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Unmixing the mix-up in the solar nebula using ε^{54}Cr and volatile element concentrations in chondrites

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The presence and preservation of two distinct regions of the protoplanetary disk, termed the non-carbonaceous (NC) - carbonaceous (CC) dichotomy, has been used to argue that NC and CC material accreted in spatially distinct regions of the disk and were isolated by a physical barrier [1]. Recent studies, however, indicate that the compositions of CC chondrites can be reproduced through mixing of NC material with CI (Ivuna-like) dust with a presumed distal origin, and calcium-aluminium-rich inclusion (CAI) material [2,3]. This implies that the NC and CC regions were not completely isolated throughout the entire history of the disk, highlighting our poor understanding of the movement and mixing of solids in the solar nebula [4,5]. Moreover, this incomplete knowledge undermines our models of planetesimal formation and planet building because the efficiencies of both streaming instability and pebble accretion are governed by the rates of solid motion in the disk.

To explore these dynamics, we examine the relationship between Cr isotopic compositions and concentrations of “plateau volatile” elements (Te, Sn, Zn, etc.) [6] in subsamples of several NC and CC chondrites. The relative amount of ^{54}Cr serves as a tracer for CI-like material [2], while plateau volatile element concentrations serve as proxies for the fraction of matrix present in each of our subsamples [7]. By exploiting the natural heterogeneity in the proportions of matrix and chondrules in each of our subsamples, this approach allows us to distinguish the distinct isotopic signals carried by each respective component. This method provides a clearer understanding of the provenance of material making up individual components of chondrites, which in turn can serve as a pivotal constraint to decipher the dynamic regimes that operated in our disk.

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