Bose and Fermi gases with Lennard-Jones interactions

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We study a model for cold Bose and Fermi gases based on the Lennard-Jones interaction, using the (Fermi-)hypernetted-chain Euler-Lagrange ((F)HNC-EL) method. For comparison, we also have carried out path integral ground state Monte Carlo (PIMC) simulations in the Bose case. By varying the density and the de Boer Quantum parameter Λ for the Lennard-Jones potential, we cover the whole range of dilute, weakly interacting gases up to the dense, strongly interacting case of liquid ^{3}He and ^{4}He.
We have calculated the ground state energy, pair distribution function $g(r)$ and static structure function $S(k)$ and the dynamic structure function $S(k,\omega)$ for a wide range of densities and coupling constants. Below about 25 percent helium equilibrium density, the simplest version of the (F)HNC-EL theory agrees with PIMC results within better than 1 percent.
We discuss the results in terms of the s-wave scattering length $a(\Lambda)$ which characterizes the potential in the limit of low densities. Our results let us assess the regime of validity of theories based on mean-field approximations or zero-range interactions.