FM 13: Open and Complex Quantum Systems I

Time: Monday 14:00–16:00 Location: 3042

Invited Talk FM 13.1 Mon 14:00 3042

Quantum Information Concepts in Open Systems — •Bassano Vacchini — Dipartimento di Fisica Aldo Pontremoli, Università degli Studi di Milano, Via Celoria 16, I-20133 Milan, Italy — INFN, Sezione di Milano, Via Celoria 16, I-20133 Milan, Italy

The talk is aimed at providing an introduction to the foundations of open system theory in the light of quantum information concepts. We will briefly introduce the basic assumptions and general concepts of the theory, such as complete positivity and quantum dynamical map, relevant to the description of dissipation and decoherence effects in quantum mechanics. We will consider some of the main methods for the treatment of open system dynamics, pointing to the relevance of correlations such as entanglement and discord. We will further mention recent developments for the definition and treatment of non-Markovian dynamics as well as quantum thermodynamical systems, where quantum information notions appear to play an important role. Relevant open questions and possibly promising future research directions will be finally mentioned.

FM 13.2 Mon 14:30 3042

Reachability in Infinite Dimensional Unital Open Quantum Systems with Switchable GKS-Lindblad Generators — •Frederik vom Ende[1], Gunther Dirr[2], Michael Keyl[3], and Thomas Schulte-Herbrüggen[1] — [1]TU Munich, 85748 Garching, Germany — [2]University of Würzburg, 97074 Würzburg, Germany — [3]Freie Universität Berlin, 14195 Berlin, Germany

In quantum systems theory one of the fundamental problems boils down to: given an initial state, which final states can be reached by the dynamic system in question. Here we consider infinite dimensional open quantum dynamical systems following a unital Kossakowski-Lindblad master equation extended by controls. More precisely, their time evolution shall be governed by an inevitable (potentially unbounded) Hamiltonian drift term, finitely many bounded control Hamiltonians allowing for (at least) piecewise constant control amplitudes plus a bang-bang switchable noise term in Kossakowski-Lindblad form (generated by some compact Lindblad-V). Generalizing standard majorization results from finite to infinite dimensions, we show that such bilinear quantum control systems allow to approximately reach any target state majorized by the initial one as up to now only has been known in finite dimensional analogues.

FM 13.3 Mon 14:45 3042

Quantum information and open-system dynamics: Complete positivity, divisibility and time-dependent transport — •Maarten Wegewijs[1,2], Viktor Reimer[2], Konstantin Nestmann[2], and Mikhail Pletyukhov[2] — [1]Peter Grünberg Institute, Forschungszentrum Jülich, Germany — [2]Institute for Theory of Statistical Physics, RWTH Aachen University, Germany

Time-evolution in quantum information theory hinges on complete-positivity (CP) which is equivalent to the Kraus form of the dynamical map and closely tied to entanglement. To exploit this in the study of the dynamics of open systems – beyond the framework of Lindblad equations – it is advantageous to strike a bridge to methods of statistical physics based on quantum master equations. In this talk, I will explain how this can be done on a very general level using standard real-time techniques, expressing Kraus operators in Keldysh diagrams. I will illustrate how the Kraus operators provide new insights into the dynamics, in particular, into the dynamics of *the environment* as it is affected by the system. Even for a system as simple as a resonant level this provides some surprising insights and allows the *continuous* fermionic bath into which the fermion decays to be effectively reduced to just two fermions. I furthermore show that different notions of Markovianity (semigroup- and CP-divisibility) correspond to clearly measurable features in the time-dependent transport current.

V. Reimer, M. Wegewijs, et al, arXiv: 1903.04195

V. Reimer, M. Wegewijs, K. Nestmann, M. Pletyukhov, arXiv:1808.09395.

FM 13.4 Mon 15:00 3042

Measurement of quantum memory effects in a trapped-ion system — •Matthias Wittemer, Govinda Clos, Ulrich Warring, Heinz-Peter Breuer, and Tobias Schaetz — University of Freiburg, Freiburg im Breisgau, Germany

Any realistic quantum system interacts with its environment. Thereby, the *open* system builds up entanglement and correlations with the environment and exchanges information. Trapped ions offer a high level of control of internal (electronic) and external (motional) degrees of freedom and are well-suited to engineer closed and open quantum systems. This allows for systematic studies of entanglement, decoherence, and thermalization in quantum systems of variable complexity [1]. With our trapped-ion system we experimentally study the flow of information in a closed quantum system between an open subsystem and its environment and measure associated quantum memory effects [2]. Thereby, we reveal that the nature of projective measurements in quantum mechanics can lead to a nontrivial bias in a measure for the degree of quantum non-Markovian behavior [3]. We prepare the environment in different quantum states and realize different interactions between system and environment to characterize the non-Markovianity and its bias as a function of these parameters, illustrating the fundamental implications of our findings for future applications.

[1] G. Clos *et al.*, Phys. Rev. Lett. **117**, 170401 (2016)
[2] M. Wittemer *et al.*, Phys. Rev. A **97**, 020102(R) (2018)
[3] H.-P. Breuer *et al.*, Phys. Rev. Lett. **103**, 210401 (2009)

FM 13.5 Mon 15:15 3042

Quantum transport between finite reservoirs — •Giulio Amato[1,2,3], Heinz-Peter Breuer[1], Sandro Wimberger[2,3], Alberto Rodriguez[1], and Andreas Buchleitner[1] — [1]Albert-Ludwigs-Universität Freiburg — [2]Universita' degli Studi di Parma — [3]Istituto Nazionale di Fisica Nucleare

We study non-interacting many-particle quantum transport across an open quantum system connecting two finite reservoirs which are initially prepared with a finite particle number imbalance. Equilibration of the reservoirs leads to a non-stationary current which vanishes once a balanced particle distribution is reached. This behaviour has been qualitatively observed in quantum transport experiments with ultracold fermionic atoms, with tunable interparticle interactions [1]. We present a theoretical model based on a set of coupled quantum-classical master equations, describing the evolution of the system together with the temporal variation of the particle number in the reservoirs. We apply this formalism to investigate nonstationary currents across a one dimensional (Bose-)Hubbard lattice. Furthermore, characteristic differences between the fermionic and bosonic dynamics will be highlighted.

[1] S. Krinner, T. Esslinger and J.-P. Brantut, J. Phys.: Condens. Matter 29, 343003 (2017)

FM 13.6 Mon 15:30 3042

Revealing hidden information by counting — •Björn Kubala[1], Andrew D. Armour[2], and Joachim Ankerhold[1] — [1]Institute for Complex Quantum Systems and IQST, Ulm University, Albert Einstein-Allee 11, 89069 Ulm, Germany — [2]School of Physics and Astronomy and Centre for the Mathematics and Theoretical Physics of Quantum Non-Equilibrium Systems, University of Nottingham, Nottingham NG7 2RD, UK

The full counting statistic of emitted photons and the investigation of large deviations of the emission power are known to provide useful insights into the dynamics of driven, dissipative quantum-optical systems. In particular, the 'rare' dynamics can reveal information about the system's behavior for a wide region of the parameter space; beyond the actual physically-realized driving and damping parameters.

Here, we employ these tools for a theoretical exploration of a Josephson-photonics device, where Cooper pairs tunneling across a voltage biased Josephson junction create photonic excitations in a microwave resonator, which is connected in series to the junction. By biasing at the corresponding excitation energy, such devices can realize a nonlinearly driven oscillator or (a nonlinear versions of) a parametric oscillator and have been shown to exhibit interesting dynamical critical points. When the state of the cavity is conditioned on measurements of the number of photons emitted one can reveal fragile features, such as cat states, which are lost within the usual unconditioned dynamics.

FM 13.7 Mon 15:45 3042

Quantum information scrambling in open systems — •Jan

Tuziemski — Stockholm University, Stockholm, Sweden

Recent theoretical and experimental studies have shown significance of quantum information scrambling for problems encountered in quantum information, high-energy physics, and condensed matter. Due to complexity of quantum many-body systems it is plausible that new developments in this field will be achieved by experimental explorations. Since noise effects are inevitably present in experimental implementations, there is a need for a better theoretical understanding of quantum information scrambling in systems affected by noise. In this talk we study indicators of quantum scrambling - out-of-time-ordered correlation functions (OTOCs) in open quantum systems. As most experimental protocols for measuring OTOCs are based on backward time evolution we consider two possible scenarios of joint system-environment dynamics reversal: In the first one the evolution of the environment is reversed, whereas in the second it is not. We derive general formulas for OTOCs in those cases as well as study in detail the model of a spin chain coupled to the environment of harmonic oscillators. In the latter case we derive expressions for open systems OTOCs in terms of Feynman-Vernon influence functional. Subsequently, assuming that dephasing dominates over dissipation, we provide bounds on open system OTOCs and illustrate them for a spectral density known from the spin-boson problem. Our results also advance understating of decoherence in processes involving backward time evolution. Based on arXiv:1903.05025