Impact of RIB Science and Neutrino Physics on Merger, Supernova, and Big- Bang Nucleosynthesis

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Abstract

Supernova (SN) SN1987A and binary neutron star merger (NSM) GW170817/SSS17a were the celestial events of the century that opened new frontiers of neutrino astronomy and multi-messenger astrophysics. The RIB science combined with these new fields would make a Renaissance in nuclear physics to seek for the origin of atomic nuclides in the universe because many abundant heavy elements are produced in explosive nucleosynthesis where the short-lived radioactive nuclei play the important roles.

Following GW and GRB detection from GW170817/SSS17a, the optical and near-infrared afterglow was observed. Although no specific r-process element was identified, the total energy release is consistent with theoretical prediction of radiative decays of r-process nuclei. NSM is a possible explanation for the solar-system r-process elements, but it could not contribute to the early Galaxy. SN is a viable candidate for the r-process because it explains the “universality” of the observed elemental abundance in metal-poor stars. In order to solve this twisted problem, we carried out r-process nucleosynthesis calculations in both SNe and NSMs, where the (n,γ), β-decay and fission reactions of neutron-rich radioactive nuclei affect strongly the final abundance [1]. Applying these results to the Galactic chemo-dynamical evolution, we find a novel solution that SNe dominated in the early Galaxy to enrich r-elements, while the NSMs have arrived later [2-4]. We will discuss important RIB physics in this scenario of cosmic and Galactic evolution.

We will also discuss the impact of SN nucleosynthesis on the physics of neutrino oscillations. The elements at A = 80-100 originate from many processes such as r-, s-, rp-, γ-, ν-, νp-processes. We find that νp-process operates strongly with amounts

of free neutrons being supplied even on proton-rich (Ye>0.5) condition via p(ν,e+)n reactions when one takes account of the effects of collective neutrino oscillations [6]. Reaction flows can reach the production of abundant p-nuclei like 94Mo, 96Ru, etc. This nucleosynthetic method turns out to be a unique probe indicating still unknown neutrino-mass hierarchy.

There is another long-standing cosmological problem of Li overproduction in the standard Big-Bang Nucleosynthesis (BBN) model. Much efforts have ever been made to measure the precise nuclear reaction cross sections to affect the BBN, which virtually did not solve the cosmic Li problem. We try to solve this problem by taking account of the fluctuations of primordial magnetic field (PMF) which is constraint with CMB anisotropies. We find that the PMF fluctuations lead to inhomogeneous radiation energy density such that the BBN goes on under the different photon temperatures [7]. This effect mimics non-Maxwellian baryonic energy distribution function such as Tsallis statistics, and Li overproduction is remarkably reduced. We will discuss the roles of RIB reactions in BBN whose significance applies to SN nucleosynthesis.

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