# ISOTOPE ANOMALIES IN CHONDRITE COMPONENTS AS TRACERS OF NEBULAR MATERIAL PROCESSING AND DISK DYNAMICS.

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**Introduction:** The use of nucleosynthetic isotope anomalies as novel tracers of source reservoirs and the genetic relationships of planetary bodies has recently let to major advances in understanding planetary genetics and early solar system dynamics [e.g., 1-3]. However, the processes and main components responsible for the generation of planetary-scale anomalies, as well as how they relate to the mineral-scale isotopic heterogeneity inherited from the molecular cloud, are poorly understood. Thus, the full potential of nucleosynthetic anomalies for constraining material processing, mixing, and transport in the disk has yet to be realized.

Direct information about the materials present at the initial stages of solar system formation – and the processes acting on them – can be obtained by the analysis of components from chondritic meteorites, namely chondrules, CAIs, fine-grained matrix and presolar grains. Although the isotopic data base for these objects is growing constantly, for many elements data are lacking or incomplete. Furthermore, isotope studies of a given sample set are often limited to a specific element, such that inter-elemental comparison of isotopic data is blurred by potential sample heterogeneities and sampling bias. Here we present multi-element compositional and Ti and Sr isotopic data of acid leachates obtained by the step-wise dissolution of Murchison (CM2), as well as of Ca,Al-rich inclusions (CAIs) from Allende (CV3). Our new data complement previous studies which investigated the same leachates for isotopic anomalies in Ca [4], Cr [5], Mo [6], W [7], and Os [8], and the CAIs for anomalies in Mo [9] and W [10]. By combining these data with concentration and isotope anomaly data of other nebular and planetary materials we will discuss the main drivers for the generation of planetary-scale isotopic anomalies in a generalized way.

**Samples and Methods:** The leachates were prepared at the University of Chicago in a procedure involving acetic acid (Leachate 1), $HNO_3$ (L2), HCl (L3), mixtures of HF and HCl (L4, L5), and laser fusion of the insoluble residue (L6) [6,8]. Four out of the five investigated CAIs are coarse-grained igneous inclusions (A-ZH-1 to A-ZH-4), while A-ZH-5 is more fine-grained and exhibits strong alteration features [10]. Multi-elemental concentration data on the samples were acquired using quadrupole ICP-MS. Strontium isotope data were obtained using a Triton TIMS at ETH Zürich, while Ti isotopes were measured using a Neptune MC-ICPMS at UofC. Data are reported relative to terrestrial standards and internal normalization to $^{86}Sr/^{88}Sr=0.1194$ and $^{49}Ti/^{47}Ti = 0.749766$, respectively.

**Results:** Absolute concentrations and relative abundances of elements in the different leachates are highly variable, suggesting efficient chemical separation of phases during leaching. The CAIs are highly enriched in refractory elements (~17xCI) and exhibit group I (A-ZH-1 to A-ZH-4) or group III (A-ZH-5) REE patterns. The leachates reveal significant Ti and Sr isotopic heterogeneity ranging from -5.1 $\varepsilon^{50}$Ti and +0.62 $\varepsilon^{84}$Sr in the first leachate to +10.5 $\varepsilon^{50}$Ti and -16.18 $\varepsilon^{84}$Sr in the residue, respectively, whereas the CAIs have homogeneous anomalies of ~9 $\varepsilon^{50}$Ti and ~ 1.2 $\varepsilon^{84}$Sr. Leachate anomalies in $\varepsilon^{50}$Ti and $\varepsilon^{46}$Ti are positively correlated, but do not plot on the linear array defined by bulk planetary materials and CAIs.

**Discussion:** Consistent with previous observations [11], our data reveal the contribution of multiple stellar sources to the solar system's Ti isotopic inventory, and highlights that the $\varepsilon^{46}$Ti - $\varepsilon^{50}$Ti correlation of bulk planetary bodies is a result of material processing and subsequent mixing within the solar protoplanetary disk. Variable admixing of CAI-like refractory material to an average inner solar nebula composition can account for a large part of the planetary-scale Ti and Sr isotope anomalies and the difference between non-carbonaceous (NC) and carbonaceous (CC) nebular reservoirs for these elements. However, combining Ti, Sr, Ca, Cr, Ni, Zr and Mo anomaly data reveals that CAIs are only the refractory component of an isotopically anomalous nebular reservoir enriched in supernova materials. The generation of planetary-scale isotopic anomalies can thus be understood as the interplay of nebular dust and three main components: CAIs, non-refractory matter with CAI-like isotopic composition, and presolar carriers. The expression of planetary-scale anomalies is a function of the elemental and isotopic composition of these components and their relative abundances at a given time and disk location.

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