Photon-induced desorption of large species at low temperature in TNOs

H. Carrascosa[1], G. A. Cruz-Díaz[2,3], G. M. Muñoz Caro[1], E. Dartois[4], Y. –J. Chen[5]

[1]CAB, [2]NASA Ames, [3]Bay Area, [4]ISMO, [5]NCU

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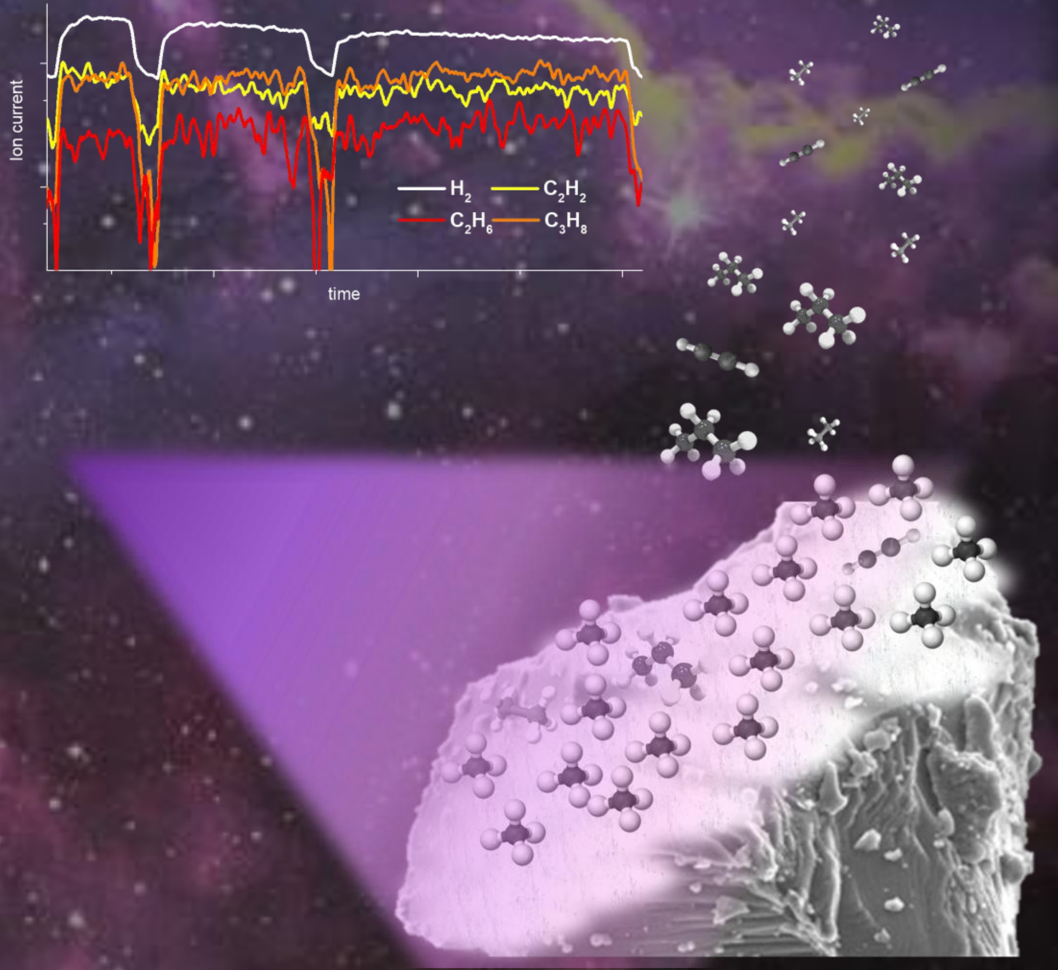
Some trans-Neptunian objects (TNOs) reveal the presence of abundant methane (CH_4) ice. Moreover, relatively large molecules, such as ethane (C_2H_6) or propane (C_3H_8), were detected in the atmosphere of TNOs, such as Pluto or Triton.

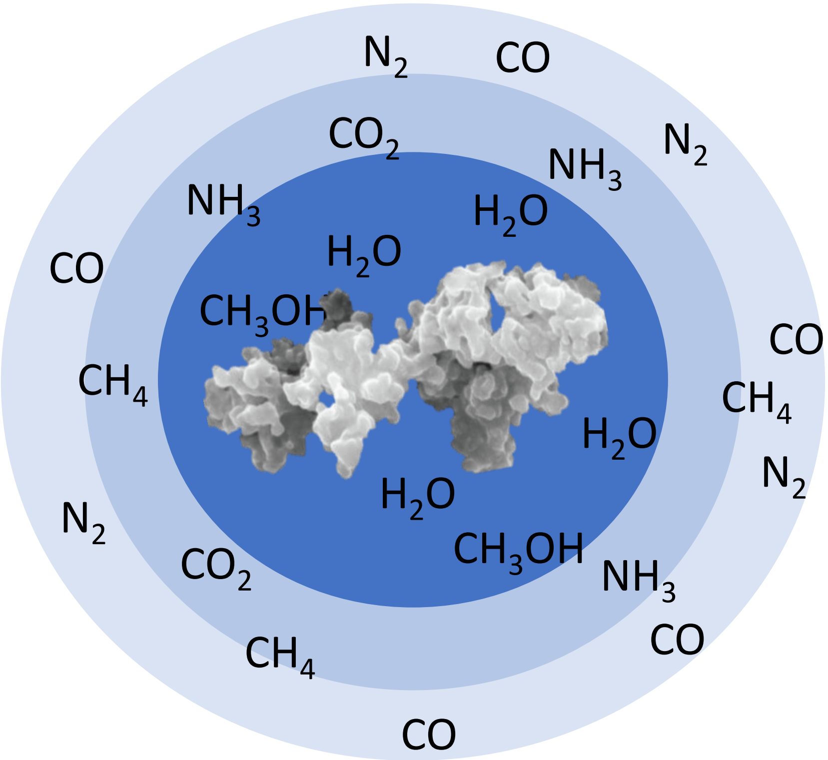
The present work aims to understand the formation and possible desorption mechanism which allows large molecules to be present in the gas phase at temperatures where their thermal desorption is negligible.

Experiments were carried out in ISAC, an ultra-high vacuum chamber equipped with a cryostat and an UV-lamp. Infrared spectroscopy and quadrupole mass spectrometry were used to monitor the solid and gas phase, respectively.

UV-irradiation of CH_4 ice led to formation of hydrocarbons. Photodesorption of C_2H_2 and photochemidesorption of C_2H_6 and C_3H_8 was observed, the latter implies an immediate ejection of these species after formation on the CH_4 ice surface.



Context: CH_4 ice mantles



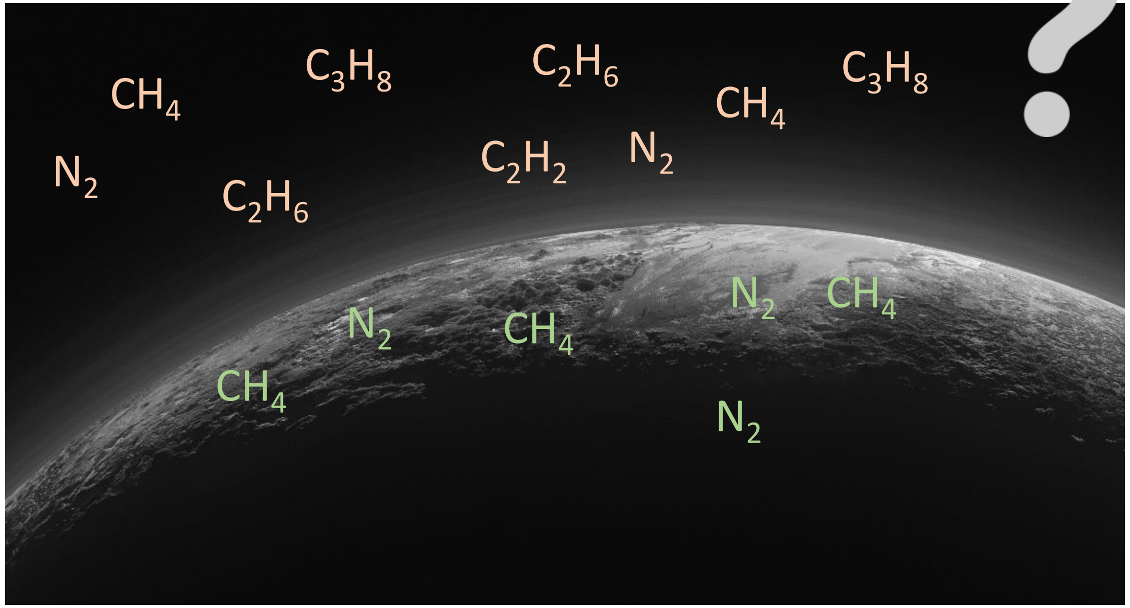
Pre-cometary ice mantle

Interstellar medium

The low temperature in TNOs inhibits the presence of large molecules in the atmosphere. Methane is the only hydrocarbon able to thermally desorb to the gas phase.

How is it possible that ethane, propane, or acetylene have been detected in TNOs' atmospheres?

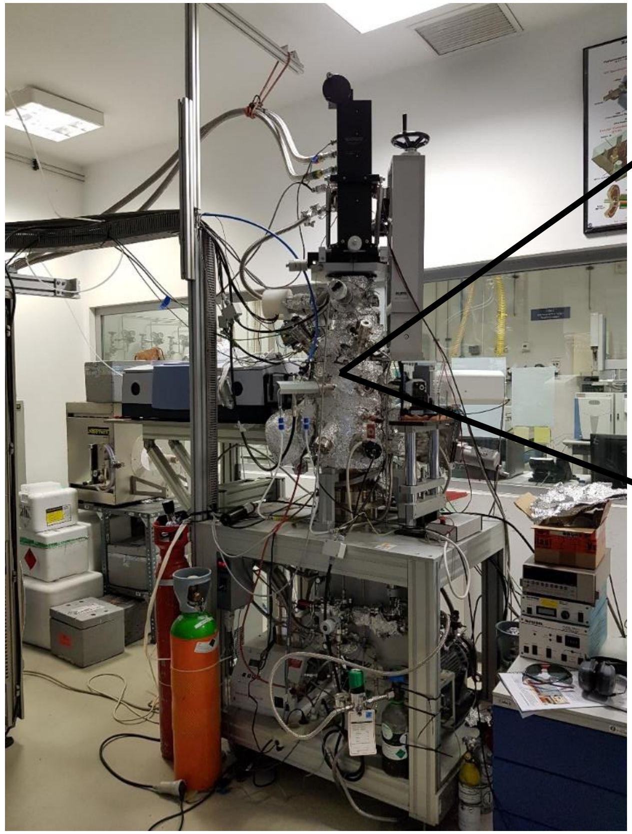
Transneptunian objects

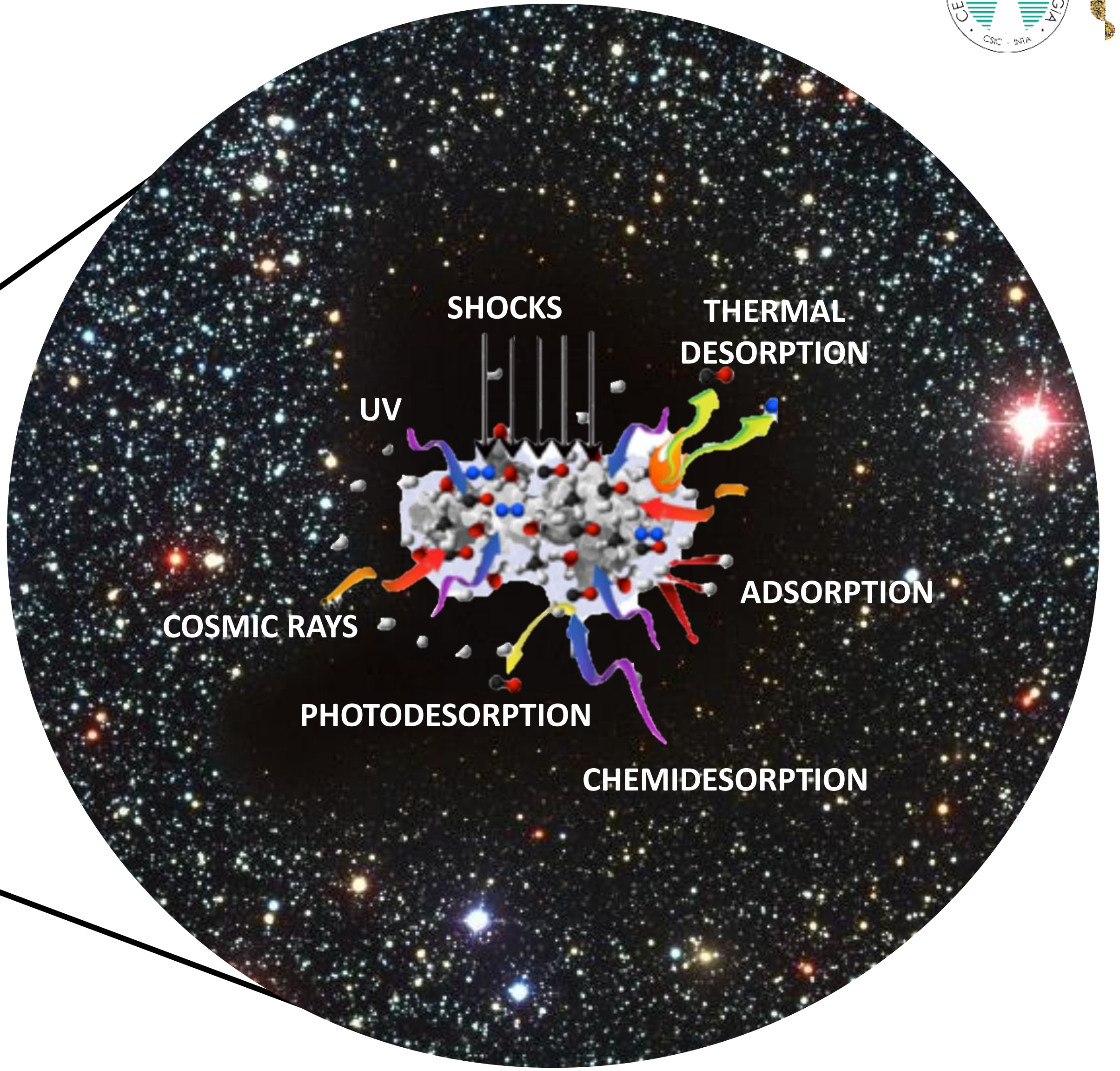


Methodology: ISAC

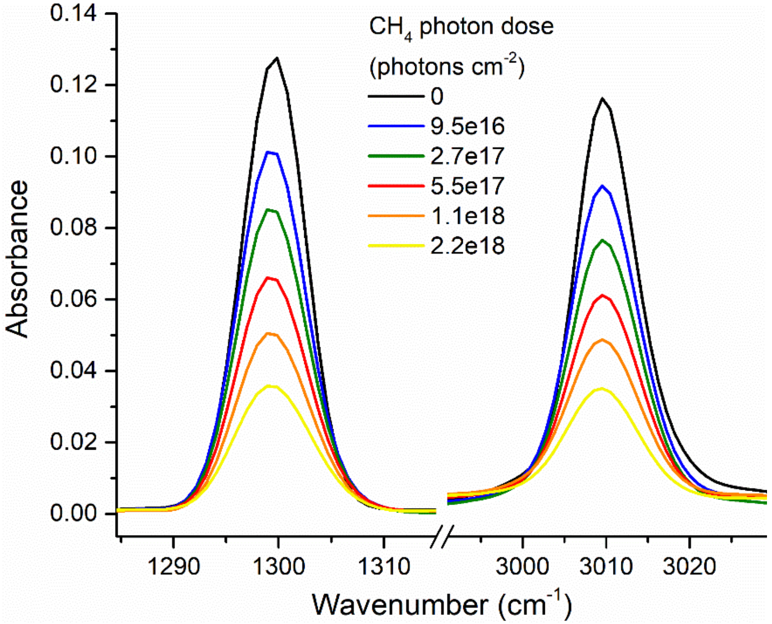
Reproduces the conditions in the ISM:

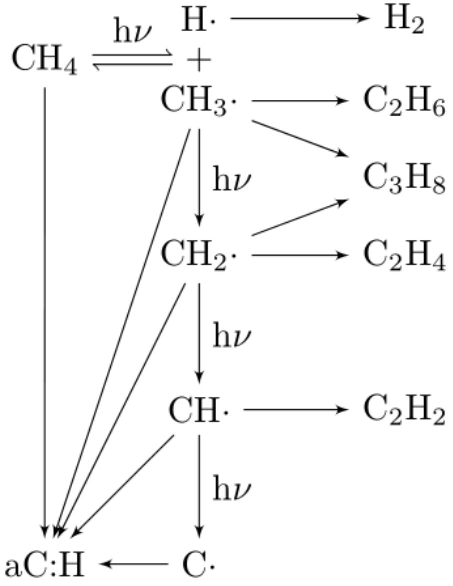
UHV → 10^{-11} mbar
T → 8 K
UV → MDHL

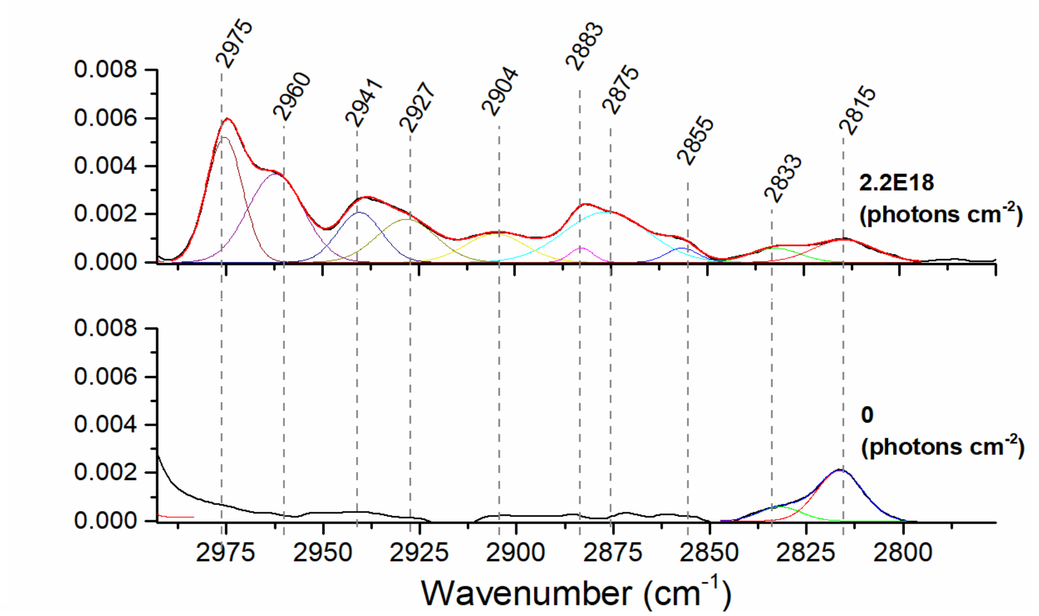




Results: formation of new species

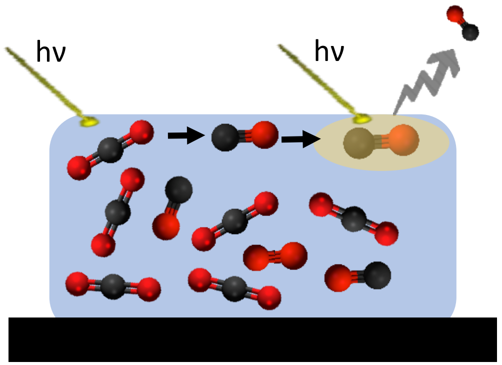






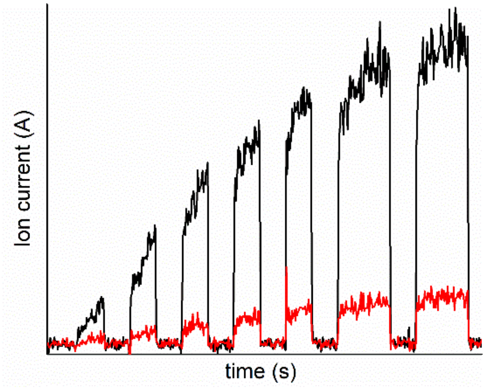
Results: photon-induced desorption mechanisms

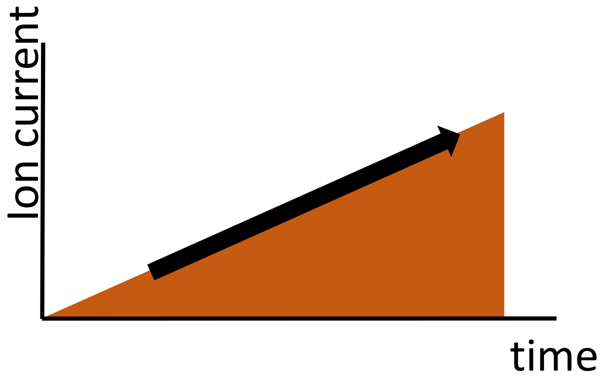
Photodesorption



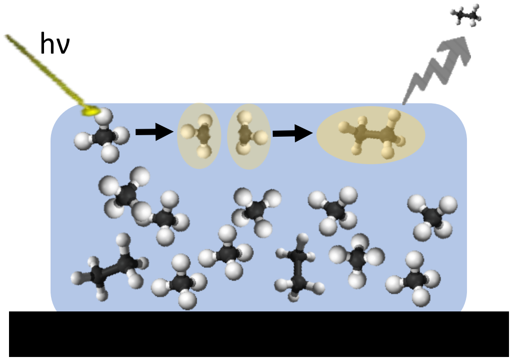
Molecules in the surface **receiving photon energy** to break intermolecular forces and desorb

CO and O_2 from CO_2 ice



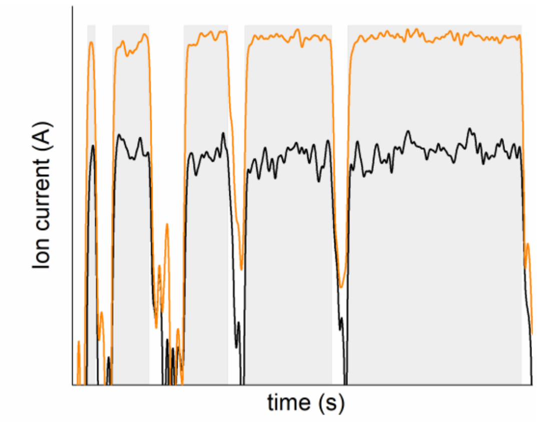


Photochemical desorption



Molecules formed in the surface **releasing their formation energy** to break intermolecular forces and desorb

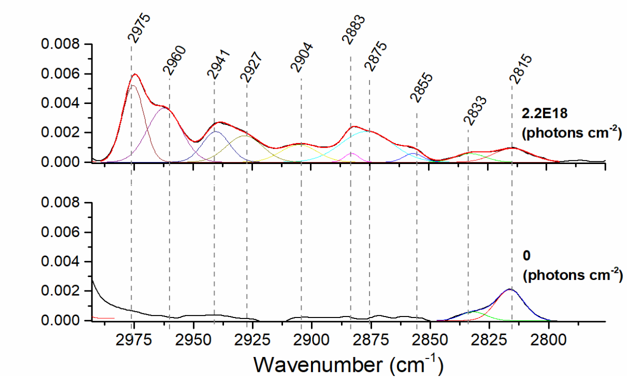
C_2H_6 and C_3H_8 from CH_4 ice



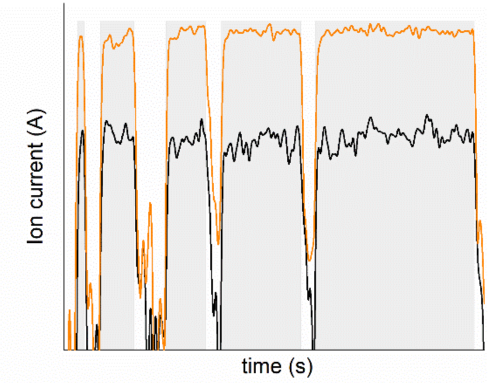
Impacts and prospects for the future

Hydrocarbons synthesis

A better understanding of CH_4 ice processes under UV radiation is a first step to explore the chemical complexity in more realistic pre-cometary ice mantles containing different molecules.

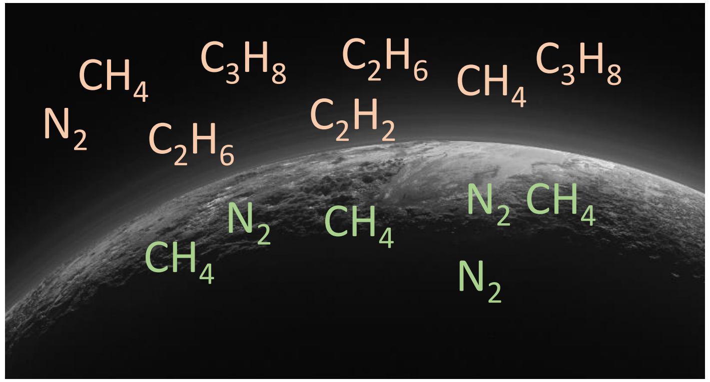


Photochemical desorption



Photochemical desorption can be applied to study the gas phase abundances of large molecules detected in different bodies.

Gas phase abundance in TNOs agrees well with the observations



Abundance in Pluto's atmosphere (Young et al. 2018)
$C_2H_6 > C_2H_2 > C_2H_4$ (C_3H_8 was not measured)

$C_2H_6 > C_3H_8 > C_2H_2 > C_2H_4$ (non-detected)
Photon-induced desorption in our experiments (Carrascosa et al. 2020)