Contribution ID: **7** Type: **Talk**

Progenitor dependence of neutrino-driven supernova explosions with the aid of heavy axion-like particles

Friday, 1 September 2023 10:10 (30 minutes)

Core-collapse supernova is an explosion event of a dying massive star at the end of its lifetime. The explosion mechanism has not been well-understood due to large numerical and physical complexity. Now that KAGRA project and Hyper-Kamiokande project are launched in Japan, we need to construct a precise supernova model to capture all possible astrophysical information from a nearby supernova in the future. In this work, we have conducted spherically symmetric core-collapse supernova simulations with the aid of heavy axion-like particles (ALPs), which possibly interact with photons and deposit energy behind a shock wave. As a result, we found that two of the ALP parameters, ALP mass and ALP-photon coupling constant, have the following relationships with the shock wave. First, heavy ALPs with high coupling constant are favorable for the shock wave to expand. However, when ALP mass exceeds a certain value (for example, m_a=600 MeV in the case of 20M_sun star), ALP emission rate decreases and the shock wave is less likely to turn into an expansion. This is because the temperature achieved inside the supernova core is not high enough to produce heavy ALPs sufficiently. In general, the maximum temperature depends on the progenitor structure. We have demonstrated such simulations for three progenitors and found that the ALP assist of explosion is effective in massive progenitors even in the case of heavy ALPs with m_a>600 MeV.

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Session Classification: Core-Collapse Supernova Explosions