Graphite grains come in a variety of morphologies, but only the rounded ones (see micrograph on facing page) appear to have large anomalies in their ^{12}C/^{13}C ratios. Amari and colleagues find that these range from 2 to 7,300 (a typical Solar System value is 89). The isotope ratios fall into several distinct groupings. The question facing experimentalists and astrophysicists alike is, how many sources of graphite does this represent?

Similar questions are being asked for those other carbon-bearing interstellar dust grains, diamond and silicon carbide. In the case of diamond, for which the ^{12}C/^{13}C ratios vary only slightly from one meteorite to another[5], and the size distribution reflects a low degree of processing[6], there need be only a single source (two at most). However, because the grains are so small (typically 1 nanometre across), analyses are done on millions of crystals rather than individuals, so the measured isotope ratios might simply represent the average of many sources of pre-solar dust. For silicon carbide grains, which are sometimes large enough to be analysed individually, isotopic information has been variously interpreted as representing one source[7], or up to 75 (ref. 8).

To settle the question, what is needed is the isolation of several grains that demonstrably come from a single source, and the newly discovered aggregates of several hundred silicon carbide grains[9] may fit the bill. For various reasons it is unlikely that the aggregation took place in the solar nebula; it is more likely to have happened close to the source of the grains. The overall isotopic compositions of the clumps are close to the average of earlier individual analyses, so — if aggregation during the chemical treatments that produced the grains can be ruled out — it looks as if the range of isotopic values seen previously could have come from a single source.

So what of the variations in ^{12}C/^{13}C for graphite? Essentially, graphite, like silicon carbide, will condense from a stellar source where the carbon/oxygen ratio is greater than 1. Carbon stars at the asymptotic giant branch phase of evolution seem good candidates for the origin of silicon carbide. Curiously, though, the carbon isotopic compositions of graphite tend not to agree with those recorded in individual silicon carbide grains. Nor do they agree with those from carbon stars — puzzling, given that these are thought to contribute most of the carbonaceous dust to the interstellar medium. Why should the solar nebula have sampled an unrepresentative part of the interstellar medium?

For those graphite grains that have high ^{12}C/^{13}C ratios it is clear that nucleosynthesis via helium-burning is required. Amari and colleagues suggest two new possibilities: Wolf–Rayet stars, at a period in their evolution when the products of helium-burning rise to the surface; and helium-burning in the outer shells of massive stars, before they explode as type II supernovae. The accompanying isotopic evidence (^{14}N/^{15}N, ^{16}O/^{18}O, ^{26}Al) does not, sad to say, enable a distinction to be drawn between these possibilities. It seems unlikely, though, that the large sizes of some of the graphite grains could be accounted for by supernovae.

It looks like graphite will turn out to have multiple sources, but for a complete understanding of those sources, we need still more isotopic measurements. In particular, noble gases seem to be essential. Krypton isotope measurements[10] pin down the origin of some of the graphite grains to a pulsing star in the asymptotic giant branch, and neon from another subset of grains bears the signature of a nova explosion[11].

Those less interested in sources than in the nature and mixture of the dust grains that were drawn into the solar nebula will want to know the average isotopic compositions of meteoritic graphite. For them, the painstaking analysis of many hundreds of individual grains may not be the quickest way forward, and progressive combustion techniques of the type employed by Ash *et al.*[12] may be preferable. Ash and co-workers discovered a component of carbon in the Allende carbonaceous chondrite characterized by ^{12}C/^{13}C of 120. With hindsight, this isotopic value probably represents the average of a single population of meteoritic graphite. Yet a further population can be distinguished by the component known as Cα, which has a ^{12}C/^{13}C ratio of 66 (ref. 13). These numbers can now be used alongside average ^{12}C/^{13}C values for diamond (92.5) and silicon carbide (37), in chemical models of Solar System formation. In the meantime, Amari and colleagues must continue their demanding task so as to satisfy the appetites of astrophysicists intent on describing the nucleosynthetic histories of Solar System materials. ☐

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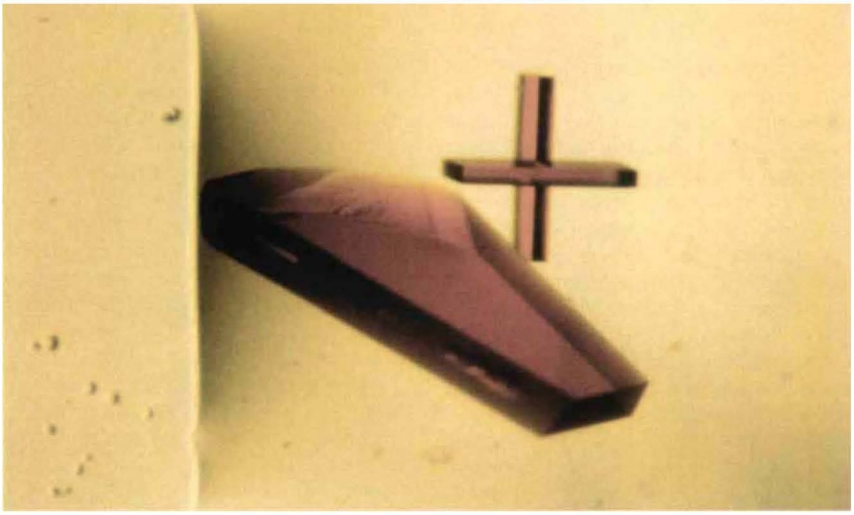
Halloween crystals



THESE macabre crystals formed over Halloween week-end last year. But sad to say neither supernatural forces, nor ingenious trick-or-treaters, have yet been implicated in their production. The cross (arms 0.5 mm in length) and coffin (complete with hinges) were a one-off, bizarre result of experiments involving crystallization of complexes of horse cytochrome *c* and its antibodies by vapour diffusion in hanging drops; normally the result is crystals 0.5 mm long resembling nothing so much as the everyday rock. The group concerned — a collaboration between researchers at the Universities of Minnesota and Illinois at Chicago, and Argonne National Laboratory — will test the reproducibility of the cross-and-coffin effect this Sunday. Ghostbusters are on standby. Those interested in the earthly aspects of the work can read about them in a paper by Ronald Jemmerson and colleagues, now in press with *Acta Crystallographica*. T.L.