Thermal Effects on (Anti)Neutrino Emission from Nuclear Processes in Pre-Supernova Stars

A.A. Dzhioev[1], **A.V. Yudin**[2], **N.V. Dunina-Barkovskaya** [2], **A.I. Vdovin**[1]

[1]Bogoliubov Laboratory of Theoretical Physics, 141980, Dubna, Russia
[2]National Research Center Kurchatov Institute, 123182, Moscow, Russia

Accurate estimates of (anti)neutrino spectra and luminosities are crucial for assessing the possibility of detecting neutrinos from pre-supernova stars. Using the thermal quasiparticle random-phase approximation method, we investigate the influence of nuclear temperature on (anti)neutrino emission during the pre-supernova phase. By comparing the ν_e and $\bar{\nu}_e$ spectra generated in neutral- and charged-current weak-interaction reactions involving both cold and thermally excited (hot) nuclei, we demonstrate that energy transfer from hot nuclei not only enhances (anti)neutrino emission but also hardens the spectrum.

Using the MESA stellar evolution code, we compute density, temperature, and chemical composition profiles for a $14.0\,M_\odot$ pre-supernova model. From these profiles, we derive the time evolution of (anti)neutrino luminosities and spectra produced by both thermal and nuclear processes. Our results show that the ν_e luminosity from electron capture on hot nuclei exceeds that from e^+e^--pair annihilation by an order of magnitude, even one day before core collapse. Moreover, we show that for $\bar{\nu}_e$ production, neutrino-antineutrino pair emission via neutral-current nuclear de-excitation (ND) process is at least as significant as pair annihilation. We also demonstrate that flavor oscillations amplify the high-energy component of the ND process in the $\bar{\nu}_e$ flux. This effect could be crucial for the detection of pre-supernova $\bar{\nu}_e$ by terrestrial detectors.