QI 28: Decoherence and Open Quantum Systems (joint session QI/Q)

Time: Thursday 11:00–12:45 Location: HS II

Invited Talk QI 28.1 Thu 11:00 HS II

Quantum-Classical Hybrid Theories - Feedback Control and Environment Purification — •Patrick P. Potts — University of Basel, Switzerland

Quantum-classical hybrid theories describe scenarios where quantum degrees of freedom interact with classical degrees of freedom. The need for such theories becomes particularly clear in feedback control, where classical measurement outcomes are fed back to a quantum system to influence its dynamics. Additionally, quantum-classical hybrid theories can be used to model a quantum system interacting with a large but finite-sized environment. In this case, the classical degree of freedom can be the magnetization of the environment.

I will present two examples of quantum-classical hybrid theories. The quantum Fokker-Planck master equation (QFPME) that describes continuous feedback control and the extended microcanonical master equation (EMME) that describes a qubit coupled to a bath of two-level systems. The QFPME allows for obtaining analytical results for feedback scenarios that previously were only accessible using numerical methods. The EMME allows for keeping track of the magnetization of the bath, as well as the classical correlations between system and bath. These methods will be illustrated with simple but relevant examples.

QI 28.2 Thu 11:30 HS II

Emergent decoherent histories from first principles — •Philipp Strasberg — Instituto de Física de Cantabria (IFCA), Santander, Spain

I overview recent progress about the emergence of decoherent histories from first principles, i.e., without the use of ensembles or approximations to the Schroedinger dynamics — akin to approaches in pure state statistical mechanics. After briefly reviewing the importance of decoherent histories to understand a unitarily evolving quantum Universe, I show that generic (non-integrable) many-body systems are characterized by an exponential suppression of interference effects (as a function of the particle number of the system) whereas integrable systems are characterized by a much weaker form of decoherence. I conclude with an outlook about how (long) (de/re)coherent histories shape the structure of the Multiverse, a hitherto unappreciated phenomenon.

QI 28.3 Thu 11:45 HS II

Quantum synchronization of twin limit-cycle oscillators — •Tobias Kehrer[1], Parvinder Solanki[2], and Christoph Bruder[1] — [1]Department of Physics, University of Basel, Klingelbergstrasse 82, CH-4056 Basel, Switzerland — [2]Institut für Theoretische Physik, Universität Tübingen, Auf der Morgenstelle 14, 72076 Tübingen, Germany

Limit cycles in classical systems are closed phase-space trajectories to which the system converges regardless of its initial state. Their quantum counterparts have been proposed for open quantum systems, exhibiting steady-state phase-space representations with ring-like structures of stable radius but no phase preference. The synchronization of such quantum systems has been studied extensively in the past decade, where an external drive can localize the phase of the steady state. Unlike in classical systems, quantum synchronization can exhibit coherence cancellations, leading to a synchronization blockade.

In this work, we propose a quantum system whose classical analogue features two limit cycles. In the classical analogue, the system can end up in either one of the limit cycles, defined by their basins of attraction and choice of initial states. In the quantum system, both limit cycles coexist independently of the initial state, i.e., the Wigner function of the steady state features two rings. Adding an external drive to a single oscillator, its limit cycles localize to distinct phases, exhibiting different synchronization behaviors within the same system. Furthermore, we demonstrate that coupling two such twin limit-cycle oscillators leads to simultaneous synchronization and synchronization blockades between different limit cycles of oscillator A and B.

QI 28.4 Thu 12:00 HS II

Exact Floquet Dynamics of Strongly Damped Open Quantum Systems — •Konrad Mickiewicz, Valentin Link, and Walter T. Strunz — Institut für Theoretische Physik, Technische Universität Dresden, D-01062, Dresden, Germany

Recent developments in simulating open quantum systems utilize Matrix Product Operator (MPO) representations to capture the temporal correlations of strongly coupled non-Markovian environments. A novel highly effective approach based on infinite MPO methods [1] yields a semigroup propagator for the open system evolution. We present how this semigroup structure can be exploited to efficiently describe periodically driven dynamics in the presence of strongly interacting environments. In particular, we are able to construct an exact Floquet propagator, enabling the direct extraction of asymptotic Floquet states without resorting to real-time evolution. We apply our results to the driven spin-boson and two-spin-boson models. In the latter, we show that the amount of entanglement generated between the qubits can be increased significantly via local driving of the system. [1] V. Link, H.-H. Tu, and W. T. Strunz, "Open quantum system dynamics from infinite tensor network contraction" Phys. Rev. Lett. 132, 200403 (2024)

QI 28.5 Thu 12:15 HS II

Open System Semigroup Dynamics beyond the Lindblad Class — •Nadine Diesel, Charlotte Bäcker, and Walter Strunz — TUD Dresden University of Technology, Dresden, Germany

Open quantum systems are of interest in many fields of study, e.g., quantum computation and quantum optics. A powerful tool in treating dissipation in open quantum system dynamics are quantum master equations. The Lindblad (GKSL) master equation is well-known for ensuring completely positive dynamical semigroup evolution, a natural framework for physical dynamics. However, is it possible to extend the class of semigroup generators beyond the Lindblad framework? We relax the strict requirement of complete positivity by introducing the concept of local (complete) positivity. Here, dynamics are defined as locally (completely) positive if a nonempty proper subset of initial states give rise to (completely) positive quantum dynamics. We analyze the existence of such dynamics for qubits and examine their potential physical implications.

QI 28.6 Thu 12:30 HS II

Entanglement phase transitions in boundary-driven open quantum systems — •Darvin Wanisch[1,2], Nora Reinić[1,2], Daniel Jaschke[1,2,3], Pietro Silvi[1,2], and Simone Montangero[1,2,3] — [1]Dipartimento di Fisica e Astronomia "G. Galilei", Università di Padova, I-35131 Padova, Italy — [2]Istituto Nazionale di Fisica Nucleare (INFN), Sezione di Padova, I-35131 Padova, Italy — [3]Institute for Complex Quantum Systems & Center for Integrated Quantum Science and Technology, Ulm University, 89069 Ulm, Germany

We present a numerical framework based on tree tensor networks that enables large-scale simulations of open quantum many-body systems and the efficient computation of entanglement monotones. We apply this framework to a paradigmatic open-system problem, the boundary-driven XXZ spin-chain. Our results demonstrate the framework's capability to probe entanglement in open systems and distinguish it from correlations with the environment. Furthermore, we find that the system undergoes entanglement phase transitions in both the coupling to the environment and the anisotropy parameter. Regarding the latter, our results connect the known transport regimes of the model to different entanglement phases, i.e., separable, area-law, and volume-law. Our work paves the way toward exploring entanglement in open systems, a necessary step for the development of scalable quantum technologies.