Hessisches Kompetenzzentrum
für Hochleistungsrechnen

Matrix Elements of Next-Generation Chiral Interactions



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Clusters
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Additional Software
COCONUT

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Introduction

The goal of ab initio nuclear structure theory is the description of nuclei from first principles without uncontrolled approximations, allowing calculations with excellent predictive power. All of these calculations require the construction of nuclear interactions, which is done using chiral e ective field theory (chiral EFT), a framework that has been extremely successful in recent years. Using these interactions directly in a many-body calculation is computational expensive, hence, we use the Similarity Renormalization Group (SRG) to “soften” these interactions. The SRG improves the convergence properties of many-body calculations, however, the SRG itself involves large-scale numerical calculations. This project provides the next generation of chiral two-body, three-body, and even four-body interactions suitable for ab initio many-body calculations.

Methods

Our main method is the SRG, which is a continuous unitary transformation of the Hamiltonian. This transformation can be written in a flow equation, that translates into a set of coupled nonlinear first-order differential equations. These are solved numerically with highly specialized codes developed within our group. The SRG decouples high- and low-momentum states and thereby prediagonalizes the Hamiltonian, which reduces the model space necessary to converge subsequent many-body calculations.

Results

In this project we have calculated matrix elements of the next generation of chiral interactions, which we developed within the Low Energy Nuclear Physics International Collaboration (LENPIC) and for the Entem-Machleidt-Nosyk interaction family. These matrix elements have been used in di erent large-scale ab initio calculations within our group or by our collaborators. Furthermore, we extended our framework to handle the consistent SRG evolution of electromagnetic operators with next-to-leading-order current contributions and the weak Gamow-Teller operator. We further investigated the effects of phenomenological 4N forces and di erent SRG schemes to mitigate SRG truncations.

Discussion

The systematic order-by-order analysis of the convergence of the chiral EFT expansion and the comparison of di erent regularization schemes are essential for a quantification of theory uncertainties for nuclear structure observables. With the Entem-Machleidt-Nosyk interaction family, we have an interaction that can provide reliable nuclear observables. The development of the interaction family within LENPIC indicates that we are missing crucial contributions either in the interaction or in the radius operator itself. In ongoing work, we will address both higher-order terms of the interaction and the radius operator. On top of that, we need to address uncertainties induced by the truncations used during the SRG.

Publications

Friman-Gayer, U. et al.: "Role of Chiral Two-Body Currents in 6Li Magnetic Properties in Light of a New Precision Measurement with the Relative Self-Absorption Technique", Phys. Rev. Lett. 126, 102501, 2021
https://doi.org/10.1103/PhysRevLett.126.102501

Hüther, T.; Vobig, K.; Hebeler, K.; Machleidt, R.; Roth, R.: "Family of chiral two- plus three-nucleon interactions for accurate nuclear structure studies", Phys. Lett. B 808, 135651, 2020
https://doi.org/10.1016/j.physletb.2020.135651

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