Proposed Lunar Measurements of *r*-Process Radioisotopes to Distinguish Origin of Deep-sea ^{244}Pu. Xilu Wang[1], Adam M. Clark[2], John Ellis[3,4], Adrienne F. Ertel[5], Brian D. Fields[5], Brian J. Fry[6], Zhenghai Liu[5], Jesse A. Miller[5], and Rebecca Surman[2], [1]Institute of High Energy Physics, Chinese Academy of Sciences, Beijing, 100049, China (wangxl@ihep.ac.cn), [2]University of Notre Dame, Notre Dame, IN 46556, USA, [3]King's College London, London WC2R 2LS, UK, [4] CERN, CH-1211 Geneva 23, Switzerland, [5]University of Illinois, Urbana, IL 61801, USA, [6]United States Air Force Academy, Colorado Springs, CO 80840, USA

Introduction: The lunar regolith contains radioactive debris from near-Earth supernova explosions. Most supernova explosions in our Galaxy occur at great distances but, over long timescales, nearby explosions are likely. Events within ~ 10 pc (30 light-years) would endanger life on Earth [1, 2] and should occur every few hundred million years. It was suggested in [3] that discovery of short-lived radioactive isotopes such as ^{60}Fe would be direct evidence for near-Earth supernova explosions, which might have affected the Earth's biosphere. Following this suggestion, live, i.e., undecayed, radioactive ^{60}Fe (half-life $t_{1/2}$ = 2.6 Myr) has been detected by multiple experimental teams in deep-ocean samples around the world [4, 5, 6, 7, 8], in cosmic rays [9], and in Antarctic snow [10]. Importantly, ^{60}Fe has also been found in *Apollo* drive tube samples of the lunar regolith [11], confirming that the radioisotope deposition was not limited to Earth but prevalent in the solar system. The *Apollo* study showed that the ^{60}Fe/^{53}Mn ratio exceeds that due to lunar bombardment by cosmic rays (and that found in meteorites), confirming that the ^{60}Fe exceeds the expected cosmogenic production. These discoveries provide compelling evidence that at least one supernova exploded within ~100 parsecs of the Earth [12, 13] within the past 3 million years.

Artemis has a unique scientific opportunity to confirm the supernova interpretation of the ^{60}Fe data, to clarify the behavior of dust in supernova remnants and possibly the direction of the recent parent supernova and, by searching for other live isotopes such as ^{53}Mn, ^{146}Sm and ^{244}Pu, could identify what type of supernova or kilonova exploded within the vicinity of Earth.

A search for ^{244}Pu holds particular importance. ^{244}Pu is one of the heaviest known nuclei, and is only produced in the so-called *r*-process, where an intense blast of neutrons captured onto the "seed" nuclei. 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 possible sources of at least the lighter *r*-process species. The discovery of ^{60}Fe on the Earth and Moon implies that one or more astrophysical explosions have occurred near the Earth within the last few Million years (Myr), probably SNe. Intriguingly, ^{244}Pu has recently been discovered in deep-sea deposits spanning the past 10 Myr, a period that includes two ^{60}Fe pulses from nearby supernovae. ^{244}Pu is among the heaviest *r*-process products, and we consider whether it was created in the supernovae, which is disfavored by nucleosynthesis simulations, or in an earlier kilonova event that seeded ^{244}Pu in the nearby interstellar medium that was subsequently swept up by the supernova debris. We discuss how these possibilities can be probed by measuring ^{244}Pu and other *r*-process radioisotopes such as ^{129}I and ^{182}Hf, both in lunar regolith samples returned to Earth by missions such as *Chang'e* and *Artemis*, and in deep-sea deposits [14, 15].

References:

[1] Ruderman, M. (1974) *Science*, *184*, 1079. [2] Ellis, J. and Schramm, D.N. (1995) *Proc. Nat. Acad. Sci.*, *92*, 235. [3] Ellis, J. et al. (1996) *ApJ, 470,* 1227. [4] Knie, K. et al. (1999) *Physical Review Letters, 83,* 18. [5] Knie, K. et al. (2004) *Physical Review Letters, 93,* 171103. [6] Fitoussi, C. et al. (2008) *Physical Review Letters, 101*, 121101. [7] Wallner, A. et al. (2016) *Nature, 532*, 69. [8] Ludwig, P. et al. (2016) *Proceedings of the National Academy of Science, 113*, 9232. [9] Binns, W. R. et al. (2016) *Science*, 352, 677. [10] Koll, D. et al. (2019) *Physical Review Letters, 123*, 072701. [11] Fimiani, L. et al. (2016) *Physical Review Letters, 116,* 151104. [12] Fields, B. D. and Ellis, J. (1999) *NewA, 4,* 419. [13] Fry, B. J. et al. (2016) *ApJ, 827*, 48. [14] Wang, X. et al. (2021) *ApJ, 923*, 219. [15] Wang, X. et al. (2021) *arXiv:2112.09607.*