Nuclear Matter at High Orders from Chiral Effective Field Theory

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Based on the symmetries of quantum chromodynamics, chiral effective field theory (EFT) has become the modern approach to nuclear interactions at the low-energy scales of nuclear physics. Nuclear matter is an ideal system for testing these with important consequences for physics ranging from finite nuclei to neutron stars: while the equation of state allows tight constraints on key quantities relevant for neutron stars, recent *ab initio* calculations of medium-mass to heavy nuclei have demonstrated that realistic saturation properties in symmetric matter are crucial for reproducing experimental binding energies and charge radii.

We report on recent advances in many-body perturbation theory for the equation of state of homogeneous nuclear matter based on chiral nucleon-, three-, and four-nucleon interactions. A novel Monte Carlo framework allows us to push state-of-the-art calculations at zero and finite temperature to high orders in the chiral as well the perturbation expansion. This gives important insights into the rates of convergence of the two expansions including improved theoretical uncertainty estimates. We explore new chiral interactions up to next-to-next-to-next-to-leading order (N3LO) in neutron and symmetric matter with focus on reproducing the empirical saturation point. Finally, we outline how these improved calculations combined with observations such as GW170817 can be used to construct the equation of state up to the densities and temperatures relevant for astrophysical simulations. Direct constraints from lattice quantum chromodynamics for nuclear forces (*e.g.*, by the CalLat collaboration) would be very exciting.