SEARCHING FOR CONTEMPORARY SUPERNOVA DUST IN DEEP-SEA SEDIMENTS

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Introduction: An excess of ^{60}Fe was discovered by [1] in ferromanganese deep-sea crusts by accelerator mass spectrometry. This was interpreted as evidence of a nearby supernova polluting the Solar System with dust because ^{60}Fe ($t_{1/2} = 2.6$ Myr) is synthesized in supernova and massive-star winds (predominantly the former), but is not produced efficiently by other mechanisms like cosmic-ray spallation. Recently, it was found that the ^{60}Fe excess (^{60}Fe/Fe=1–10 $\times 10^{-15}$) is indeed global (as it should be if the ^{60}Fe has an extraterrestrial origin) and present in two different epochs (1.7–3.2 and 6.5–8.7 Myr ago) [2,3]. Measurements by [4] extended this detection to the Moon with the discovery of ^{60}Fe concentrations well above background (^{60}Fe/Fe=3.6×10^{-15}) in Apollo 12 soils. The time of the lunar deposition of ^{60}Fe was estimated to be broadly consistent with the deep-sea measurements. All of these measurements, considered together, provide convincing evidence that supernova grains arrived at the Earth-Moon system ∼2 Myr ago.

The solar wind and interplanetary magnetic field would have effectively shielded the Solar System from gas and plasma ejected from a nearby supernova, so it was likely supernova dust grains that carried the ^{60}Fe signature to Earth and the Moon [5]. Most of this dust likely vaporized upon atmospheric entry [5]. However, if any supernova dust survived, it would represent an extremely valuable sample of contemporary supernova dust that can be compared with well-studied presolar (>4.6 Gyr old) supernova dust [6].

Abundance Estimates: If supernova grains impacting the Moon had high enough speed, the vaporized impactor material would exceed the Moon's escape velocity and not be retained in the lunar soil. However, [4] measured a similar concentration of ^{60}Fe as that seen on Earth by [2]. Using energy constraints, we conservatively calculate the impact speed of a supernova grain to be $<$ 10 km/s. We then calculate the peak atmospheric heating temperature of such a grain, following [7], and find that grains less than 2 μm will not be heated above 1500° C. Therefore, refractory supernova grains, such as SiC (2730° C) and graphite (∼4000° C) should easily survive atmospheric entry and would be found intact on the ocean floor.

Next, we calculate the abundance of 1 μm contemporary SiC supernova grains per 100 grams of 2-Myr-old deep-sea sediments by using the ^{60}Fe/Fe measurements of [2], the estimated ^{60}Fe/Fe in freshly synthesized supernova material [8], the atom fraction of Fe in presolar supernova grains, the fraction of presolar supernova grains that are SiC, and other considerations. Again using conservative estimates, we estimate there are 50–500 1 μm contemporary supernova SiC grains per 100 grams of the deep-sea sediments measured by [2].

Methods: We were allocated 200 grams of deep-sea sediments from the Antarctic Marine Geology Research Facility. These sediments were collected by the ELTANIN expeditions, sampled from cores measured by [2] and at similar depths: E49-53 (∼385 cm depth) and E45-21 (∼753 cm). The sediments resembled dried mud macroscopically. Backscattered electron imaging and EDX of the soils revealed they were primarily composed of calcium carbonate in the form of calcareous fossils like coccoliths (several μm in size). Cosmic spherules and barite (released by calcareous microorganisms [9]) are also present in the sediments.

We used HF, HCl, and nitric acids to dissolve 50 grams of the E49-53 sediments. After multiple rounds of acid treatment, we were left with $<$ 1 gram of residue, mostly barite.

Future Work: Next, we will use diethylene triamine penta-acetic acid to dissolve the majority of the barite residue [10]. We will micropipette this residue onto an SEM stub and use SEM-EDX imaging to search for hot spots in Si and C. We expect a similar abundance of presolar and contemporary SiC grains in the residue. To identify the contemporary SiC grains we will use the Wash U NanoSIMS to measure (live) ^{26}Al. The initial ^{26}Al/^{27}Al in presolar SiC X grains (of likely supernova origin) is 0.01–0.6 [6]. The contemporary supernova grains we seek are ∼3 half-lives old, meaning they would contain 10–600 ppm of ^{26}Al (SiC X grains contain a few atomic % Al). The NanoSIMS sensitivity for Al far exceeds this value (even at high mass-resolving power), so it will be relatively straightforward to detect ^{26}Al at these levels if it is present.

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