Supernova Relic Neutrinos and the Supernova Rate Problem: Analysis of Uncertainties and the Role of Failed Supernovae

MATHEWS, Grant J. (University of Notre Dame)
HIDAKA, Jun (Meisei University)
KAJINO, Toshitaka (NAOJ/University of Tokyo)
SUZUKI, Jyutaro (NAOJ)

We have investigated [1] the possibility of detecting the various contributions to the supernova relic neutrino background in a 10^6 ton next-generation water Čerenkov detector such as the proposed Hyper-Kamiokande. Massive stars ($M \geq 8\,M_\odot$) culminate their evolution as core collapse supernovae (CC-SNe). Such supernovae are unique sources for all three flavors of energetic neutrinos.

Neutrinos emerge from deep within the interior of core collapse supernovae. As such, supernova neutrinos have the potential to provide information regarding the physical processes that take place inside the star. The emitted neutrinos can almost freely stream from the time of the early galaxy formation epoch until the present time without absorption in the intergalactic material. Hence, the detection of this diffuse background of accumulated neutrinos can be used to study the supernova history from the beginning of galaxy formation [1,2] and also provide information on neutrino properties such as flavor oscillations and/or the neutrino temperatures produced in supernova explosions.

We analyzed prospects for measuring the average neutrino temperatures and also the prospect of solving the disparity between the supernova rate inferred from the cosmic star formation rate and that directly observed [2]. Figure 1 shows an example of the predicted neutrino spectrum in the case that a large population of faint black-hole forming supernovae are needed to explain the supernova rate problem [1]. Figure 2 illustrates how one might determine the average electron anti-neutrino temperature from the detected positron event rate. This figure shows the ratio of the event rate at the observed spectrum peak to the rate at 25 MeV. There is a very strong correlation between this ratio and neutrino temperature that characterizes the different representative supernova models identified. Even in different neutrino oscillation cases the relationship between characteristic neutrino temperature from the supernova models and this ratio is quite robust.

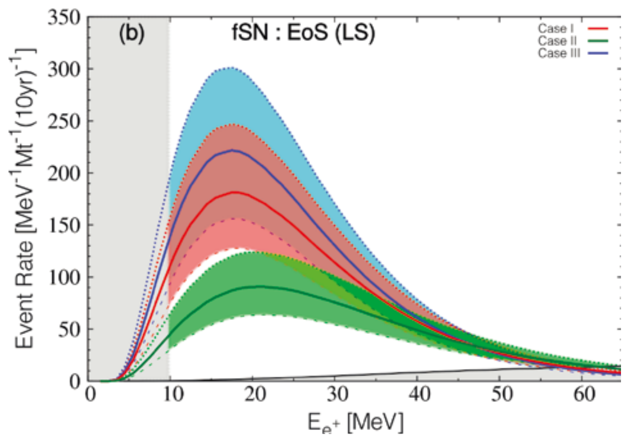

Figure 1: Example of the predicted e^+ energy spectra from relic neutrinos as a function of e^+ energy where $E_\nu = E_{e^+} + 1.3$ MeV. In this case failed fSNe account for a factor of two difference between supernova rate deduced from the massive SFR and the observed supernova rate. Different bands correspond to different neutrino oscillation scenarios. Grey areas denote the backgrounds from terrestrial reactors and atmospheric neutrinos.

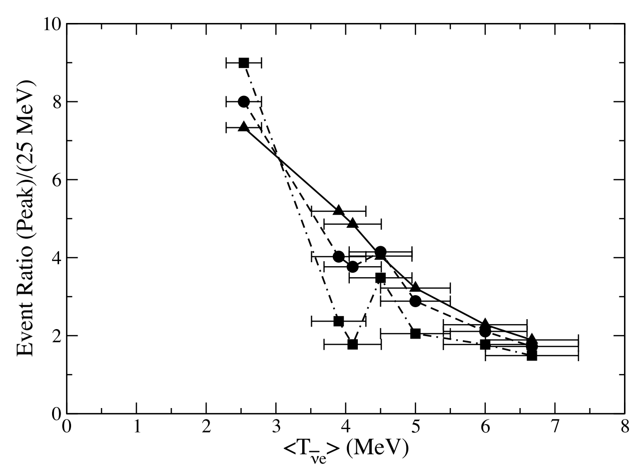

Figure 2: Sensitivity or the average neutrino temperature ratio of events at the observed positron peak to events with a positron energy of 25 MeV, corresponding to the 7 fiducial SN collapse models studied in [1].

References

[1] Mathews, G. J., et al.: 2014, *ApJ*, **790**, 115.
[2] Horiuchi, S., et al.: 2011, *ApJ*, **738**, 154.