Dissipative Quantum Systems

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Our research efforts are focused on advancing methods to treat open quantum systems; such quantum systems couple to many "environmental" degrees of freedom. Instead of describing their dynamics with the *unitary* Schrodinger equation, the dynamics of open systems is often described by non-unitary *dissipative* quantum master equations, which are differential equations for the density operator. We apply our methods to study dissipative quantum materials, quantum energy conversion devices, quantum sensing and computing. We have been collaborating with experimentalists realizing quantum dissipative systems in e.g., NV centres and superconducting qubits. I am looking for *one* student to work on *one* of the projects described below, or other projects in my group (please check my recent publications).

Project #1 Dissipative Landau-Zener tunneling: from weak to strong environment coupling

Description: The Landau Zener tunneling in a driven two-level system provides insights into the performance of a quantum annealer, one of the paradigms for quantum computing (used for example by the D-Wave company). From both the fundamental side and for applications, we are interested in developing theoretical-computational methods to simulate such driven-dissipative dynamics.

Objectives: To simulate the dynamics of the *dissipative* LZ model from weak to strong coupling to the environment, and compare to experimental results [1]. Towards this goal, we will use quantum master equations that are valid at weak coupling and in the adiabatic limit, as well as extend our recent work [2]. The student will learn the theory of open quantum systems and will use or implement methods to study driven-dissipative dynamics. As they progress, they will interact with the experimental group of Prof. Lupascu at UW [1].

Project #2 Dissipative dynamics in interacting spin baths

Description: Standard modeling of a dissipative environment is that of harmonic oscillators, corresponding to, e.g., phonons or radiation modes. Spin baths however are common in nature, and furthermore are more natural to implement on quantum computers. Our calculations indicate that spin baths lead to dynamics that is very distinctive from the harmonic bath model.

Objectives: To study quantum dissipative dynamics within various spin baths: non interacting and interacting, at low and high temperatures; to possibly extend studies to out-of-equilibrium scenarios and study quantum heat transport between interacting baths. As for methodology, the student may use in-house codes, implement the repeated interaction model (for noninteracting baths) [3] or adopt/extend quantum master equations [2].

Requirements

Students *do not need* to come with prior knowledge of the field. I am looking for curious students who are motivated to get involved in projects combining theory and numerical simulations. Students will be directed by the PI (Segal) and by graduate students in the group. They will learn and use in-house codes as well as write their own codes as they progress.

[1] X. Dai, et al., Dissipative Landau-Zener tunneling: crossover from weak to strong environment coupling, arXiv:2207.02017.

[2] N. Anto-Sztrikacs, A. Nazir, and D. Segal, Effective Hamiltonian theory of open quantum systems at strong coupling, PRX Quantum 4, 020307 (2023)

[3] F. Ciccarello, S. Lorenzo, V. Giovannetti, and G. M. Palma, Quantum collision models: Open system dynamics from repeated interactions, Physics Reports, 954, 1 (2022).