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# Chemical composition of Pluto's aerosols analogues

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## Abstract

The discovery of haze in Pluto's atmosphere on July 14<sup>th</sup>, 2015, has raised lots of questions. To help understand the data provided by the *New Horizons* spacecraft, Pluto's aerosols analogues were synthesized and their chemical composition was determined by high-resolution mass spectrometry (Orbitrap technique).

## 1. Introduction

On July 14<sup>th</sup>, 2015, when Pluto was flown by the *New Horizons* spacecraft, aerosols were detected in its atmosphere, mainly composed of molecular nitrogen N<sub>2</sub>, methane CH<sub>4</sub>, with around 500 ppm of carbon monoxide CO [1,2,3]. These aerosols aggregate into several thin haze layers that extend at more than 350 km of altitude [4,5]. These aerosols may impact Pluto's atmospheric chemistry and climate [6,7]. To support these ideas, we have produced Pluto's aerosols analogues and analyzed their chemical composition by high-resolution mass spectrometry (ESI/Orbitrap technique).

## 2. Experimental setup

### 2.1. Pluto's aerosols analogues synthesis

We used the PAMPRE experiment [8] (LATMOS, France) to synthesize Pluto's aerosols analogues. PAMPRE is a Radio-Frequency Capacitively Coupled Plasma generated in a gas mixture representative of Pluto's atmosphere. For this study, the gas mixture was composed of variable proportions of molecular nitrogen and methane, with 500 ppm of carbon monoxide [2,3], at a pressure of  $0.9 \pm 0.1$  mbar and at ambient temperature. Two types of analogues were produced (see Table 1).

Table 1: Types of Pluto's aerosols analogues produced with the PAMPRE experiment.

Composition of the gas mixture	Corresponding altitude on Pluto [2]
99% N <sub>2</sub> : 1% CH <sub>4</sub> : 500 ppm CO	400 km
95% N <sub>2</sub> : 5% CH <sub>4</sub> : 500 ppm CO	600 km

### 2.2. High-resolution mass spectrometry (HRMS) study

We analyzed the soluble fraction of Pluto's aerosols analogues, dissolved in a 50:50 (v/v)% methanol:acetonitrile mixture. The analytical instrument used was the LTQ Orbitrap XL (*ThermoFisher Scientific*). The ionization source was the ElectroSpray Ionization (ESI), in positive mode. The mass analyzer was the Orbitrap.

## 3. Chemical composition of Pluto's aerosols analogues inferred from ESI/Orbitrap analysis

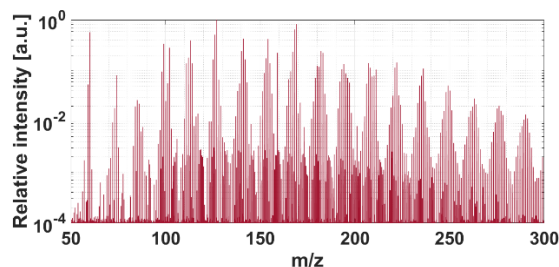


Figure 1: ESI+/Orbitrap mass spectrum of the soluble fraction of Pluto's aerosols analogues.

Our HRMS study has evidenced: (1) the molecules constituting Pluto's aerosols analogues are composed of a repetition of a co-polymeric (CH<sub>2</sub>)<sub>m</sub>(HCN)<sub>n</sub> pattern ; (2) nitrogen atoms are an important constituent of these molecules ; (3) oxygenated

molecules represent a significant proportion of this complex molecules mixture ; (4) the CH<sub>4</sub> mixing ratio, and so the altitude of the aerosols formation, has an impact on the reactivity between N<sub>2</sub>, CH<sub>4</sub> and CO, and especially a higher CH<sub>4</sub> mixing ratio results in a boosted incorporation of oxygen atoms in the molecules constituting Pluto's aerosols analogues.

## 4. Discussion and Conclusion

In our analogues, heavy unsaturated molecules have been detected. These molecules, likely very reactive, may interact with gaseous molecules and serve as condensation nuclei for clouds [6], impacting Pluto's climate. From *New Horizons* image dataset, seven Pluto's clouds candidates have been identified. These clouds could be due to the condensation of HCN, C<sub>2</sub>H<sub>2</sub>, C<sub>2</sub>H<sub>6</sub>, C<sub>2</sub>H<sub>4</sub> or CH<sub>4</sub> [9]. The study of the interactions between our analogues and the previously mentioned gas molecules is needed to further refine Pluto's atmospheric models.

The presence of O-bearing molecules in our analogues being significant, we can hypothesize that Pluto's oxidized aerosols may influence Pluto's atmospheric thermal profile, by absorbing longer ultraviolet wavelengths [10]. This kind of radiative cooling may explain that Pluto's atmosphere, at about 400 km of altitude, is around 30 K colder than theoretically predicted [4,7]. Experimental study on the aerosols optical indices is of high need.

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