JOURNAL CLUB: Observation of Hilbert space fragmentation and fractonic excitations in 2D

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12:00 to 13:00
Seminar Room

The relaxation behaviour of isolated quantum systems taken out of equilibrium is among the most intriguing questions in many-body physics[1]. Quantum systems out of equilibrium typically relax to thermal equilibrium states by scrambling local information and building up entanglement entropy. However, kinetic constraints in the Hamiltonian can lead to a breakdown of this fundamental paradigm owing to a fragmentation of the underlying Hilbert space into dynamically decoupled subsectors in which thermalization can be strongly suppressed[2,3],<a id="ref-link-section-d8416629e434_2" title="Moudgalya, S., Prem, A., Nandkishore, R., Regnault, N. & Bernevig, B. A. in Memorial Volume for Shoucheng Zhang (eds Lian, B. et al.) 147-209 (World Scientific, 2020);

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" href="https://www.nature.com/articles/s41586-024-08188-0#ref-CR4" data-track="click" data-track-action="reference anchor" data-track-label="link" data-test="citation-ref">4,[5]. Here we experimentally observe Hilbert space fragmentation in a two-dimensional tilted Bose-Hubbard model. Using quantum gas microscopy, we engineer a wide variety of initial states and find a rich set of manifestations of Hilbert space fragmentation involving bulk states, interfaces and defects, that is, two-, one- and zero-dimensional objects. Specifically, uniform initial states with equal particle number and energy differ strikingly in their relaxation dynamics. Inserting controlled defects on top of a global, non-thermalizing chequerboard state, we observe highly anisotropic, subdimensional dynamics, an immediate signature of their fractonic nature[6,7],<a id="ref-link-section-d8416629e441_2" title="Will, M., Moessner, R. & Pollmann, F. Realization of Hilbert space fragmentation and fracton dynamics in 2D. Preprint at

https://arxiv.org/abs/2311.05695

(2023)." href="https://www.nature.com/articles/s41586-024-08188-0#ref-CR8" data-track="click" data-track-action="reference anchor" data-track-label="link" data-test="citation-ref">8,[9]. An interface between localized and thermalizing states in turn shows dynamics depending on its orientation. Our results mark the observation of Hilbert space fragmentation beyond one dimension, as well as the concomitant direct observation of fractons, and pave the way for in-depth studies of microscopic transport phenomena in constrained systems.

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