

## THE ORIGIN OF IRON ISOTOPIC HETEROGENEITY IN THE PROTOPLANETARY DISK

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**Introduction:** Meteorites display distinct nucleosynthetic isotope compositions with striking differences for some elements, e.g., Ti, Cr, Zr, Mo [1-4]. Different nucleosynthetic compositions likely reflect the contributions of material from distinct regions of the protoplanetary disk [5]. Recent work distinguishes two isotopic reservoirs within the young protoplanetary disk, termed *carbonaceous* (CC) and *non-carbonaceous* (NC), representing the outer and inner solar system, respectively [e.g., 1,2]. The CC material is characterised by larger isotope variations in both neutron-rich [e.g., 1-4] and neutron-poor isotopes [e.g., 6] for many elements compared to NC material. The origin of these offsets is still highly debated, but may be linked to supernovae contributions [e.g., 5]. Iron isotopes show nucleosynthetic variations in bulk meteorites relative to the Earth for  $\mu^{54}\text{Fe}$  [7-8], while the  $\mu^{58}\text{Fe}$  values for iron meteorites show no variations [8]. A dichotomy between the CC and NC reservoirs based on  $\mu^{54}\text{Fe}$  in iron meteorites was recently proposed [8], implying a prolonged spatial separation between the outer and inner Solar System. To provide a rigorous assessment on this and evaluate the origin of nucleosynthetic Fe isotope variations, we present high-precision, mass-independent Fe isotope data. We determine the nucleosynthetic variability in chondrites, iron meteorites, and eucrites and assess mixing processes in the protoplanetary disk. Additionally, elements including Fe are susceptible to the effects of Galactic Cosmic Rays (GCR) that lead to spallation and neutron capture and disturb isotope ratios [9]. Thus, GCR-induced Fe offsets were corrected using  $\epsilon^{196}\text{Pt}$ , which can be used as a neutron dosimeter [9, 10].

**Samples and Methods:** High-precision Fe isotope analyses were performed for 11 iron meteorites from the IAB, IIIAB, IVA, IVB, IC, and IID groups, 19 chondrites from the CV, CM, CO, CI, CR, CB, EH, H, and LL groups, and 2 basaltic eucrites. The selection covers a range of CC and NC materials. The iron meteorites were previously digested for Pt isotope analysis and, hence, Pt data were available for the same sample aliquots to correct for GCR [10,11]. Fifteen chondrites and the eucrites were previously digested by [12, 13]. Additionally, 2 COs and 2 CIs were dissolved for this study. Iron was purified using a one-stage anion exchange chromatography procedure. All Fe isotope analyses were performed with a Thermo Scientific Neptune Plus MC-ICP-MS at ETH Zürich. Samples were measured relative to bracketing standards and corrected for instrumental mass bias using the exponential law and internal normalization to  $^{57}\text{Fe}/^{56}\text{Fe}$  of 0.023096 [14]. The external reproducibility (2 SE) is  $0.02 \pm 0.02$  for  $\epsilon^{54}\text{Fe}$ , and  $0.00 \pm 0.04$  for  $\epsilon^{58}\text{Fe}$  for 142 analyses of three digestions of the terrestrial standard BHVO-2, where  $\epsilon^i\text{Fe}$  is the parts-per-10000 deviation from a terrestrial standard.

**Results and Discussion:** Our new Fe isotope data for bulk meteorites show  $\epsilon^{54}\text{Fe}$  values that are enriched compared to Earth for both the CC and NC meteorite groups. The iron meteorites show a correlation between  $\epsilon^{54}\text{Fe}$  and  $\epsilon^{196}\text{Pt}$  and GCR-induced offsets to  $\epsilon^{54}\text{Fe}$  were corrected based on these data. The NC groups range from the terrestrial value up to  $\epsilon^{54}\text{Fe} + 0.37$ . Despite their CC-affinities, the CI chondrites fall within the NC field and yield  $\epsilon^{54}\text{Fe}$  identical to the terrestrial composition within uncertainties, consistent with [7]. This may confirm that the Earth has accreted a significant amount of CI material. Additionally, it significantly extends the range for the CC meteorites from the terrestrial composition to +0.50, overlapping values measured for the NC reservoir. Therefore,  $\epsilon^{54}\text{Fe}$  data do not show a dichotomy between the CC and NC reservoirs, in contrast to findings based on iron meteorites alone [8].

Most  $\epsilon^{58}\text{Fe}$  variations are not resolvable from the terrestrial value. However, our  $\epsilon^{58}\text{Fe}$  data reveal consistently higher values for CC groups with a range from -0.20 to 0.39, in comparison to NC groups that vary from -0.35 to 0.19. Correlated variability between  $\epsilon^{54}\text{Fe}$  and  $\epsilon^{58}\text{Fe}$  defines a linear trend for the NC materials. The NC best fit line can be reproduced by admixing material from an asymptotic giant branch (AGB) star of 2 solar masses (yields taken from [15]). These data are in good agreement with a model predicting the thermal destruction of interstellar medium grains with near-solar composition closer to the Sun, resulting in an enrichment of s-process nuclides in that region [16].

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