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Configuration-interaction time-dependent density functional theory for nuclear dynamics

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Abstract

The time-dependent density functional theory (TDDFT) is a fundamental framework to describe the nuclear collective time-dependent processes, from small-amplitude collective oscillations to large-amplitude processes such as fission and heavy-ion reactions. However, due to the mean-field approximation, it only includes the one-body dissipation effect and cannot describe the spreading widths of one-body observables.

In this work, a configuration-interaction time-dependent density functional theory (CI-TDDFT) for nuclear dynamics is developed. In this framework, the correlated nuclear many-body wave function is expanded in terms of time-dependent many-particle configurations built from a common set of orthonormal single-particle states. The equations of motion for both the expansion coefficients and the single-particle states are derived self-consistently using the Dirac-Frenkel time-dependent variational principle. This formulation extends conventional time-dependent density functional theory (TDDFT) by incorporating configuration mixing and beyond-mean-field correlations, while preserving energy and particle-number conservation.

As an illustrative application, the method is implemented using the relativistic point-coupling functional PC-PK1 in the particle-hole channel and a monopole pairing interaction in the particleparticle channel, and is applied to the study of isoscalar giant monopole resonance in ^{58}Ni and ^{60}Ni. Numerical tests show that both the total energy and particle number are conserved, with relative deviations within 4×10^{-4} during the time evolution. Compared with conventional TDDFT, CITDDFT yields broader strength distributions for giant monopole resonances while keeping the main peak positions close to those from TDDFT. This broadening is associated with configuration mixing in the valence space and suggests a coupling of the monopole oscillation to additional collective degrees of freedom. These results demonstrate the potential of CI-TDDFT as a quantum, microscopic beyond-mean-field framework for nuclear dynamics.

References

[1] Y. P. Wang, B. Li, D. Vretenar, T. Nikšić, P. W. Zhao, and J. Meng, *Physical Review C*, under review.