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CORRELATED PAIRS NEAR THE FERMI SURFACE

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One of the problems of the fifties, which occupied a lot of many body physicists dealing with strongly interacting Fermi systems of infinite extent like nucleon matter or liquid ^{3}He, was the occurence of a singularity at the Fermi surface in the Bethe-Goldstone (BG) equation. It was generally believed, at that time, that this singularity was associated with the existence of a superfluid state[1].

In the next two decades we can observe a few developments[2]. The approach I would like to discuss is the generalization of the BG equation. It includes, apart from particle-particle (pp) ladders, hole-hole (hh) ladders and all possible mixed pp and hh ladders. The generalized ladder equation of Mehta[3] and the Galitskii-Feynman (GF) equation investigated by the Manchester group[4] comprise the same type of ladder diagrams with the property that particles and holes are treated completely symmetrically. Metha's equation does not lose the BG equation singularity. The Manchester group, on the other hand, has not noticed any problem near the Fermi surface but has discovered that the GF T-matrix possesses a pole in the bound-state region which corresponds to the formation of bound-state pairs in the medium.

Results obtained by using symmetrical ladder equation are interesting because we know that bound composite clusters of fermions comprised of an even number of fermions (particles) and/or an even number of their superfluid-like phase[5]. As an example we have the Cooper pairs which are responsible for superconductivity in weakly interacting Fermi systems.

We have decided to examine a generalized ladder equation again, but in the context of the coupled-cluster (CC) method; the CC method is flexible and general enough to enable investigation of the pairing from different points of view and with better and better approximation. We have solved[6] the complete ladder (CLAD) equation of the CC method, corresponding to generalized ladder equations of the perturbation theory, for the separable two-body interaction. We have restricted ourselves to one-term S-wave interaction but the extension to both multi-term separable interactions and to arbitrary higher partial waves would be straightforward. The solution for the states close to the Fermi surface contains both the bound-pairs and the singularity. To understand that result better we have examined excited states[7]. Using the Emrich's ansatz for the excited state, we have solved the ladder type equation corresponding to the CLAD equation of the ground state. The solution is characterized entirely by the quantities which describe the pairing of the ground state. For the attractive interaction, the excited state has lower energy than the ground state which means that our reference state choosen to be a filled Fermi-sphere plane-wave determinant is not the best possible point of departure. For the repulsive interaction, on the other hand, we observe a real excitation for densities above a certain critical density and no excitation below that density; in the latter range of density we also do not observe any pairing in the ground state.

Both results, for the ground state and for the excited state, suggest the existence of the pairing in a many-fermion strongly interacting system. The question arises whether the observed pairing exists in the exact solution of the Schrödinger equation. To examine that, we should find a suitable truncation scheme of the CC method which would give a possibility to see the pairing in its successive levels[8]. We cannot apply the Bochum truncation scheme[9], because it was invented to describe the normal ground state of strongly interacting systems; by introducing a gap at k_F in the single-particle energy spectrum, this method relegates the pairing correlations near the Fermi surface to the terms of a very high order.

Presently we know how to treat the short-range repulsion of a two-body interaction, but we do not know how to describe properly the Fermi surface.

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