Q 33: Open Quantum Systems

Time: Wednesday 14:30–16:30 Location: HS 1199

Q 33.1 Wed 14:30 HS 1199

Multimode-cavity picture of non-Markovian waveguide QED — Luca Ferialdi[1], •Dario Cilluffo[2], G. Massimo Palma[1,3], Giuseppe Calajò[4], and Francesco Ciccarello[1,3] — [1]Università degli Studi di Palermo, Dipartimento di Fisica e Chimica Emilio Segrè, via Archirafi 36, I-90123 Palermo, Italy — [2]Institut für Theoretische Physik and IQST, Albert-Einstein-Allee 11, Universität Ulm, 89069 Ulm, Germany — [3]NEST, Istituto Nanoscienze-CNR, Piazza S. Silvestro 12, 56127 Pisa, Italy — [4]Istituto Nazionale di Fisica Nucleare (INFN), Sezione di Padova, I-35131 Padova, Italy

We introduce a picture to describe and intrepret waveguide-QED problems in the non-Markovian regime of long photonic retardation times (resulting in delayed coherent feedback). The framework is based on an intuitive spatial decomposition of the waveguide into blocks. Among these, the block directly coupled to the atoms embodies an effective lossy multimode cavity leaking into the rest of the waveguide (in turn embodying an effective white-noise bath). The dynamics can be approximated by retaining only a finite number of cavity modes that yet eventually grows with the time delay. The picture allows to explicitly connect emission properties subject to feedback to the standard Purcell effect in a cavity, both in the usual bad-cavity limit and beyond, thus providing an explicit link between waveguide QED and cavity QED.

Q 33.2 Wed 14:45 HS 1199

Landau-Zener dynamics in the presence of a non-Markovian reservoir — •Raphaël Menu and Giovanna Morigi — Universität des Saarlandes, Saarbrücken, Germany

We analyse the Landau-Zener dynamics of a qubit, which is simultaneously coupled to a dissipative auxiliary system. By tuning the coupling, the qubit dynamics ranges from a dephasing master equation to a strongly coupled qubit-auxiliary system, which is effectively a non-Markovian reservoir for the qubit. We determine the quantum trajectories in the different regimes . For each regime we analyse the distribution of each trajectory in terms of the time-dependent probability of a diabatic transitio. Depending on the strength of the coupling, we observe multipeaked configurations, which undergo transitions to narrow distributions. These transitions are signalled by a higher probability that a jump occurs. The behavior of the probability of a quantum jump as a function of the coupling and of the time of the sweep, in turn, allows us to shed light on the stages of the dynamics when the environment is detrimental and when instead it corrects diabatic transition. It shows, in particular, that memory effects can be beneficial. It further sheds light on the role of pausing in annealing and when it is advantageous.

Q 33.3 Wed 15:00 HS 1199

Dynamically Emergent Quantum Thermodynamics: The Non-Markovian Otto Cycle — •Irene Ada Picatoste[1], Alessandra Colla[1], and Heinz-Peter Breuer[1,2] — [1]Physikalisches Institut, Universität Freiburg, Hermann-Herder-Straße 3, D-79104 Freiburg, Germany — [2]EUCOR Centre for Quantum Science and Quantum Computing, University of Freiburg, Hermann-Herder-Straße 3, D-79104 Freiburg, Germany

Using an open-system approach to quantum thermodynamics at arbitrary coupling [1] we study the Otto cycle in the strong-coupling and non-Markovian regimes [2]. Our investigation is based on the exact treatment of the dynamics of the system when coupled to a thermal reservoir, which we describe employing the Fano-Anderson model. We study the effects of strong coupling and a structured environment, and find that a non-Markovian bath can exchange both heat and work with the system. We identify a regime of enhanced efficiency occurring when the peak of the spectral density is located within the frequency range of the cycle, and explain this through an analysis of the renormalized frequencies emerging from the system-bath interaction.

[1] A. Colla and H.-P. Breuer, Open-system approach to nonequilibrium quantum thermodynamics at arbitrary coupling, May 2022, 10.1103/PhysRevA.105.052216.

[2] I. A. Picatoste, A. Colla and H.-P. Breuer, Dynamically Emergent Quantum Thermodynamics: Non-Markovian Otto Cycle, Aug 2022, axXiv: 2308.09462 [quant-ph].

Q 33.4 Wed 15:15 HS 1199

Thermodynamic behaviour of giant artificial atoms with non-Markovian thermalization — •Mei Yu, H. Chau Nguyen, and Stefan Nimmrichter — University of Siegen, Siegen, Germany

Superconducting qubits, when coupled to either a meandering transmission line or to surface acoustic waves, enable the creation of giant artificial atoms. These artificial atoms, if connected to a waveguide through multiple separated contacts, can be made to interact with a travelling bosonic field at multiple points in time. This results in a tailored memory effect and non-Markovian dynamics that has been demonstrated experimentally [1]. We investigate scenarios in which one or more giant atoms couple to thermally excited waveguide radiation via multiple contacts, leading to non-Markovian equilibration processes. We then apply such setups in case studies of non-Markovian heat transport and refrigeration between independent thermal reservoirs

[1] G. Andersson, B. Suri, L. Guo, T. Aref, and P. Delsing, Non-exponential decay of a giant artificial atom, Nature Physics 15, 1123 (2019).

Q 33.5 Wed 15:30 HS 1199

Thermodynamic role of general environments: from heat bath to work reservoir — •Alessandra Colla and Heinz-Peter Breuer — Institute of Physics, University of Freiburg, Hermann-Herder-Straße 3, D-79104 Freiburg, Germany

Environments in quantum thermodynamics usually take the role of heat baths. These baths are Markovian, weakly coupled to the system, and initialized in a thermal state. Whenever one of these properties is missing, standard quantum thermodynamics is no longer suitable to treat the thermodynamic properties of the system that result from the interaction with the environment. Using a recently proposed framework for open system quantum thermodynamics at arbitrary coupling regimes [1], we show that within the very same model (a Fano-Anderson Hamiltonian) the environment can take three different thermodynamic roles: a standard heat bath, exchanging only heat with the system, a work reservoir, exchanging only work, and a hybrid environment, providing both types of energy exchange. The exact role of the environment is determined by the strength and structure of the coupling, and by its initial state.

[1] A. Colla, H.-P. Breuer, Physical Review A 105, 052216 (2022)

Q 33.6 Wed 15:45 HS 1199

non-Markovian processes might behave like Markov processes — •bilal cantürk and heinz-peter breuer — Institute of Physics, University of Freiburg, Hermann-Herder-Straße 3, D-79104 Freiburg, Germany

The Chapman-Kolmogorov equation is generally considered to be the main characteristic of Markov processes. However, we have shown by construction that there are also non-Markovian processes that satisfy the Chapman-Kolmogorov equation. This evidence allows us to further clarify the distinction between Markov and non-Markovian processes in both classical and quantum systems. In addition, our results allow us to construct some specific non-Markovian processes, called P-divisible processes.

Q 33.7 Wed 16:00 HS 1199

Characterizing the time dependence of quantum gates — Alessio Belenchia[1], Daniel Braun[1], Giovanni Gramegna[2], and •Stanislaw Soltan[1] — [1]Eberhard Karls Universität Tübingen, Tübingen, Deutschland — [2]Università degli Studi di Bari Aldo Moro, Bari, Italien

Current state-of-the-art quantum computers exhibit some non-markovian memory effects that make the actual quantum gates deviate from the ideal case. Characterization of such errors is an ongoing challenge. Successfully addressing this challenge could enable the correction of errors or, alternatively, harness these effects to enhance the control of qubits' states and for dissipative-based computation. We analyze the possible generalization of long sequence gate set tomography that takes into account the possible time dependence of quantum gates. A form of time dependence must be assumed and we derived it from the post-markovian master equation. The time dependence of the gates is taken to be explicit in the case of the simplest models of the memory effects. For more complex ones, it is reformulated as the time-independent interaction between the system of interest and auxiliary virtual qubits.

Q 33.8 Wed 16:15 HS 1199

Stochastic unraveling of pseudo-Lindblad equations —
•Tobias Becker and André Eckardt — Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstrasse 36, 10623 Berlin, Germany

For the efficient simulation of open quantum systems we often use quantum jump trajectories given by pure states that evolve stochastically to unravel the dynamics of the underlying master equation. In the Markovian regime, when the dynamics is described by a Gorini-Kossakowski-Sudarshan-Lindblad (GKSL) master equation, this procedure is known as Monte Carlo wave function (MCWF) approach. However, beyond ultraweak system-bath coupling, the dynamics of the system is not described by an equation of GKSL type, but rather by the Redfield equation, which can be brought into pseudo-Lindblad form. Here negative dissipation strengths prohibit the conventional approach. To overcome this problem, we propose a pseudo-Lindblad quantum trajectory (PLQT) unraveling. It does not require an effective extension of the state space, like other approaches, except for the addition of a single classical bit.