Observation of Universal Hall Response in Strongly Interacting Fermions

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The Hall effect, which originates from the motion of charged particles in a magnetic field, has deep consequences for the description and characterization of materials, extending far beyond the original context of condensed matter physics. Although the Hall effect for non-interacting particles is well explained, understanding it in interacting systems still represents a fundamental challenge even in the small-field case. Here [1] we directly observe the build-up of the Hall response in an interacting quantum system by exploiting controllable quench dynamics in an atomic quantum simulator, see Figure 1. By tracking the motion of ultracold fermions in a two-leg ribbon threaded by an artificial magnetic field, we measure the Hall response as a function of synthetic tunnelling and atomic interactions. We unveil an interaction-independent *universal* behaviour above an interaction threshold, in clear agreement with theoretical analyses [2-3]. Our approach and findings open new directions for the quantum simulation of strongly correlated topological states of matter.

References

[1] To appear in **Science**, arXiv:2205.13567

[2] Universal Hall Response in Interacting Quantum Systems, S. Greschner, M. Filippone and T. Giamarchi, **Phys. Rev. Lett. 122**, 083402 (2019).

[3] Vanishing Hall Response of Charged Fermions in a Transverse Magnetic Field, M. Filippone, C.-E. Bardyn. S. Greschner, T. Giamarchi, **Phys. Rev. Lett. 123**, 086803 (2019).

Figures

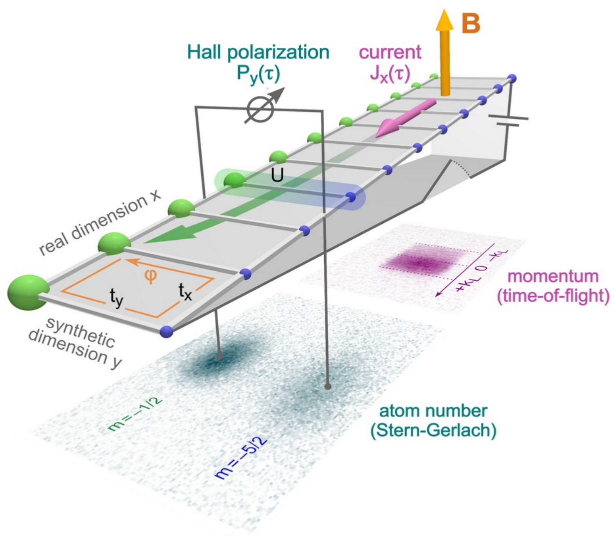

Figure 1: Scheme of the experiments. A synthetic ladder is realized by trapping fermionic ^{173}Yb atoms in a 1D optical lattice with direction $\hat{x}$ and coupling their nuclear spin states $m_{\rm F}=-1/2$ and $m_{\rm F}=-5/2$ via a two-photon Raman transition. The position-dependent phase of the Raman coupling simulates an effective magnetic field B described by an Aharonov-Bohm phase φ per unit cell. An atomic current is activated by suddenly tilting the ladder with an optical gradient, equivalent of equivalent to a constant electric field E_x. The growing (diminishing) size of the green (blue) spheres visualizes the leg population imbalance (Hall polarization) induced by the Hall drift. The time-dependent longitudinal current $J_x(\tau)$ and the Hall polarization $P_y(\tau)$ are measured with time-of-flight imaging and optical Stern-Gerlach detection, respectively (typical acquisitions are shown in the two images below the ladder).