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Cometary dust organics analogues: production, composition and scattered light

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Abstract

Polarimetric observations of cometary comae may be used to infer dust particles properties through experimental simulations. Cometary organic solid materials are poorly known. Here different organic materials found in nature or synthetic are studied. Their light scattering response was correlated to their chemical composition (under heating or not). Some cometary dust analogues were obtained by mixing them with silicates and lifted in the PROGRA2 light scattering experiment.

1. Introduction

Cometary dust is mainly composed of silicates and carbon-bearing compounds. Infrared spectra observations provide important knowledge about the temperature conditions of their formation or their evolution through the determination of the ratio of crystalline/amorphous varieties in the silicates. Up to now, it is more difficult to disentangle the numerous organics. When comets approach to the Sun, the volatile ices and refractory organic compounds are heated and they release compounds, which are retrieved in the gas phase. However, the source materials are still only poorly known. Some information can be inferred by the study of the IOM (insoluble organic matter) in meteorites or IDPs captured in the Earth atmosphere and supposed to be of cometary origin. Organics were also found in the particles captured by the STARDUST spacecraft. The particles captured by the COSIMA instrument of the Rosetta mission in the coma of 67P/Churyumov-Gerasimenko [1] revealed very fluffy and large aggregates of carbonaceous compounds with sizes larger than 50 μm made of sub-micron-sized grains. The dust optical scattering done by the ejected particles at 3.7-3.4 au is dominated by 100 μm to millimeter-sized particles ([2], GIADA-OSIRIS results).

Laboratory simulations of light scattering by cometary analogue particles help to disentangle different physical properties by comparison to observational data. The linear polarization depends on the geometry of observations (phase angle) and on the particles properties (size and size distribution, structure and refractive indices). It also depends on the wavelength of observations. Our PROGRA2 light scattering experiment is perfectly adapted to study particles between 20 and 500 μm, levitating in a cloud, or in microgravity conditions, or by an air-draught [3]

2. Samples

This study aims to test how the nature and composition of organics materials from different origins relate to their light scattering response as cometary analogues. We hence used different organics: natural coals (State University Coal Bank and Data Base), industrial carbon blacks, laboratory-synthesized organics. Four types of synthetic organics were produced, with relevance for cometary study: (1) polymers of HCN synthesized in solution at the LISA laboratory [4], (2) solid organic particles synthesized in an electric discharge from mixtures of N2:CH4 gases at room temperature with the PAMPRE experiment at LATMOS laboratory [5], and (3) solid organic particles synthesized in an electric discharge from mixtures of $CO:N_2:H_2:H_2O$ gases at temperatures higher than 500°C in the Nebulotron instrument at CRPG laboratory [6]. The last two types of organics differ in size distribution and shape of the grains and structure of the particles and in their elemental composition (e.g. N related to C) depending on their formation conditions [6,7]. Some of these organics were heated ex-situ at 200-500°C; leading to progressive carbonization and increase of polyaromatics components. (4) Organic-coated silicates were produced by Fischer-Tropsch reaction of CO, N2, H2 gas on amorphous Fe-silicate grains at 560°C (NASA/Goddard Space Flight Center). Different classes of organic compounds were identified: saturated and unsaturated hydrocarbons, alkyl-benzenes, phenols, styrenes, and traces of polycyclic aromatic hydrocarbons [8].

Each organic material was characterized by infrared and/or Raman spectroscopy. The shape and size distribution of the grains is measured on SEM images. The size distribution of the lifted agglomerates is directly measured on the PROGRA2 images.

3. Light scattering results

Most of the heated materials present a higher polarization in the red wavelength than in the green one, corresponding to a change in the composition of the materials, i.e., a change in the refractive indices (at room temperature the wavelength effect is inverse or neutral). Under heating (from 200°C to 550°C), organic bearing materials become darker and the spectra bluer, consistently with aromatization of the organic fraction [9]. The analysis of our heated samples shows similar results [10].

Analogues of cometary particles, will be made by mixing organic particles of different origins with silicates of different shapes, structures and compositions (Mg and Fe-rich) and results will be compared to those obtained for coated silicates. The results obtained with PROGRA2 will be compared to observational results.

6. Summary and Conclusion

The production of cometary dust analogues, made of silicates, mixed or not with organics, are detailed. Their composition is compared to materials found in meteorites and IDPs. Some of these materials were heated, simulating organic formation in warm regions of the solar nebula [6]; or their heating after ejection from the nucleus in the coma when the comets are close to the Sun. Their composition is compared to materials found in meteorites and IDPs.

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