The Origin of Chromium Isotopic Anomalies in Lunar Rocks

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The most plausible model for the formation of the Moon is that a Mars-sized planetary embryo impacted the Earth late in its acretion and the Moon accreted mainly from the impactor [1]. However no large isotopic anomalies have been detected for Ti and O, which would be definitive evidence for the presence of extraterrestrial materials in the Moon [2,3]. Another element that could provide further constraints on the origin of the lunar material is Cr [4]. A recent study found that the Cr isotopic composition of the Moon was compromised by cosmogenic effects, which was corrected by correlating Cr isotopic shifts in lunar samples with variations in $^{150}Sm/^{152}Sm$ ratio [5]. The issue with this approach is that Sm isotopic variations are produced by capture of secondary thermal neutrons while ^{54}Cr is primarily a product of spallation on Fe targets.

In this study, we revisted the Cr isotopic composition of the Moon by analyzing a series of lunar samples and meteorites. We found notable excesses in both $\varepsilon^{53}Cr$ (~0.4ε) and $\varepsilon^{54}Cr$ (~1.1ε) in the lunar samples. The anomalies of $\varepsilon^{53}Cr$ and $\varepsilon^{54}Cr$ are positively correlated, with a slope of ~3, similar to the slope found in iron meteorites [4], indicating that they have a cosmogenic origin. We have devised a new method to correct Cr isotope measurements for the presence of cosmogenic effects. This approach allows us to ascertain the pre-exposure lunar $\varepsilon^{54}Cr$ value. The implications of this new determination will be presented.

References: [1] Canup, R.M. and Asphaug, E. (2001) Nature 412, 708-712. [2] Young E. D. et al. (2016) Science 351, 493-496. [3] Zhang, J. et al. (2012) Nat Geosci 5, 251-255. [4] Qin, L. et al. (2010) GCA 74, 1122-1145. [5] Mougel et al. (2018) EPSL 481, 1-8.