Gd and Dy isotopic composition of CAIs:

Characterizing the fingerprint of a supernova injection

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An integrated isotopic study of meteoritic materials

Slight differences between the non-radiogenic isotope compositions of the first solids in the Solar System (calcium-aluminum–rich inclusions, or CAIs) and terrestrial rocks are pervasive. For heavier elements (38 < Z > 62), these isotopic differences are likely caused by the input of supernova material that was not incorporated into the CAI-forming region [1]. These distinct nucleosynthetic differences between CAIs and terrestrial rocks provide the opportunity to determine the isotopic character of the last significant supernova to input material into the Solar System.

Like previous elements studied for this purpose, gadolinium (Gd, Z=64) and dysprosium (Dy, Z=66) have multiple stable isotopes with variable inputs from *p*-, *s*-, and *r*-process nucleosynthesis. In addition to the information gained about nucleosynthetic signatures, Gd isotopic compositions can be used to monitor the thermal neutron fluence [e.g., 2-4] experienced by CAIs. In this study, we present Gd and Dy isotope compositions of four Allende CAIs for which we have previously reported Sr, Mo, Ba, Nd, Sm, and U isotopic compositions [1,5].

Results

CAIs provide no evidence of a significant interaction with thermal neutrons, confirming our previously reported Sm data [1]. This permits a straightforward interpretation for both Gd and Dy in the context of nucleosynthetic signatures. When compared with terrestrial rocks, both Gd and Dy isotopic systems in CAIs contain a relative *r*-process deficit of ~30 ppm.

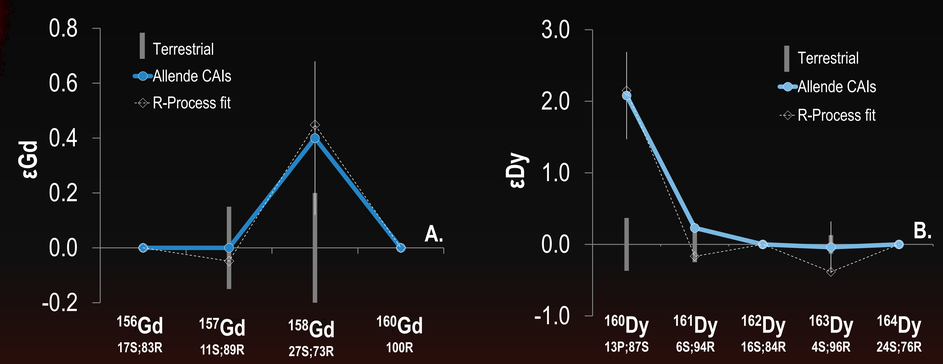


Fig. 1A/B. **The average isotope compositions of Gd and Dy in multiple Allende CAIs. Data are given relative to terrestrial composition in parts per 10,000. The grey bars represent 2SD reproducibility on terrestrial standards. Contributions of the *p*-, *s*-, & *r*-processes are given below each isotope. Note the excellent agreement with an *r*-process deficit model fit, shown by the dashed line. For elements A<140 in CAIs, there is an apparent excess of *r*-process material. For elements A>140 in CAIs, there is an apparent deficit of *r*-process material, as shown in Fig. 2.**

Discussion

In order for the "bulk" Solar System—as given by terrestrial standards—to change from the composition of CAIs (Fig. 1A) to what is present in the terrestrial planets, a supernovae must have injected material with the isotopic composition given in Fig. 2B. This represents the isotopic fingerprint of the last significant material that was mixed into the Solar System.

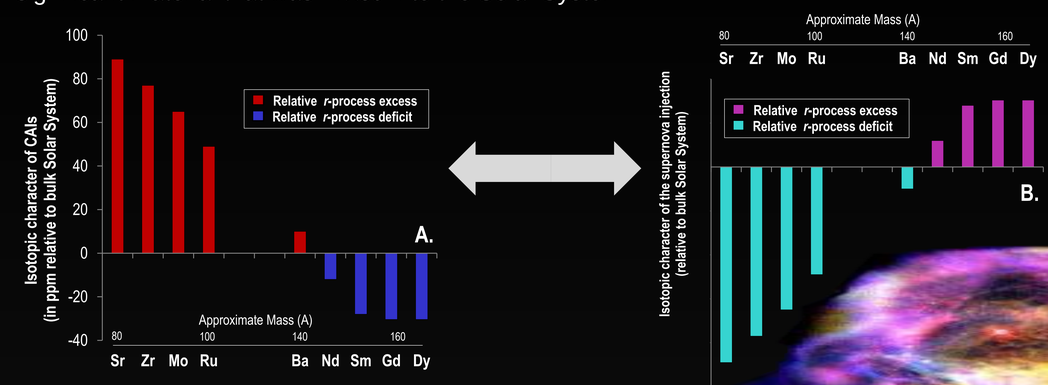
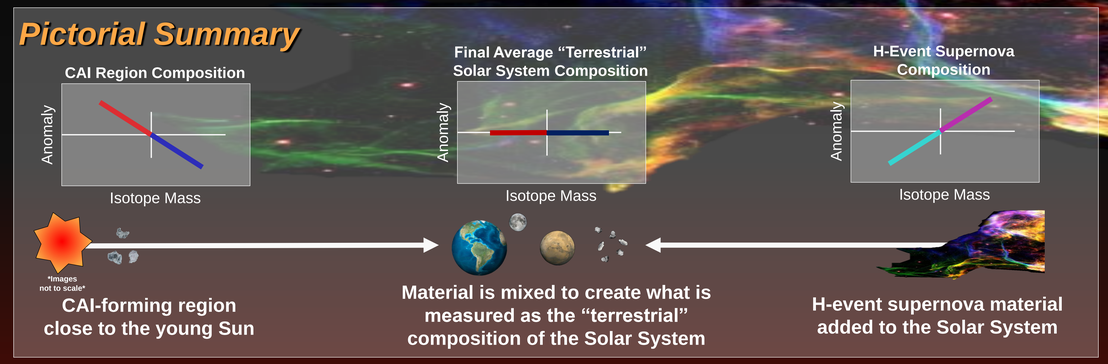


Fig. 2A/B. **The average isotopic anomaly by element measured in CAIs, relative to the terrestrial standards is given in Fig. 2A. In order to create the "average" Solar System composition given by terrestrial standards, material with the isotopic character of Fig. 2B must have been added.**

Pictorial Summary



Works Cited

[1] Brennecka et al. (2013) *PNAS*, 110, 17241. [2] Eugster et al. (1970) *JGR*, 75, 2753. [3] Lugmair & Marti (1971) *EPSL*, 13, 32. [4] Russ et al. (1971) *EPSL*, 13, 53. [5] Brennecka et al. (2010) *Science*, 327, 449.

Acknowledgements

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