Strongly Interacting Fermi Gases

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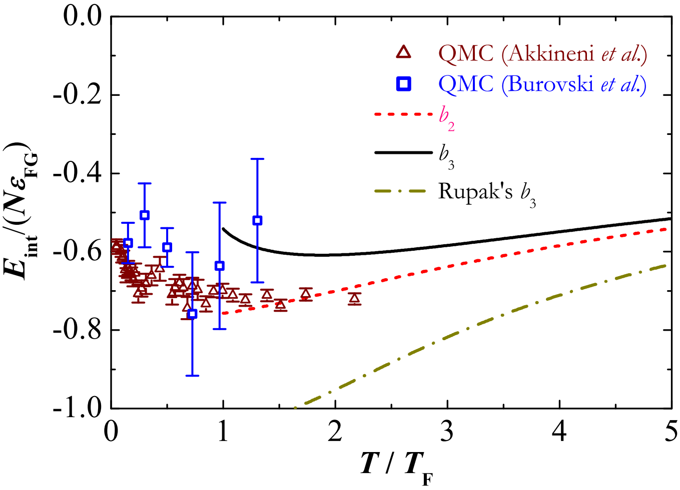
Stongly correlated Fermi gases are of wide interest. They pose many unanswered questions in quantum many-body systems, ranging from neutron stars, hadrons, and quark matter through to high T_c superconductors. Recent investigation of Feshbach resonances in ultracold atomic Fermi gases have opened new, quantitative opportunities to address these challenges. However, a profound understanding is plagued by the large interaction strength, for which the use of perturbation theory requires infinite order expansions.

At temperatures above the transition temperature we are able to use a reliable virial expansion method, which allows a controllable study of the thermodynamics of stongly correlated Fermi gases near the BEC-BCS crossover region [1,2]. Our theoretical prediction for the third order coefficient was completely different to previously predicted values. It has now been experimentally confirmed to high accuracy by Salomon's group at ENS [3]. Further, an important challenge in ultracold superfluid gases is to observe second sound. We approached this problem in a trapped unitary Fermi gas by solving the Landau two-fluid equations [4]. Our result has stimulated an experimental group at Innsbruck to set up an experiment to measure second sound.

Virial Expansion for a Strongly correlated Fermi Gas



We proposed a practical way to study strongly interacting Fermi gases, by determining the virial expansion coefficients for both harmonically trapped and homogeneous cases. We calculated the third order coefficient at finite temperatures, obtaining a radically different result to an earlier calculation by Rupak. At resonance, we obtain the T-independent coefficient, $b_3^{hom} \approx -0.29095295$. Our prediction has been confirmed by experiments carried out by international partner investigators at ENS (IFRAF), Paris.

Second Sound in a Trapped Fermi Gas

Using a variational approach, we solve the equations of two-fluid hydrodynamics in a unitary Fermi gas trapped by a harmonic potential. We show that the density fluctuations (first sound) weakly couples to the entropy fluctuations (second sound) of the system, giving rise to a typical hybridization effect where the frequencies cross. We predicted the value of the frequency splitting caused by hybridization and show how the coupling results in a beating in the density response. This gives a promising way of exciting and detecting second sound in this system.

References

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