VANADIUM ISOTOPE CONSTRAINTS ON THE SOLAR IRRADIATION HISTORY OF CV CAIS

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Introduction: Based on (i) the presence of high temperature minerals rich in refractory elements (Ca, Al, Ti) [1], and (ii) quantitative constraints from the co-production of ^{50}V and ^{10}Be through *in situ* irradiation by solar particles [2], CAIs are widely thought to have formed within ~0.1 AU from the proto-Sun. Yet, CAIs are most abundant (up to ~3 vol%) in meteorites that are considered to have accreted within the outer regions of the Solar System [e.g. 3]. The anchoring of the CAI forming region at the inner edge of the proto planetary disc (PPD) therefore requires their efficient transport to the outer Solar System, potentially above the disk midplane by stellar outflows [4,5] or at the disk midplane by a meridional flow [6,7]. The precise location of the CAI factory has profound implications for our understanding of the structure and dynamical evolution of the PPD, before any planet formed.

Because V only has two stable isotopes (^{50}V and ^{51}V), direct distinction between effects from in-situ irradiation, nucleosynthetic isotope anomalies, and/or mass-dependent stable isotope fractionation is not possible, which could potentially introduce a bias in our interpretation of V isotope variations in CAIs. Here, we present the first coupled V and stable Sr isotope measurements in five coarse-grained and three fine-grained CAIs from the Allende CV3 meteorite. The element Sr has (i) a 50 % condensation temperature (T_{50}(Sr) = 1464 K) that is very close to that of V (T_{50}(V) = 1429 K; [8]), and (ii) four stable isotopes, which facilitates identification of nucleosynthetic and kinetic isotope fractionation effects. For a subset of CAI samples, we also present their ^{10}Be-^{10}B systematics and Rare Earth Element (REE) patterns. Combining these results with literature data, we re-evaluate the available records of early Solar System irradiation in meteorites and the associated constraints on the cosmolocation of the CAI factory in the nascent Solar System.

Results: Our data reveal a clear, positive δ^{51}V-δ^{88}Sr correlation (R^2=0.995) that extends over ~5 ‰ and includes five coarse-grained and one fine-grained CAI. We show that this isotope trend follows predictions from kinetic isotope fractionation during partial condensation and evaporation, therefore setting stringent contraints on the relative volatilities of V- and Sr-bearing species in the early Solar System. In addition, two analyzed fine-grained inclusions plot significantly below the δ^{51}V-δ^{88}Sr trend, indicating perturbation of their original δ^{88}Sr by partial equilibration with aqueous fluids of chondritic composition.

The strong δ^{51}V-δ^{88}Sr correlation precludes a significant influence of irradiation processes on the V isotope composition of CAIs. Using numerical modeling of ^{50}V and ^{10}Be co-production by irradiation from the young Sun [9,10], we show that very little – in any – of the ^{10}Be in CV CAIs could have been produced via *in situ* irradiation in the vicinity of the proto-Sun. In line with the homogeneous levels of ^{10}Be excess in CV CAIs [11], this result implies that most of ^{10}Be in CV CAIs was already present in the protosolar nebula when CAIs formed, and that the location of CAI formation need not have been as close to the proto-Sun as previously thought. Overall, our findings indicate that CAI formation during molecular cloud infall and PPD build-up likely occurred at larger heliocentric distances than previously considered, potentially up to planet-forming regions.

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