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Mid-Infrared Spectroscopy of Chondrites: The Link to Observations of Circumstellar Disks and Comets

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Abstract

We compare mid-infrared spectra of dust in circumstellar disks and comets with FTIR absorbance spectra of components in primitive meteorites (CAI, chondrules, and matrix).

1. Introduction

Mid-infrared spectroscopy is a technique which allows identifying the structural and mineralogical composition of dust (< ~10 µm) in various astronomical environments – like circumstellar or protoplanetary disks, or in comets. In order to characterise the dust in astronomical spectra, laboratory data is needed for comparison. There are abundant studies of pure minerals, often made especially for this purpose [1].

Here we present mid-infrared spectra of bulk chondrites, as well as their characteristic components: chondrules, Calcium-Aluminium-rich Inclusions (CAIs) and fine grained matrix. Since these materials are the first processed materials in our Solar System, any identification of such components in other young solar systems would allow linking the detailed knowledge of our Solar System materials to astronomical observations.

Recent studies indicate that the dust observed in circumstellar disks is produced by fragmentation of processed material in the mid-plane of these disks and transported to the surface, where it can be observed in the mid-infrared. Furthermore, the 10 µm range of the astronomical spectra is dominated by the signal of the hot, inner disk [2]. Thus the infrared spectra from astronomical observations are an ideal probe of the place in a young solar system where important material processing in our own Solar System 4.6 Gyr probably took place. It also allows linking the laboratory spectra of powdered material directly to the observations.

The STARDUST space probe showed chondrule like materials in comet 81P/Wild 2 [3]. This motivates a comparison of chondritic spectra with IR observations of comets.

2. Techniques

For this study, a series of chondrules separated from the Allende CV chondrite, as well as several bulk chondrites, were characterized using SEM/EDX, and then ground to a fine powder in the µm size range. The powder was embedded in KBr, and pressed to pellets. We used a Perkin Elmer Spectrum One IR workbench at the Natural History Museum in London. The wavelength range measured was 2.5 - 25 µm, with a spectral resolution of 1 cm^{-1}.

Further laboratory data was used from earlier studies in this and similar projects (e.g. matrix [4]).

3. Results

In figure 1 we present results for laboratory and astronomical spectra dominated by of olivine features at ~11.2 µm and at ~10 µm. The latter feature is also typical for amorphous material, so the intensity ratio between these two bands allows estimating the degree of materials processing in circumstellar environments [2].

Astronomical spectra for Herbig star (systems with masses of 2-8 times our sun) HD100456, low-mass system EK Cha and short-period comet Hale Bopp [5,6] as representative of our Solar System are very similar to each other, indicating the mineralogical similarity between the these different systems.

Of the chondrite materials, the relatively featureless bulk ordinary chondrite spectrum of Baratta is similar to the cometary and Herbig system data. The averaged spectrum of olivine-rich chondrules reproduces the EK Cha spectrum very well: the strong 10 µm band indicates the high content of amorphous mesostasis in the chondrules, the 11.2 µm band olivine, the shoulder at ~9.3 µm signals slight pyroxene content.

Spectra like that for another short-period comet, 9P/Tempel1 shows a 10 µm band in comparable size to the 11.2 µm olivine bands, with a shoulder at ~9.3 µm. This spectra fall between the olivine-rich chondrule material, but are also very similar to type 2 chondrite material from shock-experiments, where they were exposed to pressures from 21 to 36 GPa [4]. This could indicate heavy processing of the pristine cometary materials e.g. by collisions in the dynamically excited early solar system.

5. Summary and Conclusions

First comparisons in the mid-infrared between spectra of chondritic materials and dust in young solar systems shows similarities between olivine-rich chondrule materials as well as shocked matrix material with dust in some circumstellar disks and comets.

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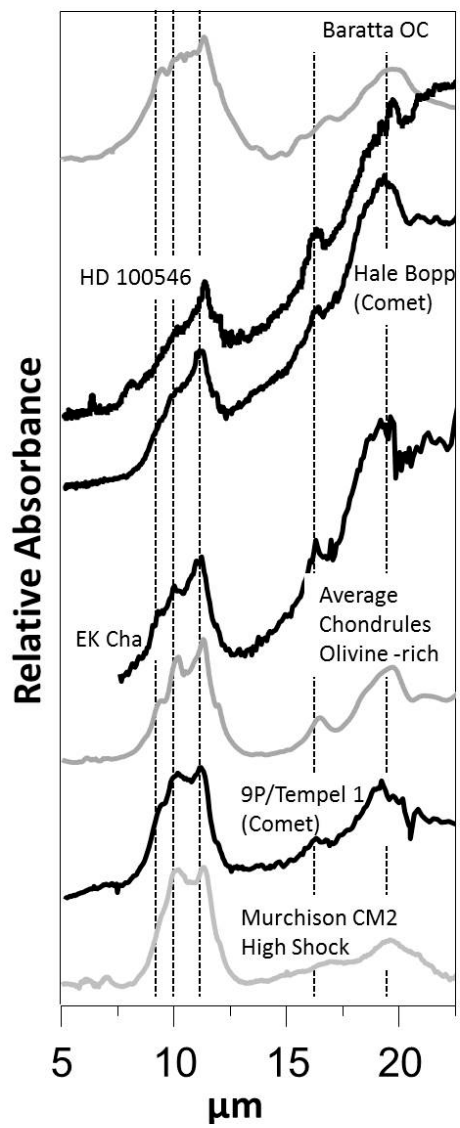

Figure 1: Comparison of laboratory FTIR spectra of chondrite materials with astronomical spectra. Black: Astronomical spectra; grey: laboratory spectra.