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Nonperturbative Effects on the Ferromagnetic Transition in Repulsive Fermi Gases

Lianyi He, Xu-Guang Huang

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It is generally believed that a dilute spin-1/2 Fermi gas with repulsive interactions can undergo a ferromagnetic phase transition to a spin-polarized state at a critical gas parameter $(k_{\rm F}a)_c$. Previous theoretical predictions of the ferromagnetic phase transition have been based on the perturbation theory, which treats the gas parameter as a small number. On the other hand, Belitz, Kirkpatrick, and Vojta (BKV) have argued that the phase transition in clean itinerant ferromagnets is generically of first order at low temperatures, due to the correlation effects that lead to a nonanalytic term in the free energy. The second-order perturbation theory predicts a first-order phase transition at $(k_{\rm F}a)_c=1.054$, consistent with the BKV argument. However, since the critical gas parameter is expected to be of order O(1), perturbative predictions may be unreliable. In this paper we study the nonperturbative effects on the ferromagnetic phase transition by summing the particle-particle ladder diagrams to all orders in the gas parameter. We consider a universal repulsive Fermi gas where the effective range effects can be neglected, which can be realized in a two-component Fermi gas of ^{6}Li atoms by using a nonadiabatic field switch to the upper branch of a Feshbach resonance with a positive s-wave scattering length. Our theory predicts a second-order phase transition, which indicates that ferromagnetic transition in dilute Fermi gases is possibly a counterexample to the BKV argument. The predicted critical gas parameter $(k_{\rm F}a)_c=0.858$ is in good agreement with the recent quantum Monte Carlo result $(k_{\rm F}a)_c=0.86$ for a nearly zero-range potential [S. Pilati, \emph{et al}., Phys. Rev. Lett. {\bf 105}, 030405 (2010)]. We also compare the spin susceptibility with the quantum Monte Carlo result and find good agreement.

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