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Organic Dust, Synthesis by Stars

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Keywords

Star dust; Stellar evolution

Synonyms

Organic grains; Organic solid particles

Definition

Organic dust consists of micron- or nanometer-sized carbon-based solid-state particles with aromatic (ring-like) and/or aliphatic (chain-like) structures. The solids could be in crystalline (periodic) form, or more likely, in amorphous (random) form. Possible examples of terrestrial counterpart are soot, which is a product of combustion of hydrocarbons in a flame, and ▶ kerogen, the most common form of organics on Earth formed from decayed living matter.

History

The existence of interstellar dust has been known since the early twentieth century through the effect of selective extinction on the light of distant stars. The chemical composition of the dust particles was initially assumed to include graphite, iron, or ice. Development in stellar nucleosynthesis led to the understanding that the element carbon is synthesized in the asymptotic giant branch (AGB) phase of stellar evolution. This led to the suggestion by Fred Hoyle that carbon-based solid particles could be produced by stars (Hoyle 1955). The possibility that some of this star dust might be organic in nature was first suggested in the 1970s (Hoyle and Wickramasinghe 1977). Later, it was suggested that organic compounds can be detected in the infrared part of the spectrum through their C–H stretching mode (Knacke 1977; Duley and Williams 1979).

After the discovery of the ▶ unidentified infrared emission (UIE) bands, it was realized that some astronomical spectra resemble the spectral features observed in automobile exhaust. This led to the suggestion that the carriers of the UIE bands may be related to polycyclic aromatic hydrocarbon molecules (Allamandola et al. 1985). This represents the beginning of the serious studies of organic compounds in space.

Overview

Since organic solids can take on many different forms, the identification of a specific organic solid is not as straightforward as in the case for inorganic minerals. Minerals generally have highly ordered lattice structure in a crystalline form and therefore possess optically active lattice vibrational modes. These produce clear infrared spectral signatures, allowing the identification of

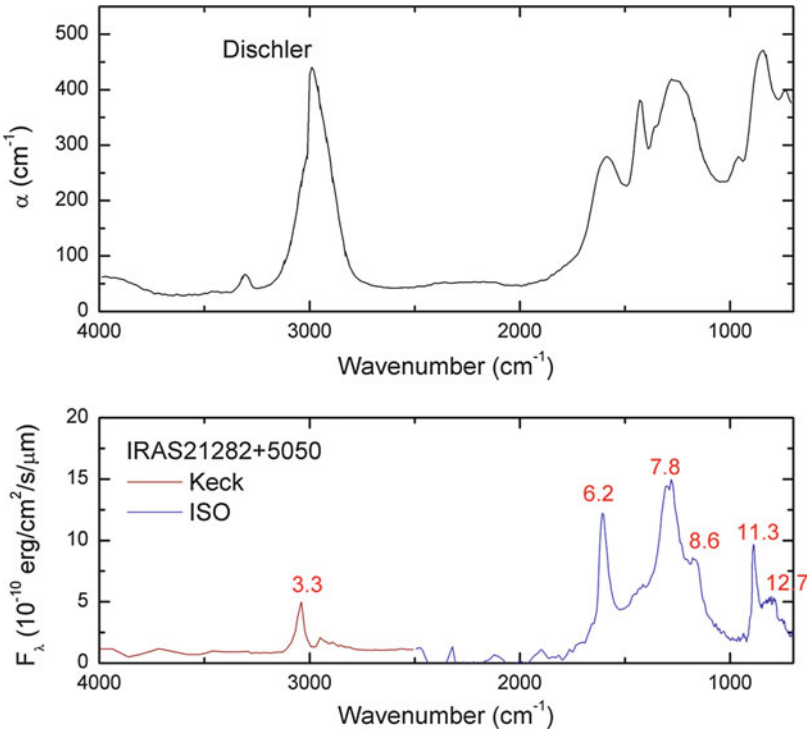

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Fig. 1 Laboratory infrared spectra of hydrogenated amorphous carbon (*top panel*) compared to the astronomical spectrum of the planetary nebula IRAS 21282+5050 (*bottom panel*). The laboratory spectrum is adapted from Dischler et al. (1983). *Horizontal axis* is in wavenumber (*inverse wavelength*). The *red labels* in the astronomical spectrum mark the unidentified infrared emission bands

exact minerals. Organic solids, however, have many electronic states, and their absorption bands are very broad. Macromolecular organic solids can be identified by their visible colors, albedo, and infrared bands. More specifically, the vibrational modes of various functional groups can be identified through comparison with laboratory spectra.

Amorphous carbonaceous solids are characterized by different sp^2/sp^3 hybridization ratios as well as mixed hybridization states. Organic particles of such structures are natural products of combustion. The first nucleation products for soot particles formed in flames have structures consisting of islands of aromatic rings linked by chains. Laboratory-synthesized carbonaceous nanoparticles are found by chemical analysis to consist of networks of chains and rings. Various laboratory experiments have been performed to simulate the synthesis of carbonaceous nanoparticles in stellar outflows. The products from vapor deposition are independent of energy injection techniques, which include laser ablation of graphite, laser pyrolysis of gases, arc discharge, microwave irradiation, UV photolysis, and flame synthesis.

By introducing hydrogen into familiar forms of carbon such as graphite (sp^2) and diamond (sp^3), a variety of amorphous C–H alloys can be created (Robertson 2002). Geometric structures of different long- and short-range order can be created by varying the aromatic-to-aliphatic ratio. The infrared spectra of these amorphous carbonaceous materials resemble the astronomical unidentified infrared emission bands seen in ► planetary nebulae and ► protoplanetary nebulae (Fig. 1). Since these amorphous carbonaceous solids have absorption bands in the visible, they can be easily excited by visible light from stars.

Many organic compounds, including hydrogenated amorphous carbon, exhibit photoluminescence, suggesting that photoluminescence by organic dust may be the source of the so-called extended red emission observed as a diffuse glow in some astronomical environments (Rusli and Amaratunga 1996).

Although carbon and hydrogen are the basic constituents of organic star dust, other abundant

heavy elements such as nitrogen, oxygen, and sulfur are also likely to be present. These amorphous compounds are sometimes collectively referred to as CHONS.

Organic grains of similar structures have been found in the Solar System. The insoluble organic matter (IOM) in carbonaceous meteorites has mixed aromatic/aliphatic structures similar to those of terrestrial kerogen. Organic dust in the Solar System is generally assumed to be manufactured in the Solar System, although certain isotopic anomaly suggests that it could be of stellar or interstellar origin (Ehrenfreund and Charnley 2000).

See Also

- ▶ Extended Red Emission
- ▶ Insoluble Organic Matter
- ▶ Interstellar Dust
- ▶ Planetary Nebula
- ▶ Polycyclic Aromatic Hydrocarbon
- ▶ Star Dust

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Organic Grains

▶ Organic Dust, Synthesis by Stars

Organic Material Inventory

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Definition

The organic material inventory is the list of materials that contain organic compounds (typically carbon, hydrogen, oxygen nitrogen. . .) that are carried on spacecraft in quantities above a specified limit. The list comprises the denomination of each compound and the total amount present inside the spacecraft. This inventory is a component of required ▶ planetary protection documentation for missions to target objects for which there is an interest in studying organic compounds that could have contributed to the origin and evolution of life in the Solar System.

Organic Molecule

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Definition

An organic molecule is any member of a large class of molecules containing carbon, and then limited by a number of somewhat arbitrary restrictions. For historical reasons, a strict definition of an organic molecule is difficult. The word "organic" dates back to the ancient Greeks.