D. Greif: *Exploring artificial quantum-many body systems with ultracold fermions in a tunable-geometry optical lattice*

Ultracold fermionic atoms in optical lattices have emerged as a versatile tool to study condensed matter model systems. Strong efforts have been directed to models for quantum magnetism, which has its origin in the exchange coupling between quantum mechanical spins and is believed to be closely connected to strongly correlated states, for example high-temperature superconductors. Yet, the low temperature scale required for entering the regime of quantum magnetism has so far hindered progress for optical lattice based systems with ultracold fermions. We report on the observation of nearest-neighbour magnetic spin correlations emerging in the many-body state of a thermalized Fermi gas in an optical lattice. The key to obtaining short-range magnetic order is a local redistribution of entropy, allowing for temperatures below the exchange energy for a subset of lattice bonds. When loading a repulsively interacting gas into either dimerized or anisotropic simple cubic configurations of a tunable-geometry lattice we observe an excess of singlets as compared to triplets consisting of two opposite spins. For the anisotropic lattice, the transverse spin correlator reveals antiferromagnetic correlations along one spatial axis. We furthermore report on experiments in of a non-interacting gas in a honeycomb optical lattice, in close resemblence to Graphene. The presence of Dirac points with adjustable properties is directly observed by identifying a minimum band gap inside the Brillouin zone from momentum-resolved interband transitions. We demonstrate full control over the Dirac point properties, such as the linear dispersion slope, the position in momentum space and the effective mass of the Dirac fermions.