Open Quantum Systems: Classical and quantum algorithms

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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 [1]. We apply our methods to study dissipative quantum materials, quantum energy conversion devices, quantum sensing and computing. We have been collaborating with our theoreticians and with experimentalists realizing quantum dissipative systems in e.g., Nitrogen Vacancy (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 group's recent publications).

Project #1 Driven-Dissipative dynamics

Description: A driven two-level (qubit) 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). Motivated by both fundamental questions and applications, we are interested in developing theoretical-computational methods to simulate driven-dissipative dynamics.

Objectives: To simulate the dynamics of the *dissipative Landau Zener model* and compare to experimental results [2]. Towards this goal, we will begin with quantum master equations that are valid at weak coupling to the environment, but beyond the adiabatic limit. The student will learn the theory of open quantum systems and will use or implement methods to study driven-dissipative dynamics.

Project #2 Open quantum systems: Quantum algorithms and energy cost assessment

Description: The repeated interactions (RI) model [3] is a class of microscopic system-bath models that mimics open quantum systems dynamics. Quantum algorithms can implement the repeated interaction model [4] to study quantum thermalization, dynamics, and quantum energy transfer.

Objectives: Develop and assess a quantum algorithm for open quantum system dynamics. We will study analytically and numerically quantum thermalization via the RI model, estimate the associated energetic cost, and aim to implement the algorithm on a quantum hardware.

Requirements

Students do not need to come with a prior knowledge in the research field. I am looking for curious and motivated students who enjoy challenges (and to challenge me) and are interested to get involved in projects combining theory and computer simulations. Students will be directed by the PI (Segal) and by graduate students. They will learn in-house codes and write their own programs.

Final note: We have a good coffee.

[1] The theory of open quantum systems. H.P. Breuer, F. Petruccione 2002.

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

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

[4] M. Pocrnic, D. Segal, N. Wiebe, Quantum Simulation of Lindbladian Dynamics via Repeated Interactions, arXiv:2312.05371