Effects of Galactic Cosmic Rays on the surface of icy objects, implication for ultra-carbonaceous Antarctic micrometeorites

Basile AUGE

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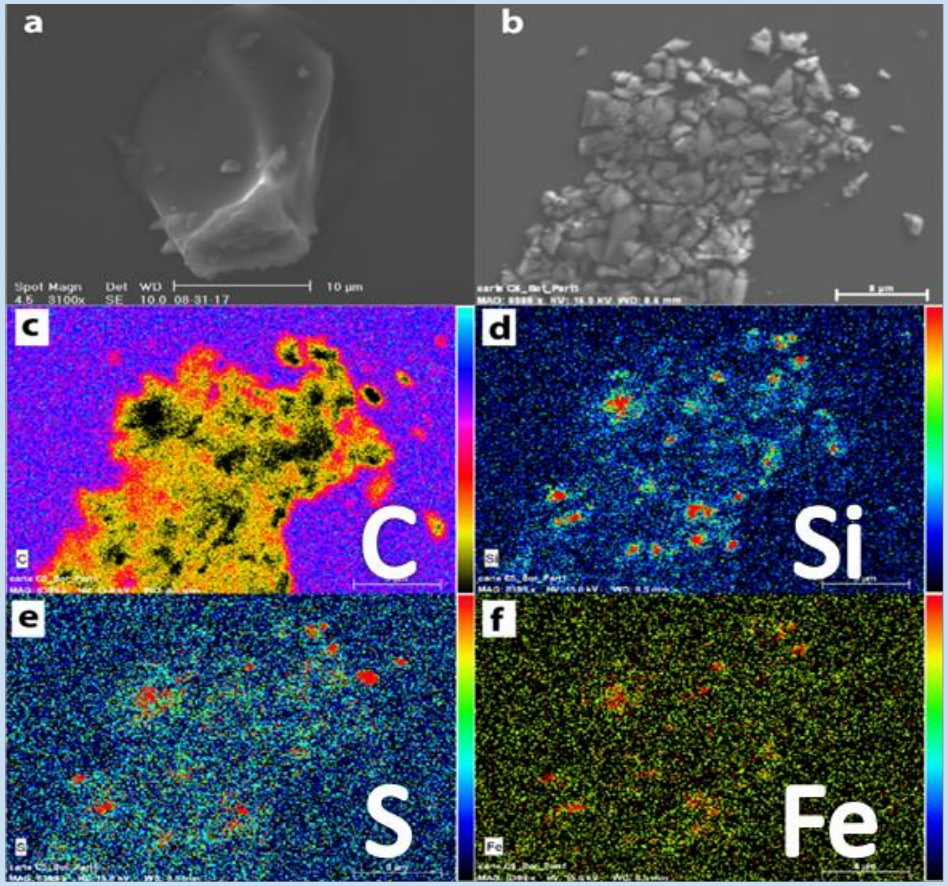
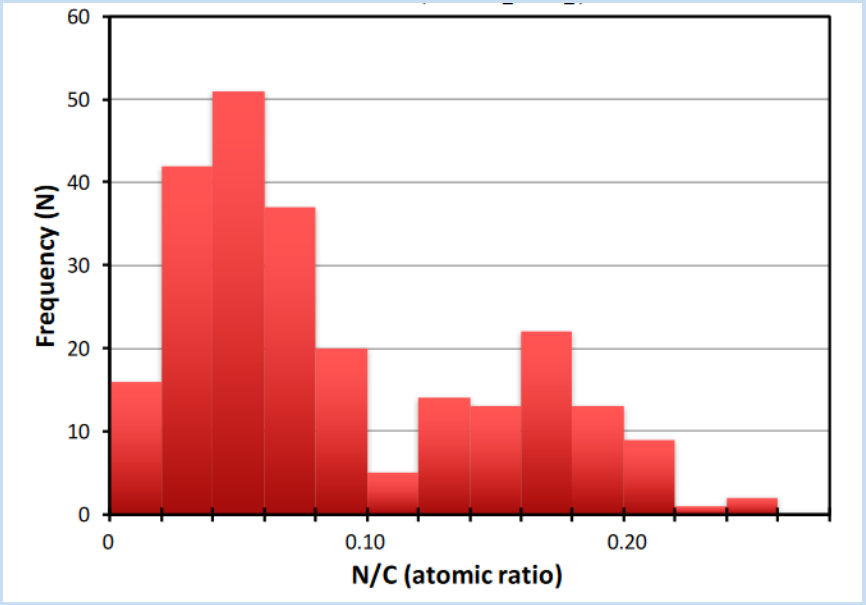
Understanding the origin of UCAMM organic matter

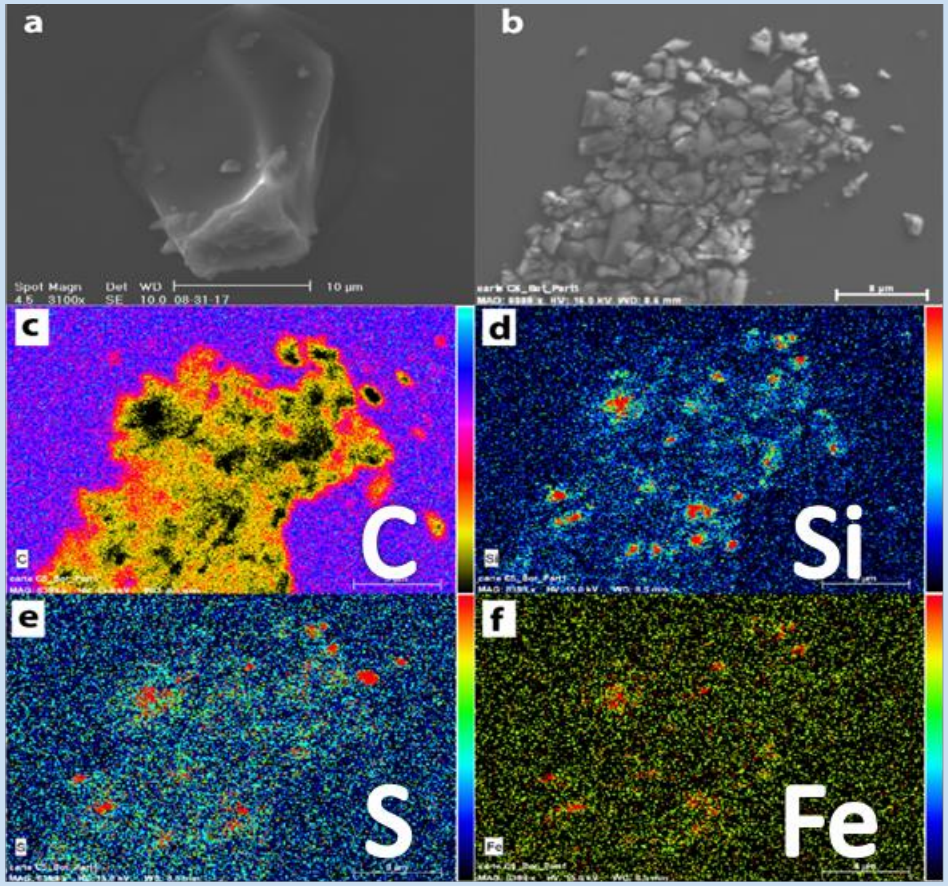


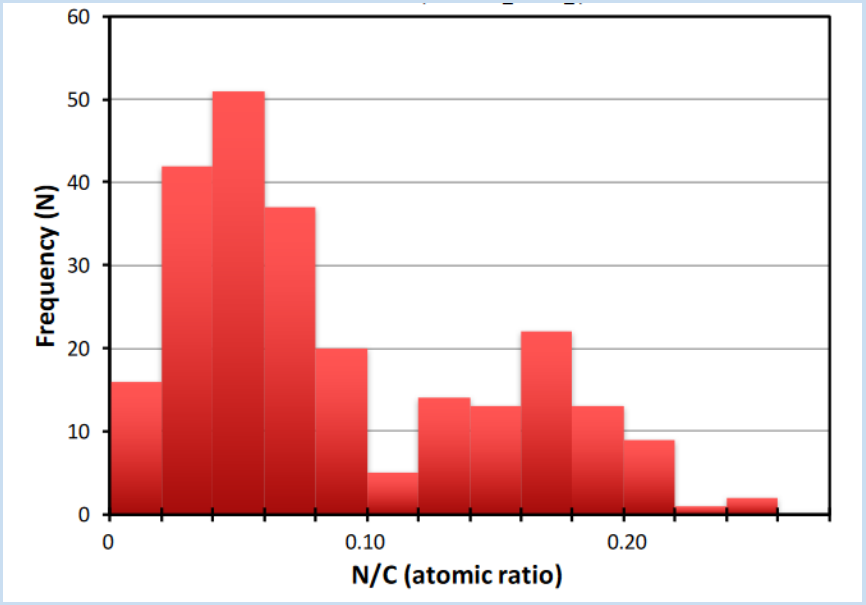


- 1% of Concordia Collection
- At least 50%w of C
- N-rich organic matter (N/C ~12%)

Dartois et al. *Icarus*, 224, 2013
Engrand et al. *LPSC*, 49, 2018

Understanding the origin of UCAMM organic matter





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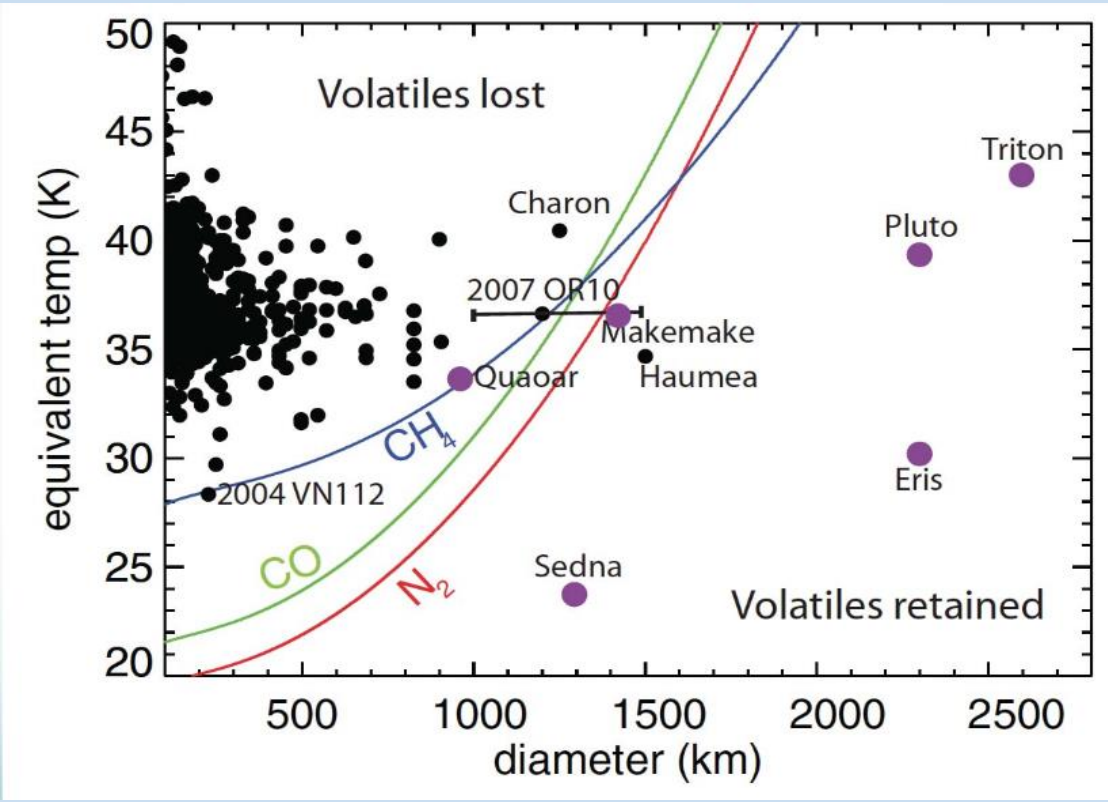
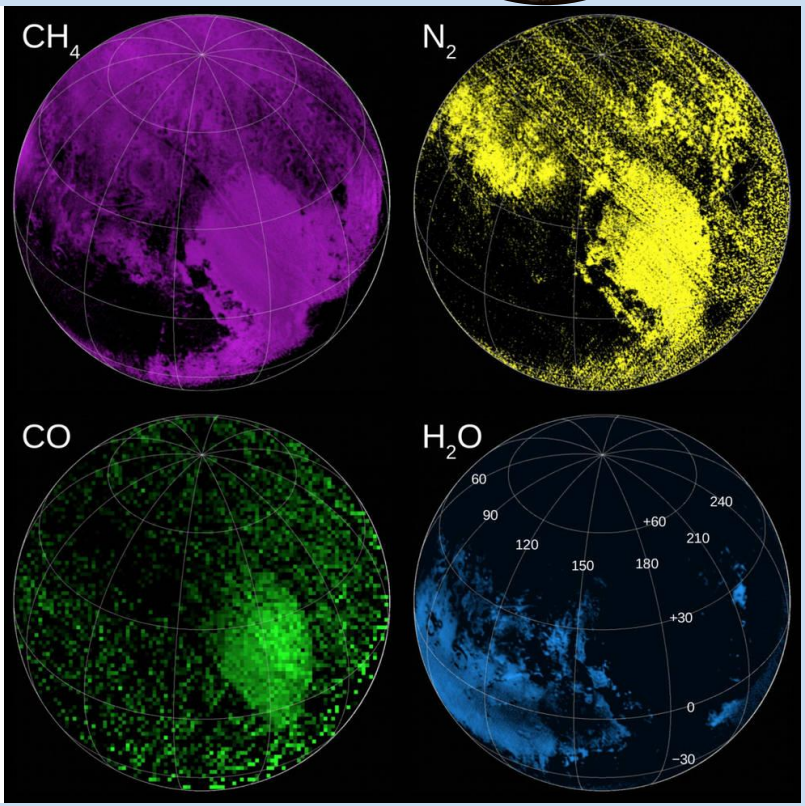
How to produce a mineral depleted N-rich organic matter in the solar system ?

Dartois et al. *Icarus*, 224, 2013
Engrand et al. *LPSC*, 49, 2018

N-rich ice surfaces





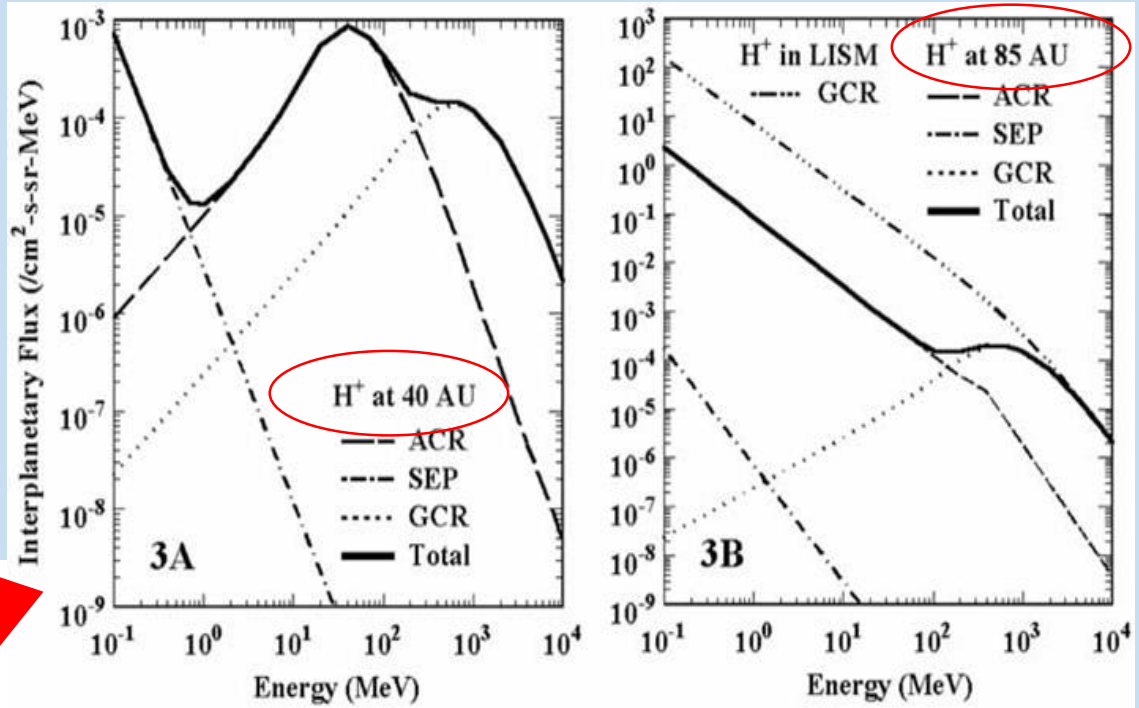
Pluto by New Horizons

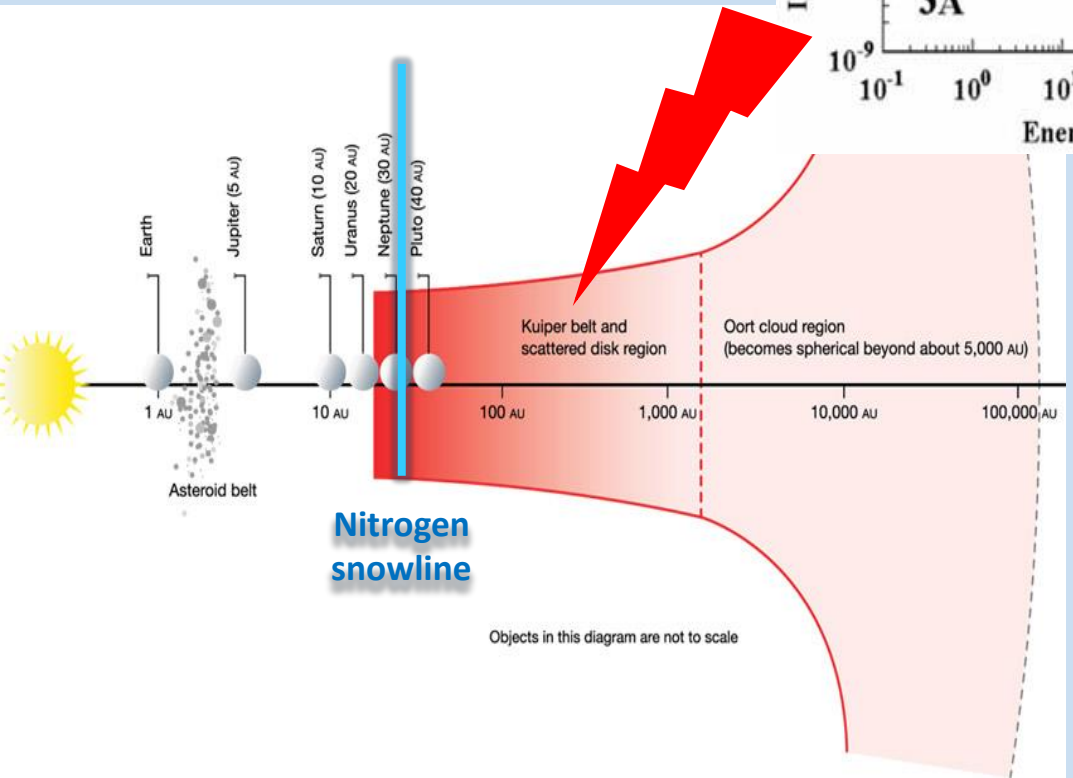
Kuiper belt – Oort cloud objects can be covered with N_2-CH_4 ices

> 30 AU > 5000 AU

Grundy et al. *Science*, 251, 2016
Brown et al. *ApJ*, 738, 2011

Radiative environment : Galactic Cosmic Rays





Exposition of icy bodies to GCR radiations

Dartois et al. *Icarus*, 224, 2013

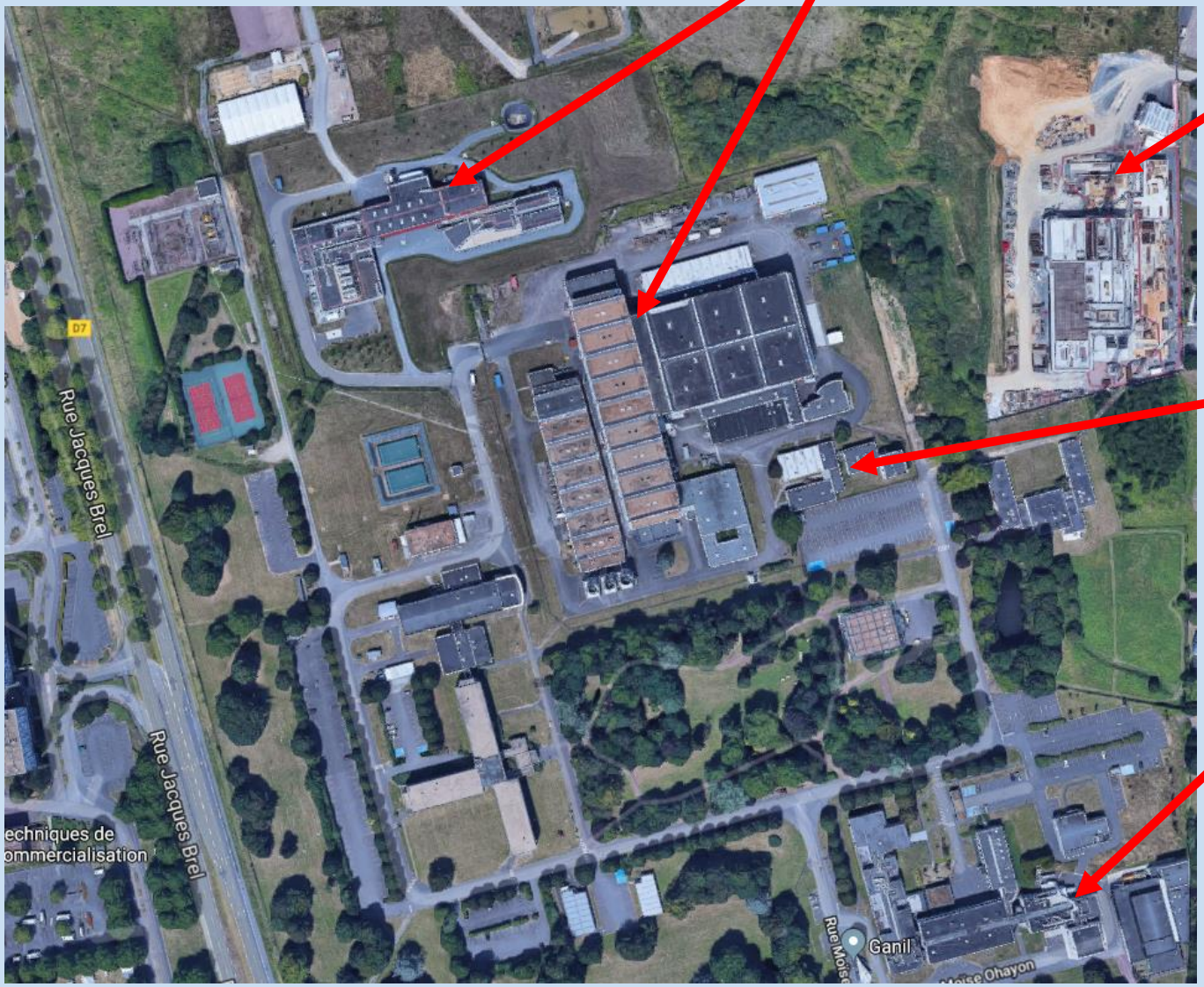
Cooper et al. *Earth, Moon and Planets*, 92, 2003

GANIL (Caen, France)

Large Heavy Ion National Accelerator

GANIL laboratoire commun CEA/DSM spiral2 CNRS/IN2P3

Archade ADVANCED RESOURCE CENTRE FOR HADRONTHERAPY IN EUROPE

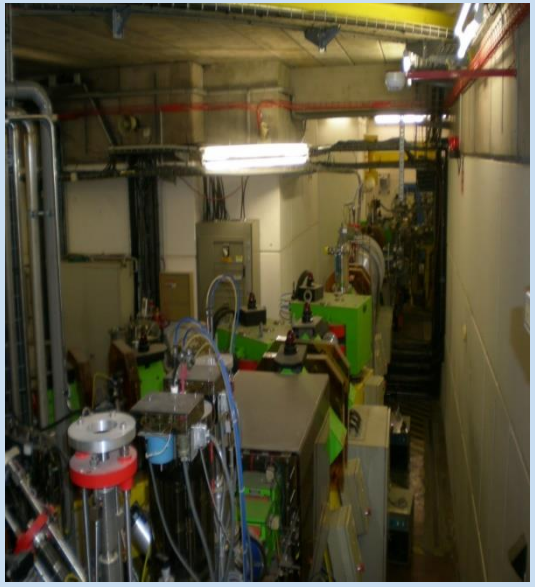


CiMap

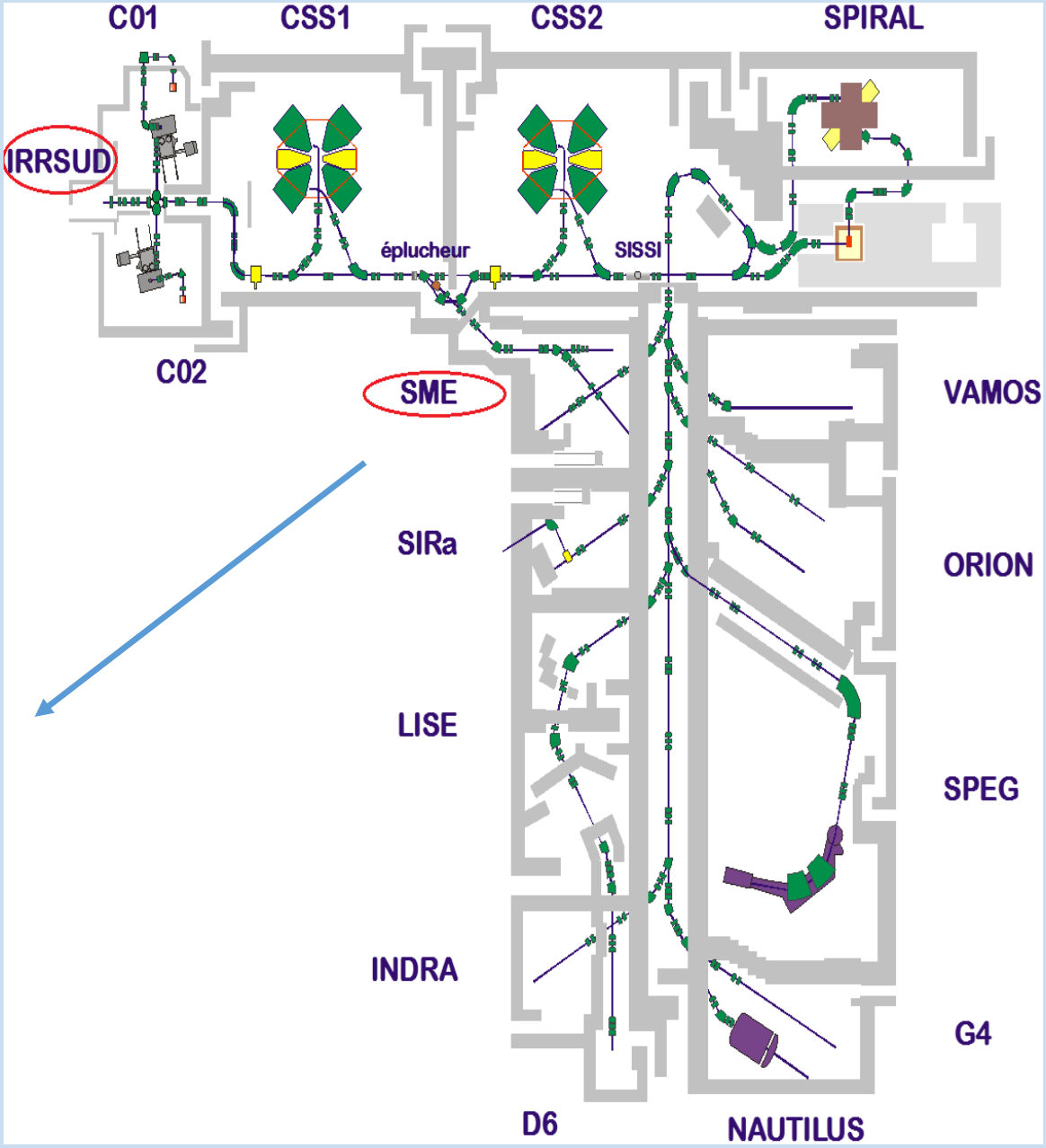
Cyceron PLATEFORME D'IMAGERIE BIOMÉDICALE

Irradiation beam lines

0,3 to 1 MeV/A



5 to 13 MeV/A



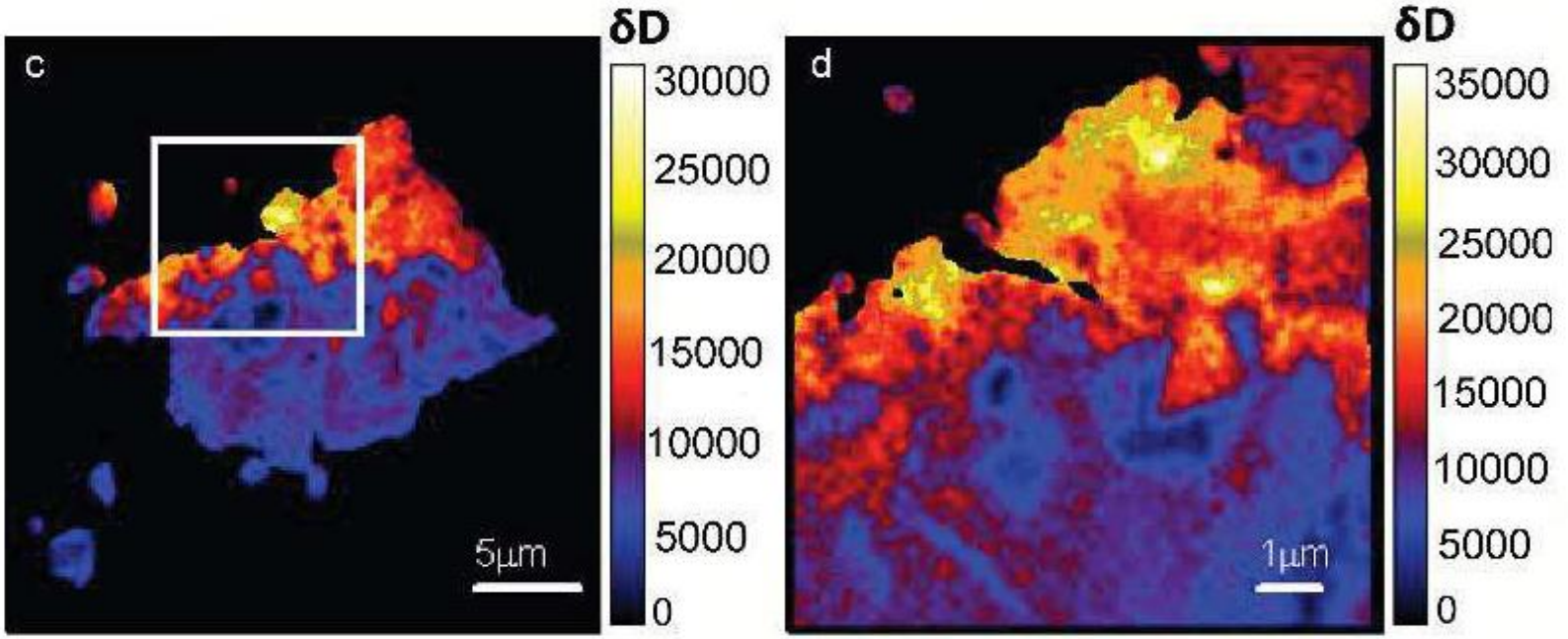
Understanding the origin of UCAMM organic matter

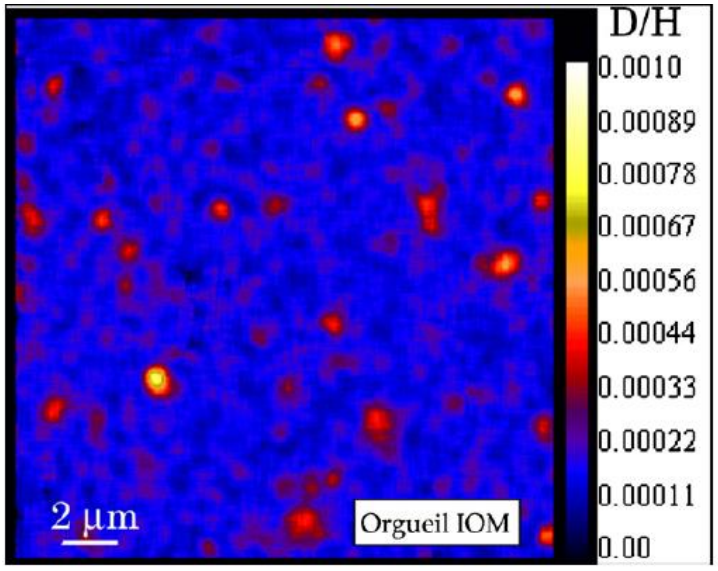
Specific organic matter found in UCAMM can be formed on N-rich icy parent bodies in the outer solar system exposed to GCR

A poly-HCN like material can be a precursor for this N-rich O-poor organic matter

Augé et al. *Astronomy & Astrophysics*, 592, 2016

A D-rich organic matter



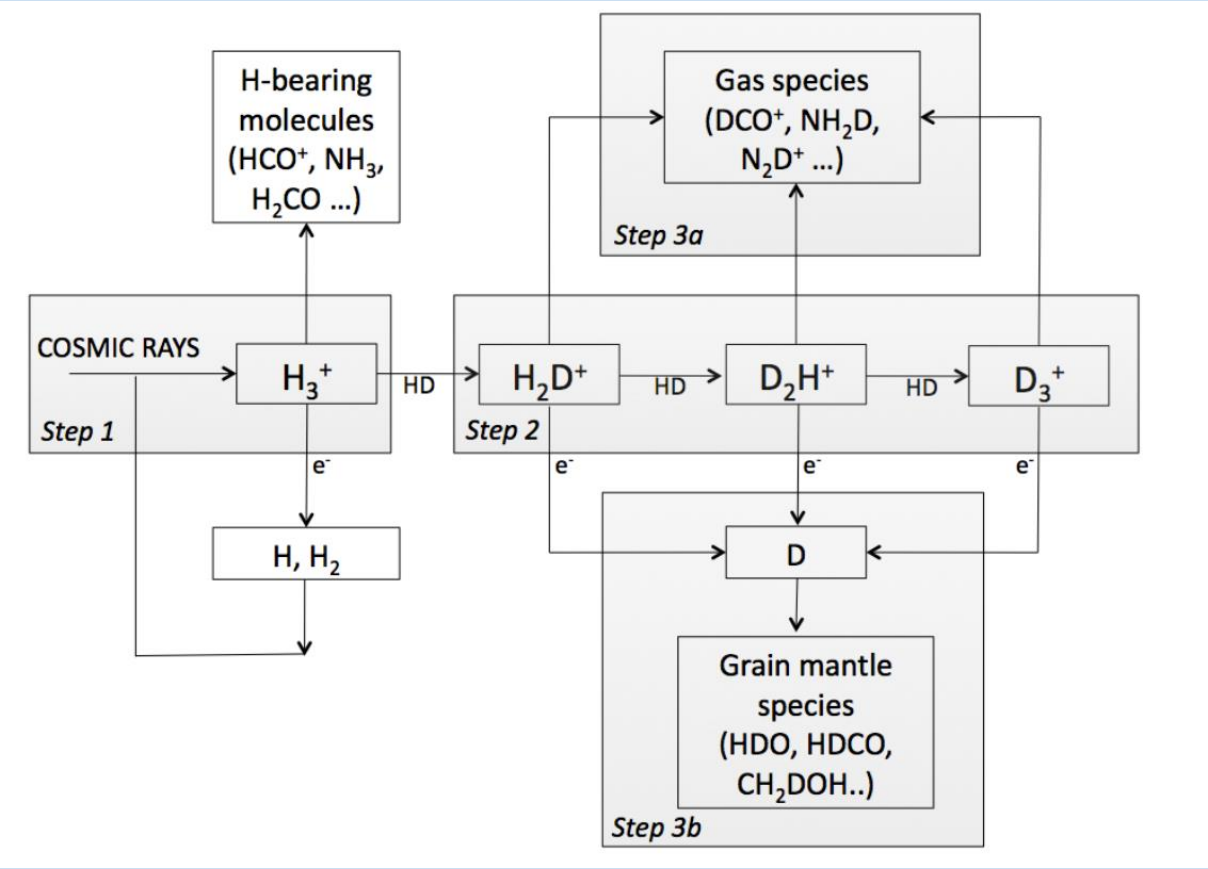


δD of 5500

- Large D-enrichment areas
- Hot spot up to 30 SMOW

Duprat et al. *Science*, 328, 2010
Remusat et al. *Comptes Rendus Geoscience*, 339, 2007

Hypothesis commonly considered



Ion-molecule reactions at low temperature in the dense phase of a molecular cloud or in a protoplanetary disk

Aikawa et al. *Astronomy & Astrophysics*, 386, 2002
Geiss et al. *Astronomy & Astrophysics*, 93, 1981

Secondary processes : irradiation effects

THE ASTROPHYSICAL JOURNAL, 840:35 (11pp), 2017 May 1

https://doi.org/10.3847/1538-4357/aa6bfc

CrossMark

X-Ray-induced Deuterium Enrichment of N-rich Organics in Protoplanetary Disks: An Experimental Investigation Using Synchrotron Light

Lisseth Gavilan[1], Laurent Remusat[2], Mathieu Roskosz[2], Horia Popescu[3], Nicolas Jaouen[3], Christophe Sandt[4], Cornelia Jäger[5], Thomas Henning[6], Alexandre Simionovici[7], Jean Louis Lemaire[8], Denis Mangin[9], and Nathalie Carrasco[1]
[1] LATMOS, Université Versailles St Quentin, UPMC Université Paris 06, CNRS, 11 blvd d'Alembert, F-78280 Guyancourt, France; lisseth.gavilan@latmos.ipsl.fr
[2] IMPMC, CNRS UMR 7590; Sorbonne Universités, UPMC Université Paris 06; IRD, Muséum National d'Histoire Naturelle, CP 52, 57 rue Cuvier, Paris F-75231, France
[3] SEXTANTS beamline, SOLEIL synchrotron, L'Orme des Merisiers, F-91190 Saint-Aubin, France
[5] Laborator ... hysics,

ELSEVIER

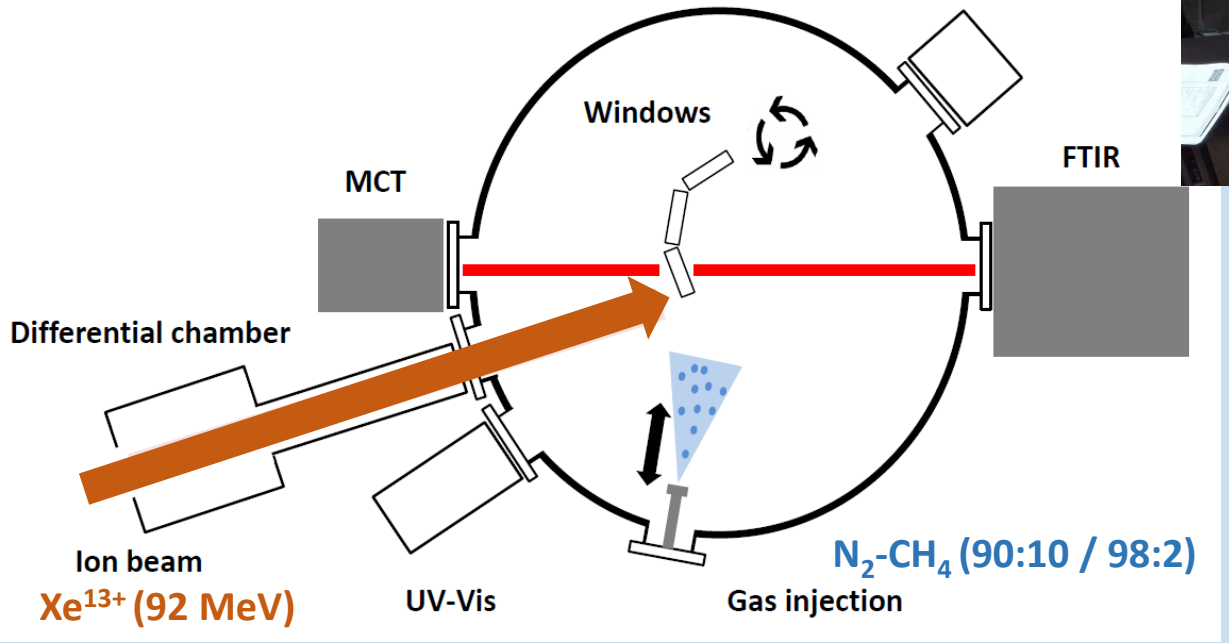
Geochimica et Cosmochimica Acta

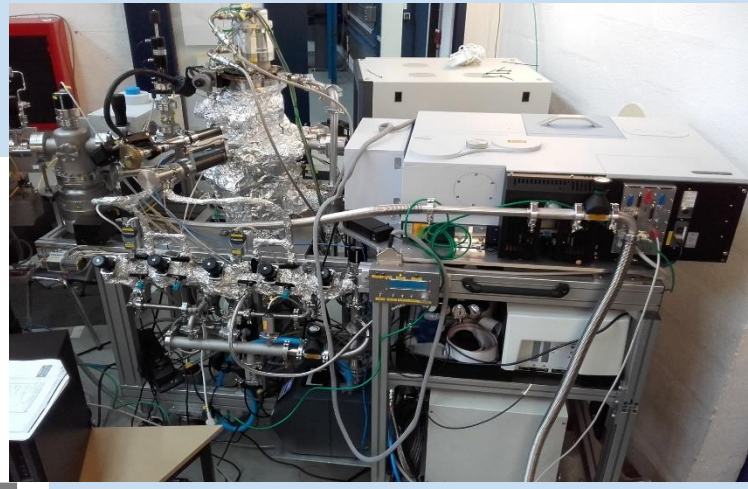
Volume 74, Issue 15, 1 August 2010, Pages 4454-4470

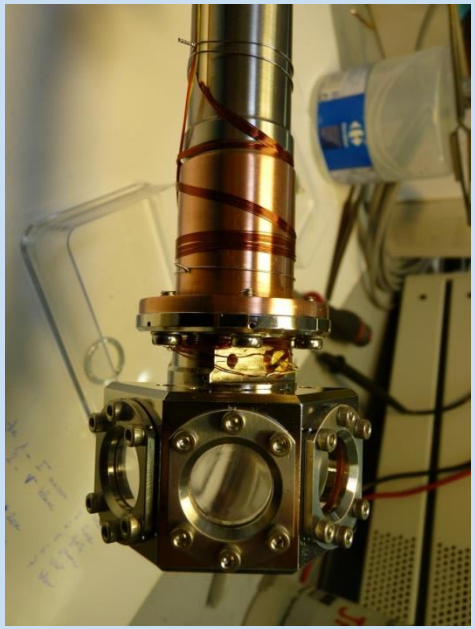
Isotopic anomalies in organic nanoglobules from Comet 81P/Wild 2: Comparison to Murchison nanoglobules and isotopic anomalies induced in terrestrial organics by electron irradiation

Bradley T. De Gregorio [a, b], Rhonda M. Stroud [a], Larry R. Nittler [c], Conel M.O'D. Alexander [c], A.L. David Kilcoyne [d], Thomas J. Zega [a]

Experimental set-up





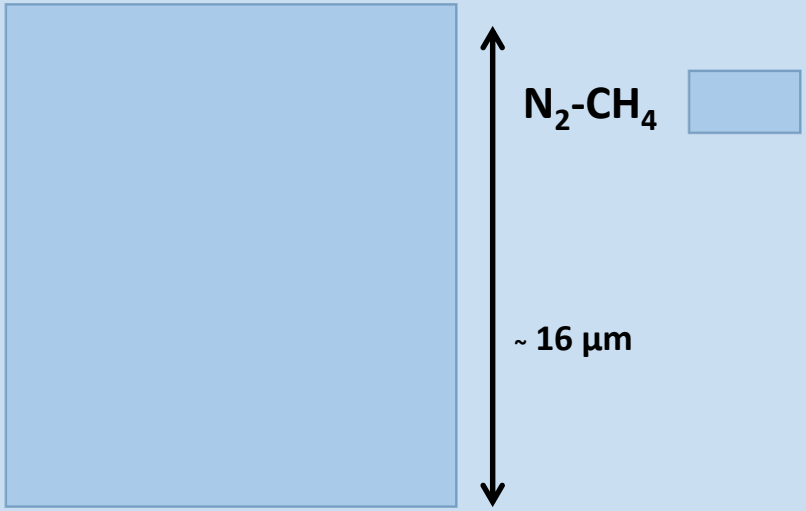


20 mm

- 1,5 10^{-10} mbar at 8 K
- 3 windows
- FTIR and Vis-UV spectrometer

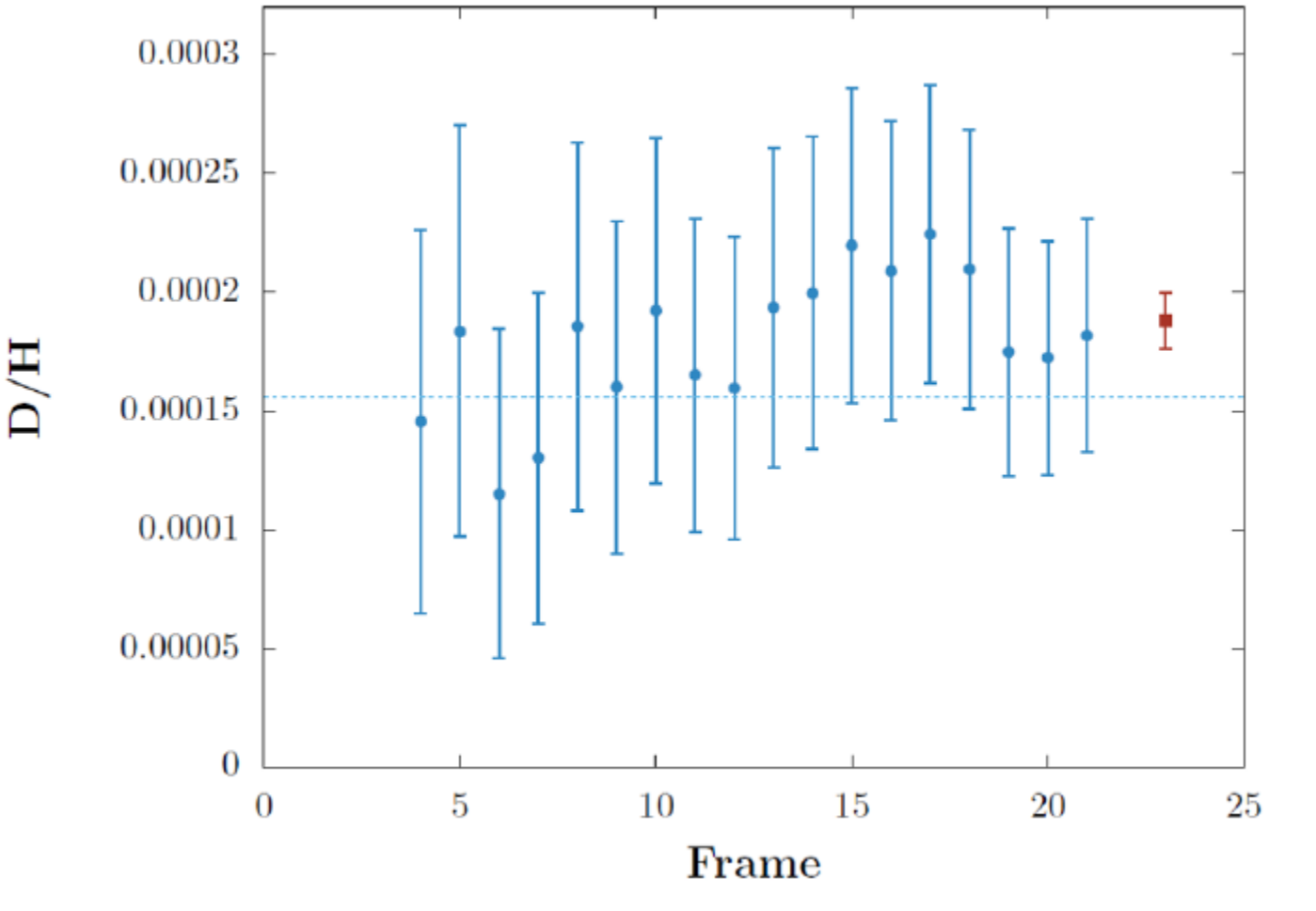
Irradiation and D-enrichment

- Irradiation with Xe^{13+} (92 MeV) up to 19 eV $molec^{-1}$
- Slow annealing to obtain solid organic residue
- NanoSIMS analyses to obtain D/H ratio or δD



Augé et al. *2018, in prep.*

Irradiation and D-enrichment



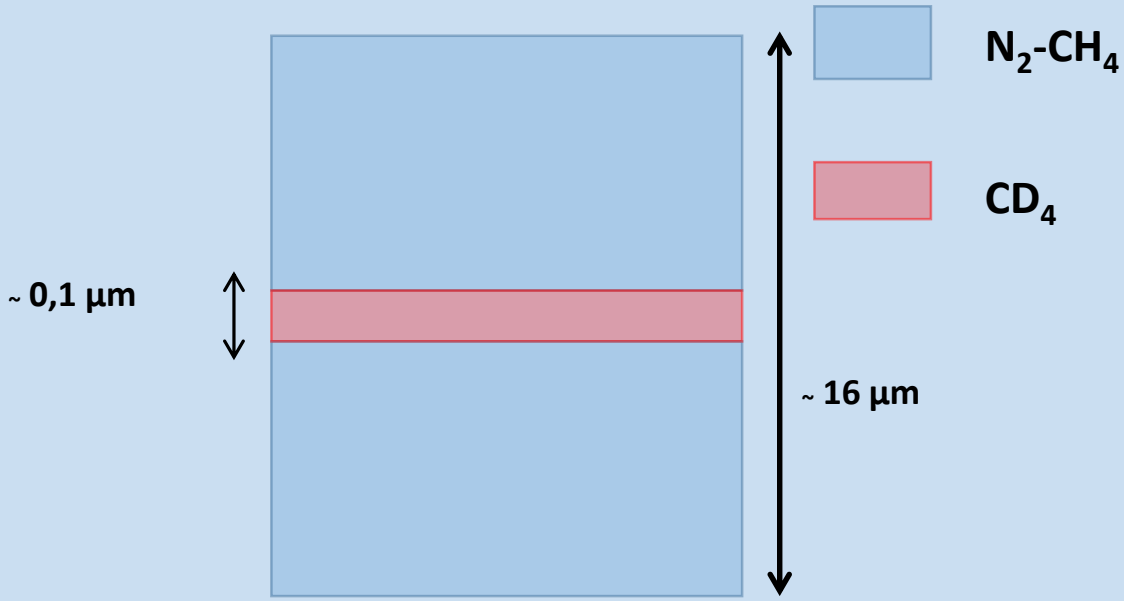
SMOW

No significant irradiation induced D-enrichment :

$\delta D = (150 \pm 100)$ ‰

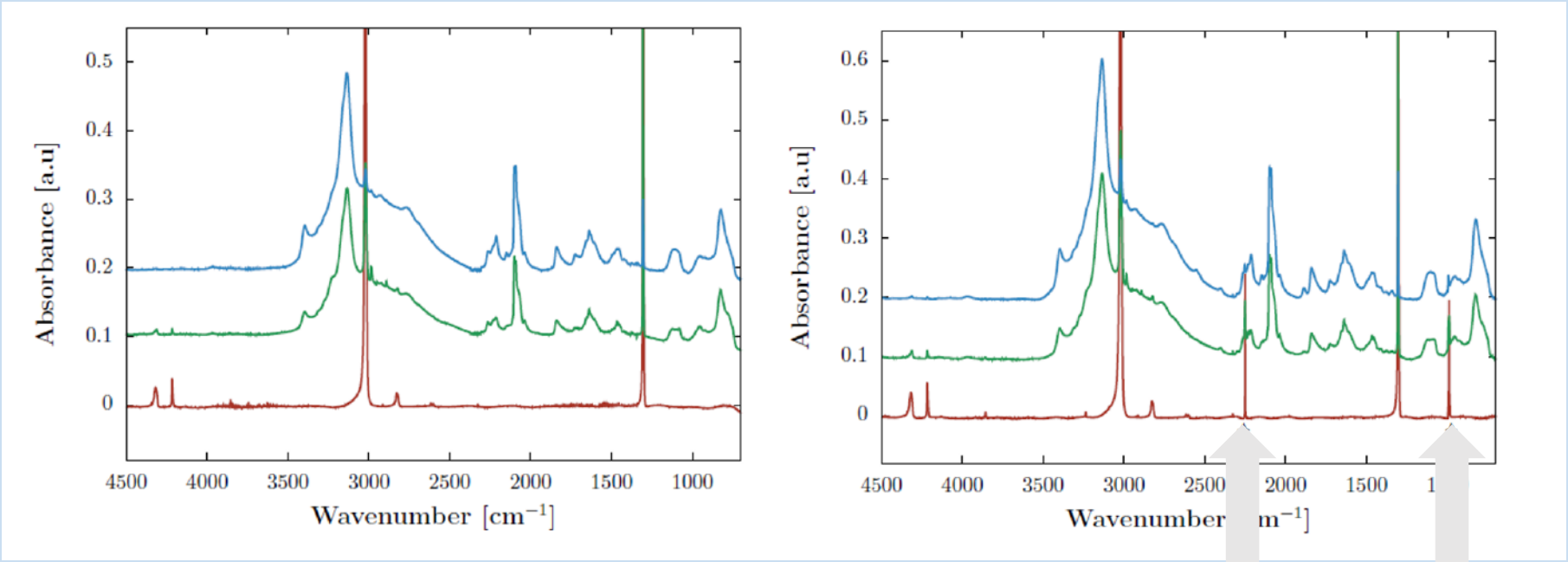
Augé et al. *2018, in prep.*

Irradiation of a D-rich ices



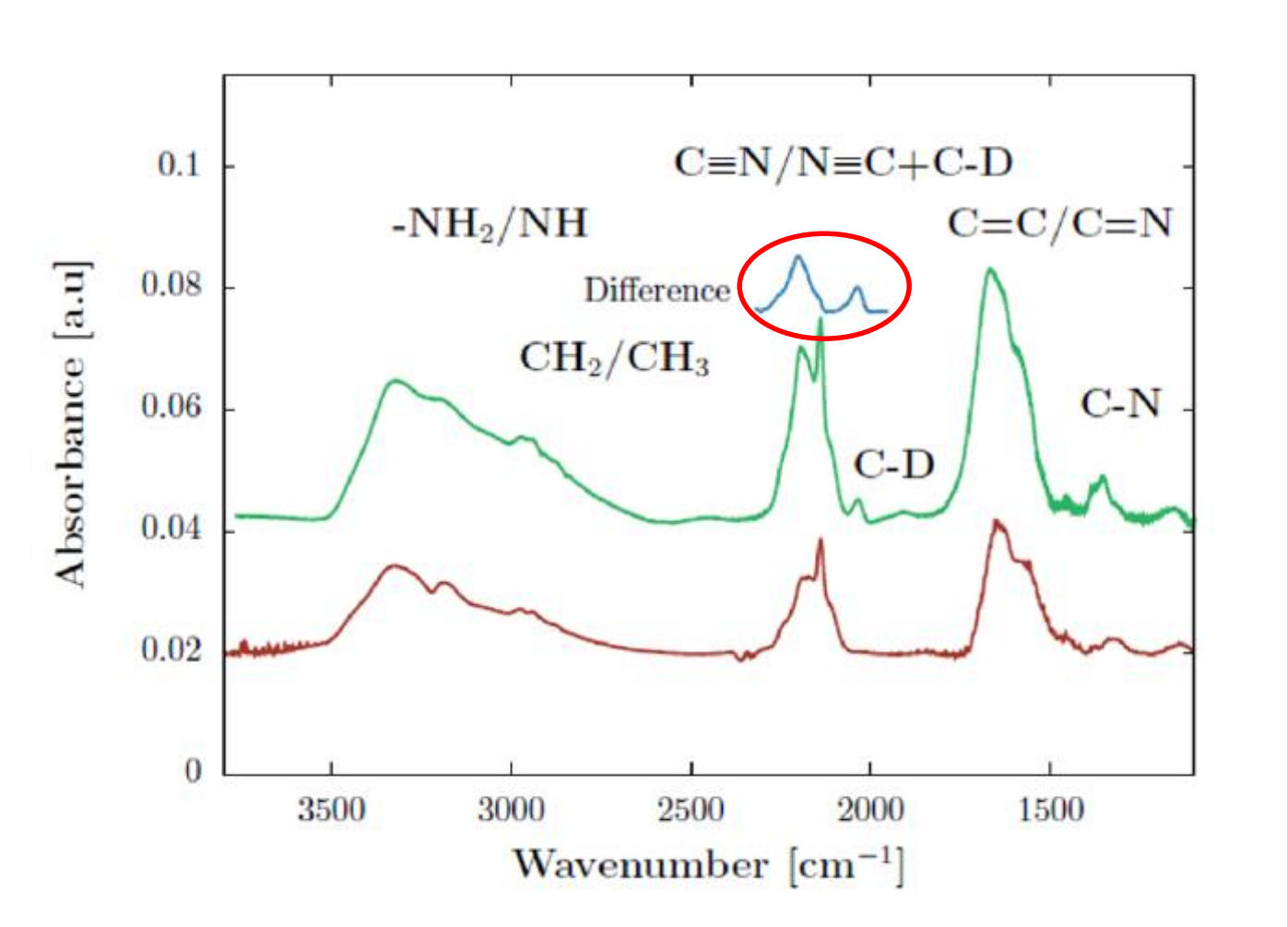
Augé et al. *2018, in prep.*

IR spectra N_2-CH_4 / N_2-CH_4 + CD_4



Augé et al. *2018, in prep.*

D-rich residue



Augé et al. *2018, in prep.*

Conclusion

- **SHI irradiation does not induce D-enrichment**
- **Irradiation of D-rich ice induces a D-incorporation in the solid residue in a reasonable astrophysical time scale**
- **Irradiation keeps the isotopic memory of initial ices**

The scenario can explain both N-rich and O-poor AND D-rich organic matter found in UCAMMs