Conference on Neutrino and Nuclear Physics (CNNP2020) Arabella Hotel and Spa, South Africa, 24-28 February 2020

Contribution ID: **77** Type: **Invited Talk**

Roles of Neutrinos in Explosive Nucleosynthesis of Supernovae and Neutron-Star Mergers and Cosmic Evolution

Wednesday, 26 February 2020 08:30 (30 minutes)

The big-bang universe, supernovae (SNe), collapsars and binary neutron-star mergers (NSMs) are the viable celestial sources of "multi-messengers". These messengers are neutrinos for weak force, gravitational waves for gravity, photons for electromagnetism, and atomic nuclei for strong nuclear force [1]. Their detection takes the keys to solve still unanswered questions such as mass hierarchy of neutrinos [2], overproduction of big-bang lithium [3], the origin of p-nuclei [4], and the origin of r-process elements [1,5]. We will discuss the roles of neutrinos and radioactive nuclei for solving these problems.
Still unknown neutrino mass and oscillations are particularly important to answer the fundamental question why we need to go beyond the standard theory of elementary particles and fields. We will, first, discuss cosmological background neutrinos and fluctuations of primordial magnetic fields in order to solve overproduction problem of primordial big-bang lithium [3]. The relic SN neutrinos also are the energetic component of cosmic background neutrinos. We will propose a method how to constrain the neutrino mass hierarchy and EOS of proto-neutron stars in the proposed HK project of detecting these energetic neutrinos [6].
A huge flux of neutrinos is emitted from proto-neutron stars or accretion disks formed in SNe, collapsars and binary NSMs. The collective flavor oscillation due to the neutrino self-interactions is presumed to occur in the deepest region inside the iron-core, while the MSW high-density resonance occurs near the bottom of He/C-layer. The light mass nuclei, 7Li and 11B, and the intermediate-to-heavy mass nuclei, 19F, 50V, 53Mn, 92Nb, 98Tc, 138La and 180Ta, are respectively produced in outer He/C-layer and inner O-Ne-Mg-layer exposed to the intense neutrino flux (-process) [2]. The intermediate mass p-nuclei, 74Se, 78Kr, 84Sr, 74Se, 92,94Mo and 96,98Ru (p-process) [4], and r-process nuclei [1] are produced in the iron-core. Therefore, nucleosynthesis of 7Li and 11B is affected by both collective and MSW effects, however all the other intermediate-to-heavy mass nuclei are affected by the collective oscillation alone, being almost free from MSW effect. We will, secondly, discuss how differently these nucleosynthetic products depend on each of collective or MSW neutrino oscillation effect, and will propose how to distinguish these two effects from each other [2].
Finally, we will discuss the origin of r-process nucleosynthesis to understand the cosmic evolutionary history of each contribution from SN, collapsar and binary NSM [5]. We here discuss the roles of GW detection and spectroscopic astronomical observation of atomic nuclei as well as nuclear experiments of radioactive nuclei [1].

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Session Classification: Invited Talks

Track Classification: Invited Talk