# QI 9: Decoherence and Open Systems I

Time: Tuesday 14:00–15:30 Location: BEY/0245

QI 9.1 Tue 14:00 BEY/0245

**Asymptotic Exceptional Steady States in Dissipative Dynamics** — •Yu-Min Hu[1] and Jan Carl Budich[1,2] — [1]Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Str. 38, 01187 Dresden, Germany — [2]Institute of Theoretical Physics, Technische Universität Dresden and Würzburg-Dresden Cluster of Excellence ct.qmat, 01062 Dresden, Germany

Spectral degeneracies in Liouvillian generators of dissipative dynamics generically occur as exceptional points, where the corresponding non-Hermitian operator becomes non-diagonalizable. Steady states, i.e., zero-modes of Liouvillians, are considered a fundamental exception to this rule since a no-go theorem excludes non-diagonalizable degeneracies there. Here, we demonstrate that the crucial issue of diverging timescales in dissipative state preparation is largely tantamount to an asymptotic approach towards the forbidden scenario of an exceptional steady state in the thermodynamic limit. With case studies ranging from NP-complete satisfiability problems encoded in a quantum master equation to the dissipative preparation of a symmetry-protected topological phase, we reveal the close relation between the computational complexity of the problem at hand and the finite-size scaling towards the exceptional steady state, exemplifying both exponential and polynomial scaling. Formally treating the weight W of quantum jumps in the Lindblad master equation as a parameter, we show that exceptional steady states at the physical value W=1 may be understood as a critical point hallmarking the onset of dynamical instability.

QI 9.2 Tue 14:15 BEY/0245

**Dissipation as a resource: non-Markovian pathways to autonomous steady-state entanglement in photonic platforms** — •Karol Kawa[1], Katarzyna Roszak[1], Radim Filip[2], and Tomáš Novotný[3] — [1]FZU – Institute of Physics of the Czech Academy of Sciences, Prague, Czech Republic — [2]Palacký University Olomouc, Olomouc, Czech Republic — [3]Charles University, Prague, Czech Republic

Decoherence is usually cast as the nemesis of entanglement in open quantum systems. Here we overturn that narrative and show that environmental engineering can, by itself, generate and stabilize entanglement. We analyze two bosonic modes, each coupled to an independent, uncorrelated thermal bath, and explore two complementary routes toward autonomous entanglement: (i) direct mode*mode coupling and˜(ii) dissipation-induced single-mode squeezing followed by passive linear optics. Going beyond previous Markov-limit studies that dismissed the possibility of steady-state entanglement by neglecting anomalous coupling terms, we perform a full non-equilibrium treatment that embraces non-Markovian noise and counter-rotating interactions. Logarithmic negativity reveals a robust, sizable entanglement in both scenarios. Our results depict an experimentally realistic blueprint compatible with contemporary photonic circuitry to transform unavoidable dissipation into a functional resource. By revealing how tailored system-bath couplings autonomously drive quantum correlations, this work enriches the toolbox of reservoir engineering and advances the quest for scalable, self-contained quantum technologies.

QI 9.3 Tue 14:30 BEY/0245

**Emergent decoherent histories from first principles** — •Philipp Strasberg — Instituto de Fisica 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 9.4 Tue 14:45 BEY/0245

**Random matrix perspective on probabilistic error cancellation** — •Leonhard Moske[1], David Luitz[1], Pedro Ribeiro[2], Tomaž Prosen[3], Sergiy Denysov[4], and Karol Zyczkowski[5,6] — [1]Institute of Physics, University of Bonn, Germany — [2]CeFEMA-LaPMET, Departamento de Fisica, Instituto Superior Tecnico, Universidade de Lisboa, Portugal — [3]Faculty of Mathematics and Physics, University of Ljubljana, Slovenia — [4]Department of Computer Science, OsloMet, Oslo Metropolitan University, Norway — [5]Faculty of Physics, Astronomy and Applied Computer Science, Jagiellonian University, Poland — [6]Center for Theoretical Physics, Polish Academy of Sciences, Poland

Probabilistic error cancellation is an attempt to reverse the effect of dissipative noise channels on quantum computers by applying unphysical channels after the execution of a quantum algorithm on noisy hardware. We investigate on general grounds the properties of such unphysical quantum channels by considering a random matrix ensemble modeling noisy quantum algorithms. We show that the complex spectra of denoiser channels inherit their structure from random Lindbladians. Additional structure imposed by the locality of noise channels of the quantum computer emerges in terms of a hierarchy of timescales.

QI 9.5 Tue 15:00 BEY/0245

**Quantum Memory in Strongly Coupled Systems via Time-Evolving Matrix Product Operators** — •Ilja List, Konrad Mickiewicz, Matteo Garbellini, Charlotte Bäcker, and Walter Strunz — Dresden University of Technology, Dresden, Germany

The steady exchange of information and energy between system and environment in open quantum systems introduces noise and dissipation into the dynamics. In the interest of modelling realistic quantum systems, it is crucial to investigate systems strongly coupled to the environment. In such non-Markovian quantum dynamics, the origin of memory effects requires a strict classification as classical or quantum. Using the paradigmatic spin-boson model, we examine numerically the behavior of open quantum systems via local quantum memory criteria based on process tensors [1]. To this end, we use the recently introduced method uniTEMPO [2] to construct the process tensors. We focus on the long-range multi-time correlations of non-Markovian open quantum systems for increasing coupling strength, and investigate the detection of quantum memory near the quantum phase transition.

[1] C. Bäcker, V. Link, and W. T. Strunz. Phys. Rev. Res. 5bfc-znkj (2025)
[2] V. Link, H.-H. Tu, and W. T. Strunz, Phys. Rev. Lett. 132, 200403 (2024)

QI 9.6 Tue 15:15 BEY/0245

**Signatures of correlated noise in cavity QED** — •Nadine Lenke and Guido Burkard — Department of Physics, University of Konstanu, 78457 Konstanz, Germany

Noise effects limit the performance of quantum computation drastically. While the effects of noise are examined in various publications a detailed theoretical description of the influence of noise correlations is missing. In this work we examine the effects of noise correlations in cavity QED. Our underlying system consists of two qubits, which are coupled to the same cavity but not directly to each other. Both qubits are affected by longitudinal noise impacting their energy separation. The effects from noise correlations are indirectly examined with the transmission through the cavity. We compare the influences of white noise and quasi-static noise in the transient regime by applying input-output theory. We find that after averaging over many measurements, the noise correlation spectral density $S_{12}(\omega)$ can be extracted from the cavity transmission amplitude $A$. We compare its dependence on $S_{12}(\omega)$ for the two noise models. We conclude that in both cases a higher noise correlation spectral density leads to a decreasing $A$. In the quasi-static noise case the reduction of the cavity transmission amplitude is weaker. We find that in special parameter settings and for certain initial conditions it is possible to extract the noise correlation spectral density for general types of noise from the second derivative of $A$ with respect to the sensitivities to the noise on the two qubits. The recreation of $S_{12}(\omega)$ can be achieved by writing this quantity as a sum of convolutions and by applying the convolution theorem.