Nuclear Fission and Solution of *r*-Process Underproduction Problem

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The origin of heavy elements like gold and uranium, called *r*-process elements, is one of the important mystery in astrophysics. There are several candidates for *r*-process sources such as the neutrino-driven wind (NDW) of core-collapse supernovae (CCSNe), magnetohydrodynamic jets (MHDJs) from CCSNe and binary neutron-star mergers (NSMs), but the major r-process source has not been identified yet.

Although the formation process of the characteristic *r*-process abundance peaks around mass numbers 130 and 195 is understood well, the elemental abundances just above and below those peaks are frequently underproduced by more than an order of magnitude in the literature. This underproduction has been interpreted as the result of the strong shell closure. It is known that the resulting elemental abundances matches well to the solar-system *r*-process abundances if the shell effects is quenched enough. However, there is no experimental evidence of the shell quenching, and some alternative solutions of the underproduction problem are desirable.

We proposed a scenario that contribution of NSMs solves the underproduction problem. In such neutron-rich environments, like NSMs, that neutron-rich fissile nuclei are synthesized, the resulting *r*-process elemental abundances are sensitive to the applied fission model. We performed numerical simulations of *r*-process nucleosynthesis for dynamical ejecta from the NSM model [1,2,3] with a realistic fission model. We used an extended version of the nuclear reaction network described in [4], where some nuclear reactions based on the KTUY nuclear mass model and a new fission fragment distributions model [5] are newly adopted.

The red line in Figure 1 [6] shows the result of the nucleosynthesis simulation for the NSM model in comparison with the solar-system *r*-process abundances [7] represented in the black dots. The flat abundance pattern between A = 100 and 160, which has not been found in the literature, is due to the new fission model adopted, which predicts that a wide mass range of fission products is formed. The results of the nucleosynthesis simulations for the NDW model and the MHDJ model taken from [8,9] are also plotted in Figure 1. Those three models shows the completely different elemental abundance patterns. The total abundance curve from all models is shown as the black line. We found that the elements produced in the NDW and NSM model supplement the underproduced elements of the MHDJ model, and the resulting total elemental abundance pattern is very close to the solar-system *r*-process abundances.

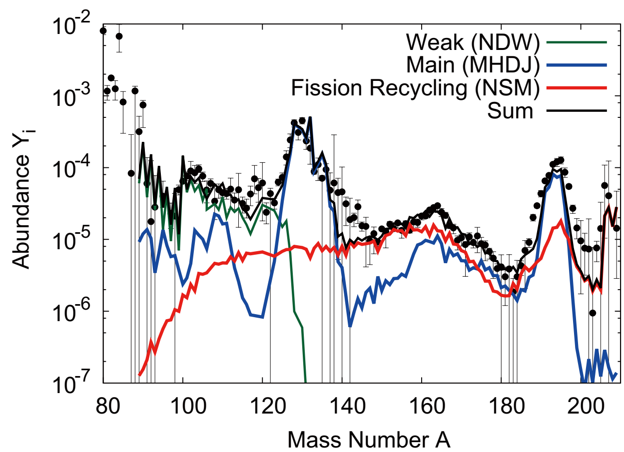

Figure 1: Solar-system isotopic *r*-process abundance pattern. Observation (black dots) vs. theoretical calculation which consists of the *r*-process in magnetohydrodynamic jet supernova model (blue), neutrino-driven wind model (green), binary neutron-star merger model (red) and total sum (black).

References

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