# DY 41: Quantum Dynamics, Decoherence, and Quantum Information (joint session DY/TT)

Time: Friday 9:30–11:15 Location: H37

DY 41.1 Fri 9:30 H37

**Entanglement phase transitions in unitary circuit games with free fermions** — •Raúl Morral-Yepes[1,2], Marc Langer[1,2], Adam Smith[3,4], Barbara Kraus[1,2], and Frank Pollmann[1,2] — [1]Technical University of Munich, TUM School of Natural Sciences — [2]Munich Center for Quantum Science and Technology (MCQST) — [3]School of Physics and Astronomy, University of Nottingham — [4]Centre for the Mathematics and Theoretical Physics of Quantum Non-Equilibrium Systems

In the recently introduced framework of unitary circuit games, two competing parties an entangler and a disentangler can induce an entanglement phase transition, distinct from measurement-induced transitions. In this work, we study such games within the context of matchgate dynamics, which correspond to free fermion systems. First, we investigate the entanglement properties of fermionic Gaussian states (FGS) and explore different methods for their disentangling. We propose a representation of FGS using a minimal matchgate circuit in a standard form, and introduce algorithms for updating this representation as unitary operations are applied. Within this framework, we define a natural disentangling procedure that reduces the number of gates in the circuit, thereby decreasing the system's entanglement. We then analyze the unitary game using this gate disentangler, observing a phase transition between a volume-law and area-law entanglement phase. The nature of this transition differs depending on whether we examine Rényi-0 or other entanglement entropies.

DY 41.2 Fri 9:45 H37

**Measurement Induced Entanglement Transitions in Random Qudit Clifford Circuits** — •Aamod Vinayak Atre, Raúl Morral Yepes, and Frank Pollmann — Department of Physics, Technical University of Munich

Random quantum circuits with local projective measurements uncover the universal dynamical properties of generic chaotic quantum many-body systems, as their unitary evolution is independent of the microscopic features of Hamiltonians. Entanglement measures characterize these universal dynamics into volume-law and area-law regimes, which exhibit bipartite entropy scaling proportional to the system volume and system boundary respectively. This continuous entanglement scaling transition, driven by the rate of measurement, has been extensively studied in spin-1/2 (qubit) systems of various spatial geometries. In this talk, we discuss the characterization the entanglement transitions in 1D random quantum circuits of spins (qudits) with arbitrary local Hilbert-space dimension $d$. This work employs the generalized stabilizer formalism, taking advantage of the Clifford group which forms a unitary 2-design on the space of unitaries. We find the nature of the entanglement transition, from volume-law to area-law regimes, to be preserved for $d > 2$. The critical measurement density increases, converging to 1/2 in the limit $d \to \infty$. Lastly, we describe the stabilizer dynamics in the limit $d \to \infty$, by a dynamical classical model.

DY 41.3 Fri 10:00 H37

**Entanglement phases, localization and ergodicity of monitored free fermions in 2D** — •Karim Chahine and Michael Buchhold — Institut für Theoretische Physik, Universität zu Köln, D-50937 Cologne, Germany

Monitored quantum systems, characterized by the interplay between unitary evolution and mid-circuit measurements, have recently emerged as a novel expression of quantum dynamics. Despite their inherently out-of-equilibrium nature, these systems can host robust quantum phases and display measurement-induced phase transitions (MIPT) in the entanglement entropy. Remarkably, they are also unique in providing a link between quantum dynamics in $D$ dimensions and quantum statistical mechanics in $D+1$ dimensions. In this talk, I will present our recent work on a new arena with a rich phenomenology: continuously monitored, $U(1)$-symmetric free fermions in 2D. I will address the emerging MIPT and its similarities and differences with Anderson-type localization transitions. Some emphasis will be put on the low-measurement regime, where intriguing features in the entanglement structure and ergodic properties emerge, revealing a richer phenomenology than previously anticipated.

DY 41.4 Fri 10:15 H37

**Spectral Properties and Magic generation of T-doped Random Clifford Circuits** — •Dominik Szombathy — Budapest University of Technology and Economics

We investigate the spectral properties and magic generation of T-doped random Clifford circuits. There is a direct relation between the structure of Pauli string orbits and the eigenvalue spectrum of a Clifford circuit. Operatively, we sample the closed trajectories with brick-wall circuits and determine the distribution of the eigenvalues $\lambda = e^{i\Theta}$. The autocorrelation function of the phases of the eigenvalues displays peculiar properties: extreme degeneracies as well as some level-repulsion, and features reminiscent of a fractal pattern.

To investigate the stability of orbits and head towards universal quantum computation, we introduce $\pi/4$ phase shift gates (T-gates). We find that even a single T-gate completely changes the properties of the circuit. By increasing the number of T-gates ($N_T$), the correlation function rapidly approaches that of the random unitary circuits. Nevertheless, some statistically significant fraction of non-trivial orbits persists at low T-gate densities ($N_T/N$).

We observe a similar phenomenology in the magic generation as a function of T-gate density. In particular, we find universal scaling of the maximum and mean magic as a function of $N_T/N$ . We also highlight the structure of magic generated by these circuits. Injecting a few T-gates the distribution is discrete but becomes continuous as $N_T$ increases. At large densities $N_T/N$ , most of the weight is found in a sharp peak well below the theoretical maximum.

DY 41.5 Fri 10:30 H37

**Magic transition in measurement-only circuits** — •Poetri Sonya Tarabunga[1,2] and Emanuele Tirrito[3,4] — [1]Technical University of Munich, Physics Department, 85748 Garching, Germany — [2]Munich Center for Quantum Science and Technology (MCQST), 80799 München, Germany — [3]The Abdus Salam International Centre for Theoretical Physics (ICTP), 34151 Trieste, Italy — [4]Dipartimento di Fisica "E. Pancini", Università di Napoli "Federico II", 80126 Napoli, Italy

Magic quantifies the distance of a quantum state to the set of stabilizer states, and it serves as a necessary resource for potential quantum advantage over classical computing. In this work, we study magic in a measurement-only quantum circuit with competing types of Clifford and non-Clifford measurements, where magic is injected through the non-Clifford measurements. This circuit can be mapped to a classical model that can be simulated efficiently, and the magic can be characterized using any magic measure that is additive for tensor product of single-qubit states. Leveraging this observation, we study the magic transition in this circuit in both one- and two-dimensional lattices using large-scale numerical simulations. Our results demonstrate the presence of a magic transition between two different phases with extensive magic scaling, separated by a critical point in which the mutual magic exhibits scaling behavior analogous to entanglement. We further show that these two distinct phases can be distinguished by the topological magic. In a different regime, with a vanishing rate of non-Clifford measurements, we find that the magic saturates in both phases.

DY 41.6 Fri 10:45 H37

**Developing a Framework for Predicting Useful Quantum Advantage in the Calculation of Molecular NMR Spectra** — •Keith Fratus, Andisheh Khedri, Juha Leppäkangas, Michael Marthaler, and Jan Reiner — HQS Quantum Simulations GmbH, Karlsruhe, Germany

Demonstrating useful quantum advantage remains a primary goal of quantum computing efforts in the NISQ era. Key to such efforts is the ability to estimate the accuracy and performance of competing classical approximation methods when exact comparisons are not available. In this talk we report on our efforts to develop and understand the behaviour of various classical approximation methods which aim to solve a specific class of chemical simulation problems. In particular, we develop classical simulation methods designed to predict molecular NMR spectra, with the aim of being able to quantify the accuracy and computational requirements of performing these simulations, even for parameter regimes which we do not directly simulate. Using such methods, we work towards a framework for predicting in which parameter regimes, system sizes, and target accuracies one can expect the

failure of classical methods for this class of systems, thus allowing for the possibility of quantum advantage.

DY 41.7 Fri 11:00 H37

**Linear differential equation approach to the Loschmidt amplitude** — •Michael Vogl — King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia

The Loschmidt amplitude is a popular quantity that allows making predictions about the stability of quantum states under time evolution. We present an approach that allows us to find a linear differential equation that can be used to compute the Loschmidt amplitude. This approach, while in essence perturbative, has the advantage that it converges at finite order. We demonstrate that the approach for generically chosen matrix Hamiltonians often offers advantages over Taylor and cumulant expansions even when we truncate at finite order. Even in low dimensional systems such as two band Hamiltonians (multi-Weyl semimetals and AB bilayer graphene) it can be used to obtain general formulas for the Loschmidt amplitude after a quench. Results readily generalize to find transmission amplitudes and specific contributions of the partition function, too. Our method can also be applied to many body spin and fermionic Hamiltonians. Here, while the approach still offers advantages, more care has to be taken than in a generic case. We also provide an estimate for a breakdown time of the approximation.