Single-atom-resolved probing of lattice gases in momentum space

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Measuring the full distribution of individual particles is of fundamental importance to characterize many-body quantum systems through correlation functions at any order. Real-space probes of individual quantum objects – ions, superconducting qbits, Rydberg atoms or neutral atoms through a quantum gas microscope – have indeed paved the way to unprecedented investigations of many-body physics. Here I will present an experiment that provides the possibility to reconstruct the momentum-space distribution of three-dimensional interacting lattice gases atom-by-atom [1]. This is achieved by detecting individual metastable Helium atoms [2, 3] in the far-field regime of expansion, when released from an optical lattice. We benchmark our technique with Quantum Monte-Carlo calculations, demonstrating the ability to resolve momentum distributions of superfluids occupying 10^5 lattice sites. It permits a direct measure of the condensed fraction across phase transitions, as we illustrate on the superfluid-to-normal transition. Our single-atom-resolved approach opens a new route to investigate interacting lattice gases through momentum correlations.

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