R-process Nucleosynthesis in Core-collapse Supernova Explosions and Binary Neutron Star Mergers

T. Suzuki[a,b], R. Shibagaki[b], T. Kajino[b,c], T. Yoshida[d] and T. Otsuka[e,f,]

[a]Nihon University, [b]National Astronomical Observatory of Japan, [c]Department of Physics, the University of Tokyo, [d]Department of Astronomy, the University of Tokyo, [e]RIKEN, Nishina Center, [f]Center for Nuclear Study, the University of Tokyo

R-process nucleosynthesis in core-collapse supernova explosions (CCSNe) and binary neutron star mergers (NSMs) are studied using new β-decay half-lives for the waiting-point nuclei obtained by shell-model calculations. Both the CCSNe and binary NSMs are promising candidates for the sites of the r-process. The evidence for binary NSMs was obtained by a recent observation of the gravitational wave; GW170817 [1].

Beta decay rates for exotic nuclei with neutron magic number of N=126 are evaluated up to Z=78 by including the contributions from both the Gamow-Teller and first-forbidden transitions. The half-lives obtained prove to be short compared to a standard finite-range-droplet model (FRDM[2]), in particular near ^{208}Pb due to the effects of the first-forbidden transitions [3, 4].

We here investigate how the change of β-decay half lives affects the r-process nucleoasynthesis. The element abundances for the r-process in neutrino-driven wind CCSNe, magnethydrodynamic jet CCSNe and binary NSMs are obtained up to the third peak as well as beyond the peak region up to thorium and uranium. The position of the third peak is found to be shifted toward a higher mass region in both CCSNe and NSMs. We find that thorium and uranium elements are produced more with the shorter shell-model half-lives and their abundances come closer to the observed values in CCSNe. In case of binary NSMs, thorium and uranium are produced as much as consistent with the observed values independent of the half-lives. This suggests that NSMs are promissing robust r-process sites for producing very heavy elements such as thorium and uranium.

References

[1] B. P. Abbott *et al.*, (LIGO-Virgo Collaboration), Phys. Rev. Lett. 119, 161101 (2017).

[2] P. Moller *et al.*, At. Data and Nucl. Data Tables 66, 131 (1997).

[3] T. Suzuki *et al.*, Phys. Rev. C 85, 015802 (2012).

[4] Q. Zhi *et al.*, Phys. Rev, C 87, 025803 (2013).