Near-infrared reflectance of tholins in methane ice: preliminary results and implications for interpretation of New Horizons’ LEISA data

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Preliminary experiments aiming at identifying the near-infrared signature of Pluto (Titan) tholins in methane ice in the wavelength range of the LEISA imaging spectrometer, 1.25-2.5 μm, have been conducted down to 87K. The presence of tholins in methane ice is ascertained by the persistence of two absorption, located at 1.54 and 1.99 μm, in two spectral regions in which pure methane has no absorption. Further experiments conducted at 30-40K shall determine whether this signature may be expected at Pluto’s surface.

Introduction
Tholins are considered to be the main darkening component of the surface of Pluto. They may form by chemical alteration of the surface ice exposed to the galactic cosmic rays, the dominant ion fluxes on the surface [1]. They may also be precipitated from UV radiation of CH4 in Pluto’s thermosphere atmosphere. Their properties depend on the methane ice phase, and vary according to the seasons, increasing toward perihelion when surface ice transforms to vapor that disperses the atmosphere, then decreasing while the atmosphere condenses and renews the surface [2, 3, Fig. 1]. Tholins of Titan composition

Figure 1. Cartoon showing seasonal evolution of Pluto’s surface and the mechanism of Tholin formation [3].

ion adequately fits Pluto’s spectrum in the near-infrared [4]. It has also been observed that vibrational absorptions of methane ice dominate the 1.2-2.5 μm spectral region of the OSIRIS Pluto’s surface spectra [5], in spite of CH4 perhaps being less abundant than N2 ice. Such considerations motivate understanding the spectral properties of tholin-methane mixtures, especially in the wavelength range of the LEISA hyperspectral sensor onboard New Horizons, 1.25-2.5 μm. In order to obtain useful data, a preliminary feasibility experiment of laboratory spectral measurement of tholin-methane ice mix was conducted at varying temperatures, allowing reconstruction of the spectral behaviour of the mix while methane gas equilibrates and solidifies during temperature decreases. Then melts and evaporates when temperature rises.

Conclusions
(1) Tholin reactivity in CH4 is very low to null. (2) Whatever its presence, CH4 dominates the spectral signature of the tholin-methane mix for the studied proportions of tholin and methane. Nevertheless, evidence of tholins is confirmed through bands located at 1.54 and 1.98 μm, regions where the methane signature is flat or convex-shaped, this result is in accord with the detection of small proportions of tholins in CH4 ice by LEISA at the surface of Pluto, even in the presence seasonal configuration where Pluto moves away from its perihelion.

Future works
Further experiments will be conducted at lower temperature and pressure in a new chamber in which tholins will be synthesized and their spectra measured in situ. Temperature will be varied more slowly in order to make sure that CH4 has enough time to equilibrate with its stability field. Experiments of tholins with CH3N2 ice mixtures will also be performed to simulate an icy composition closer to Pluto’s surface.

Results
A selection of the obtained spectra is provided on Fig. 4. Noise is mainly attributed to the 15 μm optical fiber length required to connect the chamber to the spectrometer. After the end of the experiment, a new tholin spectrum was taken out of the Andromeda chamber and compared to a spectrum taken immediately after synthesis. The two spectra are almost similar; apart from a general steeper slope. The tholins have not significantly reacted with methane during the experiment.

Figure 4. (a) Summary of the tholin-methane mix experiment and comparison with the tholin spectrum after synthesis and after experiment with a spectrum of pure methane (methane spectrum multiplied by 5 vertically). (b) Zoom on the two persistent tholin absorptions, continuum removed. The tholin absorptions at 1.54 and 1.99 μm are observed throughout the experiment.

References