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Laboratory simulation of Pluto's atmospheric chemistry

Lora Jovanovic (1), Thomas Gautier (1), Nicolas Jaisle (1), Ludovic Vettier (1), Nathalie Carrasco (1)
(lora.jovanovic@latmos.ipsl.fr)
(1) Laboratoire Atmosphères, Milieux, Observations Spatiales (LATMOS), Guyancourt, France

Abstract

The detection of thin haze layers in Pluto's atmosphere highlighted the complex photochemistry occurring in it. In order to understand the processes leading to the formation of Pluto's aerosols, we produced in laboratory a plasma mimicking Pluto's atmospheric chemistry and we analyzed this plasma by *in situ* mass spectrometry.

1. Introduction

During Pluto's elliptical orbit, the surface ices made of molecular nitrogen N_2, methane CH_4 and carbon monoxide CO undergo a sublimation/condensation cycle that supplies Pluto's tenuous seasonal atmosphere [1,2]. This atmosphere is mainly composed of N_2 and CH_4, with 515 ± 40 ppm of CO [3,4]. On July 14th, 2015, when Pluto was overflown by the *New Horizons* spacecraft, photochemical aerosols aggregating as several thin haze layers and extending at more than 350 km of altitude were detected [5,6]. By analogy with Titan, it is supposed that a complex atmospheric chemistry initiated by far-ultraviolet and Lyman-α solar photons takes place high in Pluto's nitrogen and methane rich atmosphere (see Figure 1). However, the exact chemical pathways forming Pluto's aerosols are not well constrained yet. To better understand these processes, we reproduced by a cold plasma Pluto's atmospheric chemistry and analyzed it by *in situ* mass spectrometry.

2. Experimental setup

2.1. PAMPRE: A cold plasma simulating Pluto's atmospheric chemistry

We used the PAMPRE experiment [7] (LATMOS, France) to reproduce for the first time Pluto's atmospheric chemistry. PAMPRE is a Radio-Frequency Capacitively Coupled Plasma generated in a gas mixture relevant to Pluto's atmosphere. The plasma was maintained at a pressure of 0.9 ± 0.1 mbar, at ambient temperature. In this study, three gas compositions were used to simulate three different altitudes in Pluto's atmosphere (see Table 1).

Table 1: Laboratory simulation of Pluto's atmosphere at different altitudes.

Composition of the gas mixture	Concerned altitude [3]
99.5% N_2 : 0.5% CH_4 : 500 ppm CO	0-350 km
99% N_2 : 1% CH_4 : 500 ppm CO	400 km
95% N_2 : 5% CH_4 : 500 ppm CO	600 km

2.2. *In situ* mass spectrometry

We used the Electrostatic Quadrupole Plasma (EQP, *Hiden Analytical*) instrument to investigate the influence of different CH_4 mixing ratio on the neutral species (RGA mode) and positive ions (+SIMS mode) constituting our cold reactive mixture.

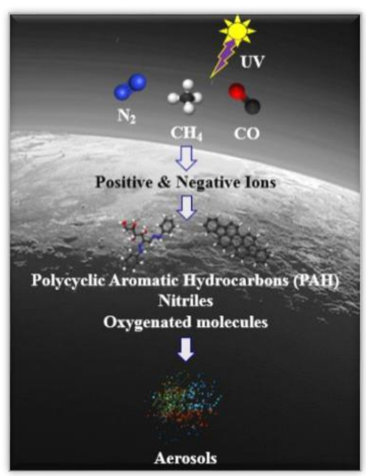

Figure 1: Simplified scheme of Pluto's aerosols formation.
Credit (background image): NASA/JHUAPL/SwRI

3. Results: A complex neutral and ion chemistry

The neutral and positive ion analyses of the gas mixtures representative of Pluto's atmosphere at different altitudes are represented in Figures 2 and 3, respectively.

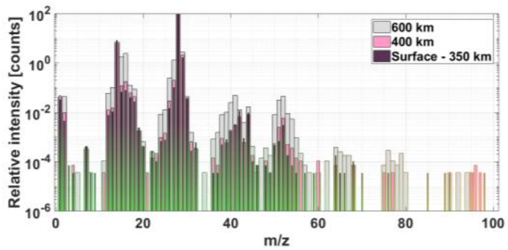

Figure 2: Influence of the CH_4 mixing ratio on the neutral species present in plasmas mimicking Pluto's atmosphere at different altitudes.

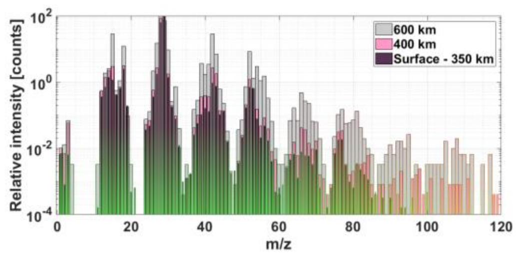

Figure 3: Influence of the CH_4 mixing ratio on the positive ions present in plasmas representing Pluto's atmosphere at different altitudes.

4. Summary and Conclusions

HCN, C_2H_2, C_2H_4 and C_2H_6 have been detected in Pluto's atmosphere, with mixing ratios varying from around 50 ppb at the surface to around 0.1% at about 600 km of altitude [3,4]. These molecules were also detected in our neutral mass spectra at *m/z* 27, 26, 28 and 30, respectively. In the mass spectra, HCN, C_2H_2 and C_2H_6 represent approximately 2%, 10% and 1% of the most abundant molecule (N_2 at *m/z* 28) intensity. Our plasma simulates therefore pretty well Pluto's atmospheric neutral chemistry, even if it seems we overestimate C_2 molecules (molecules with 2 heavy atoms, C or N).

The positive ion mass spectra revealed a non-negligible complex positive ion chemistry, with the production of heavy molecules up to *m/z* 120.

Finally, our results have shown a strong dependency of neutral and ion chemistry to the CH_4 mixing ratio, expressed by a more pronounced formation of heavier molecules, with increasing methane percentage. Condensation of C_2 molecules on Pluto's aerosols has been proposed to explain C_2 hydrocarbons profiles [8,9]. However, C_2 molecules are known to also contribute to further organic growth. We observe heavier molecules in our mass spectra when the CH_4 mixing ratio increases (higher altitudes). We hypothesize that the production of these heavy molecules from the addition of C_2 molecules could explain the depletion of C_2 hydrocarbons at higher altitudes in Pluto's atmosphere.

Acknowledgements

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