

Probing and controlling dipolar many-body dynamics in disordered spin ensembles in diamond

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The dynamics of interacting, disordered quantum systems is a central topic in many-body physics. Dense ensembles of nitrogen-vacancy centres (NVs) in diamond provide a unique platform to realise a strongly interacting, intrinsically disordered spin systems with long-range dipolar interactions at room temperature. This enables access to rich many-body physics including thermalisation, non-equilibrium dynamics, and dimensional crossovers.

In this talk, I will first introduce the NV as a controllable spin platform and discuss how interactions within an ensemble give rise to complex many-body behaviour. I will then explain how we can probe the spin environment and selectively control interactions with Hamiltonian engineering techniques. A central challenge in using these systems as quantum simulators is the lack of precise knowledge of the interaction within a sample. I will present my work on using tailored pulse sequences as spectroscopic tools to characterise the spin bath and extract key parameters governing the system dynamics. This provides a route towards quantitative control of disordered spin ensembles and the exploration of emergent many-body physics in solid-state quantum simulators.