Early Solar System dynamics inferred from nucleosynthetic anomalies in individual chondrules

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Isotopic anomalies in meteorites and their components act as tracers for genetic relationships and can provide key constraints into early dynamic processes in the solar nebula [1]. Since chondrules represent the principal component of bulk chondrites, they were one of the most abundant solids in the early solar nebula. As such, obtaining isotopic compositions of individual chondrules is key for understanding the origin of isotope anomalies in bulk chondrites as well as mixing and transport processes in the early solar nebula.

Here we present coupled ε^{54}Cr and ε^{50}Ti [2] data for individual chondrules from enstatite (EC), ordinary (OC), and carbonaceous (CV, CR) chondrites. Whereas the EC and OC chondrules display very limited isotopic variability and are indistinguishable from their host meteorites, CV chondrules cover a much wider range of compositions in both ε^{54}Cr and ε^{50}Ti. The ε^{50}Ti variations found among CV chondrules have been attributed to heterogeneous admixture of CAIs (or CAI-like material) during chondrule formation [2]. However, admixture of refractory material does not markedly effect the Cr isotopic composition of a chondrule, as Cr is not a refractory element and is thus depleted in CAIs relative to chondrules.

To account for variations in ε^{50}Ti and ε^{54}Cr in the same chondrules (some of which are higher than their respective bulk value) the presence of a component with an elevated, possibly CAI-like ε^{54}Cr (~6.5 [3]), but with a much higher Cr/Ti ratio than CAIs is required. The ε^{54}Cr variability among CV chondrules would thus reflect the heterogeneous distribution of non-refractory material with CAI-like ε^{54}Cr, whereas the ε^{50}Ti variations reflect the heterogeneous distribution of refractory material, or CAIs themselves. This work suggests that compared to EC and OC chondrules, the CC chondrule forming region contained a higher proportion of nebular material with a CAI-like isotopic composition. Hence variations in ε^{50}Ti and ε^{54}Cr in chondrules would trace different proportions of refractory and less-refractory components of this material in each chondrule.

[1] Dauphas & Schauble (2016), Annu.Rev. Earth Planet. Sci. 44: 709–83 [2] Gerber et al. (2017) ApJL 841:L17 [3] Trinquier et al. (2009), Science 324: 374-376