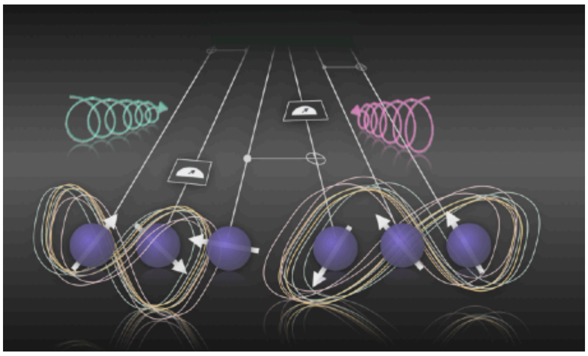
CentraleSupélec

Internship proposal

Steering quantum states through measurements

Context: The advantage of quantum processors draws from the complexity of highly entangled quantum states which make them hard to simulate on classical computers. However, one of the key barriers in the way of viable quantum processors is decoherence which occurs because real quantum systems are rarely fully isolated, and are in a sense continuously monitored by degrees of freedom beyond our control. Surprisingly, recent findings show that quantum states can remain highly entangled, as long as the measurements occur below a certain rate [1-4]. Entanglement can even be enhanced by simultaneously measuring physical operators that do not commute [5,6]. This procedure can also be used to dynamically tailor complex quantum states which can be potentially useful for quantum error correction.



A random quantum circuit consisting of entangled qubits that undergo unitary gate operations and quantum measurements while interacting with a noisy environment.

One of the main challenges in this field is the experimental observation of these measurement-induced phase transitions. Because quantum measurements are inherently random, they rapidly drive the system's density matrix toward a maximally mixed state. As a result, average expectation values of physical observables fail to reveal the transition, which instead requires to track quantum information quantities such as entanglement entropy. This makes experimental detection particularly difficult. In contrast, following a single, post-selected measurement trajectory—where outcomes are fixed—leads to fundamentally different physics. In a recent study, we bridge this gap by examining measurement processes in which only selected subsets of trajectories are retained [7]. Our findings suggest that the complex ensemble behavior of the full system may be reflected in the more experimentally accessible average properties of these subsets.

Objective: The objective of this research project is to study the interplay between partial post selection schemes and conditional feedback. To demonstrate these ideas we will consider the case of non-interacting electrons undergoing entangling unitary evolution disrupted by disentangling quantum measurements. We will study the effect of local injection and depletion of particles on the measured dynamics. We will next consider the effect of a conditional feedback on steering towards a complex quantum state.

Project: We will address these questions using a combination of analytical and numerical tools. We will study analytically the averaged Lindblad equation of the monitored/dissipative dynamics and the non Hermitian model corresponding to a single post-selected trajectory. We will also simulate the quantum trajectories and calculate different entanglement measures such as the entanglement entropy.

Environment: The project will take place at SPMS lab at CentraleSupelec.

Contact: Interested candidates can send a CV, and motivation letter to:
dganit.meidan@centralesupelec.fr

Extension: There is a possibility to extend this project to a doctorate thesis (funding secured).

Applicants Profile: Master in physics, proficiency in analytical tools, proficiency in Python background in many body physics and condensed matter theory.

Keywords: Entanglement entropy, measurements induced phase transition, open quantum systems.

References:

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