From semiempirical models to machine learning: Predicting excitation energies and stellar alpha α-decay half-lives

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Abstract

The prediction of nuclear properties in regions far from stability remains one of the main challenges in nuclear physics and nuclear astrophysics due to the lack of experimental data and the limitations of existing theoretical models. In particular, the characterization of heavy and superheavy nuclei, including their excited states and decay properties under astrophysical conditions, is essential for improving our understanding of nucleosynthesis processes and the limits of nuclear stability. We recently developed a semiempirical excitation-energy-dependent alpha-decay law and incorporated it into a formalism for calculating temperature-dependent stellar alpha-decay rates. The model showed that stellar temperatures can significantly modify alpha-decay half-lives, with most nuclei exhibiting reduced half-lives, while some display longer lifetimes due to the population of isomeric states [1]. Building on this framework, we propose combining traditional nuclear models with machine learning to predict excitation energies and then calculate temperature-dependent alpha-decay half-lives of heavy and superheavy nuclei beyond experimentally accessible regions [2]. Beyond their predictive capability, these models may reveal systematic trends in nuclear structure and alpha-decay behavior, guiding future theoretical developments and experimental investigations while improving the nuclear physics input required for astrophysical nucleosynthesis calculations.

References

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