

# Neutrinos from Presupernova Stars

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Some evolved massive stars such as Betelgeuse and Antares are located at the distance of hundreds parsec. When such a star explodes as a supernova, neutrino events will be observed by current and future neutrino detectors even before the supernova explosion, i.e., the neutrinos from the presupernova star will be detected. The neutrino event rate in neutrino detectors during silicon burning of massive stars has been evaluated by considering neutrino emission by pair-neutrino process (Odzywolek et al. 2004). Recently, detailed studies on neutrino events from presupernova stars have been carried out using the evolution data of massive stars from silicon burning (e.g., Kato et al. 2015, Asakura et al. 2016, Yoshida et al. 2016, Kato et al. 2017).

We investigate the evolution of the neutrino spectra from the silicon burning until the core-collapse of 12, 15, and 20 solar-mass stars. Then, we evaluate the neutrino events by current neutrino detectors, KamLAND and Super-Kamiokande, and by future neutrino detectors, JUNO, Hyper-Kamiokande, and DUNE. We discuss the possibility of the observations of stellar interior just before the supernova explosions using the time variation of neutrino events from the presupernova stars (Yoshida et al. 2016).

We evaluate the inverse beta-decay events by KamLAND before a supernova explosion. The event number is expected to be 4-14 for seven days before the supernova. The variation is mainly due to the progenitor mass and neutrino mass hierarchy. We also evaluate the supernova alarm time using the presupernova neutrino events of KamLAND. The expected alarm time for a supernova explosion is 3.5-18 hours and less than 3.6 hours for the normal and inverted mass hierarchies, respectively. We expect that earlier supernova alarm is possible in future neutrino detector JUNO. The time variation of the neutrino events per unit time can be a good indicator for observing stellar interior just before the supernova explosion. The expected neutrino events per one hour by JUNO usually increase with time. However, we also expect the reduction and a minimum at about ten hours before the explosion in the 15 solar-mass star model. This reduction corresponds to the ignition of the oxygen shell burning. Thus, the time variation of the neutrino events would reveal the stellar interior and burning processes just before the supernova explosion.

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