Q 47: Open Quantum Systems

Time: Thursday 11:00–13:00 Location: HS 3219

Q 47.1 Thu 11:00 HS 3219

Optimal Cooling in Markovian Quantum Systems — •Emanuel Malvetti — School of Natural Sciences, Technische Universität München, 85737 Garching, Germany — Munich Center for Quantum Science and Technology & Munich Quantum Valley, 80799 München, Germany

We address the task of cooling a Markovian quantum system to a pure state. Here the system drift takes the form of a Lindblad master equation and we assume fast control over the unitary group. This setting allows for a natural reduction of the control system to the eigenvalues of the state density matrix. We give a simple necessary and sufficient characterization of systems which are (asymptotically) coolable, and present explicit time-optimal cooling protocols for chosen low-dimensional systems. As an outlook we connect the task of cooling subsystems to embedding non-Markovian dynamics using a Markovian shell.

Q 47.2 Thu 11:15 HS 3219

Quantum speed limit for perturbed open systems — •Benjamin Yadin, Satoya Imai, and Otfried Gühne — Naturwissenschaftlich-Technische Fakultät, Universität Siegen, Walter-Flex-Straße 3, 57068 Siegen, Germany

Quantum speed limits provide upper bounds on the rate with which a quantum system can move away from its initial state. Here, we provide a different kind of speed limit, describing the divergence of a perturbed open system from its unperturbed trajectory. In the case of weak coupling, we show that the divergence speed is bounded by the quantum Fisher information under a perturbing Hamiltonian, up to an error which can be estimated from system and bath timescales. We give two applications of our speed limit. Firstly, it enables experimental estimation of quantum Fisher information in the presence of decoherence that is not fully characterised. Secondly, it implies that large quantum work fluctuations are necessary for a thermal system to be driven quickly out of equilibrium under a quench.

Q 47.3 Thu 11:30 HS 3219

Adiabatic quantum trajectories in engineered reservoirs — •Emma King[1], Luigi Giannelli[2,3,4], Raphaël Menu[1], Johannes Kriel[5], and Giovanna Morigi[1] — [1]Theoretische Physik, Universität des Saarlandes, D-66123 Saarbrücken, Germany — [2]Dipartimento di Fisica e Astronomia “Ettore Majorana”, Università di Catania, Via S. Sofia 64, 95123 Catania, Italy — [3]CNR-IMM, UoS Università, 95123 Catania, Italy — [4]INFN Sezione di Catania, 95123 Catania, Italy — [5]Institute of Theoretical Physics, Stellenbosch University, Stellenbosch 7600, South Africa

We analyze the efficiency of protocols for adiabatic quantum state transfer assisted by an engineered reservoir. The target dynamics is a quantum trajectory in the Hilbert space and is the fixed point of a time-dependent master equation. We specialize to quantum state transfer in a qubit and determine the optimal schedule for a class of time-dependent Lindblad equations. The speed limit on state transfer is extracted from a physical model of a qubit coupled to a reservoir, from which the Lindblad equation is derived in the Born-Markov limit. Our analysis shows that the resulting efficiency is comparable to the efficiency of the optimal unitary dynamics. Numerical studies indicate that reservoir-engineered protocols could outperform unitary protocols outside the regime of the Born-Markov master equation, namely, when correlations between the qubit and reservoir become relevant. Our study contributes to the theory of shortcuts to adiabaticity for open quantum systems and to the toolbox of protocols of the NISQ era.

Q 47.4 Thu 11:45 HS 3219

Stochastic unravelling of Lindblad equation for N coupled oscillators — Juan Moreno[1], •Abhijit Pendse[1], and Alexander Eisfeld[1,2] — [1]Max Planck Institut für Physik komplexer Systeme, Nöthnitzer Str. 38, 01187 Dresden, Germany — [2]Universität Potsdam, Institut für Physik und Astronomie, Karl-Liebknecht-Str. 24-25, 14476 Potsdam, Germany

The dynamics of a system of N coupled oscillators in presence of gain/loss can be understood by solving the Lindblad master equation numerically. However, the time propagation of the density matrix presents limitations in the computational memory since its size increases exponentially with the number of oscillators N. In this talk, we will present an alternative way to study the dynamics of this system using the quantum state diffusion formalism (QSD). In this formalism, the dynamics of the density matrix is given by a mean over an ensemble of trajectories that are obtained by propagating a stochastic QSD equation. This stochastic equation is written in terms of a non-Hermitian Hamiltonian, whose diagonalization leads to QSD equation that is only coupled via noise correlations. This allows one to do time propagation of N individual oscillators without dealing with the memory limitations that are present in the numerical solution of the Lindblad equation.

Q 47.5 Thu 12:00 HS 3219

Collision models from the perspective of fast scattering events — •Michael Gaida and Stefan Nimmrichter — Universität Siegen, Deutschland

A collision model is a blueprint for generic opensystems in which the environment is modeled as a sequence of ancillas unitarily interacting with the system. It can be viewed as a mathematical idealization of scattering processes in which kinetics are reduced to a mere swichting on and off of the interaction. Such models are capable of describing thermalization processes if one restricts to energy preserving interaction terms, but the link to dynamical scattering models with both internal and motional degrees of freedom remains to be explored. Recently this link has been investigated in a one-dimensional setting [1, 2]. Here we consider two and three-dimensional scenarios and study under which conditions they can be described by collision models, once the motional degrees of freedom are averaged out. Specifically, we focus on (non-relativistic) high energy scattering and the energy exchange between internal and kinetic energy. We identify the parameter regimes and interaction types that lead to Gibbsian or non-Gibbsian equilibrium state of the internal degrees of freedom.

[1] S. L. Jacob, M. Esposito, J. M. R. Parrondo, and F. Barra, Quantum scattering as a work source, Quantum 6, 750 (2022).

[2] S. L. Jacob, M. Esposito, J. M. Parrondo, and F. Barra, Thermalization induced by quantum scattering, PRX Quantum 2, 020312 (2021).

Q 47.6 Thu 12:15 HS 3219

Spin Coherence in Strongly-Coupled Spin Baths in Quasi Two-Dimensional Layers — Philip Schätzle[1,2] and •Walter Hahn[1] — [1]Fraunhofer Institute for Applied Solid State Physics IAF, Tullastr. 72, 79108 Freiburg, Germany — [2]Department of Sustainable Systems Engineering (INATECH), University of Freiburg, Emmy-Noether-Str. 2, 79110 Freiburg, Germany

We investigate the spin-coherence decay of NV^--spins interacting with the strongly-coupled disordered bath of the substitutional nitrogen defects in diamond layers. We show that the short-time decay follows a stretched-exponential function with a dimensionality-dependent stretched-exponential parameter that challenges analytical predictions. We find that this discrepancy is caused by the hyperfine interaction which strongly modifies the bath dynamics. We use a novel method based on the correlated-cluster expansion applied to partitions of the bath, which includes important high-order spin correlations. The results pave the way for enhanced materials for quantum-technology devices.

Q 47.7 Thu 12:30 HS 3219

Dissipative quantum phase transition in an interacting many-particle system: from two-level to multilevel spins — •Lukas Pausch, François Damanet, Thierry Bastin, and John Martin — Institut de Physique Nucléaire, Atomique et de Spectroscopie, Université de Liège, Belgium

The dissipative Lipkin-Meshkov-Glick model of N all-to-all interacting two-level systems subject to collective and/or individual decay is known to display a dissipative phase transition. There, the collective or individual nature of the dissipation defines the order of the phase transition and the characteristics of the different phases, while having no impact on the position of the critical point.

Here, we investigate a generalization of this model to d-level spins ($d \geq 2$). While basic features of the transition, such as the critical point, remain identical to the two-level case, the spin expectation values that characterize the different phases become ever more distinct from each other as d increases. Furthermore, depending on the exact form of the dissipator, the critical point transforms into a critical region that grows with d. Around the phase transition, the steady state of the system is entangled, and different choices of the dissipator may lead to a suppression or even an enhancement of entanglement by the individual dissipation.

Q 47.8 Thu 12:45 HS 3219

Exceptional points at x-ray wavelengths — •Fabian Richter and Adriana Pálffy — Julius-Maximilians-Universität Würzburg, Am Hubland, 97074 Würzburg, Germany

Non-Hermitian Hamiltonians allow for an effective description of dissipative systems. They exhibit a variety of exciting phenomena that cannot be observed in the Hermitian realm. Exceptional Points (EPs) are a prime example thereof. At EPs not only the complex eigenvalues, but also the eigenvectors coalesce and sensitivity to perturbations is enhanced. This concept has recently found fertile ground in optics and photonics where non-Hermitian eigenstates can be created and superposed through optical gain and loss [1]. So far, these concepts have been mostly discussed in the optical regime. Similar control of x-rays is desirable due to their superior penetration power, high focusability and detection efficiency.

Here, we investigate theoretically non-Hermitian x-ray photonics in a thin-film cavity setup containing Mössbauer nuclei resonant to the x-ray radiation entering under grazing incidence. These cavities present loss that can be controlled via adjustment of the cavity geometry and the x-ray incidence angle [2]. We show that external magnetic fields may be used to tune the system towards EPs and explore the rich topological properties of the x-ray thin-film nanostructures.

[1] L. Feng *et al.*, Nature Photon. **11**, 752-762 (2017).

[2] X. Kong, D. Chang, A. Pálffy , Phys. Rev. A **102**, 033710 (2020).