Localization and thermalization in many-body nuclear spin systems

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Quantum devices could perform tasks with much better performances than classical systems, with profound implications for cryptography, chemistry, material science, and many areas of physics. However, to reach this goal we need to control large quantum systems, where the many-body dynamics becomes often fragile and very complex.

Among the many questions and challenges that arise when working toward this goal, I will address two questions in my talk: How does a close quantum system thermalize (thus losing its "quantum power")? How can we preserve quantum information in the presence of strong interactions?

Using a nuclear spin chain as an exemplary experimental system, and the tools of Hamiltonian engineering, I will show how spin chains can transport information and entanglement. I will then show how disorder can quench the transport of information, a phenomenon known as localization. This phenomenon might actually be a feature in some situations, as it allows preserving local quantum information for later retrieval and prevents thermalization. Is localization however possible even in the presence of long-range interaction? I will show experimental signatures that a logarithmic growth of long-range correlation is still present in interacting systems, a sign of many-body localization. I will further discuss how metrics of information scrambling such as out-of-time ordered correlations can be used to distinguish thermalization from the long-time equilibrium phase of prethermalization.