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Isotopic evolution and distribution of the neutron-rich nuclides in the solar nebula inferred from chromium isotopes in iron meteorites

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Isotopic anomalies recorded the early evolution information of the protoplanetary disk of Solar System and have revealed a dichotomy among meteoritic materials (carbonaceous/CC and non-carbonaceous/NC) [1]. Magmatic iron meteorites, which are the fragments of the metallic cores of differentiated planetesimals, may document the isotopic signatures during the very early period of Solar System due to the earlier accretion of their parent bodies relative to the chondrites [1]. However, the primordial Cr isotopic signatures for most iron meteorites were severely masked by cosmogenic effects [2]. Daubréelite ($FeCr_2S_4$) and chromite ($FeCr_2O_4$) could preserve the pre-cosmic-exposure Cr isotopic compositions of their host meteorites as they have a very low Fe/Cr (~0.5) ratio. In this study, we recovered these minerals from iron meteorites and obtained their mass-independent Cr isotopic compositions to understand the distribution and evolution of the neutron-rich nuclides in the solar nebula.

Our results showed that the isotopic dichotomy holds for the Cr isotopic system in iron meteorites, with NC irons exhibiting ^{54}Cr deficit and CC irons exhibiting ^{54}Cr excess relative to the Earth. The $\varepsilon^{54}Cr$ value correlates with the $\varepsilon^{53}Cr$ value for the NC and CC iron meteorites, respectively. The correlation among NC iron meteorites suggests a temporal evolution in the formation region of NC planetesimals, indicating gradual radial homogenization in the inner solar system disk. In contrast, the correlation among CC meteorites suggests the spatial heterogeneity of pre-solar ^{54}Cr-enriched grains in the outer solar system. The unique isotopic characteristic of the Earth possibly reflects the natural outcome of a gradual homogenized inner solar system disk which is initially heterogeneous.