Formation of the solar system inferred from nucleosynthetic isotope anomalies and short-lived radionuclide abundances

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Recent work has shown that nucleosynthetic isotope anomalies for several elements such as Ti and Cr are distinctly larger in carbonaceous chondrites (CC) than most non-carbonaceous (NC) meteorites (Warren, 2011 EPSL). This indicates a fundamental isotope dichotomy between the inner and outer proto-planetary disk, possibly as a result of the formation of Jupiter (Kruijer et al., 2017 PNAS). Because such nucleosynthetic isotope dichotomy is not limited to refractory elements and also because the CC-NC isotope offset is decoupled from the presolar carriers causing the internal isotope heterogeneity of meteorites, the isotope dichotomy is considered to reflect an inherited isotope heterogeneity of the parental molecular cloud of the solar system rather than thermal processing in the solar nebular (Burkhardt et al., 2019 GCA). Yet, the origin of the isotope dichotomy remains elusive. By combining the nucleosynthetic isotope anomalies with short-lived radionuclide abundances, here we discuss the origin of the isotope dichotomy and a possible formation scenario for the solar system. We have recently shown that a short-lived radionuclide ^{92}Nb (half-life ~37 Ma) was enriched by ~70% in the CC reservoir relative to the NC reservoir (Iizuka et al., 2016 EPSL; Hibiya et al., 2019 LPSC). This finding requires the production of ^{92}Nb in a core-collapse supernova (CCSN) and the enrichment of CCSN-ejecta in the outer proto-planetary disk. We argue that the enrichment of CCSN-ejecta in the CC reservoir can account well for the observed nucleosynthetic isotope dichotomy, considering that CCSN-ejecta involve nuclides synthesized by rapid- and gamma-processes during CCSN and by slow-process during the pre-CCSN evolution. Furthermore, a combined ^{92}Nb-^{60}Fe cosmochronology indicates that the CCSN occurred ~30 Ma before the solar system formation. Given that the CC reservoir represents the early infalling molecular cloud to form a proto-solar (Burkhardt et al., 2019 GCA), we propose that the CCSN ejecta served as a nucleus for the collapsing molecular cloud.

Keywords: isotope dichotomy, core collapse supernova, niobium-92, proto-planetary disk, molecular cloud

