Strongly Interacting Fermi Gases

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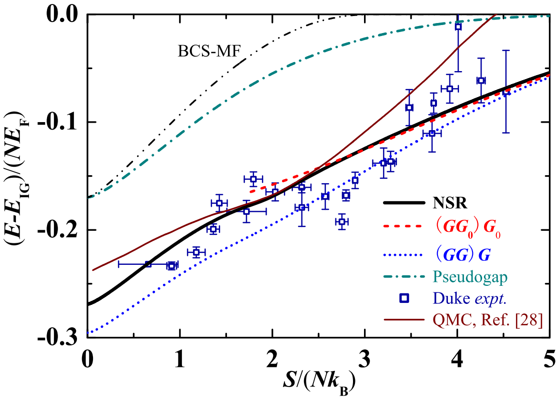
Strongly interacting Fermi gases are of great interest. Interacting fermions are involved in some of the most important unanswered questions in condensed matter physics, nuclear physics, astrophysics, and cosmology. In 2008, we presented a systematic comparison of strong-coupling theories, predicted the finite-temperature phase diagram of a polarized system and investigated the collective modes in multicomponent attractive Fermi gas[1-4].

Comparative study of strong-coupling theories In the strongly interacting regime the main theoretical difficulty lies in the absence of any small coupling parameter, which is crucial for estimating the errors of approximate approaches.



In the paper [1], using experimental data as a benchmark, we present an unbiased test of several strong-coupling theories that are commonly used in the literature, including QMC simulations. From this comparison, we show the simplest theory, our below-threshold version of the Nozieres and Schmitt-Rink treatment, which incorporates pairing fluctuations, appears to be quantitatively accurate at unitarity. We find it describes the observed thermodynamics extremely well at all temperatures at unitarity, except near the superfluid transition temperature. Some earlier theories clearly fail completely.

Polarized Fermi gases Recently, two experimental groups at MIT and Rice University have successfully created a two-component atomic Fermi gas with unequal spin populations. This type of matter is of great interest, and has stimulated intense efforts towards studying this unsolved theoretical problem in condensed matter and particle physics. Motivated by these experiments, we have investigated the properties of an ultracold atomic Fermi gas with spin population imbalance in a quasi-one-dimentional trap [3]. Our exact results are being tested by an ongoing experiment at Rice University which is searching for the predicted exotic, spatially modulated or FFLO states in a highly elongated harmonic trap.

Multicomponent Fermi gases Recent advances in ultracold atomic Fermi gases make it possible to achieve a fermionic superfluid with multiple spin components. In this context, any mean-field description is expected to fail, owing to the presence of tightly bound clusters or molecules that consist of more than two particles. By using the exact Bethe ansatz solution and a local density approximation treatment of the harmonic trap, we have investigated the equation of state of a multicomponent Fermi gas [4]. We show that there is a peak in the collective mode frequency at the critical density for a deconfining transition to many-body state that is analogous to the quark matter color superconductor state expected in neutron star interiors.

References

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