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Light scattering by Organic materials in dust clouds when approaching the Sun: Laboratory simulations

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Abstract

When solid particles approach the Sun, their properties may change with their temperature mainly if they include organics. These variations can be detected by different methods. One of them is the linear polarization of the solar light scattered by the particles. The polarization depends on the physical and optical properties of the particles such as their size, structure, albedo and on the phase angle.

1. Introduction

Dust particles properties may vary with an increase of their temperature when they approach the Sun. The main components of these dusts, e.g. in cometary comae or in the interplanetary dust cloud are silicates and organics in compact and fluffy particles. Evolutions in their composition and in their physical properties are correlated with their thermal degradation. Numerical and laboratory simulations are necessary to interpret the changes of the solar light scattered by the particles observed with remote sensing. We first study clouds of some organics and the variation of the linear polarization of the light they scatter. In a second part, we propose mixtures of particles, which may correspond to the composition of the interplanetary dust cloud at different solar distances in the ecliptic plane. We finally compare the obtained results with observations and numerical simulations.

2. Samples

2.1 Organics

We used both commercial samples (e.g. Poly-Acrylo-Nitril, PAN) and $C_xH_yN_z$ components, produced in our laboratories by different syntheses processes (e.g. HCN polymers from liquid HCN by LISA-Univ Paris 12) and Titan tholins produced with the PAMPRE experiment (LATMOS-CNRS) in N_2-CH_4 gas mixtures [3]. The samples are progressively heated from the ambient temperature to 200°C-300°C and above. The light scattered by clouds of unheated and heated organic particles are studied with the $PROGRA^2$ instrument at two wavelengths, 543.5 nm and 632.8 nm [1].

2.2 Interplanetary dust analogues

The thermal properties and the light scattered by the particles are numerically modelled and the observational results are fitted to help for their interpretation [2]. We have used the modelling results as the size distribution, ratio of compact and fluffy particles and ratio of silicates and dark organics to prepare different dust mixtures and we studied the light scattered by the levitating samples as dust analogues at different solar distances.

3. Light scattering results

3.1 Organics

Color, structures and sizes

Figure 1 Color variations vs temperature for PAN

When progressively heated, the color of PAN, initially white, becomes red and darkens progressively. At the beginning, the color changes without any mass loss, indicating a changing of the chemical composition. When the temperature is high enough, materials evaporate, with morphological structure variations (Fig 2a). The darkening of the color with heating is found for all the samples.

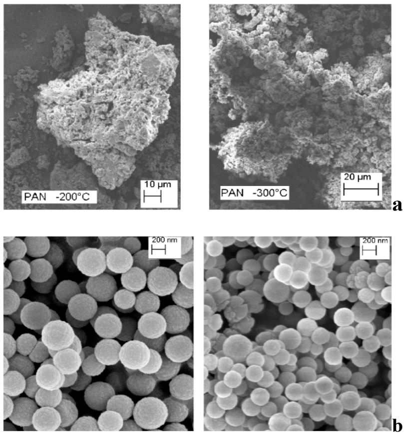

Figure 2 Morphological structure of heated organics. a. PAN particles (200°C and 300°C). b.Tholins particles: left 25°C, right 300°C. (SEM-FEG images: S. Borensztajn, UPMC Univ Paris 06, UPR15).

For the tholins samples, the structure of the grains is about preserved up to 300°C but the mass and the average size decreases with formation of aggregates (Fig. 2b).

Polarization phase curves

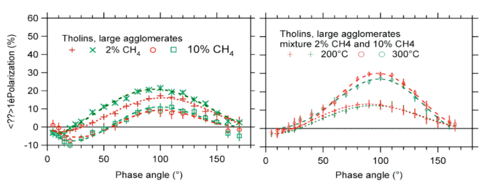

Figure 3 Polarization phase curves for unheated tholins and a heated mixture of the same tholins. Change in spectral gradient for the heated sample.

The shape of the phase curves is characteristic of irregular particles with a maximum positive polarization at about 90° phase angle, an inversion angle in the range 15°-50° depending on the sample, its albedo and size distribution. The spectral gradient is mainly positive for heated samples even if it is negative at ambient temperature. Fig 3 gives an example of such variation of the spectral gradient for the tholins. A similar behaviour is found for poly-HCN and PAN.

2.2 Interplanetary dust analogues

As suggested by numerical models: mixtures of 60% organics and 40% silicates of different origins and structures (35% fluffy aggregates with different sizes of the constituent grains) can reproduce the phase curve deduced from observations of the local polarization found in the interplanetary dust clouds at 1.5 AU from the Sun. The variation of the amplitude of the positive polarization at 90° phase angle from 1.5 AU to 0.5 AU is also correctly reproduced.

3. Summary and Conclusions

- Laboratory simulations of thermal variations of organics indicate some similar behavior for their physical and optical properties. The materials are darker at high temperature and their mass progressively decreases as suggested by the extended sources in cometary coma dust.

-An agreement is found between observations, numerical and experimental simulations (polarization and albedo) of the local properties in the interplanetary dust cloud between 1.5 AU to 0.5 AU from the Sun in the ecliptic plane.

Acknowledgments

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