

# Laboratory Investigation of Pluto's Surface Organic Matter

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## Origin of the organic matter on Pluto's surface

3 hypotheses:

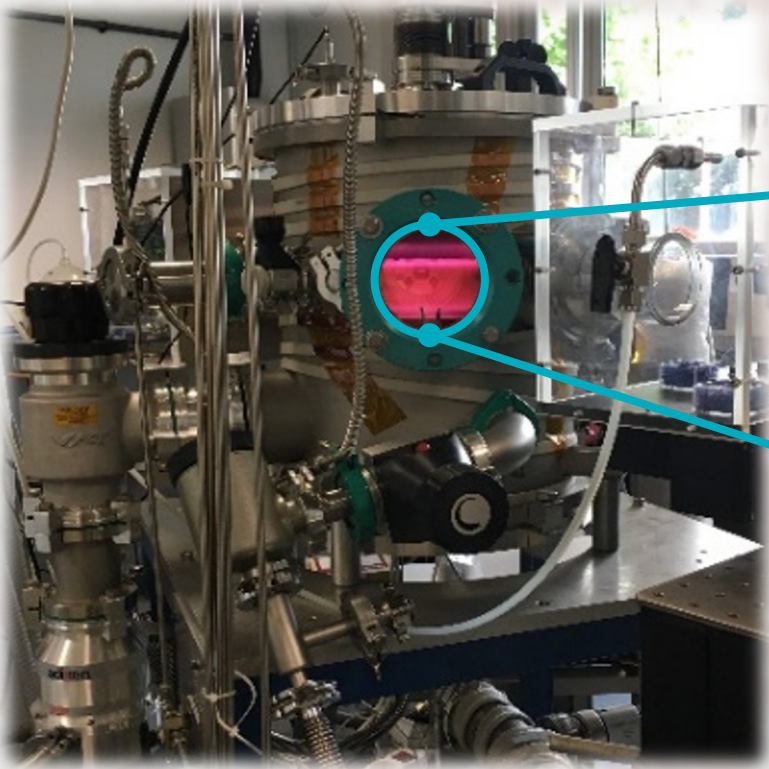
- Formation during the giant impact forming the Pluto-Charon binary system (Sekine+2017)
- Irradiation of the volatile ices on the surface of Pluto by solar UV radiations, galactic cosmic rays and solar wind charged particles (Cruikshank+2015)
- Sedimentation of atmospheric photochemical aerosols onto the surface (Grundy+2018, Protopapa+2020)



Fig. 1: Pluto's encounter hemisphere as imaged by New Horizons/LORRI on July 14<sup>th</sup>, 2015

## How to reproduce in the laboratory Pluto's surface organic matter?

Fig. 2: PAMPRE experimental setup (LATMOS, France)



- Analogues of Pluto's atmospheric aerosols

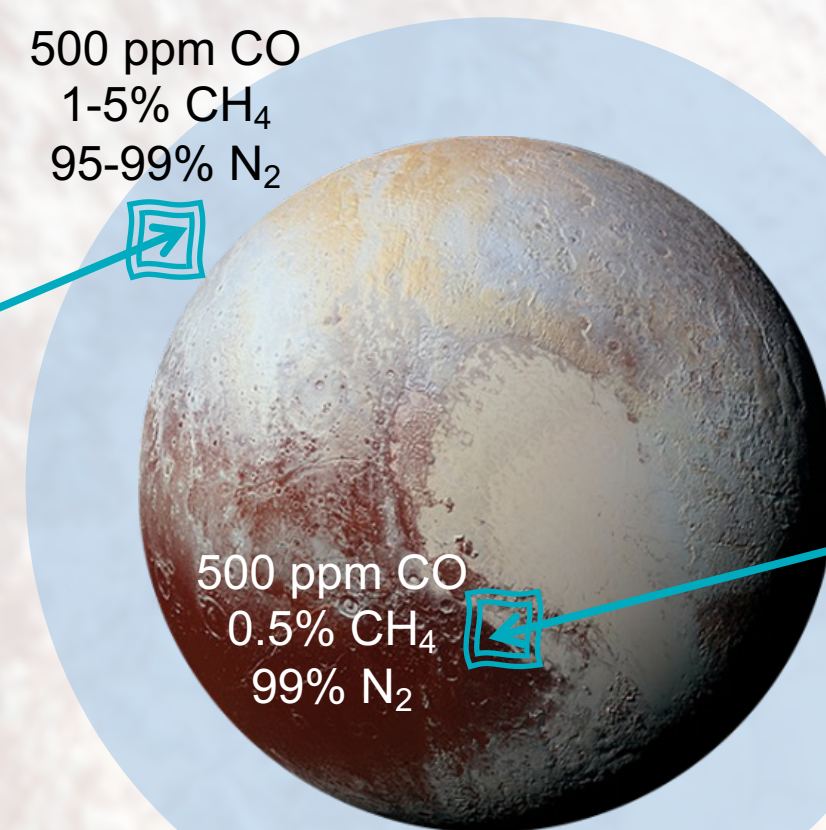
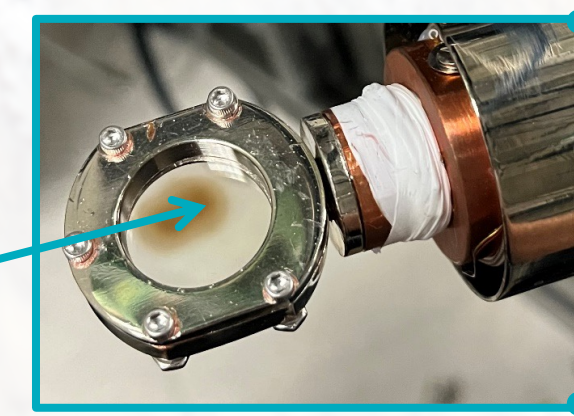


Fig. 3: TOAST-Acquabella experimental setup (JPL)



- Analogues of Pluto's surface ices

## Atmospheric aerosols

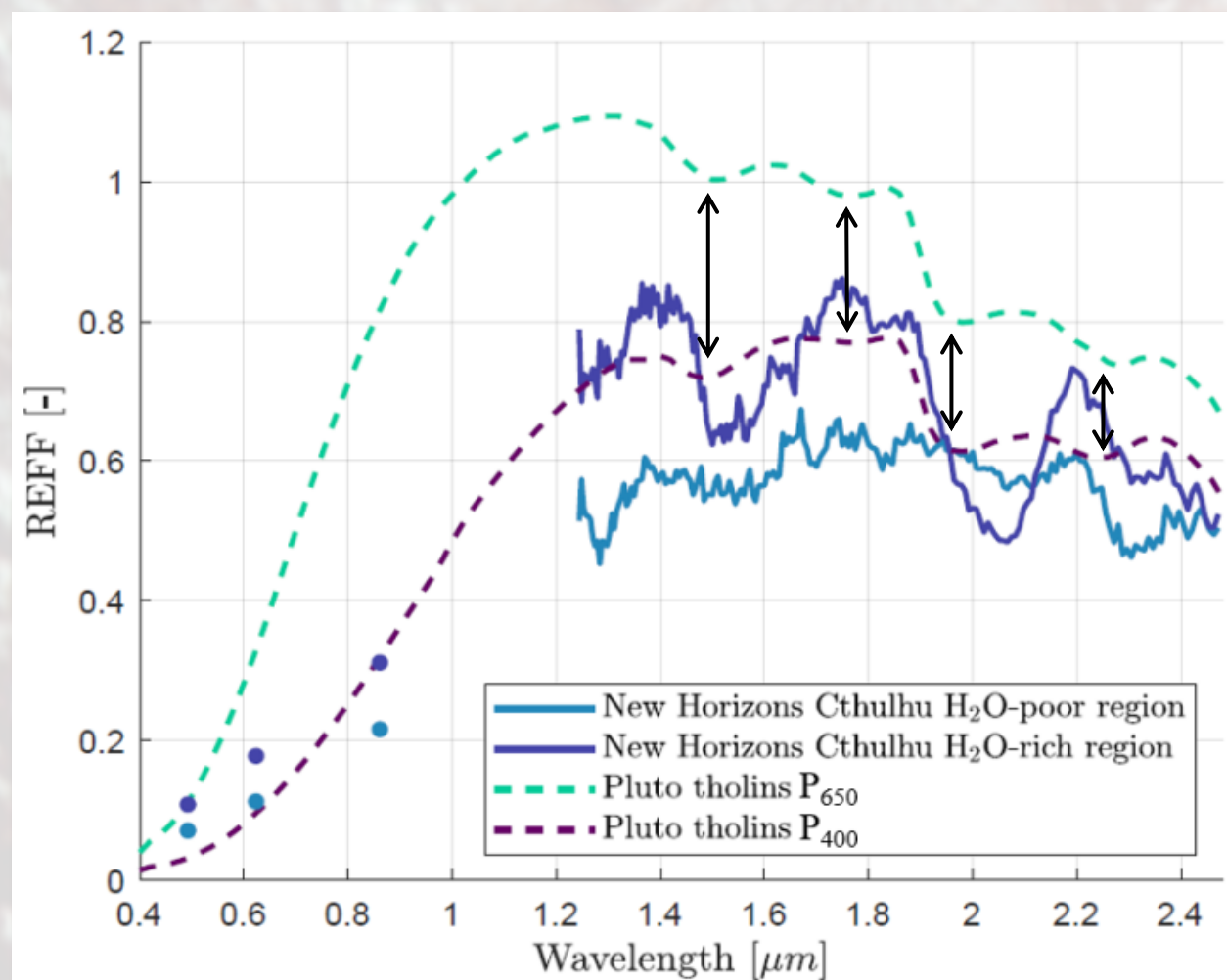


Fig. 4: Comparison between New Horizons/MVIC+LEISA data and reflectance spectra of Pluto aerosol analogues (Fayolle+2021)

- Overall decrease in intensity of all fundamental absorption bands
  - Sputtering & radiolysis
- Chemical evolution of the material, dehydrogenation
- Effect on the near-IR? In agreement with New Horizons/LEISA data?

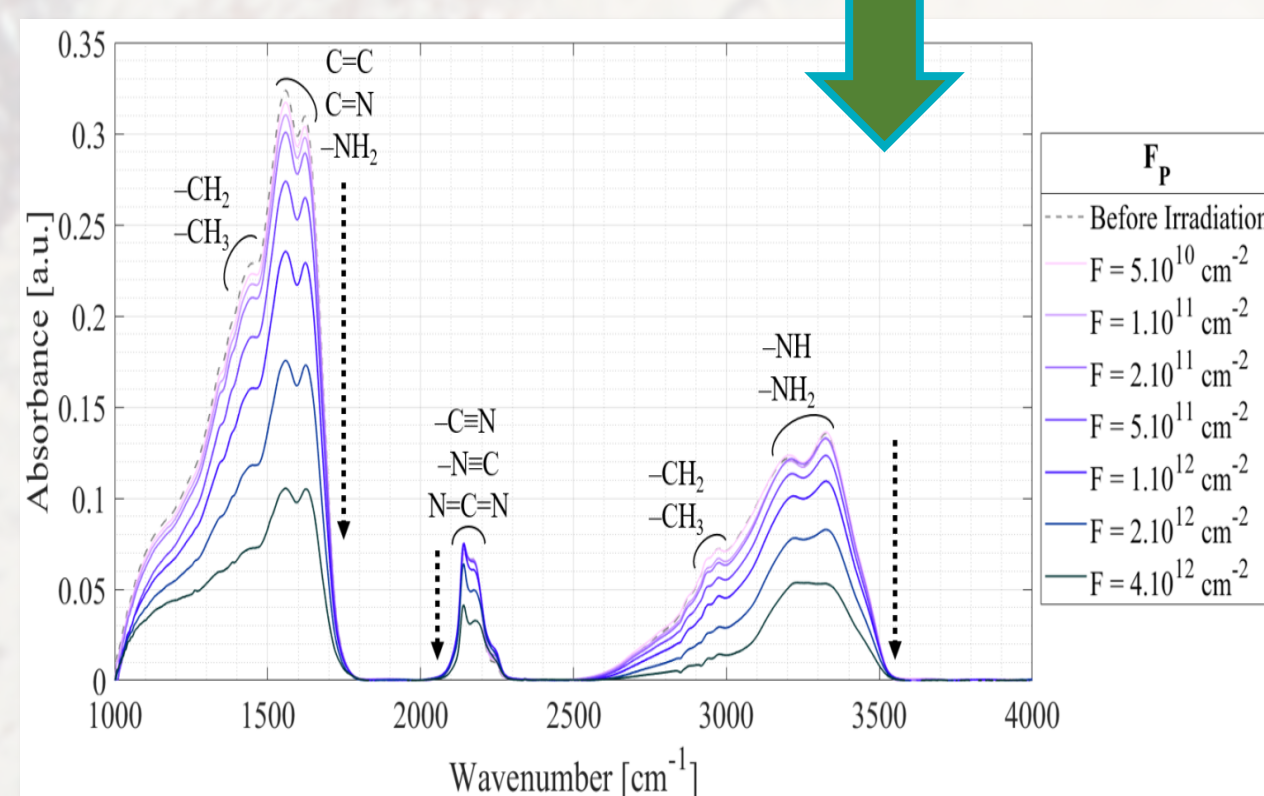


Fig. 5: Mid-IR spectra of Pluto aerosol analogues before and after sequential irradiations by 75 MeV <sup>136</sup>Xe heavy ions

## Preliminary results

- Photometric level in the near-IR well reproduced by Pluto aerosol analogues
- Absorption bands in the near-IR found in Pluto aerosol analogues but not in New Horizons/LEISA data
- 3 hypotheses suggested
  - Contamination of soil by interplanetary dust
  - High porosity of the dark terrains at Cthulhu Regio
  - Irradiation of the surface by galactic cosmic rays

## Surface ices

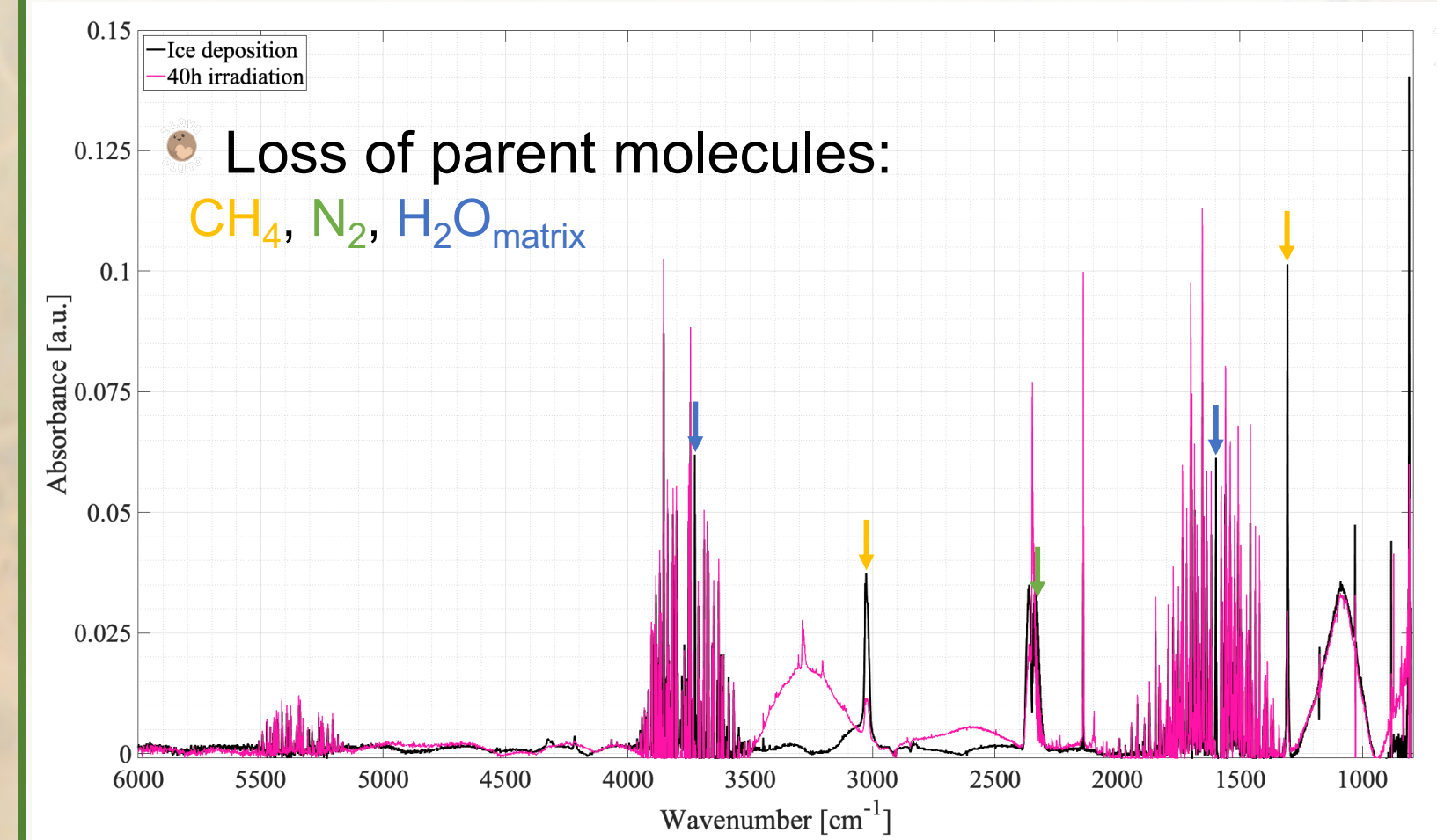


Fig. 6: Mid-IR spectra of Pluto ice analogues before and after irradiation by UV photons

- New bands after irradiation:
  - C<sub>2</sub>H<sub>2</sub> (3282, 3271 cm<sup>-1</sup>), C<sub>2</sub>H<sub>4</sub> (3108, 2990, 1437 cm<sup>-1</sup>), C<sub>2</sub>H<sub>6</sub> (2987, 1467 cm<sup>-1</sup>), CO<sub>2</sub> (2348 cm<sup>-1</sup>), H<sub>2</sub>CO (2800, 2720 cm<sup>-1</sup>), N<sub>2</sub>O (2236 cm<sup>-1</sup>), NO (1875 cm<sup>-1</sup>), HCN (3287, 2100, 2096 cm<sup>-1</sup>), HC<sub>3</sub>N (3205, 2267, 2065 cm<sup>-1</sup>)

## Conclusion

- Nature of the organic matter at Cthulhu Regio:** complex mixture of organic molecules including N and O atoms, polymeric nature
- Origin of the organic matter at Cthulhu Regio:** sedimentation followed by irradiation of Pluto's atmospheric photochemical aerosols and/or surface ice chemistry?

## Future work

- Optical constants of irradiated samples to compare to New Horizons data to assess the atmospheric or surface origin of Cthulhu's organic matter
- Mix Pluto aerosol analogues with Pluto ice analogues and irradiate the mixture, determination of optical constants, comparison to New Horizons data

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Publications:

● Jovanović, Gautier, Broch, Protopapa, Bertrand, Rannou, Fayolle, Quirico, Johann, En Naciri & Carrasco (2021). *Icarus*, 362, 114398. ● Fayolle, Quirico, Schmitt, Jovanovic, Gautier, Carrasco, Grundy, Vuitton, Poch, Protopapa, Young, Cruikshank, Dalle Ore, Bertrand & Stern (2021). *Icarus*, 367, 114574. ● Jovanović, Gautier, Vuitton, Wolters, Bourgalais, Buch, Orthous-Daunay, Vettier, Flandinet & Carrasco (2020). *Icarus*, 346, 113774.

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