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Oxygen isotopic distributions in the solar nebula: insights via sample return miAl-Mg systematics in planetary materials

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NASA's Genesis and Stardust Discovery Missions have returned materials from the center and the periphery of the planetary formation region, in the form of solar wind and of dust from a Jupiter family comet, respectively [1,2]. The oxygen isotopic compositions of both samples measured by secondary ion mass spectrometry [3,4] show interesting similarities to some components of chondritic meteorites and also important differences to the O isotopic compositions of planetary materials. The solar wind is strongly enriched in 16O compared to bulk meteorites and inner solar system rocks, demonstrating that essentially all inner solar system materials have had their oxygen isotopic compositions affected by one or more non-mass-dependent fractionation processes prior to accretion. The existence of 16O-enrichments in calcium-aluminum-rich inclusions in meteorites, interplanetary dust, and comet Wild 2 (sampled by Stardust) broadly similar to that inferred for the Sun implies that these phases sampled solar material and then escaped thorough mixing with the isotopically heavy reservoir, characteristic of planetary dust [5] or ices [6-9]. The timescale of the mixing process must have been rapid and must have incurred in such a way as to preserve size-sorting and mineralogical differences in CAI and refractory inclusion type over different asteroidal (and perhaps cometary) parent bodies. Measurements of O isotopes [10] in low-density (porous) chondritic interplanetary dust particles (IDPs) do not show the 16O-enrichments that would be expected if isotope-specific CO photolysis generated the O isotopic shift from solar values by a self-shielding mechanism. This expectation is based on an assuming that these IDPs represent primitive outer solar system dust, which, while plausible, is not proven. It is ironic that the Stardust mission to bring back material from the outer solar system has, so far, been dominated by analyses of materials from the inner solar system. A direct measurement of O isotopes in either ice or dust from a comet would provide strong constraints on mixing and transport mechanisms in the solar accretion disk.

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