JOURNAL CLUB: Observation of Strong-to-Weak Spontaneous Symmetry Breaking in a Dephased Fermi Gas

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Seminar Room

Symmetry-based classification of quantum phases of matter is one of the most foundational organizing principles in physics; however, an analogous framework for mixed, decohered quantum states has only begun to emerge. A central new concept is strong-to-weak spontaneous symmetry breaking (SW-SSB), a sharp transition in mixed quantum states that is invisible to any observable linear in the density matrix and that has since been predicted across a broad class of open and monitored quantum systems. It also provides a unifying language for phenomena as disparate as the decodability of topological quantum memories and the emergence of classical hydrodynamics from decohered quantum dynamics. Here we report the first experimental observation of SW-SSB, in dephased single-component fermionic matter imaged by a quantum gas microscope. A quantum-classical estimator built on a machine-learned Gaussian reference state gives direct access to the nonlinear Renyi-1 and Renyi-2 correlators that diagnose SW-SSB, and reveals long-range Renyi order in the dephased Fermi liquid. Adding a commensurate superlattice drives the underlying fermions through a metal-to-insulator transition that, after full dephasing, manifests as a sharp SW-SSB phase transition. Our results uncover the symmetry principle behind information-theoretic transitions in open quantum systems, and extend Landau's symmetry paradigm into the regime of real, decohering quantum devices.

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