

Nuclear Cosmochronometer for Supernova Neutrino process

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Short-lived radioisotopes with half-lives of 0.1-10 Myr are known as nuclear cosmochronometers to evaluate the passing time from a nucleosynthesis event such as s-process in an AGB star or r-process to the solar system formation (SSF). Neutron rich short-lived radioisotopes such as ¹²⁹I and ²⁴⁴Pu, which were predominantly produced by the r process, have been studied in order to evaluate the age of the last supernova (SN) around the solar system. However, the recent studies show neutron star mergers are a candidate for the r process. Thus, there is no robust cosmic clock for the last SN before the SSF.

We focus our attention on neutron-deficient short-lived radioisotopes, in particular, which may be produced by neutrino-process. This is because the neutrino process can occur only in core-collapse SNe. In an early phase, a huge number of neutrinos are emitted from a proto neutron star formed in the center of a massive star. Some neutrinos interact with preexisting isotopes and thereby produce rare neutron deficient isotopes such as ¹³⁸La, and ¹⁸⁰Ta as well as ⁷Li and ¹¹B.

There are five neutrino-deficient short-lived isotopes of ⁵³Mn, ⁹²Nb, ⁹⁷Tc, ⁹⁸Tc, ¹⁴⁶Sm. We have proposed the neutrino-process origin for unstable isotopes for ⁹²Nb ($T_{1/2}=35$ Myr) [1] and ⁹⁸Tc ($T_{1/2}=4.2$ Myr) [2]. We have calculated neutrino-induced reaction cross section involved using the QRPA model and statistical model. We have calculated the neutrino-isotope abundances in SNe using SN models. In the case of ⁹²Nb, its initial abundance at SSF could be reproduced by the later input model. It is found that it is possible to explain the origin of ⁹²Nb by the SN neutrino process. In contrast, for ⁹⁸Tc, the upper limit for the initial abundance was reported. The calculated result is consistent with the observed upper limit. We discuss possible age for the last SN for various neutrino process chronometers.

[1] T. Hayakawa et al. *Astrophys. J.* 779, L9 (2013).

[2] T. Hayakawa et al. *Phys. Rev. Lett.* 121, 102701 (2018).