Reliability of near-term quantum simulators: the role of chaos and applications to cold atom experiments

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Quantum simulators are widely seen as one of the most promising near-term applications of quantum technologies. These devices are expected to be able to simulate complex quantum systems that are not efficiently simulatable on a classical computer. However, it remains unclear to what extent a device without fault tolerant error correction can output reliable results in the presence of realistic imperfections.

In this talk I will present two implementations of quantum simulators that allow us to study experimentally the power and limitations of these analog devices. First, I will describe a small-scale programmable quantum processor based on the optimal control of the dynamics within the electronic ground state of single neutral atoms. By theoretically studying spin models which present quantum critical behavior, such as the transverse field Ising and the Lipkin-Meshkov-Glick models, we characterize how well different quantities related to the quantum dynamics, can be extracted from a noisy simulation, and relate the observed behavior with the onset of quantum chaos in these systems. Then, I will describe a measurement-based feedback simulator based on a large ensemble of symmetrically coupled neutral atoms, which is suitable for exploring the emergence of chaos from quantum dynamics.