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The impacts of nuclear reaction uncertainties on explosive nucleosynthesis of core-collapse supernovae

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Massive stars ($> 10M_\odot$) undergo core-collapse supernova explosions at the end of their evolution. These explosions release elements ranging from helium to the iron peak, which are (produced during the stellar evolution) to iron peak elements (synthesized in explosive nucleosynthesis near the supernova core region). Although the explosion mechanism of core-collapse supernovae is not fully understood, 1D spherically symmetric explosion models have been constructed that relatively well reproduce the observed elemental abundances. Such models are ideal to systematically study the impact of nuclear reaction rates on the nucleosynthesis. Some of the nuclear reactions in explosive nucleosynthesis, certain nuclear reactions can be accessed through accelerator experiments, offering the potential to investigate undetermined reaction rates that are important in astrophysics.

We have developed a nucleosynthesis code with Monte-Carlo framework that accounts for the uncertainties in nuclear reaction rates and applied it to processes beyond iron. Given its general applicability, our framework is naturally suited for studying explosive nucleosynthesis in supernovae. In this study, we investigate 1D explosion models using the "PUSH" method, which simulates explosions by mimicking the enhanced neutrino heating observed in multi-dimensional simulations. We focus on nucleosynthesis in progenitors with solar and sub-solar metallicity and metal-poor representatives of masses around $M_{\rm ZAMS} = 16M_\odot$. Detailed post-process nucleosynthesis calculations with Monte Carlo analysis is employed to comprehensively explore the effects of uncertainties in relevant reaction rates. Additionally, we identify "key reaction rates" for explosive nucleosynthesis based on statistical analysis of our Monte Carlo nucleosynthesis calculations.

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