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Meteoritic oxide grain from supernova found

Meteorites contain tiny (0.002–10 μm) mineral grains which formed around stars or in stellar explosions[1,2]. These grains have unusual isotope compositions that reflect those of the stars in which they formed. Stardust composed of nanodiamonds, silicon carbide (SiC), silicon nitride (Si_3N_4) or graphite are believed to derive from a range of stellar types[1,2], whereas the oxygen-rich grains found to date are thought to originate only in red giants and asymptotic giant branch stars[3]. We report here an oxide grain that is extremely rich in the isotope oxygen-16 (^{16}O), in an acid-resistant residue of the Tieschitz meteorite. This grain, T84, probably derives from the ejecta of a type II supernova and is the first reported oxide grain derived from such a source, despite ^{16}O being the third most abundant isotope ejected by supernovae (after hydrogen and helium)[4].

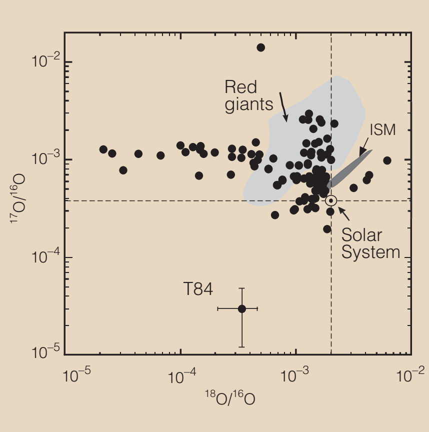

Figure 1 Oxygen-isotopic ratios of meteoritic grains. Filled circles, 103 presolar oxide grains from meteorites; light grey, range observed in red giants; dark grey, range in the gaseous interstellar medium (ISM). Grain T84 is unusually rich in ^{16}O, and probably formed in the ejecta of a type II supernova.

The favoured explanation for the origin of ^{16}O enrichments in calcium–aluminium-rich inclusions (CAIs) in meteorites has been that ^{16}O was carried into the solar nebula by refractory oxide grains (for example, aluminium oxide, Al_2O_3) from supernovae[5]. Although our discovery of T84 indicates that micrometre-sized refractory oxide grains do indeed form in supernova ejecta, the abundance of such grains in meteorites is probably too low to account for the ^{16}O excesses observed in CAIs.

We compare the oxygen-isotope ratios of T84 with those of 102 other presolar oxide grains from meteorites[3], together with the ranges of these ratios in red giants[6] and in the interstellar medium[7] (Fig. 1). Like most of the grains, T84 was identified by isotopic imaging in an ion microprobe[3]. Its isotopic composition is: $^{17}O/^{16}O = 3.0 \pm 1.8 \times 10^{-5}$, $^{18}O/^{16}O = 3.4 \pm 1.3 \times 10^{-4}$.

Unfortunately, T84 was completely consumed during measurement because of its small size (about 0.5 μm) and its mineralogy cannot now be determined. We estimate that the abundance of grains such as T84 in Tieschitz is less than 0.25 parts per billion.

The composition of T84 indicates that it formed in a stellar environment very rich in ^{16}O. Massive stars synthesize copious amounts of ^{16}O by burning helium, carbon and neon deep in their interiors[4]. The freshly made ^{16}O is expelled into the interstellar medium either by type II supernova explosions or, in stars whose masses are more than 30 times that of the Sun, by strong winds during a so-called WO phase[8]. Type Ia supernovae also eject material rich in ^{16}O (ref. 9).

Either supernovae or WO stars are potential sources of T84, but WO stars are extremely rare in the Galaxy whereas supernova explosions are relatively common. Furthermore, type II supernovae eject far more ^{16}O than do type Ia, so a type II origin for T84 is more likely.

The discovery of T84 shows that oxide grains from supernovae were present in the early Solar System, but the abundance of such grains in meteorites is surprisingly small. Galactic dust production rates, calculated supernova yields, and the observed fraction (1%) of presolar SiC grains from supernovae suggest that Al_2O_3 grains produced by supernovae should make up 10–70% of presolar oxides[3,10] rather than the amount observed, which is less than 1%.

The dust produced by supernova 1987A (ref. 11) is much smaller than the grains described here and T84 is at the small end of what can be currently analysed in the ion microprobe. Supernovae may thus produce much smaller oxide grains than do red giants, and they could have been systematically excluded from the presolar oxide data set. Furthermore, detailed analysis of SN1987A's spectra indicates that the dust formed there was not oxygen-rich, but was possibly metallic iron[11]. Perhaps oxides do not easily condense from supernova ejecta, despite the extremely oxidizing conditions.

The very low abundance of presolar ^{16}O-rich oxide grains seems to rule out supernova Al_2O_3 as the prime carrier of ^{16}O enrichments in CAIs. Instead, ^{16}O may have been carried into the early Solar System by supernovae-derived ^{16}O-rich silicates rather than oxides. Alternatively, the Solar System's oxygen-isotope heterogeneity may have resulted largely from non-mass-dependent isotopic fractionation[12].

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Polarization vision helps detect transparent prey

Transparency enables aquatic organisms to avoid detection by visual predators. But we have found that this camouflage can be broken using a visual mode evolved by several predators, such as squid. Under partially linearly polarized lighting, squid detect zooplankton prey at a distance 70% greater than those achieved under non-polarized illumination. The role of polarization sensi-

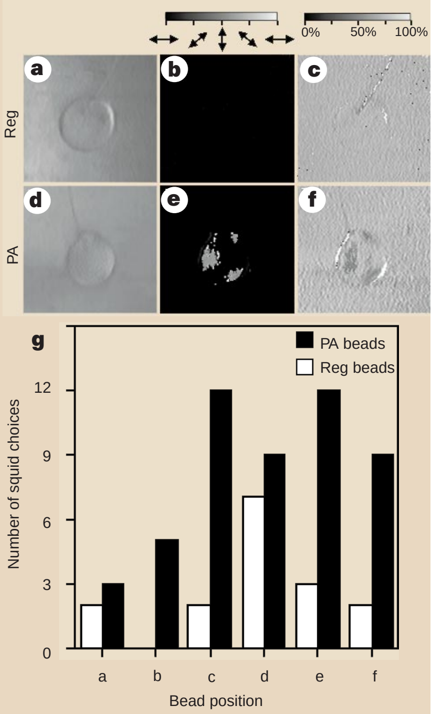

Figure 1 Adult squid choices of glass beads that mimicked prey. **a–f,** Glass beads (1 cm diameter, equal transparency in the 400–650 nm range) appear identical to a human observer (**a**,**d**). Using a submersible imaging polarimeter[9], the light intensity (**a**,**d**), e-vector orientation (**b**,**e**) and percentage of linear polarization (**c**,**f**) were measured at each pixel in an image. Some beads (**d–f**) were heat-stressed during manufacture and hence were polarization-active (PA), whereas others (**a–c**) were not stressed and did not affect the light's polarization (Reg). **g,** Fifteen squid examined more than one bead in the 15-minute period, resulting in 66 bead choices. Scoring was by one of two volunteers, neither of whom knew the identities (Reg or PA) of the glass beads. Bead position (**a–f**, across the tank, 20 cm from each side, and 16 cm between them; **a**, left-most position as a squid approached the beads) was a significant factor in the animals' choices ($\chi^2 = 11.1$, $P < 0.05$), but there was a significant preference for the PA beads independent of the bead's location ($\chi^2 = 11.22$, $P < 0.05$).

tivity in predation is confirmed by squid's preference for transparent, yet polarization-active, targets that mimic their prey.

In aquatic environments, many organisms are transparent or translucent, rendering them difficult to detect[1]. However, some of these planktonic organisms contain polarization-active tissues[2].

Using the new retardance-measuring polarized-light microscope (Pol-Scope)[3] and standard linear polarization microscopy, we inspected the tissues of 20 zooplanktonic species to determine the polarization-active structures in their bodies. Muscle fibres and rhabdomeric photoreceptors showed strong retardance up to one-quarter of the wavelength. Edge birefringence could be detected in only a few organisms, and was most noticeable in chaetognaths and in the antennae of crustaceans.

Natural illumination is often partially linearly polarized[4], so transparent but polarization-active organisms may be rendered conspicuous when viewed by a polarization-sensitive visual system[5]. We tested the role of polarization vision in prey selection and detection in adults and hatchlings of the squid *Loligo pealei,* which is known to be polarization-sensitive[6].

We examined the choices of adult squid when presented with small transparent glass beads that mimicked prey items and which were either polarization-active (PA) or had no effect on the polarization characteristics of light passing through them (regular beads, Reg). Six of these beads (three Reg, three PA) were suspended in midwater at one end of a rectangular tank measuring 370 × 120 cm and containing water to a depth of 40 cm. Of 50 animals tested, 10 did not respond to the beads and were excluded from analysis.

Of the remaining 40, half were tested with the PA beads in positions as shown in Fig. 1a, c, e and half with the PA beads as in Fig. 1b, d, f. Beads were illuminated from behind through a glass window. The light was filtered through a wax-paper depolarizer and a Polaroid HN38S linear polarizing filter, creating a partially polarized light field comparable to the marine environment[4]. Additional dim illumination was provided by overhead fluorescent lights. Results (number of bead choices) were analysed using the χ^2 goodness-of-fit test with equal expected frequencies.

Adult squid preferred PA beads over Reg beads (Fig. 1g). This preference was evident from: total squid choice in a 15-min period (Fig. 1; PA = 50, Reg = 16; $\chi^2 = 17.52$, $P < 0.0001$); first approach of each squid (PA = 33, Reg = 7; $\chi^2 = 16.90$, $P < 0.0001$); and the squids' overall preferences (PA = 30, Reg = 4, equal number of Reg and PA choices = 6; $\chi^2 = 19.88$, $P < 0.0001$).

We also examined predation on live zooplankton by squid hatchlings. We introduced hatchlings ($n = 250$) into an experimental tank illuminated through a side window with either linearly polarized or depolarized light. We recorded the hatchlings' feeding behaviour with a video camera for 60 minutes. The first 100 attacks in each trial (polarized or depolarized illumination) were measured when the predator:prey density was 1:50. We also measured 25 attacks in each illumination setting with a predator:prey ratio of 1:140.

Squid hatchlings attacked planktonic prey under polarized illumination at a 70% greater distance than under depolarized illumination (6.09 ± 2.92, as against 3.58 ± 1.26 squid body lengths, average ± s.d., $P < 0.001$, Kolmogorov–Smirnov 2-sample test). Prey densities did not affect the attack distances ($P > 0.1$, Kolmogorov–Smirnov 2-sample test). Attacks had similar success rates under polarized and depolarized illumination (86 and 74%, $\chi^2 = 7.78$, $P > 0.05$, χ^2 with equal expected frequencies), indicating that a greater attack distance does not impair prey capture.

Loligo pealei, like other squid, is a pelagic visual predator. Both young and adults feed on transparent zooplankton[7,8]. Adults are predominantly crepuscular predators, feeding at times when the partial polarization of the underwater light field is at its maximum[7]. We predict that polarization-based predation may be common among other polarization-sensitive planktivores such as fish and crustaceans.

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Ultradry seed storage cuts cost of gene bank

Today we are faced with an urgent challenge to organize the efficient conservation of biodiversity. In the case of plants, one way of doing this is to store their seeds in a gene bank. The effective preservation of seeds depends on their moisture content and on the storage temperature, which can present a problem in developing countries where the costs of cold storage are prohibitive. Here we describe a way of storing seeds under ultradry conditions at ambient temperatures which not only improves their longevity and vigour but also promises to be a cost-effective technique for germplasm conservation.