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How to consistently use modern nuclear forces in an ab initio technique

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One of the challenges faced while studying the nuclear many-body problem is the nature of the nucleon-nucleon interaction. The full details are described by the theory of Quantum Chromodynamics (QCD), but for realistic calculations approximate models must be used. Historically these have been phenomenological potentials fit to experimental data. However, in recent decades, models for the nucleon-nucleon interaction were produced from a power counting expansion in Chiral Effective Field theory (EFT). As a result, these modern nuclear interactions have an advantage over the phenomenological potentials, since they have a connection to the symmetries of the underlying theory of QCD.

To investigate the nuclear many-body problem, we employ an ab initio approach. Quantum Monte Carlo (QMC) consists of a family of powerful stochastic methods for solving the many-body Schrodinger equation. QMC methods provide very accurate results, at the cost of being computationally expensive. In addition to their accuracy, QMC methods have the benefit that we can build the appropriate physics, such as pairing, directly into them.

Combining these two tools, QMC methods and the Chiral-EFT derived nucleon-nucleon interaction, leads to something of a contradiction. The Chiral-EFT potential is designed to be used perturbatively at the many-body level, but this is almost never the case, due to the fact that combining a non-perturbative technique (QMC) with a perturbative potential is not a trivial problem. This work attempts to remedy this inconsistency. To show this, we explore a variety of low-density neutron matter systems that have a direct application to neutron-rich systems such as the inner crust of neutron stars.

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