The BEC-BCS Crossover: Tuning Strong Correlations in a Dilute Gas

Selim Jochim
Department of Physics, Heidelberg University, Germany
jochim@uni-heidelberg.de
http://www.lithium6.de

Using ultracold gases, researchers have been able to realize states of matter that had been predicted long before in a very beautiful manner. Some of the most striking examples are the Bose-Einstein condensate, or the Mott-insulating state in a lattice.

Ultracold gases have furthermore contributed tremendously to understanding states of matter that had been under intense investigation for decades. A particularly extreme example is the continuous crossover from a Bose-Einstein condensate of molecules (BEC) to a Cooper-paired state of weakly attractive fermionic atoms (BCS): The atomic interactions can be tuned by simply applying a magnetic field using so-called Feshbach resonances in such a controlled way that initially the attraction between atoms is large enough such that molecules are formed from two fermionic atoms that are then bosonic in nature. As the attraction between these molecules is reduced, the binding becomes weaker, and the size of the molecules grows until their size becomes comparable with the interparticle spacing. Reducing the attraction further, the bound state between two atoms vanishes completely, and the system is paired only in a many-body context, a behavior that is well known from BCS theory. In fact, this crossover regime has been under intense theoretical investigation for decades, in particular as very high critical temperatures can be found ($> 0.15\, T_{\mathrm{F}}$).

The very high critical temperatures observed in this so-called crossover regime motivated further studies bringing these systems closer to real solid-state materials, with the vision to get inspiration for a better understanding of high-T_c materials. During the past years we have therefore investigated this crossover in reduced dimensions by shaping the trap confining the atoms in such a way that motional degrees of freedom are frozen out. This leads to the observation of the so-called Berezinskii-Kosterlitz-Thouless phase, a topological phase with quasi-long range order, and also to the identification of a regime in which pairing occurs at unexpectedly large temperatures.

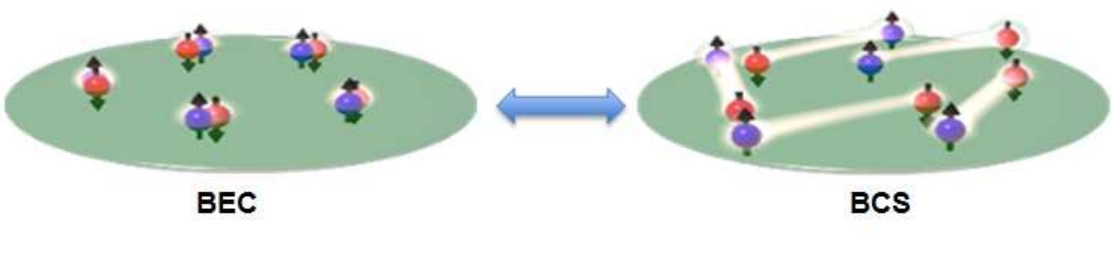

Figure 1: Schematic illustration of the BEC-BCS crossover.