Supernova Nucleosynthesis Enhanced by Collective Neutrino Oscillations

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Neutrinos are produced inside high energy astrophysical sites such as core-collapse supernovae, neutron star mergers and the early universe. Neutrino spectra can be affected by inner materials and neutrino themselves. Therefore, we can reveal properties of astrophysical phenomena by observing emitted neutrinos.

In core-collapse supernovae, energetic neutrinos are emitted from a proto-neutron star after the core-bounce. Non-linear neutrino flavor transitions called "collective neutrino oscillations" [1] are induced by coherent scatterings of self-interacting neutrinos outside the proto-neutron star. Collective neutrino oscillations transform the spectra of all neutrino species. Such modified neutrino spectra could change reaction rates of electron antineutrino absorptions on free protons, which is expected to affect νp process nucleosynthesis [2]. However, contributions from neutrino flavor transitions on such nucleosynthesis are still unknown.

In this work [3], we study the impact of collective neutrino oscillations on the νp process nucleosynthesis by combining realistic three flavor multiangle simulations with network calculations. Fig. 1 shows antineutrino spectra after collective neutrino oscillations. The energetic electron antineutrinos are produced in normal neutrino mass hierarchy (Fig. 1a). On the other hand, flavor transitions are highly suppressed owing to multiangle effects in inverted neutrino mass hierarchy (Fig. 1b). As shown in Fig. 2, the abundances of p-nuclei are enhanced by collective neutrino oscillations up to 10^4 times in normal mass hierarchy, which reflects the increased $\bar{\nu}_e$ flux in Fig. 1a. Our results imply the necessity of collective neutrino oscillations for the precise nucleosynthesis in neutrino-driven winds and also help understand the origin of solar-system isotopic abundances of molybdenum 92, 94 and ruthenium 96, 98.

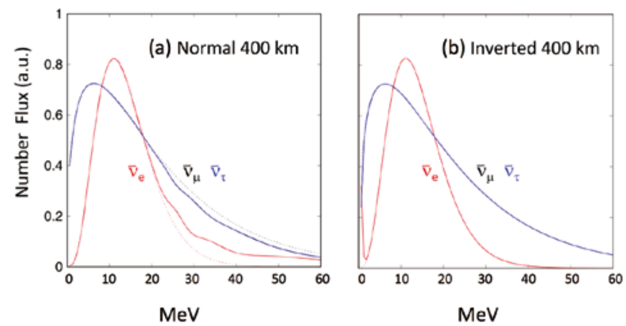

Figure 1: Antineutrino spectra after collective neutrino oscillations. Fig. 1a(b) represents the case of normal (inverted) neutrino mass hierarchy, respectively. The dotted lines are corresponding to initial spectra.

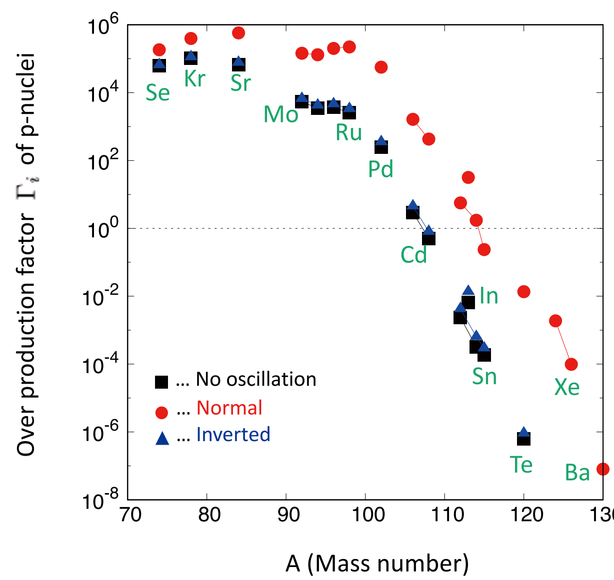

Figure 2: Nuclear abundances of p-nuclei (^{74}Sr, ^{78}Kr, ..).

References

[1] Duan, H., et al.: 2006, *Phys. Rev. D*, **74**, 105014.
[2] Wanajo, S.: 2006, *APJ*, **647**, 1323.
[3] Sasaki, H., et al.: 2017, *Phys. Rev. D*, **96**, 043013.