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Isotopic constraints on the Martian sulfur cycle

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The processes that established the sulfur budgets and isotopic compositions of the Earth, the Moon, and Mars remain poorly understood. Mass independently fractionated sulfur (MIF-S) signatures preserved in primitive meteorites have been attributed to incorporation of Ultraviolet-photolysis of S in the early solar nebula[1–5]. On Earth, extensive geological processing has likely obscured such signatures. In contrast, recent studies have demonstrated evidence for eruption of atmospherically processed sulfur from the interiors of the Moon and Mars, despite the absence of plate tectonics on these bodies[6,7]. This suggests that atmosphere-mantle sulfur exchange may have been widespread during early planetary evolution, although alternative explanations, such as incomplete mixing of isotopically anomalous planetary building blocks, remain viable.

Martian meteorites provide an opportunity to evaluate these competing processes. Estimates of the bulk sulfur isotope composition of the Martian mantle (using shergottites) is generally considered homogeneous, with no evidence of MIF-S preservation[8,9]. In contrast, nakhlites and the polymict breccias preserve clear MIF-S signatures that are attributed to assimilation of isotopically anomalous crustal sulfur[10,11]. Recent *in situ* analyses of shergottites reveal large MIF-S anomalies and variable $\delta^{34}S$ values, consistent with early atmosphere-mantle interaction[7], calls into question the S isotope composition of the Martian mantle.

Here, we plan to present *in situ* and bulk sulfur isotope data for two nakhlites (NWA 10720 and Bir Moghrein) and three shergottites (ALH 77005, EET 79001, and RBT 04261). By integrating sulfur isotope systematics with detailed petrological characterisation, this study aims to distinguish crustal versus mantle sulfur contributions and assess the relative roles of atmosphere-mantle exchange and heterogeneous planetary precursors in shaping the sulfur isotopic evolution of Mars.

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