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LINEAR POLARIZATION MEASUREMENTS WITH CLOUDS OF THOLINS PRODUCED BY RADIO-FREQUENCY PLASMA

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ABSTRACT. The linear polarization of the light scattered by fluffy agglomerates of tholins produced by a RF plasma is correlated to the physical properties of the samples. The results are compared to space observations of Titan's aerosols.

1. Introduction

Observations of the scattered light and its linear polarization by Titan's aerosols were conducted onboard space probes such as Pioneer 11 and Voyager 2 [1, 2] for the integrated measurements from outside the atmosphere and by DISR/Huygens during its descent in the atmosphere. Analysis by numerical model of fractal aggregates with about 3000 constituent grains, deduce a size for the grains in the 0.1 μm diameter (or smaller) in aggregates in a size range of microns at altitude above 60 km [3]. Nevertheless such models do not exclude the possibility of larger aggregates. These aerosols are at the origin of the yellow haze that gives Titan's peculiar color. They are produced in a N_2-CH_4 gas mixture and are made of organics. To learn about their formation process, composition and morphology, experiments have been developed to produce similar materials (called by the generic term tholins) under conditions as close as possible to Titan's atmosphere.

The PAMPRE experiment uses a capacitely coupled plasma technique in a N_2-CH_4 gas mixture [4]. Depending on the experimental conditions, the grains average diameter varies in the range (0.05-1) μm [5]. When the grains are ejected outside the plasma they stick together in agglomerates (partially by electrostatic forces). In the present paper, we concentrate on the morphology and optical properties of such agglomerates. The light scattered by tholins is studied with the PROGRA2-vis instrument by the air-draught technique [6]. The lifted particles are fluffy agglomerates with an average size of (50-100) μm. The equivalent size distribution is measured on the polarization maps. The largest particles progressively settle down; some fluffier and smaller particles float during a longer time allowing to study particles smaller than the resolution limit (10 μm). In that case the laser beam in the field of view seems to be continuous.

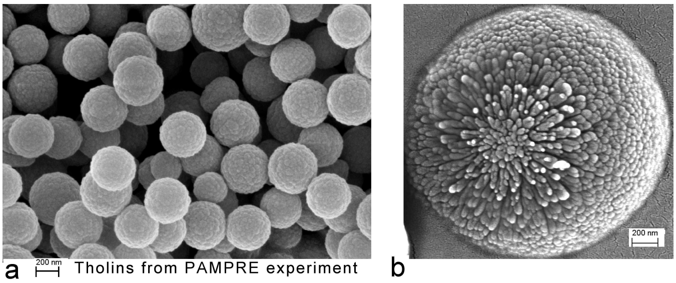

Figure 1. SEM images of tholins particles (UPMC Paris 06/LISE)

Figure 2. Decreasing darkness of the samples with increasing methane content in the gas mixture.

2. Morphology and size of the grains

The constituent grains are approximately spherical (Fig. 1a). During their formation they seem to grow radially (Fig. 1b), creating surface irregularities similar to those on a cauliflower. When they are collected they agglomerate most probably by electrostatic forces and may be partly flattened or eventually sinter into aggregates.

For each sample the size distribution of the grains is obtained from the SEM images [5]. The size of the grains in the plasma increases during about 150 s and tends toward an asymptotic value. To obtain grains with a limited average size, it is necessary to adjust the discharge duration by a pulse mode of the plasma.

3. Light scattering results

3.1. Reflectivity. The samples are darker when the initial ratio of methane in the gas mixture decreases (Fig. 2). This can be the result of an increase of the average size of the grains but also to different chemical composition of the samples. The scattered intensity increases with increasing wavelength [7] on the bidirectional reflectance spectra in the visible spectral domain i.e. the absorption decreases when the wavelength increases for all the samples.

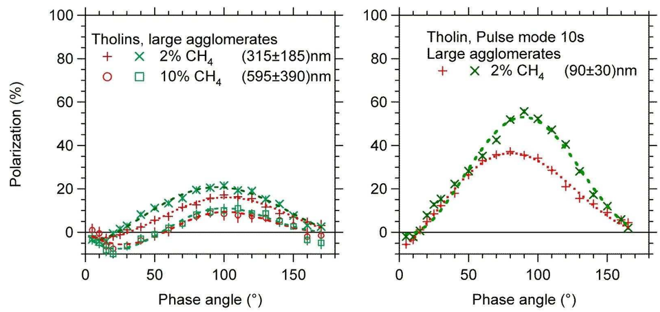

Figure 3. Polarization phase curves for 2 tholins at 2 wavelengths (543.5 nm and 632.8 nm)

3.2. Phase curves. Polarization phase curves obtained for two different initial gas compositions are presented in Fig 3. The samples studied in Fig 3b were produced with the pulse technique. The curves have the usual shape obtained for irregular particles [6]. The amplitude of the positive branch mainly depends on the size of the constituent grains (for agglomerates with similar size distribution) as can be seen in Fig 3 and Fig. 4a. A negative spectral gradient is noticed for the three samples and for all samples with large agglomerated grains. Agglomerates smaller than 5 μm are tentatively studied for the 2% CH_4 gas mixture. The phase curves present some small Mie undulations and the spectral gradient in polarization is positive.

3.3. Amplitude of the positive branch as a function of constituent grains size. The amplitude of the positive branch increases up to a maximum value when the size of the agglomerates increases; this maximum value increases with decreasing average diameter of the constituent grains (Fig. 4a). The size distribution of the agglomerates is about the same for the different samples and allows the study of the amplitude as a function of the size of the grains. In Fig. 4b, the amplitude of the positive branch on the different phase curves for tholins produced with 2% methane obtained by tuning the plasma duration decreases with the increase of size of the constituent grains (full symbols). For different initial conditions the data (materials with different absorptions, open symbols) are on the same exponential fits. The size of the grains seems to be the main parameter when the average size of the agglomerates is about the same for the different samples.

4. Discussion and future work

To reproduce the optical properties deduced for Titan's aerosols from observations by space probes (Pioneer 11 and Voyager 2), grains with diameters smaller than 100 nm are needed (Fig 4a) or in the atmosphere above 140 km altitude from DISR. The absorption of light by the tholins, decreasing when the wavelength increases (in the visible domain). PAMPRE tholins in large agglomerates reproduce the negative spectral gradient of polarization observed from outside the atmosphere (Pioneer 11 and Voyager 2). In a first approximation, large size agglomerates simulate the thick atmosphere. Tholins reproduce the

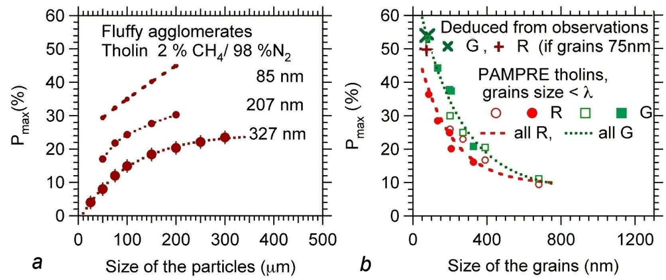

Figure 4. Amplitude of the positive branch vs sizes (a) of constituent grains (b) of agglomerates. Comparison to remote integrated observations on the whole atmosphere (extrapolated to the wavelengths used in the experiment).

positive spectral gradient observed by DISR from inside the atmosphere for agglomerates smaller than 5 μm.

We will present polarization results for other initial conditions (e.g. 5 % CH_4) and a complementary study of the effect of smaller sizes for the agglomerates to interpret the variation of spectral gradient (this study is allowed by more sensitive cameras on the PROGRA2 instrument).

Acknowledgments

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