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Organics of likely interstellar origin in the Paris chondrite

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Abstract

We studied some fragments from the Paris meteorite through infrared and Raman micro-spectroscopy. The infrared signatures of a few 10 µm-sized grains show quite a good match with infrared spectra of the interstellar medium toward the Galactic Center in both the 3.4 µm and 6 µm regions. Raman measurements show that these grains were probably highly irradiated and/or poorly thermally altered. These results suggest that the Paris meteorite may have preserved some of its organic material from interstellar origin.

1. Introduction

The Paris meteorite is a CM chondrite [1] composed of two lithologies, one being less altered than the other [9]. Previous studies on CM meteorites, e.g. Murchison [5], have shown a good match between their infrared (IR) organic signatures around 3.4 µm and the spectrum of the interstellar medium (ISM). In this work, we compare the IR spectra of some fragments extracted from the Paris chondrite with those of the ISM in the 3.4 µm region as well as, for the first time, in the 6 µm region.

2. Experimental methods

A 50 µm-sized fragment extracted from the few milligrams of the Paris meteorite provided by the MNHN has been crushed in a diamond compression cell. This preparation mode improves the signal to noise ratio and minimizes the scattering effects in IR measurements [6]. After crushing we obtained a 90 µm sized grain (called "bulk" in the following) and 22 little (less than 10 µm in diameter) fragments detached from the "bulk" (called "excavated" grains in the following). The IR spectra were obtained on the French synchrotron SOLEIL using a Nicolet NicPlan microscope coupled to a Fourier Transform infrared spectrometer Nicolet 6700 Thermo Scientific with a Mercury-Cadmium-Tellurium detector (for mid-IR) and a bolometer (for far-IR). Spatial resolution was above 5 µm and the spectral resolution was 4 cm^{-1} for mid-IR spectra and 8 cm^{-1} for the far-IR spectra. Raman spectra were obtained with a spectrometer DXR from Thermo Fisher using a 532 nm laser focused with an objective x100 in a spot of about 0.7 µm and a laser power below 1 mW. For each spectrum, we performed twelve acquisitions of five seconds each.

3. Results and discussion

We compare in Figure 1 the IR spectra obtained from the "bulk" and from one of the "excavated" fragments. The bulk is composed mostly of phyllosilicates, carbonates and organics. The "excavated" grain is also composed of phyllosilicates and organics. The two spectra show very different signatures in the 6 µm (~ 1600 cm^{-1}) region, revealing the presence of Polycyclic Aromatic Hydrocarbons (PAHs) in the "excavated" fragment, and in the 3.4 µm (~2950 cm^{-1}) region, revealing different structures of the aliphatic hydrocarbons. The spectra of the "excavated" fragments match well the ISM spectra toward the infrared sources GCS3 and GCS4 obtained by the Short Wavelength Spectrometer onboard the Infrared Space Observatory in both these wavelength ranges. The CH_2/CH_3 ratio determined through the 3.4 µm band for the "bulk" is 2.2 ± 0.2, which is in good agreement with the ISM value of 2.5 ± 0.4 [8]. This ratio could not be determined for the "excavated" fragments but, as they are less structured than in the "bulk" spectrum, their CH_2/CH_3 ratio has to be very small. A low CH_2/CH_3 ratio can result from the destruction of the aliphatic chains by irradiation [4] or from the shortening of the chains due to aromatization under heating [3]. To distinguish between these two processes and compare the degree of order of the organic matter, we compared the Raman characteristics (the so-called D and G-bands [7]) in the "bulk" and in the "excavated" fragments. The positions, widths and intensities of the Raman signatures of aromatics depend on their degree of order [2], i.e. the thermal metamorphism they have experienced. We show here that the “excavated” fragments have suffered very low heating or have been highly irradiated. This result tends to suggest that irradiation may be the process that shortened the aliphatic chains and thus, that these fragment could be of interstellar origin.

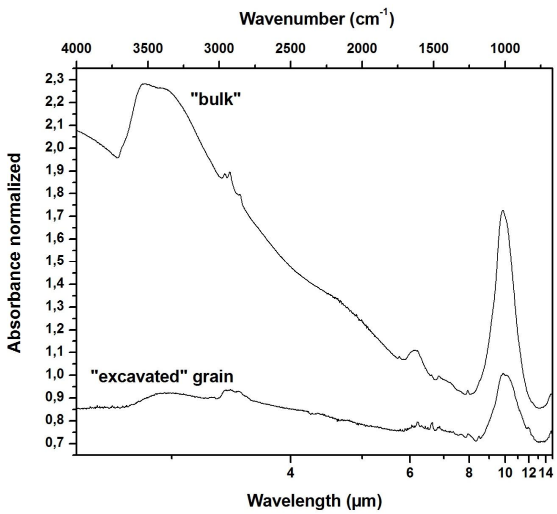

Figure 1: IR spectra of the “bulk” (upper spectrum) and of one of the excavated fragments (lower spectrum). Absorbance has been normalized to the silicate peak at 10 µm and the upper spectrum was shifted in the Y-axis for clarity.

6. Summary and Conclusions

In this work, we have excavated very peculiar aromatic-rich fragments in the Paris chondrite without any solvent extraction. We show that these fragments have similar IR signatures than the ISM regarding to the 3.4 and 6 µm spectral regions. The structure of the aromatics in these fragments, deduced from our Raman measurements, indicates that they have been highly irradiated and/or that they have suffered very low heating suggesting a possible interstellar origin or processes in the solar nebula mimicking those taking place in the interstellar medium.

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