetry has in detecting levels of entanglement. Our protocol paves the way for detecting entanglement in many-body systems using scanning tunneling microscopy and angle-resolved photoemission spectroscopy, thus offering exciting prospects beyond the detection of entanglement via the dynamical spin response accessed in neutron scattering experiments.

10:30am **Workshop: Coffee Break - SCGP Cafe**

Title: Coffee Break

11:00am **Workshop: Andreas Ludwig - SCGP 102**

Speaker: Andreas Ludwig

Title: Universality Classes of Entanglement Transitions in Random Tensor Networks and Monitored Quantum Circuits

Abstract: TBA

12:00pm **Workshop: Lunch - SCGP Cafe**

Title: Lunch

2:30pm **Workshop: Wen Wei Ho - SCGP 102**

Speaker: Wen Wei Ho

Title: Completely ergodic quantum dynamics in quasiperiodically-driven systems

Abstract: Ergodicity in closed quantum systems is often defined through statistical properties of stationary states of the Hamiltonian, such as Berry's conjecture for single particle chaotic systems, and the eigenstate thermalization hypothesis (ETH) for many-body systems. However, not all quantum systems possess stationary states, such as in the case of Hamiltonians with general time-dependence. This begs the question whether a notion of quantum ergodicity can be suitably defined for such dynamics. In this talk, I propose a dynamical notion of quantum ergodicity without reference to energy eigenstates, in which any time-evolved state visits every point in Hilbert space uniformly over time. We call this complete Hilbert space ergodicity (CHSE). I will establish that there exists a family of simple, quasi-periodic driving protocols --- quantum drives generated by the Fibonacci word and its generalizations --- for which CHSE can be rigorously proven to occur. I will then describe general constraints arising from the number of fundamental frequencies of a quasi-periodic drive and the dimensionality of the system, in allowing for or obstructing the emergence of CHSE. Our results provide a basis toward understanding how thermalization arises in general time-dependent quantum many-body systems, and in fact implies a more stringent form of local equilibration that has been recently introduced, called deep thermalization.

3:30pm **Workshop: Tea - SCGP Cafe**

Title: Tea

4:00pm **Workshop: Žiga Krajnik - SCGP 102**

Speaker: Žiga Krajnik

Title: Dynamical universality of charged single-file systems and integrable spin chains

Abstract: We introduce and discuss dynamical universality of charge fluctuations in charged single-file systems. The full counting statistics of such systems out of equilibrium generically undergo first and second order dynamical phase transitions, while equilibrium typical fluctuations are non-Gaussian and given by a universal distribution. Similar phenomenology of dynamical criticality is observed in equilibrium in the easy axis and isotropic regimes of an integrable spin chain. While the easy axis regime does not satisfy a single-file kinetic constraint, it nevertheless supports the non-Gaussian distribution of the charged single-file universality class. Fluctuations at the isotropic point are also anomalous and distinct from those of the Kardar-Parisi-Zhang universality class.

Friday, September 1st

9:00am **Workshop: Breakfast - SCGP Cafe**

Title: Breakfast

9:30am **Workshop: Pasquale Calabrese - SCGP 102**

Speaker: Pasquale Calabrese

Title: The quantum Mpemba effect

Abstract: The Mpemba effect is the counterintuitive and controversial phenomenon that hot water cools faster than cold one. Here I will introduce an analogous effect recently proposed and observed in extended quantum systems in which a symmetry is explicitly broken by the initial state, but it is restored by the time evolution. To study this phenomenon we introduce a new quantity, dubbed entanglement asymmetry, which is a measure of symmetry breaking inspired by the theory of entanglement in many-body states.

10:30am **Workshop: Coffee Break - SCGP Cafe**

Title: Coffee Break

11:00am **Workshop: Karelian Schoutens - SCGP 102**

Speaker: Karelian Schoutens

Title: Integrable supersymmetric quantum circuits

Abstract: We study integrable brick-wall circuits, taking as our building brick a 2-qubit gate that derives from a factorizable S-matrix in integrable, supersymmetric qft in 1+1D. We study the resulting integrable Floquet dynamics in various regimes and track the implications of the supersymmetry. Generalising to the case where the scattering particles have unequal mass leads to a Hamiltonian limit displaying non-trivial topological phases.

12:00pm **Workshop: Lunch - SCGP Cafe**

Title: Lunch

1:15pm **Workshop: Michael Gullans - SCGP 102**

Speaker: Michael Gullans

Title: Crystalline Quantum Circuits

Abstract: Random quantum circuits continue to inspire a wide range of applications in quantum information science and many-body quantum physics, while remaining analytically tractable through probabilistic methods. Motivated by an interest in deterministic circuits with similar applications, we construct classes of nonrandom unitary Clifford circuits by imposing translation invariance in both time and space. We discuss examples in (1+1)-dimensions on the square and Kagome lattices using the formalism of Clifford quantum cellular automata before switching to expanding geometries defined on tree graphs. We focus on the properties of quantum error correcting codes generated by these circuits. We present a general strategy to achieve fault-tolerance for these dynamically generated codes by adding redundancy to the encoding evolution. We develop efficient decoding algorithms for tree circuits and find high fault-tolerance thresholds under circuit-level noise. Joint work with G. Sommers and D. A. Huse

2:30pm **Workshop: Shivaji Sondhi - SCGP 102**

Speaker: Shivaji Sondhi

Title: Classical non-relativistic fractons

Abstract: I will discuss some results on the classical mechanics of non-relativistic fractons in its simplest setting - that of identical one dimensional particles with local Hamiltonians characterized by by a conserved dipole moment in addition to the usual symmetries of space and time translation invariance. Locality leads to a "Machian" dynamics in which a given particle exhibits finite inertia only if within a specified distance of at least another one. For well separated particles this leads to immobility, much as for quantum models of fractons discussed before. For two or more particles within inertial reach of each other at the start of motion we get an interesting interplay of inertia and interactions. Interestingly, Machian clusters exhibit physical limit cycles in a Hamiltonian system even though mathematical limit cycles are forbidden by Liouville's theorem.

3:30pm **Workshop: Tea - SCGP Cafe**

Title: Tea