Nuclear Weak Interactions and Supernova Neutrino- and R-Processes

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Recent progress in nuclear structure physics is expected to contribute to the understanding of explosive nucleosyntheses in Supernovae (SNe). Accumulated knowledge on the nuclear structure of weak transitions (i.e. GT, spin-dipole and higher mutipole transitions) provides critical information to understand neutrino-process nucleosynthesis in core-collapse SNe. The advancement of radioactive nuclear beam physics also helps understand still unknown astrophysical origin of r-proces nucleosynthesis.

We first discuss our recent theoretical studies of nuclear weak-interactions and neutrino-nucleus cross sections on 4He, 12C, 40Ar, 56Fe, 56Ni, 138La, 180Ta, and others. We then discuss application to neutrino-process nucleosynthesis in SNe. The light element (LiBeB isotopes) synthesis in carbon-rich He-layer is strongly affected by the MSW matter-effect of neutrino oscillation, while the heavier element (FeCoNi isotopes, 138La, 180Ta, etc.) synthesis in the inner Si- and ONeMg-layers are almost free from the MSW effect but subject to the flavor-mixing effect due to the neutrino self-interactions. We present how to determine the unknown neutrino-oscillation parameters from nucleosynthetic studies of the observed light-to-heavy element abundances in neutrino-process by taking account of both MSW- and self-interaction effects on SN neutrinos. We also discuss nuclear physics uncertainties.

We secondly discuss r-process nucleosynthesis in different models of explosion mechanisms, i.e. neutrino-heated supernova winds, binary neutron-star mergers, and magneto-hydrodynamic explosion of gamma-ray bursts (GRBs). In particular among them, we discuss GRB r-process. Very peculiar abundance pattern has recently been discovered in most metal-deficient oldest halo stars HE 1327-2326 and HE 0107-5240 with [Fe/H] = -5.4 and -5.3, respectively. We will show that our GRB nucleosynthesis model of black hole forming Hypernovae which are associated with accretion disks can explain the peculiar abundance pattern including r-process elements.