Goldschmidt 2026 Abstract
https://doi.org/10.46427/gold2026.35775

Stellar environment and timescales of solar system formation inferred from correlated short-lived and stable isotopic variations

TSUYOSHI IIZUKA[1], YUKI HIBIYA[1] AND TAKEHITO HAYAKAWA[2]

[1]The University of Tokyo
[2]National Institutes for Quantum Science and Techonology

Short-lived radionuclides (SLRs) have been used to constrain the birth environment of the Sun and the timescales over which they were synthesized and the protosolar disk evolved. The chronology commonly assumes that SLRs were uniformly distributed in the protosolar disk. However, this assumption has been challenged by the discrepancy between the timescales defined by the SLR (26Al and 92Nb) and assumption-free Pb-Pb chronometers. In addition, it has been demonstrated that carbonaceous and non-carbonaceous meteorites exhibit fundamentally different nucleosynthetic anomalies in stable isotopes, especially for non-volatile elements such as Ti. The stable-isotope dichotomy indicates the heterogeneous distribution of at least one stellar component between the inner and outer protosolar disk, but its stellar origin remains elusive.

By combining the SLR and stable-isotopic variations, we examine the stellar origin and validate the use of SLRs as chronometers for early solar system events and stellar nucleosynthesis. Our compilation shows that the heterogeneity of 26Al and 92Nb correlates with stable Ti isotopic variation. This correlation can be explained by the uneven distribution of ejecta from a nearby core-collapse supernova (CCSN), especially if the progenitor star has an initial mass of ~25 solar masses. We propose using this correlation to calibrate varying 26Al-92Nb abundances for early solar system chronology. The calibrated 26Al chronometer indicates a ≥1 Myr gap between the parent-body accretion ages of carbonaceous and non-carbonaceous chondrites. We also introduce a new cosmochronology method that couples SLR and stable isotopic variations to date the CCSN. This method offers three advantages over conventional approaches. First, it does not assume the homogeneous distribution of SLRs. Second, it remains valid even if the SLR has multiple stellar and galactic sources. Third, by linking the SLR and stable isotopic heterogeneity, the progenitor mass of the CCSN can be well constrained, thereby reducing age uncertainty. The Al-Ti cosmochronology indicates that the CCSN occurred at 20-30 pc from the protosolar cloud, ~0.9 Myr before CAI formation. These findings imply that the Sun formed from a molecular cloud compressed by a stellar wind from a ~25 solar mass star and polluted by ejecta from the subsequent CCSN explosion.