Mean-Field vs RPA Calculation of the Energy of fn Impurity Immersed in a Spin 1/2 Superfluid

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In this work, we calculate the energy of an impurity weakly coupled to a spin 1/2 fermionic superfluid. We show that the divergences resulting from three-body physics can only be cured using a proper description of the excitations of the many-body background. We highlight the crucial role played by interactions between quasiparticles which are overlooked within the BCS (Bardeen-Cooper-Schrieffer) mean-field theory of fermionic superfluidity. By contrast, we prove that their addition using the Random Phase Approximation (RPA) allows us to regularize the energy of the impurity. Finally, we show that these beyond mean-field corrections should be observable by the analysis of the frequency shift of the impurity center of mass oscillations in an external confining potential.