MAR12-2011-001054

Abstract for an Invited Paper
for the MAR12 Meeting of
the American Physical Society

From ultracold Fermi Gases to Neutron Stars

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Ultracold dilute atomic gases can be considered as model systems to address some pending problem in Many-Body physics that occur in condensed matter systems, nuclear physics, and astrophysics. We have developed a general method to probe with high precision the thermodynamics of locally homogeneous ultracold Bose and Fermi gases [1,2,3]. This method allows stringent tests of recent many-body theories. For attractive spin 1/2 fermions with tunable interaction (^{6}Li), we will show that the gas thermodynamic properties can continuously change from those of weakly interacting Cooper pairs described by Bardeen-Cooper-Schrieffer theory to those of strongly bound molecules undergoing Bose-Einstein condensation. First, we focus on the finite-temperature Equation of State (EoS) of the unpolarized unitary gas. Surprisingly, the low-temperature properties of the strongly interacting normal phase are well described by Fermi liquid theory [3] and we localize the superfluid phase transition. A detailed comparison with theories including recent Monte-Carlo calculations will be presented. Moving away from the unitary gas, the Lee-Huang-Yang and Lee-Yang beyond-mean-field corrections for low density bosonic and fermionic superfluids are quantitatively measured for the first time. Despite orders of magnitude difference in density and temperature, our equation of state can be used to describe low density neutron matter such as the outer shell of neutron stars.

[1] S. Nascimbène, N. Navon, K. Jiang, F. Chevy, and C. Salomon, *Nature* **463**, 1057 (2010)
[2] N. Navon, S. Nascimbène, F. Chevy, and C. Salomon, *Science* **328**, 729 (2010)
[3] S. Nascimbène, N. Navon, S. Pilati, F. Chevy, S. Giorgini, A. Georges, and C. Salomon, Phys. Rev. Lett. **106**, 215303 (2011)