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Extreme oxygen isotope ratios in the early solar system: a stellar encounter with the young Sun or irradiation in protosolar outflows?

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Abstract.

The oxygen isotopic mapping by ion microprobe of the deuterium-rich acid insoluble organic macromolecule extracted from the Murchison meteorite revealed the presence of micrometer-sized silica-rich grains having extreme $^{18}O/^{16}O$ and $^{17}O/^{16}O$ ratios ($\sim 10^{-1}$). Such extreme ratios have previously been reported only once : in CO_2 from the circumstellar enveloppe of the binary post-AGB star HR4049 (Cami & Yamamura 2001). However, by contrast with typical presolar interstellar grains preserved in primitive meteorites, which show a compositional scatter attributed to multiple stellar sources, 36 grains accounting for 1 ppm of the total meteorite show a mixing between a single endmember source of heavy oxygen and solar or close-to-solar oxygen. Silicon isotopes in these grains do not show any deviation from solar. These extremely unusual compositions are not explained by conventional stellar nucleosynthesis models. Neither interactions with Galactic Cosmic Rays, nor isotope selective photochemistry due to CO self-shielding, nor non-mass-dependant fractionations during chemical reactions can explain the observed compositions. However we show that irradiation of a gas of solar composition by particles with characteristics of ^{3}He-rich impulsive solar flares can produce these compositions provided a selective chemical trapping of the nuclear-induced oxygen exists. We therefore propose two explanations for these extremely unusual oxygen isotope ratios in micrometer-sized silica-rich grains from the Murchison carbonaceous chondrite. (1) The young Sun encountered an exotic evolved star comparable to HR4049. (2) These compositions were produced in the solar system itself during an active phase of the young Sun by high energy particle irradiation of the circumsolar gas followed by a chemical trapping of the anomaly and condensation of SiO_2-rich grains. A possible locale for the condensation of these grains may be energetic, SiO-rich protosolar outflows.

References

Cami, J. and Yamamura, I. (2001) Discovery of anomalous oxygen isotopic ratios in HR4049. A&A 367, L1-L4.