

Carboxylic acids at the surface of comet 67P/CG?

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Abstract

A broad feature centered at 3.2 μm has been detected in the reflectance spectra of comet 67P/Churyumov-Gerasimenko collected by the VIRTIS/Rosetta imaging spectrometer. This band points to the presence of semi-volatile organics, however to date no firm identification of molecular species has been done. In this study, we have focused on the experimental spectral characterization of carboxylic acids, which have been proposed as candidates for the 3.2 μm broad band. We show that simple carboxylic acids are not viable candidates, because of their thermal stability in regard to the surface temperature, and/or due the shape/size of their 3 μm band that does not fit VIRTIS spectra. We infer that if carboxyl groups are the main carrier of the 3.2 μm band, it should be present in a low mass macromolecule, along with OH groups in side chains that favor hydrogen bond. A balance ratio between OH groups and aliphatics CH_2/CH_3 must also be respected. Last, intimate mixtures do not fit VIRTIS data, and small spots of semi-volatiles on the surface of opaque material must be considered to account for 3.2 μm band.

1. Introduction

The VIRTIS instrument (Visible InfraRed Thermal Imaging Spectrometer) aboard the Rosetta spacecraft has detected a broad feature centered at 3.2 μm in the reflectance spectra of comet 67P/Churyumov-Gerasimenko, which might be consistent with the presence of semi-volatile organics, also possibly detected by the COSAC and PTOLEMY instruments [1-4]. Carboxylic acids have been proposed as candidates as these molecules in the liquid form display a broad absorption band that fit that of the 3.2 μm band. In this study, we have focused on the experimental spectral characterization of pure and

mixed (with other organics) carboxylic acids, which have been proposed as candidates to account for the 3.2 μm broad band [1-2]. Carboxylic acids are also the main component in the soluble organic fraction in primitive meteorites, with several tens of carboxylic, dicarboxylic and hydroxylated acids identified so far [5]. The thermal stability of these molecules has also been studied (desorption kinetics), in order to infer their presence at the surface of the nucleus.

2. Methods

Experiments have been run at IPAG with a Vertex 70v FTIR spectrometer equipped with a GLOBALBAR source and a DTGS detector for transmittance spectra. Thin films of low weight carboxylic acids were condensed as ices on a KBr window held at 25 K, and warmed up with a resistor and a PID controller (Lake Shore 331) until the sublimation of the acid. Carboxylic acids available in the solid state at room temperature were prepared with a spin coater, by deposition in a vacuum furnace and pellet. Mid-infrared spectra ($4000 - 400 \text{ cm}^{-1}$) were collected with a 4 cm^{-1} spectral resolution. The reflectance spectra of mixture of carboxylic acid with graphite or basalt (as analogs of dark refractory cometary materials) were done using spectro-gonio radiometer in the spectral range 500-4200 nm.

3. Results

The experiment results of figure 1 shows that C1-C4 carboxylic acids with an aliphatic side chain display a broad feature in the 3 μm region controlled by the –OH group, onto which are superimposed C-H stretching and combination modes. This band has however components towards long wavelengths (3.67-4.35 μm), which do not appear in VIRTIS spectra. Above C5, the prominent and sharp aliphatic massif at 3.4 μm dominates the 3 μm region and does not account for the broadness of the 3.2 μm feature.

We also investigated dicarboxylic (C4 fumaric acid) and hydroxylated acids (C2 glycolic and C3 lactic acids). The presence of several –OH groups leads to a broadening of the 3 μ m feature with respect to their related monocarboxylic acids, however side bands between 3.67 and 4.35 μ m are still present.

Figure 2 presents the reflectance spectra of mixture of hydroxylated carboxylic acids with basalt and graphite. Graphite with sub-micrometric grain has very low reflectance and is used as an analog of refractory grains. There is not any features appeared on granular mixture and dissolved mixture. As another way to see the features of hydroxylated acid in reflectance spectra, we changed the graphite to basalt, which is brighter than graphite. We also observed that basalt hydration could not be suppressed and we need to improve this issue. And the results from reflectance spectra support a surface composed of refractory dark materials along with small semi volatiles patches geographically distributed [6-7].

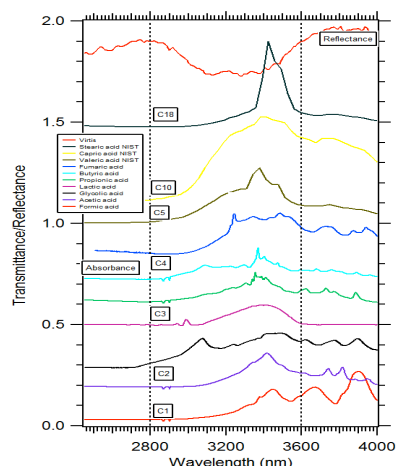


Figure 1: Comparison of a reflectance spectrum of VIRTIS with transmission spectra of carboxylic acids

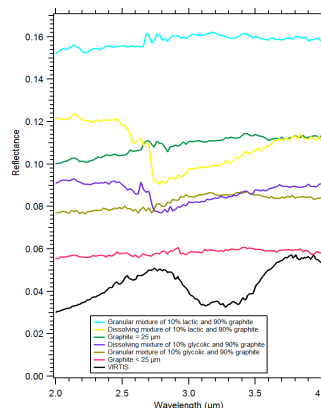


Figure 2: Reflectance spectra of graphite and mixtures of hydroxylated acids with graphite

4. Conclusions

In this study, we have reported on the transmittance and reflectance spectra of carboxylic acids. Simple carboxylic acids are not thermally stable (sublimation temperature around 200K) and they do not fit the spectrum of comet 67P/CG. Large carbon chain is also not spectrally match so the balance ratio between COOH and OH groups in side chain is mandatory to produce a broad band. Small spots of ice on the surface of opaque material must be considered to account for 3.2 μ m band.

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