



**HAL**  
open science

## Laboratory simulation of Pluto's atmospheric chemistry

Lora Jovanovic, Thomas Gautier, Nicolas Jaisle, Ludovic Vettier, Nathalie Carrasco

► **To cite this version:**

Lora Jovanovic, Thomas Gautier, Nicolas Jaisle, Ludovic Vettier, Nathalie Carrasco. Laboratory simulation of Pluto's atmospheric chemistry. EPSC-DPS Joint Meeting 2019, Sep 2019, Geneva, Switzerland. pp.EPSC-DPS2019-957-1. insu-02202103

**HAL Id: insu-02202103**

**<https://insu.hal.science/insu-02202103>**

Submitted on 31 Jul 2019

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

# 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](mailto: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  $515 \pm 40$  ppm of  $CO$  [3,4]. On July 14<sup>th</sup>, 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- $\alpha$  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  $0.9 \pm 0.1$  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, *Hidden 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.

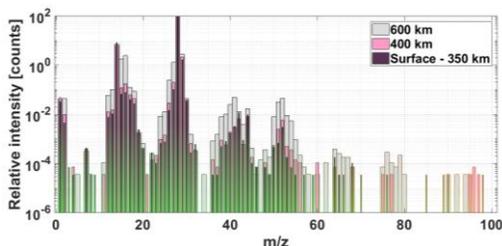


Figure 2: Influence of the CH<sub>4</sub> mixing ratio on the neutral species present in plasmas mimicking Pluto's atmosphere at different altitudes.

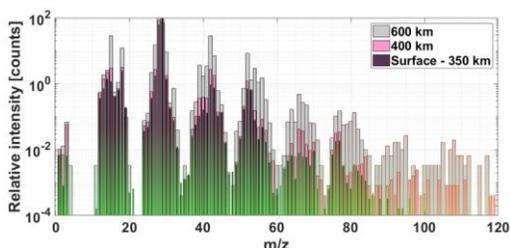


Figure 3: Influence of the CH<sub>4</sub> mixing ratio on the positive ions present in plasmas representing Pluto's atmosphere at different altitudes.

### 4. Summary and Conclusions

HCN, C<sub>2</sub>H<sub>2</sub>, C<sub>2</sub>H<sub>4</sub> and C<sub>2</sub>H<sub>6</sub> 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<sub>2</sub>H<sub>2</sub> and C<sub>2</sub>H<sub>6</sub> represent approximately 2%, 10% and 1% of the most abundant molecule (N<sub>2</sub> at *m/z* 28) intensity. Our plasma simulates therefore pretty well Pluto's atmospheric neutral chemistry, even if it seems we overestimate C<sub>2</sub> 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<sub>4</sub> mixing ratio, expressed by a more pronounced formation of heavier molecules, with increasing methane percentage. Condensation of C<sub>2</sub> molecules on Pluto's aerosols has been proposed to explain C<sub>2</sub> hydrocarbons profiles [8,9]. However, C<sub>2</sub> molecules are known to also contribute to further organic growth. We observe heavier molecules in our mass spectra when the CH<sub>4</sub> mixing ratio increases (higher altitudes). We hypothesize that the production of these heavy molecules from the addition of C<sub>2</sub> molecules could explain the depletion of C<sub>2</sub> hydrocarbons at higher altitudes in Pluto's atmosphere.

### Acknowledgements

We are grateful to the European Research Council Starting Grant *PrimChem* for funding this work (grant agreement n° 636829).

### References

- [1] Stern S. A. *et al.*: The Pluto system: Initial results from its exploration by New Horizons. *Science*, Vol. 350, aad1815, 2015.
- [2] Forget F. *et al.*: A post-New Horizons global climate model of Pluto including the N<sub>2</sub>, CH<sub>4</sub> and CO cycles. *Icarus*, Vol. 287, pp. 54-71, 2017.
- [3] Young L. A. *et al.*: Structure and composition of Pluto's atmosphere from the New Horizons solar ultraviolet occultation. *Icarus*, Vol. 300, pp. 174-199, 2018.
- [4] Lellouch E. *et al.*: Detection of CO and HCN in Pluto's atmosphere with ALMA. *Icarus*, Vol. 286, pp. 289-307, 2017.
- [5] Gladstone G. R. *et al.*: The atmosphere of Pluto as observed by New Horizons. *Science*, Vol. 351, aad8866, 2016.
- [6] Cheng A. F. *et al.*: Haze in Pluto's atmosphere. *Icarus*, Vol. 290, pp. 112-133, 2017.
- [7] Szopa C. *et al.*: PAMPRE: A dusty plasma experiment for Titan's tholins production and study. *Planetary and Space Science*, Vol. 54, pp. 394-404, 2006.
- [8] Luspai-Kuti A. *et al.*: Photochemistry on Pluto: Part I. Hydrocarbons and Aerosols. *Monthly Notices of the Royal Astronomical Society*, Vol. 472, pp. 104-117, 2017.
- [9] Wong M. L. *et al.*: The photochemistry of Pluto's atmosphere as illuminated by New Horizons. *Icarus*, Vol. 287, pp. 110-115, 2017.