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Spectroscopic evidence for interstellar grain clumps in meteoritic inclusions

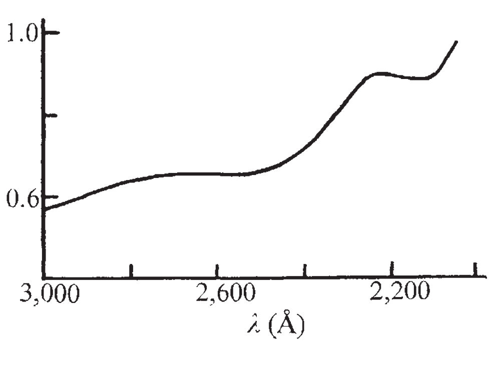
THE occurrence of a primitive, presolar grain component in carbonaceous chondrites has been indicated by several independent lines of evidence, including the discovery of isotopic abundance anomalies[1,2]. The occurrence of organic molecules, including amino acids, in these meteorites is also known[3,4], but their connection with a genuinely pre-solar grain component has been conjectural. We show here that an extract of organic material from the Murchison carbonaceous chondrite has an ultraviolet spectrum with an absorption band centred at $\lambda \approx$ 2,200 Å. The similarity of this feature with the well-known interstellar absorption band at the same wavelength, gives strong credence to an interstellar grain component within this meteorite.

Carbonaceous chondrites contain a significant mass fraction of organic compounds, mainly in the form of aromatic polymers. Typically about 30% of this material is of relatively low molecular weight and could be extracted by using hexafluoroisopropanol as a solvent. The remaining 70% is of higher molecular weight and is usually insoluble[3].

A sample of the Murchison chondrite (supplied by Dr. Onuma) was used to obtain an organic molecule extract with hexafluoroisopropanol. The absorption spectrum of this extract (Fig. 1) shows a conspicuous absorption hump centred at $\lambda \approx$ 2,200 Å, having a half-width $\approx$300 Å and bearing a remarkably strong similarity to the well-known interstellar extinction feature[6–8]. A band of this type is a property of a wide class of organic molecules having conjugated double bonds, for example, C C–C C, C, C–C C C, C, C = C – C = O, with a typical cross-section of ~4 10^{-17} cm^2 (refs 9, 10).

Although the 2,200-Å absorption band in the interstellar extinction curve has usually been attributed to graphite particles[11–13], this explanation is unsatisfactory. Spherical or nearly spherical graphite particles of radii ~ 150 Å are required to reproduce the observed features of the astronomical band[14]. Non-spherical particles, or spherical particles with much larger radii will shift the band centre away from λ 2,200 Å, or distort the symmetry of the band. An origin of the interstellar λ 2,200 Å feaure in terms of complex organic molecules lodged in grain clumps would have an advantage in that the mean absorption profile (arising from electronic transitions in an ensemble of molecules) has a central wavelength and width which are independent of the shapes and sizes of the host grain clumps. On the basis of this interpretation, the astronomical and meteoritic spectral data would provide further supporting evidence for a connection between pre-solar interstellar material and inclusions in carbonaceous chondrites.

Fig. 1 The absorption curve of organic material in the Murchison carbonaceous chondrite extracted using hexafluoroisopropanol as a solvent.



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Prebiotic molecules and interstellar grain clumps

INTERSTELLAR molecules detected by radioastronomical techniques in clouds such as OMC 1 and 2 in the Orion Nebula and Sgr B2 in the galactic centre span a wide range of types and complexity. Among the heaviest of the molecules recently discovered is cyanodiacetylene[1] (H—C C—C≡C—C≡N). There have been earlier detections of precursors to the simplest known amino acid glycine (formic acid and methanimine), and probable detections of polyoxymethylene polymers and copolymers[2–5] in interstellar clouds. We discuss here a possible identification of organic molecules of even greater complexity, and its implications for the start of biological activity.

Large departures from thermodynamic equilibrium in the interstellar medium and the co-existence of solid grains, molecules, radicals, ions and ultraviolet photons provide conditions which are ideal for the assembly of 'exotic' molecular species. If clumping of 100 Å-sized dust grains occurred by a process which we have discussed[6], highly complex organic molecules could be formed and become securely trapped during the 'welding' process of smaller grains. Such grain clumps could be widely dispersed amongst the particulate material in the Galaxy, being responsible for most of extinction and polarisation of starlight.

The spectral identification of highly complex organic species in the interstellar medium might seem hopeless. A property