nuclear fission in r-process nucleosynthesis

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Abstract

Half of heavy elements are considered to be produced by the rapid neutron-capture process, which is called the r-process. It is still unknown where the r-process occurs although core collapse supernovae, neutron star mergers, and gamma-ray bursts are proposed to be viable candidate sites for the r-process. One of the reasons is that explosive conditions of these astrophysical sites are poorly understood despite recent progress in numerical simulations for the lack of precise observational data. Another reason is that we need many unknown nuclear data on extremely neutron-rich unstable nuclei, such as nuclear masses, beta half-lives, neutron-capture cross sections, nuclear fission modes, etc., for the theoretical calculations of r-process nucleosynthesis. These nuclear input data are still far to reach in laboratory experiments. Theoretical calculations of the r-process nucleosynthesis therefore are largely subject to nuclear physics uncertainties.
In this talk, I would like to discuss the effects of nuclear fission of very neutron-rich actinide elements on the r-process nucleosynthesis [1]. The r-process path would eventually reach very neutron-rich actinides that are heavy enough to be fissile and the nuclear fission affects the final abundance pattern of the r-process elements. Nuclear fission is expected to account for smoothed abundance pattern along with the universality of the r-process elements discovered among metal-deficient halo stars and the solar system. Our model of nuclear fission is based on phenomenological theoretical studies of the formation of super-heavy elements [2] where both fusion and fission modes are theoretically calculated in Langevin equation of motion for predicting realistic fission fragment distributions.

We carry out r-process nucleosynthesis for various candidate sites of the core collapse supernovae (both neutrino-driven winds and magneto-hydrodynamic jets), the neutron star mergers, and the gamma-ray bursts with realistic fission fragment distributions. We investigate how strongly the fission affects the final r-process yields depending on the environmental conditions of these astrophysical sites. We also discuss physical conditions for the operation of fission cycles in order to clarify how they work for smoothing the abundance pattern and satisfy the universality.

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