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BCS Pairing Gap in the Infrared Limit of the Similarity Renormalization Group

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Effective interactions have been used to compute the pairing gap for nuclear and neutron matter in several schemes. Most often the BCS approach is based on having the scattering phase-shift as the basic input of the calculation. On the other hand, there is an arbitrariness in this procedure, as there are infinitely many interactions leading to the identical phase-shift. In this work we analyze the impact of phase-shift equivalent interactions within the BCS theory on the $^1S_0$-channel pairing gap for a translational invariant many-fermion system such as nuclear and neutron matter. We solve the BCS pairing gap equation on a finite momentum grid for a toy model separable Gaussian potential in the $^1S_0$-channel explicitly evolved through the Similarity Renormalization Group (SRG) transformation and show that in the on-shell and continuum limits the pairing gap vanishes. For finite size systems the momentum is quantized and the on-shell limit is realized for SRG cutoffs comparable to the momentum resolution. In this case the pairing gap can be computed directly from the scattering phase-shifts by an energy-shift formula
$\Delta_{nn}(p_F) = \Delta\epsilon_F \delta_{nn}^{^1S_0}(p_F)/\pi$,

where p_F is the Fermi momentum and $\Delta\epsilon_F$ is the level spacing at the Fermi energy. While the momentum grid is usually used as an auxiliary way of solving the BCS pairing gap equation, we show that it actually encodes some relevant physical information, suggesting that in fact finite grids may represent the finite size of the system. For the harmonic oscillator shell model the level spacing at the Fermi energy becomes $\Delta\epsilon_F = \hbar\omega \sim 41\ A^{-1/3}$ MeV such that $\Delta_{nn}(p_F) \sim 4\ A^{-1/3}$ MeV. The comparison with double differences from binding energies of stable nuclei is satisfactory and the discrepancy with the large scale analysis may be attributed to three-body forces.

Summary

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