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The initial C isotope ratio for the solar system

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Introduction: Light stable isotope compositions of meteorites, planets, and the Sun constrain how our solar system formed and the nature of the formation environment, with the Sun considered most representative of the bulk starting material. The NASA *Genesis* mission succeeded in measuring O and N isotope ratios in returned solar wind samples [1], [2]. Extrapolation of the solar wind results to the solar photosphere demonstrate that Earth's O and N reservoirs experienced a very different isotopic history than that of the bulk Sun. *Genesis* has not yet reported a C isotope ratio. Here we reanalyze solar photosphere spectral data to determine the C isotope ratio of the sun.

Spectroscopy of the photosphere: CO rovibrational transitions dominate the 2-5 micron spectral window of the photosphere. Shuttle-borne ATMOS FTS data contains thousands of CO fundamental and first-overtone lines, recorded at high signal-to-noise ratio and at high spectral resolution [3], [4]. We used the latest CO dipole moment functions [5] to reduce line strength uncertainties.

Results: Our ^{18}O abundance for the temperature-enhanced photosphere is $\delta^{18}O_{SMOW} = -50 \pm 11‰$, which is the same within errors as the inferred ratio from *Genesis* [1]. Our ^{17}O value is $\delta^{17}O_{SMOW} = -65 \pm 33‰$, which cannot distinguish between the *Genesis* photosphere value and a terrestrial value at the 2-σ level. With good agreement with *Genesis* O isotope results, we now determine a C isotope ratio. We find the photosphere has $\delta^{13}C_{PDB} = -48 \pm 7‰$. Earth mantle carbon is believed to have a mean $\delta^{13}C = -5$ ‰ [6], implying that bulk terrestrial C is enriched in ^{13}C relative to the Sun by nearly as much as bulk terrestrial O is enriched in ^{18}O. Our results confirm measurements of solar wind in lunar regolith grains [7], and disagree with TiC data from the Isheyevo meteorite which have $\delta^{13}C \sim 0$ ‰ [8].

Implications: Our results demonstrate that bulk Earth, Mars, and asteroids, are enriched in ^{13}C relative to the starting material that formed the solar system. Possible enrichment scenarios, including CO self-shielding in the nebula [9], and inheritance of ^{13}C-rich grains, will be discussed. The key point is that the surficial C on Earth, including ocean carbonates and bicarbonate, is not representative of initial solar system C. The processes that altered the initial C isotope ratio are likely to be common to other solar-mass planetary systems.

References: [1] McKeegan KD *et al.* (2011) *Science* 332: 1528–1532. [2] Marty B et al. (2011) *Science* 332: 1533–1536. [3] Abrams MC et al. (1996) *Applied Optics* 35**:** 2747–2751. [4] Ayres TR et al. (2013) *Astrophysical Journal* 765: 46–71. [5] Li G et al. (2015) *Astrophysical Journal Supplement Series* 216: 15–32. [6] Deines P (2002) *Earth Science Reviews* 58: 247-278. [7] Hashizume K et al. (2004) *Astrophysical Journal* 600: 480-484. [8] Meibom A et al. (2007) *Astrophysical Journal* 656: L33-L36. [9] Clayton RN (2002) *Nature* 415: 860–861.