Many manifestations of nonperturbative QCD

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Neutron matter in the unitary limit and effective nuclear forces

We analyze the unitary Fermi gas in its ground state from an implicit renormalization point of view and compute the effective range dependence of the Bertsch parameter. The tenet of the theory is the scale separation between low and high momentum which we take as the Fermi momentum, and the assumption that energy phenomena below it can be re-parameterized into the low momentum coefficients of the interaction. This choice of separation scale reduces the calculation to the mean field level. After imposing the physical renormalization conditions on the pseudo-potential, given by contact interactions in momentum space, we obtain $\xi = 0.42$ for a vanishing effective range. The result holds for a wide range of systems, including ultra-cold atoms interacting through van der Waals forces and assumes that there are no many-body forces. We analyze departures from the unitary limit due to finite range and scattering length corrections for the case of neutron matter considering a set of contact interactions up to NNLO. We also review some aspects of renormalization of two-nucleon chiral forces.

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