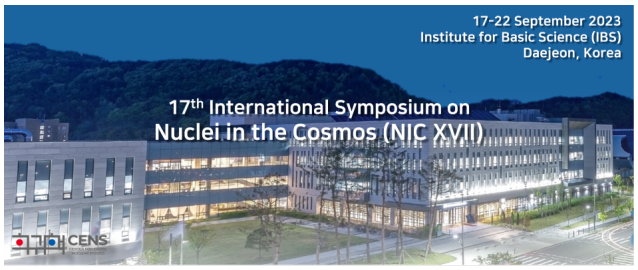

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New Observable Signal of r-, i-, and s-process Nucleosynthesis in Collapsar Jet

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In the era of multi-messenger astronomy, the afterglow of energetic photons emitted from the decay of long-lived neutron-rich actinides is an important observable signal for the rapid neutron-capture process (r-process) which occurred in the compact gravitational objects, i.e., binary neutron star merger (NSM), magneto-hydrodynamic jet supernova (MHDJ SN), and collapsar, which is an explosion of single massive star collapsing to a black hole. We calculated the collapsar nucleosynthesis including the fission of wide ranges of heavy nuclei for a long time (up to 10^17 seconds). We have recently found [1], for the first time, that the intermediate and slow neutron-capture processes (i- and s-processes) operate at a relatively later time in collapsar nucleosynthesis as secondary processes, when the primary r-process nuclei capture the neutrons produced by the fission of long-lived neutron-rich actinides. Here we show that the collapsar provides with another significant observable signal in the nucleosynthesis of heavy atomic nuclei.
In this article, we show the roles of neutron-capture reactions on unstable nuclei near the stability line in the i-process as well as those on extremely neutron-rich nuclei in the r-process. We also propose that the pronounced odd-even pattern in the mass-abundance relation near rare earth elements in metal-deficient halo stars could be a piece of observational evidence of the collapsar s- and -processes [1]. The s- and i-processes are believed to occur in asymptotic giant branch (AGB) stars to provide half of heavy atomic nuclei $90 \leq A$ in the Milky Way. Collapsar nucleosynthesis is one of the dominant sites for the production of heavy r-process nuclei over the entire history of Galactic chemical evolution until solar system formation [2]. Therefore, our finding [1] would motivate to improve an accepted standard interpretation that the solar r-abundance is the residual of the measured solar-system abundance subtracted by the s-abundance.

[1] Z. He, M. Kusakabe, T. Kajino, S.-G. Zhou, H. Koura, S. Chiba, submitted (2022).
[2] Y. Yamazaki, Z. He, T. Kajino, G. J. Mathews, M. A. Famiano, X.-D. Tang, J.-R. Shi, ApJ. 933 (2022), 112.

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