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**Quantum dynamics of a single, mobile spin impurity**

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Quantum magnetism describes the properties of many materials such as transition metal oxides and cuprate superconductors. One of its elementary processes is the propagation of spin excitations. Here we study the quantum dynamics of a deterministically created spin-impurity atom, as it propagates in a one-dimensional lattice system. We probe the full spatial probability distribution of the impurity at different times using single-site-resolved imaging of bosonic atoms in an optical lattice. In the Mott-insulating regime, a post-selection of the data allows to reduce the effect of temperature, giving access to a space- and time-resolved measurement of the quantum-coherent propagation of a magnetic excitation in the Heisenberg model. Extending the study to the bath's superfluid regime, we determine quantitatively how the bath strongly affects the motion of the impurity. The experimental data shows a remarkable agreement with theoretical predictions allowing us to determine the effect of temperature on the coherence and velocity of impurity motion. Our results pave the way for a new approach to study quantum magnetism, mobile impurities in quantum fluids, and polarons in lattice systems.