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r-Process Radioisotopes from Near-Earth Supernovae and Kilonovae

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The astrophysical sites where r-process elements are synthesized remain mysterious: it is clear that neutron-star mergers (kilonovae, KNe) contribute, and some classes of core-collapse supernovae (SNe) are also likely sources of at least the lighter r-process species. The discovery of the live isotope Fe60 on the Earth and Moon over the past decades implies that one or more astrophysical explosions occurred near the Earth (within ~100pc) within the last few Myr, probably a SN. Intriguingly, several groups have reported evidence for deposits of Pu244, some overlapping with the Fe60 pulse, but pointing to a different origin like KNe. Motivated by the Pu244 observations, we propose that ejecta from a KN enriched the giant molecular cloud that gave rise to the Local Bubble in which the Sun resides. This hypothesis is also consistent with the most recent Pu244 measurements by Wallner et al. (2021).

Accelerator Mass Spectrometry (AMS) measurements of Pu244 and searches for other live isotopes could probe the origins of the r-process and the history of the solar neighborhood, including triggers for mass extinctions, e.g., at the end of the Devonian epoch. Thus, we carried out the nucleosynthesis calculations of the abundances of live r-process radioisotopes produced in SNe and KNe. Given the presence of Pu244, other r-process species such as Zr93, Pd107, I129, Cs135, Hf182, U236, Np237 and Cm247 should be present. Their abundances could distinguish between SNe and KNe scenarios, and we discuss prospects for their detection in deep-ocean deposits and the lunar regolith. With current AMS sensitivities, I129 is the most promising isotope to detect, and we find that the AMS I129 measurements in Fe-Mn crusts already constrain a possible nearby KNe scenario. Thus, we urge searches for r-process radioisotopes in deep-ocean Fe-Mn crusts, and in the lunar regolith samples brought to Earth recently by the Chang'e-5 lunar mission and upcoming missions including Artemis.

Primary author: WANG, Xilu (University of Notre Dame)

Co-authors: CLARK, Adam; ELLIS, John; ERTEL, Adrienne; FIELDS, Brian; LIU, Zhenghai; MILLER, Jesse; SURMAN, Rebecca

Presenter: WANG, Xilu (University of Notre Dame)

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