Nucleosynthesis in Asymmetric, Core-collapse Supernovae of Massive Stars

Shin-ichiro FUJIMOTO[1], Masaomi ONO, Masa-aki HASHIMOTO[2] and Kei KOTAKE[3]

[1] *National Institute of Technology, Kumamoto College, Kumamoto, Japan*
[2] *Kyushu University, Department of Physics, Fukuoka, Japan*
[3] *Fukuoka University, Department of Physics, Fukuoka, Japan*

E-mail: fuji@kumamoto-nct.ac.jp

(Received Sep. 10, 2016)

We investigate nucleosynthesis in core-collapse supernovae (SNe) of massive stars of 10.8-$40M_\odot$, based on 2D hydrodynamic simulations of the SN explosion. We follow long-term evolution of the explosion over 1s after the core bounce, adopting a neutrino-core model, with which we evaluate the evolution of neutrino luminosities and temperatures. We adopt two sets of parameters for the core model; one results in early explosion of 0.2-0.4s after the bounce and the other later explosion of 0.4-0.6s. We then calculate abundance evolution of the SN ejecta through post-processing calculation using a large nuclear reaction network. We find that for both the early and later explosion cases, the explosion energy, $E_{\rm exp}$, and ejected masses of ^{56}Ni, ^{57}Ni, and ^{44}Ti strongly correlate with the compactness parameter at $2.5M_\odot$. Only for the early explosion case, we well reproduce a correlation of the mass of ^{56}Ni to $E_{\rm exp}$ observed in Type II-Plateau SNe and find two progenitors (~ 20 and $25M_\odot$) whose $E_{\rm exp}$, and the masses of ^{56}Ni and ^{57}Ni are comparable to those in SN1987A.

KEYWORDS: Supernovae, Nucleosynthesis

1. Introduction

Recent study on the evolution of massive stars [1] shows that properties of the progenitors largely change in terms of their main-sequence mass, $M_{\rm ms}$, due to convection and convective burning in a core and a surrounding shell. For more than 100 progenitors [2], spherical simulations from core collapse to SN explosion have been performed with a hydrodynamic code, in which gray-neutrino transport and small nuclear reaction network are taken into account and simplified neutrino-core model is adopted [3]. For the neutrino-core model tuned for a progenitor ($\sim 20M_\odot$) to explode as SN1987A-like, explosion energies, remnant masses, and ejected masses of nuclei have been found to strongly depend on the progenitor mass. We note that the tuned SN1987A-like progenitor explodes at later phase, or > 500ms after the core bounce. Similar but 2D study is conducted by [4] with a hydrodynamic code, in which more elaborate neutrino transport is implemented and properties of neutrinos are self-consistently calculated without a neutrino-core model. They showed that explosion energies, remnant masses, and ejected masses of nuclei have strong mass-dependence as in 1D simulations [3] but correlate with a compactness parameter, $\xi_{2.5} = (M/M_\odot)/(R(M)/1000{\rm km})$, where M is a mass of $2.5M_\odot$ and $R(M)$ is a radius that encloses this mass. Although many progenitors explode at a later phase (> 500ms after the bounce), there is no progenitor that explode as SN1987A-like, not as in 1D case [3].

In the present study, we examine nucleosynthesis during SN explosion of about 20 progenitors, based on 2D hydrodynamic simulations of the explosion. employing with a simplified