Light Element Synthesis in Core-collapse Supernovae

NAKAMURA, Ko (NAOJ)

YOSHIDA, Takashi, SHIGEYAMA, Toshikazu (University of Tokyo)

KAJINO, Toshitaka (NAOJ / Graduate University for Advanced Studies)

Most of elements lighter than iron are synthesized via thermonuclear burning reactions in stars. Light-element isotopes such as Li, Be, and B (LiBeB) are, however, not produced in stellar burning phase because of the absence of stable nuclei with mass number of 8 and the fragility of ^{7}Li against hot proton. They are known to be produced from some cosmological and astrophysical processes: ^{7}Li from big bang nucleosynthesis; ^{7}Li and ^{11}B from asymptotic giant branch (AGB) stars and novae; and all stable isotopes of LiBeB from Galactic cosmicray (CR) nucleosynthesis. Another possible candidate is the neutrino-induced nucleosynthesis in core-collapse supernovae, where a fraction of neutrinos emitted form a proto-neutron star would interact with stellar materials and produce ^{11}B in inner C-rich shells and ^{7}Li in He-rich envelopes (Figure 1).

The supernova neutrino process is necessary to account for the high ^{11}B-to-^{10}B ratio observed in meteoritres. We investigated the neutrino process in Type Ic supernovae (SNe Ic), which should be terminal explosion of massive stars without H and He envelopes, to evaluate accurately the contribution of the neutrino process to Galactic Li(Be)B. Previous studies were limited in Type II explosions and this is the first report on the neutrino process in SNe Ic.

We consider a very energetic explosion of a 15 $M_{\odot}$ C/O star with the explosion energy $E_{ex} = 3 \times 10^{52}$ erg corresponding to SN 1998bw. The explosion is simulated with 1-dimensional special-relativistic hydrodynamic code and nucleosynthesis is calculated as a postprocess. We assume a supernova neutrino model that neutrino luminosity decreases exponentially with a time scale of 3 s and that the neutrino temperature of each species does not change with time.

Our results[1] show that light elements are produced via the neutrino process both in the innermost region and in the outer envelope. In the innermost region, ^{4}He coming from α-rich freezeout is excited by neutrinos then decays to ^{3}H and ^{3}He, followed by α-capture reactions to produce ^{7}Li and ^{7}Be. In the outer layers, neutral current reactions of neutrinos produce ^{11}B (and ^{11}C). SNe Ic can produce LiBeB also by spallation reactions[2]. Resulting yield of ^{11}B from our SN 1998bw model with total neutrino energy of 3×10^{53} erg is about $1.6 \times 10^{-6} M_{\odot}$, which is comparable to the value estimated from typical SNe II model[3].

However, the frequency of highly energetic SNe Ic is quite low and borons in meteorites should be dominated by those that originated from SNe II and Galactic CRs. Contribution from SNe Ic might be outstanding in metaldeficient stars because an SN Ic progenitor is surrounded by its wind material and the light elements produced in the explosion are likely to be inherited directly by next generations of stars, which would show high BeB abundances as a Be-rich halo star HD106038 [4].

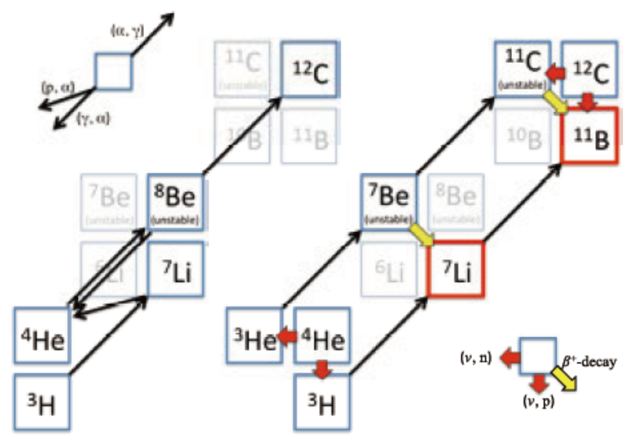

Figure 1: Nuclear reaction chain associated with LiBeB. *left*: Reactions in H and He burning. *right*: Neutrino-induced reactions producing ^{7}Li and ^{11}B.

References

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[2] Nakamura, K., Shigeyama, T.: 2004, *ApJ*, **610**, 888.
[3] Rauscher, T., et al.: 2002, *ApJ*, **576**, 323.
[4] Smiljanic, R., et al.: 2008, *MNRAS*, **385**, L93.