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Three-Nucleon Forces in Chiral Perturbation Theory

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In the past decade, there has been substantial progress in the derivation of nuclear forces from chiral effective field theory (EFT). Accurate two-nucleon forces have been constructed at next-to-next-to-next-to-leading order (N³LO) and applied [together with three-nucleon forces (3NF) at NNLO] to nuclear few- and many-body systems—with a good deal of success. This may suggest that the 80-year old nuclear force problem has finally been cracked. Not so! In particular in the 3NF sector, there are substantial open issues, which is the focus of this talk. The leading 3NF (at NNLO) is well known and well tested. It is sizable, improves predictions (of three-nucleon scattering and the spectra of light nuclei), but also leaves unresolved issues. Recently, the derivation of the chiral 3NF at N³LO has been completed and first applications have been performed. This 3NF involves only leading vertices and no free parameters, contributes only modestly and, thus, may not be the solution of the open problems. Therefore, we have to proceed to N⁴LO of the Δ -less theory (or N³LO of the Δ -full theory). We argue that the latter may be sizable and has the potential to be the missing piece in the 3NF puzzle.