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I. Introduction

On July 14th, 2015, the *New Horizons* spacecraft flew by Pluto and revealed the presence of aerosols in the atmosphere [1,2,3] and a curiously dark reddish equatorial region named Cthulhu [1,4]. These photochemical aerosols, extending at more than 350 km of altitude [2,3,5], may affect Pluto atmospheric chemistry and climate [6,7]. Furthermore, it was suggested that these aerosols sediment to constitute the non-icy dark material on the surface of Pluto [4,8]. To interpret the data provided by *New Horizons*, the atmospheric (*e.g.* [7]) and surface models (*e.g.* [4,9]) have so far used the optical constants determined for Titan tholins. Nevertheless, since optical constants strongly depend on the chemical composition of the materials [10], and as Pluto tholins differ chemically from those of Titan [11], Pluto aerosol analogues were synthesized in laboratory and their optical constants were determined by spectroscopic ellipsometry.

II. Experimental setup and analyses protocol

- **Synthesis of Pluto tholins**

We used the PAMPRE experimental setup [12] (LATMOS, France) to synthesize Pluto tholins as thin films onto silicon wafers. For this study, the gas mixture injected into the reactor was composed of variable proportions of N_2 and CH_4, with 500 ppm of CO [5,13], to simulate photochemical aerosols formed at different altitudes on Pluto (Table 1). The experiments were conducted at a pressure of 0.9 ± 0.1 mbar and at ambient temperature.

Table 1: Types of Pluto tholins analyzed in this study

Composition of the gas mixture	Corresponding altitude on Pluto [5]	Name of the sample
99.5% N_2 : 0.5% CH_4 : 500 ppm CO	< 350 km	P_H
99% N_2 : 1% CH_4 : 500 ppm CO	400 km	P_{400}
95% N_2 : 5% CH_4 : 500 ppm CO	600 km	P_{600}

- **Spectroscopic ellipsometry**

We used the UVISEL (*Horiba Jobin Yvon*) spectroscopic ellipsometer to analyze Pluto tholins thin films. Spectroscopic ellipsometry is a technique measuring the changes in the polarization state between incident and reflected light on the sample, as a function of wavelength. DeltaPsi2® software was used to fit the ellipsometric data. More precisely, a modified Tauc-Lorentz dispersion model determined the thicknesses of the thin films, and a wavelength-by-wavelength inversion method was used to retrieve the refractive indices *n* (Fig. 1) and the absorption coefficients *k* (Fig. 2), from 270 to 2100 nm.

III. Optical constants of Pluto tholins from UV to near-IR

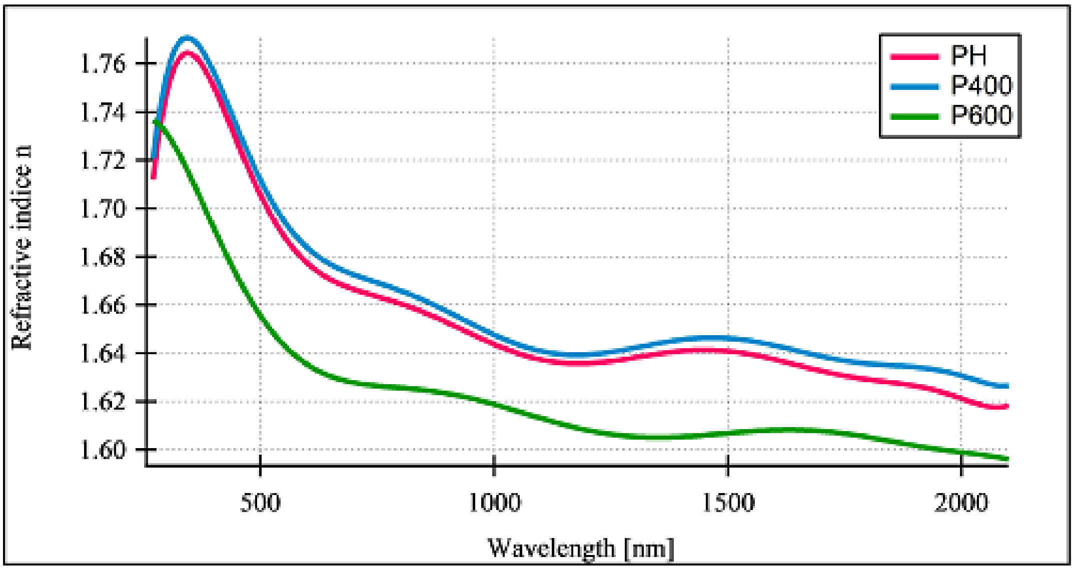

Fig. 1: Refractive indices *n* of Pluto tholins determined by spectroscopic ellipsometry

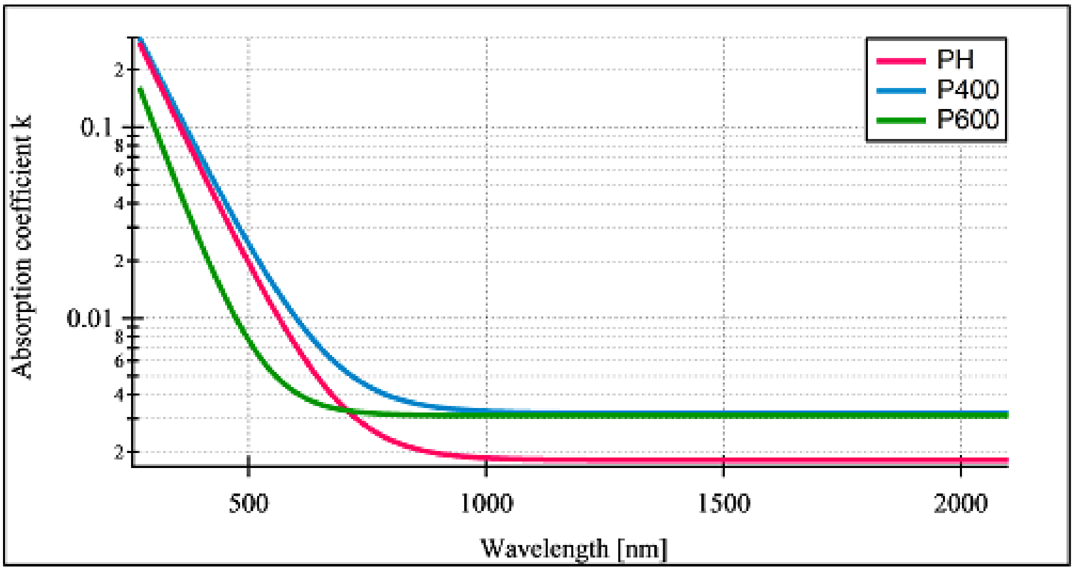

Fig. 2: Absorption coefficients k of Pluto tholins determined by spectroscopic ellipsometry

Our study shows: (1) the refractive indices n of Pluto tholins vary from 1.60 to 1.77, and such n -values can correspond to organic polymers [14]; (2) a strong absorption of UV and Visible radiation by Pluto tholins, due to their N- and O-bearing molecules [15,16,17]; (3) a lower absorption in the near-IR with k-values of a few 10^{-3}; (4) a dependency of n and k indices to the altitude of aerosols formation, with especially higher n- and k-values in the UV-Vis spectral range for Pluto low-altitude aerosols (P_H and P_{400}).

IV. Discussion and Conclusion

Due to higher n-values for the samples P_H and P_{400}, compared to the P_{600} sample, we can suppose that aerosols formed in Pluto's lower atmosphere (≤ 400 km of altitude) will differently scatter the light compared to aerosols formed at higher altitudes (> 400 km of altitude) [18], and thus differently affect the photon flux reaching the lower atmosphere and the surface. The strong absorption below 600 nm is likely due to the presence of N- and O-bearing molecules with lone pair, N- and O-containing polycyclic aromatic compounds and unsaturated molecules with extensive conjugated multiple bonds [14-17]. Since the nitrogen and oxygen content is higher in low-altitude tholins [11], their k indices are higher in the UV-Vis wavelength range. We can thus suppose that in Pluto's atmosphere the aerosols formed at different altitudes will differently absorb the photon flux and differently affect Pluto atmospheric and surface radiative transfer [18].

As Pluto tholins are chemically different from Titan's [11], we propose a new set of optical constants to update Pluto atmospheric and surface models that were hitherto based on the optical constants of Titan tholins.

Acknowledgements

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