NUCLEOSYNTHESIS DURING FREEZE-OUT EXPANSIONS IN CORE-COLLAPSE SUPERNOVAE

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Abstract

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We identify two basic families of isotopes in the mass range $12 \leqslant A \leqslant 122$ produced during freeze-out expansions near the mass-cut of core-collapse supernovae. The majority of isotopes are classified in the first family, where their mass fraction profile depends on the characteristic phase transition of the freeze-out. The isotopes of the second family include the magic nuclei and their locality, which become nuclear flow hubs and do not sustain any phase transition. We use exponential and power-law adiabatic profiles, and introduce additional non-monotonic profiles to mimic explosion asymmetries and reverse shock nucleosynthesis. We perform reaction rate sensitivity studies to identify nucleosynthesis trends of radioactive trace elements. Non-monotonic profiles involve longer non-equilibrium nucleosynthesis intervals compared to the exponential and power-law profiles, resulting in mass fraction trends and yield distributions which may not be achieved by the monotonic profiles. In addition, we compare the yields of ^{44}Ti and ^{56}Ni produced from post-processing the thermodynamic trajectories from three different core-collapse models – a Cassiopeia A progenitor, a double shock hypernova progenitor, and a rotating 2D explosion – with the yields from the exponential and power-law profiles. Our analysis suggests that radioactive trace elements may be produced by multiple types of freeze-out expansions in core-collapse events, and that

reaction rates in combination with timescale effects for the expansion profile may account for the paucity of ^{44}Ti observed in supernovae remnants and ^{53}Mn in presolar grains.