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Sulfur isotope anomaly in the Ryugu asteroid

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Ivuna-type carbonaceous chondrites (CI) have geochemical compositions similar to the solar photosphere. Their sulfur (S) isotope composition might thus reflect the average nebular gas. However, most CI chondrites have undergone sulfur oxidation on Earth. This may introduce a bias for the determination of S isotope ratios of the bulk nebula, as sulfide oxidation causes sulfur isotope fractionation. In contrast with CI meteorites, samples collected by the Hayabusa2 mission from the Ryugu asteroid have never interacted with an oxygen-rich atmosphere. They offer a unique opportunity to determine the S isotope ratio of CI objects.

Using wet chemistry and isotope ratio mass spectrometry, we determined the S speciation and isotopic composition of the A0481 Ryugu sample and of a series of CI chondrites. We found CI meteorites to have 4.5 ± 0.5 wt.% S on average, consistent with previous estimates. Sulfur is mostly carried by oxidized components such as sulfates and elemental sulfur (S^0). The Ryugu sample contains 4.5 ± 0.1 wt.% S, similar to bulk CI meteorites, although S occurs mostly as sulfides. No sulfates were detected, but we found about 10 ± 3 % of the S in the Ryugu sample to occur as elemental sulfur.

The S isotope compositions of sulfides, sulfates and S^0 in CI meteorites largely reflect a pattern of sulfide oxidation. Wether oxidation occurred in Earth or on the parent bodies is not clear. In contrast, Ryugu sulfides show unfractionated $\delta^{34}S$ values, consistent with minimal oxidation. The S isotope ratios of the Ryugu S^0 is also inconsistent with being produced by sulfide oxidation. Of all samples measured here, only the S^0 from Ryugu exhibits small but resolvable $\Delta^{33}S$ and $\Delta^{36}S$ anomalies. We argue that it represents a component associated with photochemistry in the nebular gas. In Ryugu, that component has not been erased by the meteorite weathering that other CI have undergone.