Quantum Simulation of the Unknown: Observation of Pseudogap Physics and Stripes in the Fermi-Hubbard Model

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What happens when quantum simulations become cold enough to surprise us? So far, quantum simulations have primarily served as impressive proof-of-principle demonstrations, realizing a wide range of many-body quantum phases. However, temperatures have remained too high to truly access uncharted regimes relevant to strongly correlated quantum materials.

In this talk, we will present a recent breakthrough in which we use an ultracold-atom realization of the Fermi–Hubbard model to explore pseudogap and stripe physics in the doped regime. By achieving a several-fold reduction in temperature, we enter a new regime and observe, unexpectedly, a pronounced peak in the compressibility near $1/8$ doping. This feature appears to separate a conventional metallic phase from a pseudogap phase, which we identify by measuring characteristic signatures of the pseudogap in the excitation spectrum. Ongoing work studies the onset of stripe formation. High-precision measurements of spin correlations reveal the formation of 'antiphase domains' of antiferromagnetism characteristic of spin stripes. We also observe an enhanced tendency to break rotational symmetry, compatible with a state of fluctuating stripes.

Altogether, this work represents a key advance in quantum simulation: it demonstrates that we can now address central open questions in condensed matter physics using controlled experiments in regimes that lie at the frontier of classical numerical methods.