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Trans-Fe elements from Type Ia Supernovae

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A Type Ia supernova (SNIa) marks the catastrophic explosion of a white dwarf in a binary system. These events play a crucial role in galactic chemical evolution and serve as pivotal standardizable candles for measuring cosmic distances, underpinning the discovery of the Universe's accelerated expansion. However, the progenitors of SNIa remain uncertain, introducing challenges to their use in cosmology and nucleosynthesis predictions.

In this work, we present a grid of five models detailing the evolution and nucleosynthesis of slowly merging carbon-oxygen white dwarfs approaching the Chandrasekhar mass. These models test a variety of physics input settings, including accretion rates, nuclear reaction rates, convection parameters, and the composition of the accreted material. During the merger process, as the mass of the primary white dwarf approaches the Chandrasekhar limit, carbon burning is initiated first on the surface before eventually igniting explosively at the center. As a consequence, the ^{22}Ne(α,n)^{25}Mg reaction activates in the outer layers of all models, producing a weak s-process-like abundance pattern, peaking at Kr, overproduced by a factor of $\sim$1000 compared to solar. The trans-Fe elements-enriched outer layer mass varies from 0.05~M$_\odot$ to 0.11~M$_\odot$, depending on the accretion rate. Our explosion simulations of these progenitor models eject significant amount of first-peak elements (e.g., Se, Kr) and light p-nuclei (e.g., ^{74}Se).

Previous theoretical studies found that a similar nucleosynthesis process during the progenitor phase may also occur on the surface of near-Chandrasekhar white dwarfs formed through the accretion of H-rich material via the single-degenerate scenario. Therefore, these results suggest trans-Fe enrichment might be a hallmark of near-Chandrasekhar SNIa ejecta, regardless of the specific progenitor channel, and could provide a new spectral signature distinguishing them from sub-Chandrasekhar explosions.

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