Open quantum systems with spin baths: 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 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 [1]. Spin baths however are common in nature, and furthermore are more natural to implement on quantum computers.

Objectives: To study quantum dynamics within various spin baths in relation to experiments in NV centres [2]. We will consider non interacting and interacting models at low and high temperatures. The student will use in-house codes and adopt/extend quantum master equations.

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 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 are interested to get involved in projects combining theory and simulations. Students will be directed by the PI (Segal) and by graduate students. They will learn in-house codes and write their own codes as they progress. Final note: We have good coffee.

[1] The theory of open quantum systems. H.P. Breuer, F. Petruccione 2002.
[2] S. Pezzagna, J. Meijer, Quantum computer based on color centers in diamond Special Collection: Quantum Computing Appl. Phys. Rev. 8, 011308 (2021).
[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