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Observation of nanoscale hydrodynamics in a strongly interacting dipolar spin ensemble in diamond[1] FRANCISCO MACHADO, CHONG ZU, BINGTIAN YE, BRYCE H KOBRIN, THOMAS MITTIGA, SATCHER HSIEH, PRABUDHYA BHATTACHARYYA, TIM O HOEHN, SOONWON CHOI, University of California, Berkeley, CHRISTOPHER LAUMANN, Boston University, DMITRY BUDKER, NORMAN Y YAO, University of California, Berkeley — Bridging the gap between the microscopic description of quantum many-body dynamics and its macroscopic emergent phenomena remains an important open problem. We experimentally tackle this challenge by probing the nanoscale diffusion in strongly interacting solid-state spin ensembles in diamond. More specifically, we harness nitrogen-vacancy (NV) centers as effective nanoscale quantum probes to initialize and detect the local spin polarization in a high-density ensemble of substitutional nitrogen defects (P1 centers). After preparing an out-of-equilibrium initial state of the P1 ensemble, we monitor its quantum quench dynamics and observe that the late time behavior can be described by emergent hydrodynamics, from which we extract the diffusion coefficients. To establish a quantitative connection between the observed hydrodynamics and the underlying microscopic Hamiltonian, we develop an effective semi-classical description for the spin dynamics. Crucially, this description allows us to understand how the interplay between disorder and long-range interactions leads to diffusive—yet non-gaussian—dynamics in the experimental observations.

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