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Supernova Nucleosynthesis with Neutrino Processes: Dependence of Fluorine abundance on Stellar Mass, Explosion Energy and Metallicity

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Abstract. We investigate the effects of neutrino-nucleus interactions on the production of Fluorine during normal supernovae and hypernovae, and discuss stellar mass, metallicity and explosion energy dependence of [F/Fe,Ne,O]. We find the clear trend of [F/Fe,O,Ne] with stellar mass and explosion energy, while no clear trend with metallicity. This trend of [F/O] can be used to constrain the contributed stellar mass by comparing with the observational abundance.

Keywords. neutrinos, nuclear reactions, nucleosynthesis, abundances, supernova: general

1. Introduction

The interaction of the neutrinos with matter and the effects on the nucleosynthesis have only been discussed for a few models (e.g., Woosley *et al.* 1990; Woosley & Weaver 1995; Yoshida *et al.* 2004; Heger *et al.* 2005; Yoshida *et al.* 2008; Nakamura *et al.* 2010). The ν-process does not affect the yields of major elements such as Fe and α elements, but it will increase those of some elements such as B, F, K, Sc, V, and Mn. In this paper, we focus on the effect of the ν-process on F during normal supernova (SN) and hypernova (HN) explosions, and discuss stellar mass, metallicity, and explosion energy dependence of [F/Fe,O,Ne].

2. Model & Method

We calculate the nucleosynthesis for core-collapse SNe with progenitor masses of $M =$ 15, 25, and 50 $M_\odot$ and initial metallicities of $Z = 0$, 0.004, and 0.02 for normal SNe and HNe. The explosion energy is set to be 1×10^{51} ergs for normal SNe, 10×10^{51} and 40×10^{51} ergs for HNe with $M_{\rm MS} = 25$ and 50 $M_\odot$, respectively. For normal SNe, the mass cut is set to meet the observed iron mass of 0.07 $M_\odot$. For HNe, the parameters of mixing fallback models are determined to get [O/Fe] = 0.5. The nuclear network includes 809 species up to ^{121}Pd (Izutani *et al.* 2009, Izutani & Umeda 2010). We adopt the ν-process up to ^{80}Kr as in Yoshida *et al.* (2008). The neutrino luminosity is assumed to be uniformly partitioned among the neutrino flavors, and decrease exponentially in time with a timescale of 3 s. The total neutrino energy is set to be $E_\nu = 3$ and 9×10^{53} ergs. The neutrino energy spectra are assumed to be Fermi-Dirac distributions with zero chemical potentials. The temperatures of $\nu_{\mu,\tau}$, $\bar{\nu}_{\mu,\tau}$ and $\nu_{\rm e}$, $\bar{\nu}_{\rm e}$ are set to be $T_\nu = 6$ and 4 MeV/k, respectively.

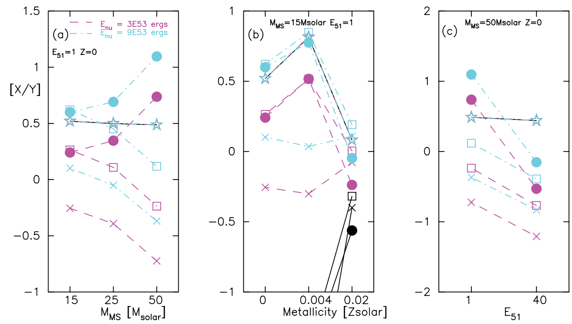

Figure 1. [F/Fe,O,Ne] (filled circles, open squares, and crosses) and [Ne/O] (stars) in the models without ν-processes (black solid lines), with ν-processes of $E_\nu = 3$ and 9×10^{53} ergs (magenta dashed lines and cyan dot-dashed lines). (a) Stellar mass dependence ([X/Y] in the models with $M_{\rm MS} = 15, 25, 50\ M_\odot$, $Z = 0$ and $E_{51} = 1$) (b) Metallicity dependence ([X/Y] in the models with $Z = 0, 0.004, 0.02$, $M_{\rm MS} = 15\ M_\odot$ and $E_{51} = 1$) (c) E_{51} dependence ([X/Y] in the models with $M_{\rm MS} = 50\ M_\odot$, $Z = 0$, $E_{51} = 1$ and 40.

3. Results and Discussion

With the ν-process, ^{19}F is produced in the O/Ne-enriched region through ^{20}Ne(ν, ν'p)^{19}F. Figure 1 (a) shows mass dependence of [F/Fe,O,Ne] and [Ne/O] in Z=0 star SNe. [Ne/O] is about 0.5 in these models. Without the ν-processes, [F/Fe,O,Ne] are ~ -5. With the ν-processes, [F/Fe,O,Ne] range from -1 to 1. [F/Fe] is higher for more massive stars because of the larger O/Ne-enriched region. By contrast, [F/O,Ne] are lower for more massive stars because the radius of the O/Ne-enriched region is larger, and the neutrino flux becomes smaller. Figure 1(b) shows metallicity dependence of [F/Fe,O,Ne] and [Ne/O] in 15 $M_\odot$ SNe. [Ne/O] is different between these models, though it is not clear whether this trend of [Ne/O] is due to metallicity or not. With the ν-processes, the F yield is increased by a factor of ~ 10 and 1000 for $Z = 0.02$ and 0, respectively. There is no clear trend of [F/Fe,O,Ne] with metallicity. Figure 1 (c) shows $E_{\rm exp}$ dependence of [F/Fe,O,Ne] and [Ne/O] in Z=0 50$M_\odot$ explosions. [Ne/O] is about 0.5 in these models. With the ν-processes, [F/Fe,O,Ne] range from -1 to 1. [F/O,Ne] are lower in the HN model. In the HN model, the shock wave reaches the O/Ne-enriched region earlier, and the region expands earlier, which causes smaller neutrino flux. [F/Fe] is also lower in the HN model, which is caused by both the larger mass of Fe and the smaller mass of F in the HN model.

It is true that ν-cross-sections contain some uncertainties. Nevertheless, the trend of [F/Fe,O,Ne] discussed above is robust for these uncertainties. For the galactic chemical evolution calculation using these yields, see Kobayashi *et al.* (2011).

References

Heger, A., Kolbe, E., Haxton, W. C., *et al.* 2005, *Phys. Lett. B.* 606, 258

Izutani, N., Umeda, H., & Tominaga, N. 2009, *ApJ*, 692, 1517

Izutani, N. & Umeda, H. 2010, *ApJ*, 720, L1

Kobayashi, C., Izutani, N., Karakas, A. I., Yoshida, T., Yong, D., & Umeda, H. 2011, *ApJ*, 739, L57

Nakamura, K., Yoshida, T., Shigeyama, T., & Kajino, T. 2010, *ApJ*, 718, L137

Umeda, H. & Nomoto, K., 2002, *ApJ*, 565, 385

Woosley, S. E., Hartmann, D. H., Hoffman, R. D., & Haxton, W. C. 1990, *ApJ*, 356, 272

Woosley, S. E. & Weaver, T. A. 1995, *ApJS*, 101, 181

Yoshida, T., Terasawa, M., Kajino, T., & Sumiyoshi, K. 2004 *ApJ*, 600, 204

Yoshida, T., Umeda, H., & Nomoto, K. 2008, *ApJ*, 672, 1043