Phase Separation in Asymmetrical Fermion Superfluids

Paulo F. Bedaque[1], Heron Caldas[1,2] and Gautam Rupak[1]
[1] *Nuclear Science Division, Lawrence Berkeley National Laboratory, Berkeley, California 94720*
[2] *Universidade federal de Sao Joao del Rey, Sao Joao del Rey, 36300-000, MG, Brazil*

The recent interest in two physical systems have revived the study of asymmetric fermionic systems, that is, systems with unequal number density (or chemical potential) for the different species. In high density strongly interacting systems, as it may be found at the core of ``neutron'' stars, the different quark flavors have different chemical potentials on account of their different masses and charges. Atomic traps can also provide an example of similar systems if a bias can be introduced when the trap is filled in order to have a larger number of one of the atom species (or hyperfine state of the same atom) . In the symmetrical situation the low energy properties of these systems are dominated by Cooper pair formation. Since it involves the attraction between two fermions with equal and opposite momenta at the their Fermi surface one could imagine that as the Fermi surfaces move apart with increasing asymmetry, the pairing would become weaker and the gap smaller, until superfluidity disappears. What actually happens is however more interesting and results from the competition between states with different particle distribution, both in momentum and real space.

A previous suggestion, which caught a lot of attention, posited that a new state, sharing properties with metals and superfluids, would be energetically favorable. We considered instead an inhomogeneous state formed by bubbles of superfluids immersed on a sea of normal gas and showed that this it is the state with smallest energy. This also implies that the other suggestions are unstable.

We find that with either both chemical potentials or both densities fixed, the most likely ground state is a mixed phase composed of bubbles of a asymmetric normal state immersed in a sea of the symmetric BCS phase. This space segregation of the excess particles suggests a possible way of detecting superfluidity in atomic traps, specially where large gaps are expected as in the case of "resonance superfluidity'" . If a optical trap can be filled with an excess number of one of the hyperfine states, the resulting ground state can be imaged in a way that discriminates between them and the bubble structure may become visible. A high concentration of the denser particle species will accumulate at some point(s) in the trap. The division of the space between the BCS and the normal components is determined by the value of the gap thus, by studying its variation with the variation of the asymmetry, we can infer the existence of the superfluidity and even the value of the gap, which is an currently an outstanding problem. A better understanding of the surface tension of the interface between the two components is necessary to make this proposal fully quantitative. As we discussed above, the qualitative arguments discussed above should be valid even if weak coupling BCS theory is not, as it is the case with the experiments with ^{6}Li .

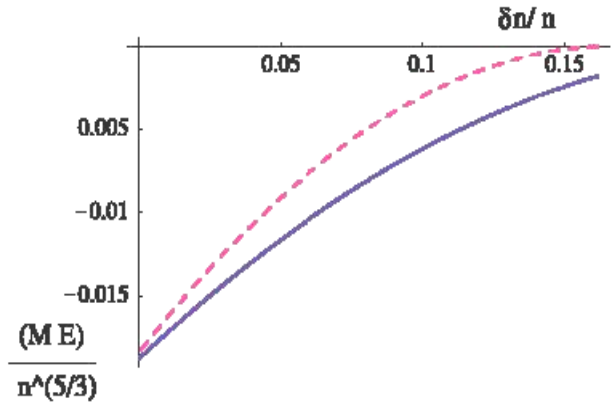

FIG. 1: Thermodynamic potential for the mixed phase and the breached pairing state as a function of the asymmetry. Solid line corresponds to the mixed phase, dashed line to the breached pairing phase.

REFERENCES

[1] P. F. Bedaque, H. Caldas and G. Rupak, *Phys.Rev.Lett.* 91:247002 (2003).

[2] W. Vincent Liu and F. Wilczek, *Phys.Rev.Lett.* 90:047002 (2003).

This document was created with Win2PDF available at http://www.daneprairie.com.
The unregistered version of Win2PDF is for evaluation or non-commercial use only.