論文の内容の要旨

Magneto-rotational core-collapse supernovae
and
nucleosynthesis in extreme astrophysical environments

(磁気回転駆動型超新星爆発と極限天体環境における元素合成)

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Almost half of heavy nuclei beyond iron are considered to be produced by rapid neutron capture process (r-process). This process occurs in extreme astrophysical environments that satisfy high density, high temperature and high neutron-richness such as core-collapse supernovae or neutron star mergers, but the main production site is still unknown. Because there are few experimental data of neutron-rich nuclei, which are the main products in the r-process, r-process simulations are carried out with theoretical nuclear data. However, the nuclear theory is not still unified and various theoretical models on nuclear physics are suggested. This variety causes uncertainty in nucleosynthesis simulations. The astrophysical modeling is also in the similar situation. To accurately model core-collapse supernovae and binary neutron star mergers, ones need to perform high-resolution general relativistic neutrino radiation magnetohydrodynamics based on correct nuclear physics and neutrino physics. But this is computationally too heavy and practically unrealistic. Thus it is important to develop each nuclear physics model and astrophysical model step by step, and apply them to the nucleosynthesis simulations to understand how the individual development affects r-process abundances.

There has been a persistent conundrum in attempts to model the nucleosynthesis of heavy elements by the r-process. Although the locations of the abundance peaks near nuclear mass numbers 130 and 195 identify an environment of rapid neutron capture near closed nuclear shells, the abundances of elements just above and below those peaks are often underproduced by more than an order of magnitude in model calculations. At the same time, there is a debate in the literature as to what degree the r-process elements are produced in supernovae or the mergers of binary neutron stars. In the first study, we propose a novel solution to both problems. We demonstrate that the underproduction of nuclides above and below the r-process peaks in main or weak r-process models (like magnetohydrodynamic jets or neutrino-driven winds in core-collapse supernovae) can be supplemented via fission fragment distributions from the recycling of material in a neutron-rich environment such as that encountered in neutron star mergers (NSMs). In this paradigm, the abundance peaks themselves are well reproduced by a moderately neutron-rich, main r-process environment such as that encountered in the magnetohydrodynamical jets in supernovae supplemented with a high-entropy, weakly neutron-rich environment such as that encountered in the neutrino-driven-wind model to produce the lighter r-process isotopes. Moreover, we show that the relative contributions to the r-process abundances in both the solar-system and metal-poor stars from the weak, main, and fission-recycling environments required by this proposal are consistent with estimates of the relative Galactic event rates of core-collapse supernovae for the weak and main r-process and NSMs for the fission-recycling r-process.

In the second study, we show that the result on protomagnetar wind simulations. The protomagnetar is one of the candidates for the r-process nucleosynthesis, but a long-term magnetohydrodynamic simulation for core-collapse supernovae is necessary to explore the protomanetar wind. We develop a simple, but fast computation code for this study. We carry out numerical simulations of protoneutron star winds with and without magnetic fields using an extension of an open source code, *GR1D*. This extension allows me to calculate magnetohydrodynamical evolution in a framework of 1.5 dimension. We discuss the effect of the magnetic field on the wind dynamics and nucleosynthesis.