Quantum simulation in a cold-atom Fermi-Hubbard system

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In the low temperature regime of strongly-correlated materials, a variety of interesting effects can be observed, described theoretically by the Fermi Hubbard model. We use ultracold fermionic atoms in a single-site- and spin-resolved quantum gas microscope to simulate such models. Compared to classic numerical simulations, we can benefit from the inherent quantum nature of our simulator to study complex processes.

Using optical superlattice structures, we can precisely control and modify the coupling strengths of the Hubbard Hamiltonian in each direction individually. This allows us to study a variety of physics effects, ranging from single particle to many-body physics [1,2], and even demonstrating building blocks for a neutral-atom based quantum computer using collisional gates in double-well potentials.

In addition, the phase diagram of the Fermi-Hubbard model still offers many interesting yet unexplored effects at very low temperatures. With the current system we were able to quantitatively explore the magnetic origin of the pseudogap via higher-order spin-charge correlations [3].

References

[1] S. Hirthe et al., Nature 613 (2023)

[2] T. Chalopin et al., arXiv:2405.19322 (2024)

[3] T. Chalopin et al., arXiv:2412.17801 (2024)

Figures

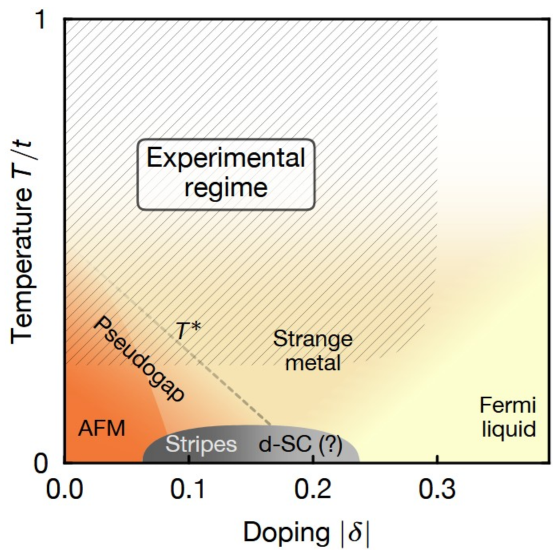

Figure 1: Phase diagram of the Fermi-Hubbard model. The striped region is explored in our experiments. Especially we are exploring a low-temperature region which shows signatures of a pseudogap phase [3].