of EH into the circulation is prevented by removal of the peripheral release sites (9). The occurrence of the ecdysial behaviors under these conditions is thought to be due to a local release of EH within the CNS. By contrast, peripheral EH targets, such as dermal glands, do not secrete their products because of the lack of circulating EH. Given the arrangement in the figure, the lack of bloodborne EH should also result in a failure of the Inka cells to release their peptide. Clearly, more work needs to be done to define the exact relation between the release and action of EH and of Mas-ETH. Also, the relation of Inka cell activity to the phases of the molt cycle needs to be explored to determine whether they are involved in assessing the "readiness" of the periphery.

Regardless of these details, the discoveries of the Inka cells and Mas-ETH have opened up an exciting new chapter in the study of the complex process of ecdysis.

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Stardust in the Laboratory

Ernst Zinner

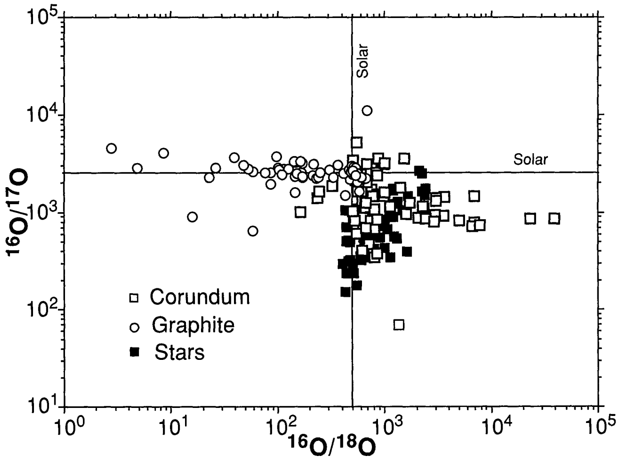
Although the elements from carbon on up are expected to be produced in different stars by a variety of nuclear processes with very different isotopic ratios (1), solar system materials—even primitive meteorites, which contain the oldest solar system objects—have uniform isotopic compositions. This uniformity could be the result of extremely thorough mixing of the source material that formed the solar system. How wide the range of isotopic compositions of this material actually is was not realized until a few years ago: Preserved stardust was discovered in meteorites, and individual micrometer-sized stellar grains were isolated and studied in detail in the laboratory (2, 3). These grains are believed to have condensed in stellar outflows and supernova ejecta and thus preserve the elemental and isotopic composition of their stellar sources. The range of their isotopic compositions not only dwarfs that observed in solar system objects but by far exceeds the range of spectroscopic observations in stars (see figure).

Although the presence of stardust in meteorites had already been indicated in the sixties by the presence of "exotic"—that is, isotopically anomalous—noble gas components in different meteorites, it took more than 20 years before the carriers of these noble gases were identified and isolated (4). Today, the list of types of stardust include diamond, silicon carbide (SiC), graphite, aluminum oxide (corundum), and silicon nitride [see, for example (2, 3, 5, 6)]. In addition, SiC and graphite were found to contain tiny subgrains of titanium, zirconium, and molybdenum carbides, identified in the transmission electron microscope (7).

The ion microprobe plays a central role for the analysis of meteoritic stardust because this instrument makes it possible to measure the isotopic compositions of individual grains down to sizes of less than 1 μm. On the basis of the isotopic compositions of the grains, two important types of stellar sources could be identified: red giant stars of low to medium mass during late stages of their evolution, and supernovae, massive stars that exploded at the end of their evolution.

Most of the SiC grains are believed to have originated from red giants, specifically from carbon-rich, thermally pulsing, asymptotic giant branch (AGB) stars (8). The AGB stars are believed to be the main source of s-process (nucleosynthesis by slow neutron capture) elements, and "bulk samples" (collections of many grains) of SiC grains carry the s-process signature in the isotopic compositions of Kr, Xe, Ba, Nd, and Sm (2). The isotopic compositions of C, N, and Mg measured in most single SiC grains generally agree with a carbon-star origin and can be explained by nucleosynthesis during H and He burning in deep stellar layers and mixing of the products to the surface of stars losing mass in strong stellar winds. The Si and Ti isotopic compositions of single grains (9) cannot be explained by nucleosynthesis taking place in a single star and indicate multiple stellar sources (10).

Corundum grains show a large range in their O isotopic ratios (see figure) and $^{26}Al/^{27}Al$ ratios (5, 11). Some grains must have formed in the expanding atmosphere of red giants. As in the case of Si isotopic compositions of SiC grains, the O isotopic compositions of individual corundum grains cannot be explained by nucleosynthetic processes taking place in a single star. Excesses in ^{17}O and moderate depletions in ^{18}O relative to the star's original composition are believed to result from mixing into the envelope of material processed in the star's interior during core H burning. However, the spread in O isotopic compositions found in meteoritic oxide grains can only be explained by assuming that different stars with different masses (variations in $^{16}O/^{17}O$) and different initial isotopic compositions (variations in both $^{16}O/^{17}O$ and $^{16}O/^{18}O$) contributed oxide grains to the solar system (12). Some grains with high $^{16}O/^{18}O$ ratios (see figure) must have come from AGB stars of intermediate mass in which H burning in deep convective layers destroyed essentially all ^{18}O.



Stardust signatures. Comparison of the oxygen isotopic ratios measured in different types of stars with those measured in individual grains of stardust found in meteorites.

Three types of presolar grains in meteorites are believed to come from supernovae: low-density graphite grains, SiC grains of the rare (1% of all SiC) type X, and even rarer silicon nitride. The ^{15}N and ^{18}O excesses found in many of these grains are

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believed to originate from the He-burning zone of massive stars at the end of their evolution, just before their explosion as supernovae (*13*). The former are produced by explosive reactions, the latter by He burning of ^{14}N during the hydrostatic evolution of the star. The large variations in Si isotopic compositions and specifically excesses in ^{28}Si are interpreted as a result of the mixing of interior stellar layers, where O burning took place, with the C-rich outer He zone during the supernova explosion (*14*). Violent mixing has indeed been observed during supernova explosions (*15*).

Additional evidence for a supernova origin was recently presented at the 58th Meteoritical Society Meeting in Washington, D.C. Nittler and co-workers from Washington University in St. Louis and Strebel and co-workers from the University of Berne found large ^{44}Ca excesses, apparently from the decay of short-lived ^{44}Ti (half-life = 58 years) in graphite and SiC grains. This radioisotope is produced only deep inside of supernovae and, together with ^{28}Si, has to be mixed into C-rich zones during the supernova explosion in order to be present in carbonaceous grains.

At the same meeting, Amari and co-workers presented evidence for ^{41}Ca in graphite grains of supernova origin in the form of ^{41}K excesses (^{41}Ca decays to ^{41}K with a half-life of 105,000 years). Finding ^{41}Ca in these grains, which also have large amounts of extinct ^{26}Al (half-life = 720,000 years), has potentially important implications for the source of these two radioisotopes, which are also found in early solar system objects (*16*). Whereas Wasserburg *et al.* (*17*) implicate an AGB star as the source of these two isotopes in the early solar system, Cameron *et al.* (*18*) revived the supernova trigger hypothesis for solar system formation and postulate that both ^{26}Al and ^{41}Ca originated in this explosive event.

At present, the isotopic data on presolar grains so far identified provide important constraints on nucleosynthesis and stellar evolution. However, it is likely that additional types of presolar grains are present in primitive meteorites and that only our lack of ingenuity to locate them keeps us from gaining even more information about our celestial ancestors.

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Optical Rockets

A very intense laser pulse can modify the index of refraction of the medium through which it travels, even to the point of producing a lens effect that focuses the beam to smaller diameters, a phenomenon known as self-focusing (*1*). If the laser travels through a gas with an intensity high enough to cause ionization, the plasma thus created can also modify the propagation of the light, although in this case, the effect is one of defocusing (in addition to the usual effects of diffraction). For a range of laser intensities, it is therefore conceivable that the effects of self-focusing and defocusing might balance each other, leading to a stable transport of laser light through a narrow channel. Recent work by the group of Mourou and co-workers at the University of Michigan shows this to be the case 2), and the results demonstrate self-channeling of laser light over a distance of 20 m (see figure).

Long light. Optical channel formed as an intense laser pulse propagates down a laboratory hallway. [Photo courtesy of G. Mourou, University of Michigan.]

A fancy bit of laser technology makes this possible. Mourou's group have used a titanium-sapphire laser system with chirped pulse amplification (*3*) to produce 100-fs pulses having an energy of 50 mJ at a wavelength of 775 nm. In chirped pulse amplification, the spectral components of the laser pulse are stretched out in space with a pair of diffraction gratings, making the peak power lower and enabling the high-gain amplifier stages to boost the energy efficiently. Once amplified, the spread spectrum is compressed into a short-duration, high-intensity laser pulse by another pair of gratings. With this technique, laser pulses approaching 100 TW (terawatts) have been produced (*4*).

Braun et al. found that the critical power for self-focusing in air was around 10 GW for a pulse energy of 2 mJ. At 15 mJ with a clean, spatially homogeneous laser beam profile, a narrow filamentary channel formed with a diameter of 80 mm. The researchers reported generation of white light along the channel and conical off-axis emission of colored light, which show up in the image as rings (see figure). Instead of being an "optical bullet," the Michigan group refers to the pulse propagation as an "optical rocket" because they believe that the pulse energy is continually resupplied by the background optical energy propagating outside of the filamentary channel.

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