Nucleosynthesis in Multi-Dimensional Core-Collapse Supernova Explosion Models

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Over the last few years, multi-dimensional simulations of core-collapse supernovae (CCSNe) have become sufficiently mature to study the nucleosynthesis in the innermost CCSN ejecta using self-consistent models. In particular, we already have quite robust explosion models for the low-mass end of the progenitor spectrum, namely for super-AGB progenitors and the lightest iron-core progenitors, which explode readily by the neutrino-driven mechanism with generically low explosion energies of 0.1Bethe and small nickel masses of a few 0.001 solar masses. Multi-dimensional simulations of these events have shown that convective overturn shortly after the onset of the explosion leads to the ejection of neutron-rich bubbles with interesting nucleosynthesis outcomes, notably high production factors for light trans-iron elements from zinc up to strontium and zirconium. Sizeable amounts of ^{48}Ca and ^{60}Fe are also produced in the neutron-rich bubbles. Variations in the electron fraction in these neutrino-processed bubbles, for example by a global asymmetry in the electron neutrino and antineutrino fluxes known as LESA ("Lepton-number Emission Self-sustained Asymmetry"), could even lead to a "weak r-process" in the ejecta from these events. By contrast, the innermost ejecta in more massive stars are more proton-rich according to recent simulations. Few trans-iron elements are made in the early neutrino-processed ejecta aside from some light p-nuclei, although more substantial νp-process nucleosynthesis can occur later during the neutrino-driven wind phase.