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On the distribution of p-process nuclides 144Sm and 142Nd in the protoplanetary disc

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Heterogeneities in the nucleosynthetic composition of meteorites for the p-nuclides are less common than for s-process isotopes and have been identified for 84Sr (e.g. Charlier et al., 2021), 144Sm (e.g. Andreasen and Sharma, 2006), 174Hf (Peters et al., 2017) and 180W (Cook et al., 2018). The origin of p-nuclide heterogeneity is unclear and is not related to specific presolar grains found in primitive meteorites. The 144Sm variations in meteorites are particularly interesting because they can be used as a proxy for the extinct p-nuclide 146Sm (half-life of 103 Ma) that decays into 142Nd. This radioactive decay system is crucial in constraining the timing of early differentiation into the mantle and crust that took place on rocky bodies. However, Sm isotope data is scarce and high precision measurements are required to place constraints on the origin and extent of p-process heterogeneity for Sm and Nd in our solar system. We therefore developed an analytical method to measure high-precision Sm isotope compositions and analysed both the Nd and Sm isotope compositions of an extensive set of meteorites.
Here we report significant variations from +31 ± 17 down to -154 ± 17 parts per million for the 144Sm/152Sm ratio in meteorites. The origin of the p-process variations in meteorites may partly related to the addition of early formed solar condensates bearing significantly different nucleosynthetic composition (e.g. Brennecka et al., 2013) to dust from the protoplanetary disc. This new data highlights the heterogeneous nature of the nebular cloud in p-nuclides at the earliest stages of the protoplanetary disc evolution. Combining these results with recent determinations of the natural s-process trend in meteorites (Frossard et al., 2022) and r-process composition estimates defined as the residuals of the s-process abundances (Bisterzo et al., 2014), we corrected the 144Sm/152Sm and 142Nd/144Nd ratios to display only p-process variations. Using this trend we constrained the p-process contribution of 142Nd to 13 ± 6 %. This contribution is considerably higher than estimates of 1 to 4 % derived from astrophysical s-process models (Arlandini et al., 1999; Bisterzo et al., 2014). Our independent estimate of the p-process contribution on 142Nd from meteorites can be used to refine astrophysical models for p- and s-processes.

References:
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Observations

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