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Planetesimal formation in the inner and outer disk: Evidence from ungrouped iron meteorites

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Isotope anomalies in meteorites reveal a fundamental dichotomy between non-carbonaceous (NC) and carbonaceous (CC) materials [1]. This dichotomy is established for both early- and late-formed planetesimals (sampled by magmatic iron meteorites and chondrites, respectively), but whether these two generations of planetesimals formed from the same or distinct materials is unclear. To address this question, we have analyzed the Fe and Ni isotopic composition for a large set of ungrouped iron meteorites, representing approximately 22 distinct parent bodies. These samples were previously characterized for their nucleosynthetic Mo and radiogenic W isotope compositions, showing that these samples derive from differentiated parent bodies that formed early and are of either the NC- (9 samples) or CC-type (16 samples) [2]. The new Fe and Ni isotopic data reveal that early- and late-formed planetesimals within either the NC or the CC reservoir cover a similar range of isotopic compositions as NC and CC chondrites. This demonstrates that early- and late-formed bodies in each reservoir accreted from the same mixture of dust components, either in long-lived pressure structures of the disk or in different substructures containing the same materials. Among the CC planetesimals, two observations stand out. First, we find that a large number of ungrouped irons have an isotopic composition identical to the late-formed CR chondrites, indicating the CR chondrite reservoir was established early and remained isolated for essentially the entire lifetime of the disk. Second, CI chondrites are the only CC meteorites whose isotopic composition is not represented among differentiated meteorites, indicating that planetesimals with this specific isotopic composition formed only late by a distinct mechanism [3] and/ or in a distinct reservoir [4] from the other CC planetesimals.

References: [1] Kleine et al. (2020) Space Sci. Rev. 216, 55. [2] Spitzer et al. (2025), Geochim. Cosmochim. Acta, submitted. [3] Spitzer et al. (2024), Sci. Adv. eadp2426. [4] Hopp et al. (2022) Sci. Adv. eadd8141.