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#松本　仁 [1)]
[(1] 慶應義塾大学理工学部

Role of helicities in core-collapse supernova explosions

#Jin Matsumoto[1)]
[(1]KiPAS, Keio University

Massive stars explode at the final phase of their evolution. These explosions are called core-collapse supernovae (CCSNe) and are very energetic and bright events in the Universe. A shock wave is excited after the bounce of the core due to the gravitational collapse of the massive star. The explosion occurs when this outwardly propagating shock wave reaches the surface of the massive star. However, it stalls in the Fe core because of the ram pressure for the shock surface in the upper stream. Although the neutrino-heating is considered to be a key process to explode the massive star, the explosion mechanism of the CCSN is not completely understood yet. In this process, neutrinos from a protoneutron star that is born at the center of the massive star after the bounce heat the matter behind the stalled shock wave. The turbulence behind the shock that originates from convection due to the negative gradient of the entropy and/or hydrodynamic instabilities drastically enhances the efficiency of the neutrino-heating. This is because if the turbulence fully develops, the matter is effectively exposed by neutrinos and can gain substantial thermal energy to overcome the ram pressure due to the mass accretion. Helicities may play an important role in the properties of the turbulence and then the explosion itself.

Our group has investigated the impact of the magnetic field on the explosion mechanism of CCSN through magnetohydrodynamics simulations with spectral neutrino transport. We have performed three-dimensional simulations for the evolution of non- and slowly-rotating stellar cores focusing on the difference in the magnetic field of the progenitors. We find that the neutrino-driven explosion occurs in both strong and weak magnetic field models. The neutrino heating is the main driver for the explosion in our models, whereas the strong magnetic field supports the explosion. In this presentation, we will introduce our results focusing on the role of helicities and magnetic fields.