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Quantum Magnetism with Ultracold Fermions in an Optical Lattice

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In my thesis, I present the observation of quantum magnetism in an ultracold fermionic quantum gas confined to a 3D optical lattice. Ultracold fermionic atoms in optical lattices have long been proposed as a general platform for studying various model systems in condensed matter physics, ranging from geometries that give rise to Dirac points, to magnetically ordered phases. Of particular interest are models for quantum magnetism, which originates from the exchange coupling between quantum-mechanical spins. Yet, reaching the low temperatures required for entering the quantum magnetism regime has proven to be challenging, and has hindered progress for systems based on ultracold fermions in optical lattices. We have addressed and overcome this challenge. We designed an original scheme that enabled us to locally redistribute entropy, such that a subset of lattice bonds reaches temperatures below the exchange energy. The key to this scheme has been a novel type of optical lattice with tunable geometry. Using this lattice, we successfully observed quantum magnetism emerging in the many-body state of a thermalized Fermi gas. Beyond that, the same lattice was the enabling tool for the realization of a tunable artificial graphene system, highlighting the versatility of our approach. This work was performed at ETH Zurich under the supervision of Prof. Tilman Esslinger.