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Repulsively and Attractively Interacting Fermi-Mixtures in Optical Lattices

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Ultracold fermionic quantum gases in optical lattices represent a unique model scheme which in principle can be used to simulate complex many-body systems, for example high-Tc superconductors. Similarly to solid state physics, our system is described by the Fermi-Hubbard Hamiltonian with the advantage that all relevant parameters can be controlled with high accuracy. A famous prediction of the Hubbard Hamiltonian is the Mott-insulator, where a metal with half-filled conduction band turns insulating due to interactions. Experimentally, we prepare a fermionic Mott-insulator with an ultracold repulsively interacting spin mixture of ^{40}K atoms in a blue detuned optical lattice. By measuring the insitu cloud size and its response to an external force - the enclosure of a red detuned optical dipole trap - as well as the number of doubly occupied sites, the insulating and metallic behaviour can be distinguished; and the Mott-insulating regions can be identified. The interactions between the atoms can conveniently be tuned with the help of a magnetic Feshbach resonance. However, the attractive side of the resonance, i.e. the attractive Hubbard-Hamiltonian, contains surprising effects as well. On tuning the interactions from the repulsive to the attractive side, we find a shrinking followed by an anomalous expansion of the atomic cloud. This unexpected expansion is related to the formation of bound pairs and can be understood with a straightforward entropy argument. This work was done together with U.Schneider, S. Will, Th. Best, S. Braun, I. Bloch and with theoretical support from T.A.Costi, R.W. Helmes, D. Rasch, A.Rosch, B. Paredes, M. Moreno-Cardoner, T. Kitagawa, E.Demler.