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## LABORATORY SIMULATION OF PLUTO'S ATMOSPHERE AND AEROSOLS.

L. Jovanovic<sup>1</sup>, T. Gautier<sup>1</sup>, N. Carrasco<sup>1</sup>, V. Vuitton<sup>2</sup>, E. Quirico<sup>2</sup>, C. Wolters<sup>2</sup>, F.-R. Orthous-Daunay<sup>2</sup>, L. Vettier<sup>1</sup>, L. Flandinet<sup>2</sup>

<sup>1</sup>LATMOS, UVSQ – Université Paris-Saclay, CNRS, Sorbonne Université, Guyancourt, France ([lora.jovanovic@latmos.ipsl.fr](mailto:lora.jovanovic@latmos.ipsl.fr)), <sup>2</sup>IPAG, Université Grenoble Alpes, CNRS, Grenoble, France

**Introduction:** During Pluto's elliptical orbit, the surface ices made of molecular nitrogen N<sub>2</sub>, methane CH<sub>4</sub> and carbon monoxide CO go through a sublimation/condensation cycle supplying its tenuous atmosphere [1,2]. This atmosphere composed of N<sub>2</sub>, CH<sub>4</sub> and around 500 ppm of CO [3,4] was suspected since the 1990's to instigate the production of photochemical aerosols [5,6]. These aerosols were finally unambiguously detected on July 14<sup>th</sup>, 2015, when Pluto was flown by *New Horizons*, by means of forward scattering observations and solar occultations. Pluto's aerosols aggregate into several thin haze layers, extending at an altitude of more than 350 km [1,3,7,8].

In order to understand not only Pluto's atmospheric chemistry, but also its climate and its heterogeneous surface, simulating in laboratory Pluto's atmosphere is of prime importance. So is producing Pluto's aerosols analogues for further physical and chemical analyses.

For the very first time, we used the PAMPRE experiment [9] (LATMOS, France) to reproduce Pluto's atmosphere and to synthesize Pluto's aerosols analogues.

**Experimental setup:** PAMPRE [9] is a Radio-Frequency Capacitively Coupled Plasma (RF CCP) generated in a gas mixture representative of Pluto's atmosphere. For this work, the gas was composed of variable proportions of molecular nitrogen and methane, with 500 ppm of carbon monoxide [3,4]. The plasma was maintained at a pressure of  $0.9 \pm 0.1$  mbar, at ambient temperature.

**Analogues synthesis.** Two types of analogues were synthesized. One with an atmosphere containing 99 % of N<sub>2</sub>, 1 % of CH<sub>4</sub> and 500 ppm of CO, setting representative of Pluto's atmosphere at 400 km of altitude [3]. The other sample was produced from a gas mixture composed of 95 % of N<sub>2</sub>, 5 % of CH<sub>4</sub> and 500 ppm of CO, condition representative of Pluto's atmosphere at 600 km of altitude [3].

**Analogues ex situ analyses.** These samples were observed by Scanning Electron Microscopy (SEM). Their chemical composition was determined by high-resolution mass spectrometry (Orbitrap technique) and infrared spectroscopy.

**Results: Morphology.** Pluto's aerosols analogues are spherical fluffy particles of 400 to 500 nm of diameter in average (Fig. 1).

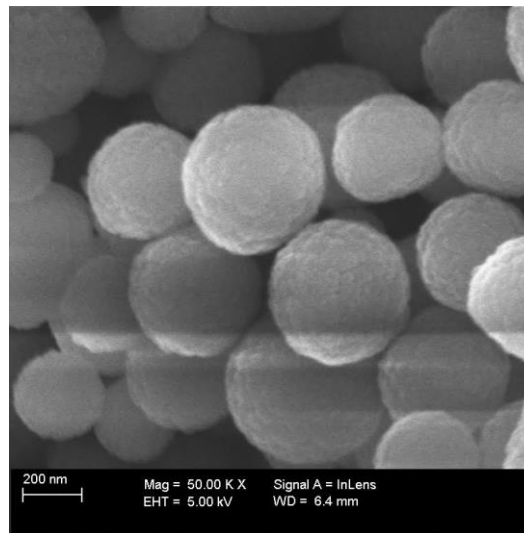


Fig. 1 : Pluto's aerosols analogues as observed by SEM.

**Chemical composition.** Our high-resolution mass spectrometry (HRMS) study has shown: (1) a copolymeric structure of the molecules constituting Pluto's aerosols analogues ; (2) an important incorporation of nitrogen atoms in these molecules ; (3) a significant proportion of oxygenated molecules in them ; (4) an impact of CH<sub>4</sub> mixing ratio, and so of the altitude of aerosols formation [3], as a different reactivity between N<sub>2</sub>, CH<sub>4</sub> and CO and especially a boosted incorporation of oxygen atoms in the molecules with increasing CH<sub>4</sub> mixing ratio.

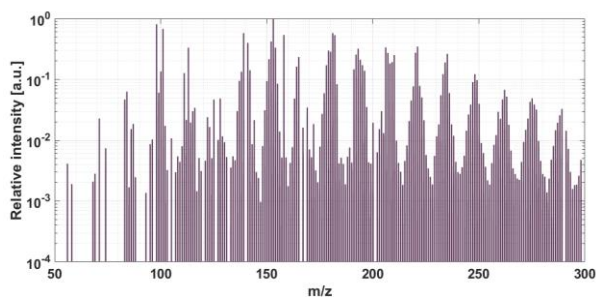


Fig. 2 : Pluto's aerosols analogues as observed by HRMS.

**Discussion and Conclusion:** The aerosols may impact Pluto's atmospheric photochemistry and climate by depleting the atmosphere of the C<sub>2</sub> hydrocarbons and by playing the role of condensation nuclei for clouds [10]. This idea can be supported by the fact that in our analogues, we have detected heavy unsaturated molecules that are likely very reactive and may therefore interact with the gaseous molecules and serve as condensation nuclei.

They can also have an influence on Pluto's atmospheric thermal profile by absorbing incident solar radiations, making that Pluto's atmosphere is around 30 K colder than theoretically predicted, at about 400 km of altitude [7,11]. Due to the presence of oxygenated molecules in our samples, we can hypothesize that Pluto's oxidized aerosols may impact Pluto's radiative cooling by absorbing longer ultraviolet wavelengths [12].

Future experimental study on the aerosols/gas interactions and on the aerosols optical indices is needed, in order to further finely constrain Pluto's atmospheric models.

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