Neutrino oscillation and expected event rate of supernova neutrinos in adiabatic explosion model

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There are a lot of problems concerning to the mechanism of core-collapsed supernova explosions and supernova neutrinos[1]. Since 99% of the gravitational energy of the collapsed core is released as neutrinos. Most of neutrino oscillation parameters have been determined by the various neutrino experiments. However, it is still very difficult to determine three neutrino oscillation parameters of the mass difference between 1–3 mass eigenstates Δm^2_{13}, the mixing angle θ_{13}, and the CP violation phase δ[2]. It is one of the most important research topics of particle physics to determine these parameter values, and it is expected that the neutrinos are important keys to solve how supernova explosions succeed.

We calculate the supernova in adiabatic explosion model using an implicit Lagrangian code for general relativistic spherical hydrodynamics[3,4]. The numerical tables of Shen's equation of state (EOS) and Timmes's EOS are adopted for the high and low density matters in this code, respectively. We solve the time evolution of the neutrino wave function along the density profile of our result, and we obtains survival probabilities of the neutrinos. The neutrinos change their flavors at resonance of neutrino oscillations, and the shock propagation influences the resonance. In the case of the normal hierarchy (the inverted hierarchy), the survival probabilities of ν_e ($\bar{\nu}_e$) are influenced by the shock wave[5]. Using these survival probabilities, we obtain the energy spectra of the neutrinos passed through the exploding supernova. We calculate expected event rates of the supernova neutrinos with Super-Kamiokande (SK) and SNO [4].

The expected event rates depend on θ_{13}, and the influence of the shock wave appears when $\sin^2 2\theta_{13}$ is larger than 10^{-3}. The neutrino signals for the shock propagation is decreased compared with the case without shock. We define time-dependent ratio of the events of high-energy to low-energy neutrinos,

$$\mathrm{Rx} = \frac{\text{the number of high-energy neutrinos}}{\text{the number of low-energy neutrinos}} \qquad (1)$$

where x refers to SK or SNO. The time-dependent ratio shows clearer signal of the shock propagation that exhibits remarkable decrease by at most factor ~2 for $\bar{\nu}_e$ in inverted hierarchy, whereas it exhibits smaller change by ~10% for ν_e in normal hierarchy (Figure 1). Both ratios R_{SK} and R_{SNO} increase with $\sin^2 2\theta_{13}$. For a given θ_{13}, the ratios with shock are smaller than the ratios without the shock. Therefore, observing time-dependent ratio of the neutrino events thus would provide a piece of very useful information to constrain θ_{13} and the mass hierarchy, and eventually help understanding the propagation how the shock propagates inside the star.

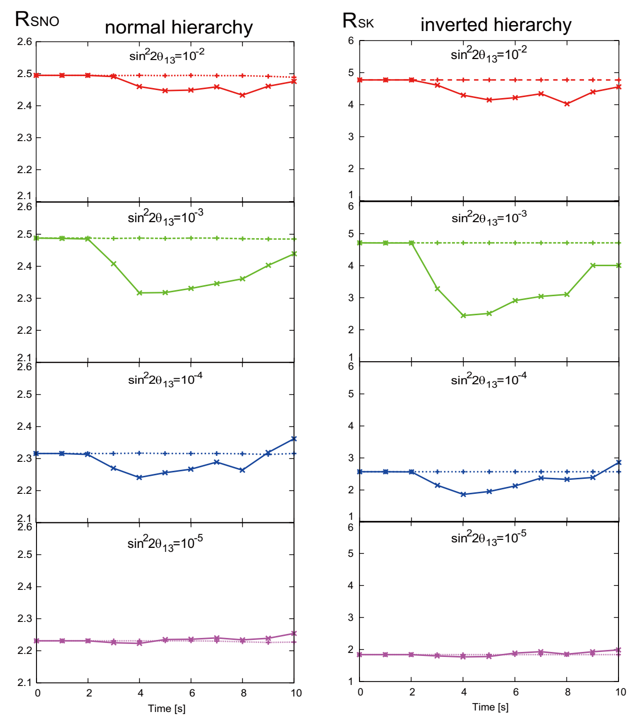

Figure 1: Left panels are R_{SNO} in the normal hierarchy, and right panels are R_{SK} in the inverted hierarchy for $\sin^2 2\theta_{13} = 10^{-2}, 10^{-3}, 10^{-4}$ and 10^{-5} from top to bottom. Solid and dashed lines are the calculated results with and without shock wave, respectively.

References

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