Neutrino nucleosynthesis of light elements in supernovae

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During a supernova explosion, a huge amount of neutrinos (about the number of 10^{58}) are emitted from a proto-neutron star. These neutrinos interact with nuclei in exploding stellar envelope and some species of nuclei are synthesized despite very small cross sections of neutrino-nucleus reactions. This synthesis process is called the nu-process. The nu-process in supernovae is one of the main production processes of light elements Li, Be, and B. We study light element synthesis through the nu-process in supernovae.

The neutrino-nucleus reaction cross sections of ^{4}He and ^{12}C are evaluated using new shell model Hamiltonians. Branching ratios of various decay channels are also calculated to evaluate the yields of Li, Be, and B. Thermal evolution of a supernova explosion corresponding to SN 1987A is numerically proceeded. Explosive nucleosynthesis with the nu-process of the supernova is calculated using a nuclear reaction network consisting of 291 species of nuclei. The neutrino energy spectra at the neutrino sphere are assumed to follow Fermi-Dirac distributions with zero-chemical potential. As a standard model of this study, the neutrino temperatures are assumed to be 4 MeV, 4 MeV, and 6 MeV for e-neutrinos, e-antineutrinos, and other flavor neutrinos and antineutrinos, and the energy released by the neutrinos is 3×10^{53} erg.

The yields of ^{7}Li and ^{11}B are obtained at a level of 10^{-7} solar mass. The ^{10}B yield is smaller by three orders of magnitude. The yields of ^{6}Li, ^{9}Be, and the radioactive nucleus ^{10}Be are found at a level of 10^{-11} solar mass. These elements are mainly produced through neutral-current neutrino reactions in the He/C layer and O/C layer of the star. The contribution from the charge-exchange reactions is much smaller. The light element yields depend on the neutrino temperatures and the energy released by the neutrinos. Therefore, the supernova contribution of ^{11}B in Galactic chemical evolution models and observations of metal-poor stars constrains the neutrino temperatures. The temperatures of mu- and tau-neutrinos and antineutrinos are constrained from the supernova contribution of ^{11}B in Galactic chemical evolution models to be in the range 4.5 MeV to 6.4 MeV. Neutrino oscillations change flavors of the neutrinos emitted from the proto-neutron star in the O/C layers or the He/C layer in the star. This flavor transition changes the neutrino energy spectra in the He/C layer, especially, the average energies of e-neutrinos and antineutrinos increase. As a result, the contribution from charge-exchange reactions becomes large. The light element nucleosynthesis is calculated including the effects of neutrino oscillations with the LMA solutions. The neutrino oscillation parameters, mass hierarchy and mixing angle θ_{13}, are parameterized. The increase in the ^{7}Li and ^{11}B yields due to the neutrino oscillations and the dependence of the yields on the oscillation parameters are demonstrated.