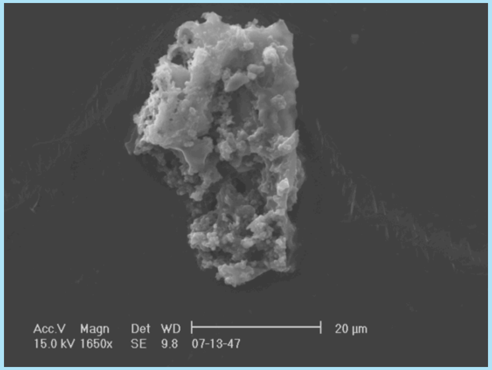
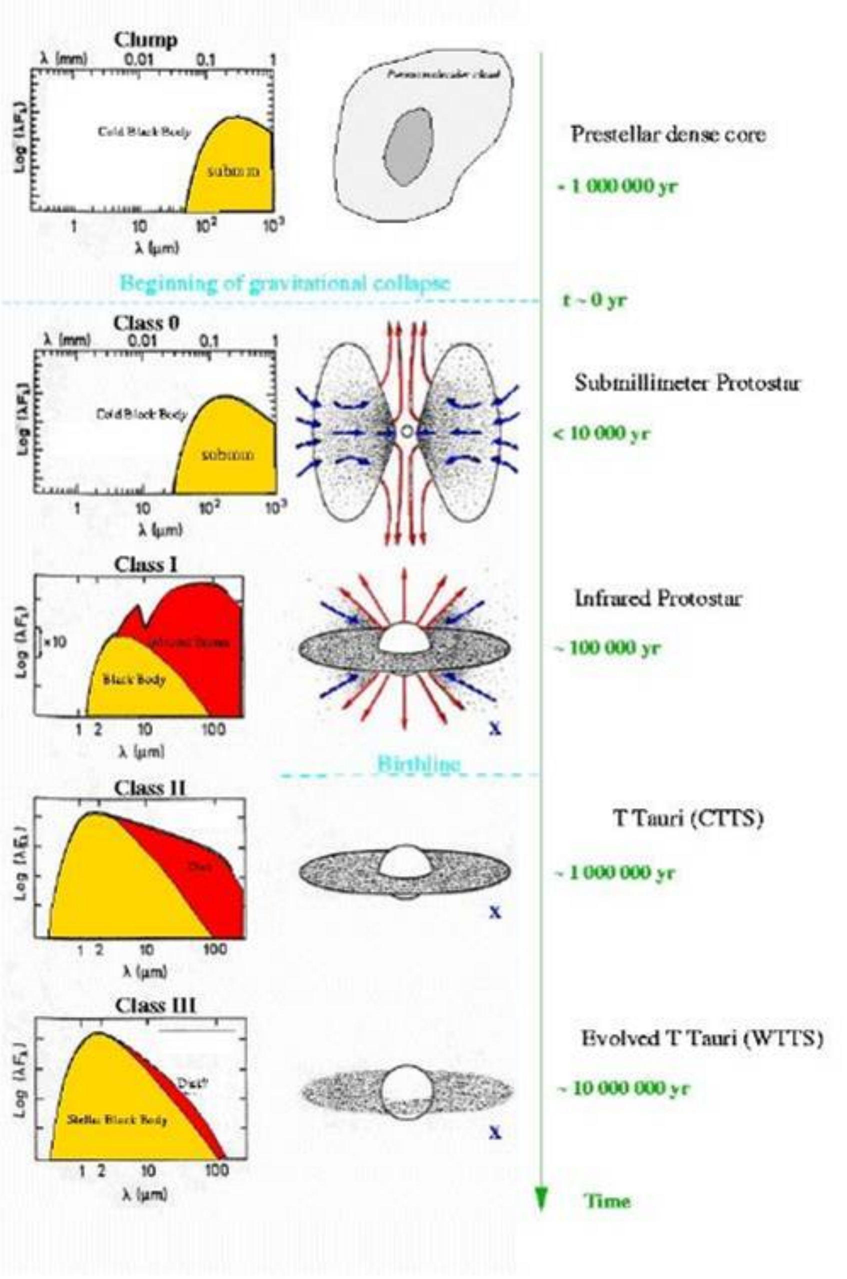
Les micrométéorites ultra-carbonées

un apport de matériau cométaire



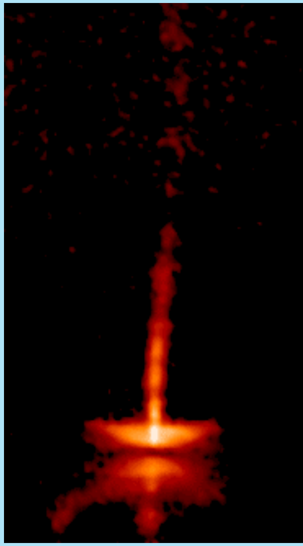
Jean Duprat
CSNSM-CNRS Univ. Paris Sud
Congrès SFE 7 Octobre 2014
Collaboration CSNSM-IAS

Before the main sequence



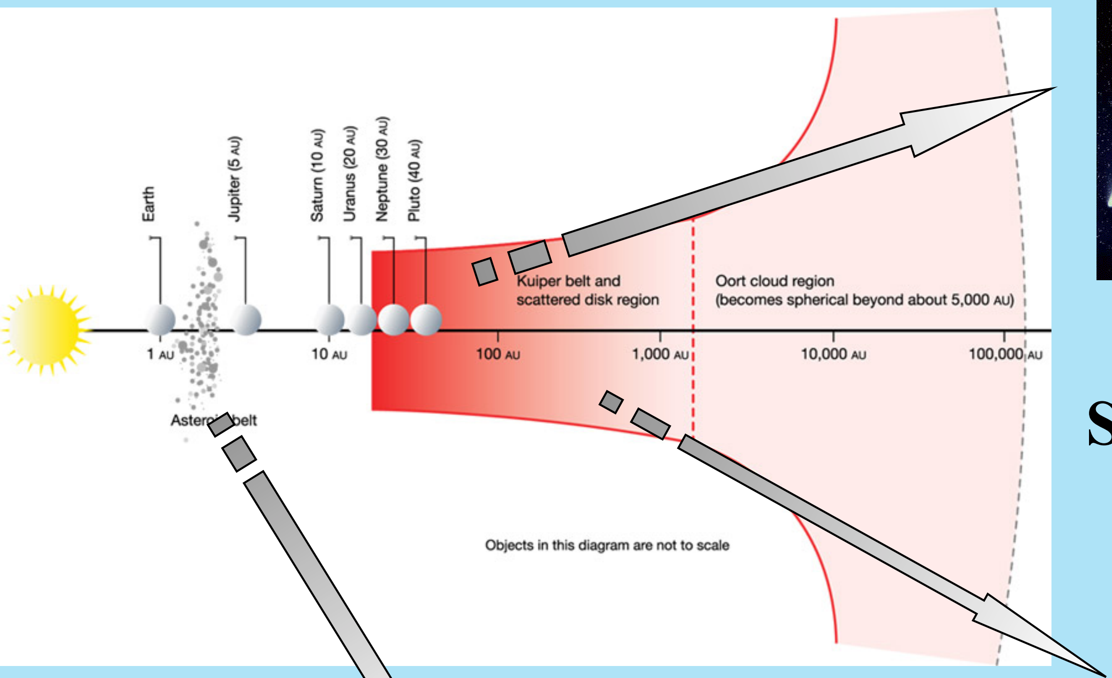
Different time scales

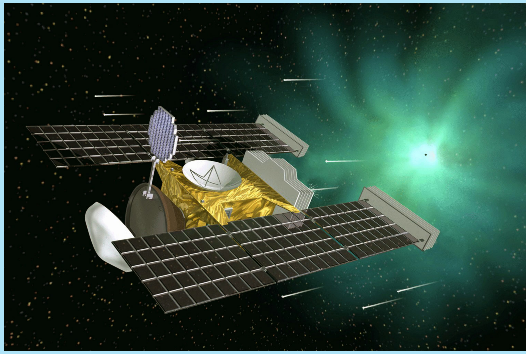
- Class 0 & I :
  - The proto-star is embedded
  - High accretion rate
  - T ~ 10^4-10^5 years
  - $M_{star} = 0.5 - 0.8\ M_{\odot}$
- Class II & III :
  - Disk of gas and debris
  - Lower accretion rate
  - T ~ 10^5-10^6 years
  - $M_{star} = 0.8 - 1\ M_{\odot}$



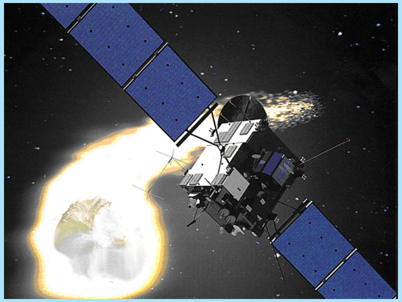
HH 30
Télescope Hubble

The solar system small bodies
Asteroids & Comets





STARDUST mission (2006)

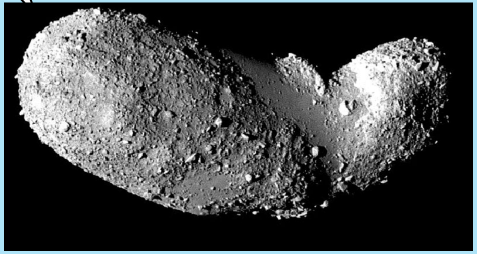


ROSETTA mission (2014)

Itokawa

Mission Hayabusa

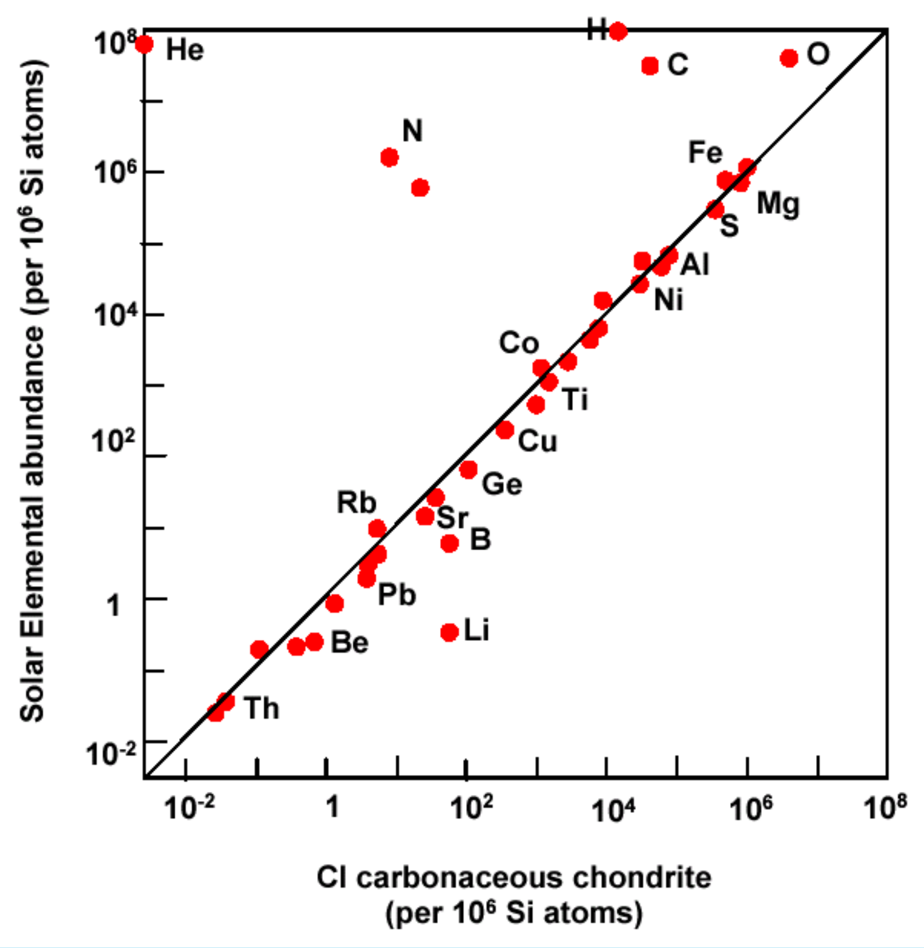
(2010)



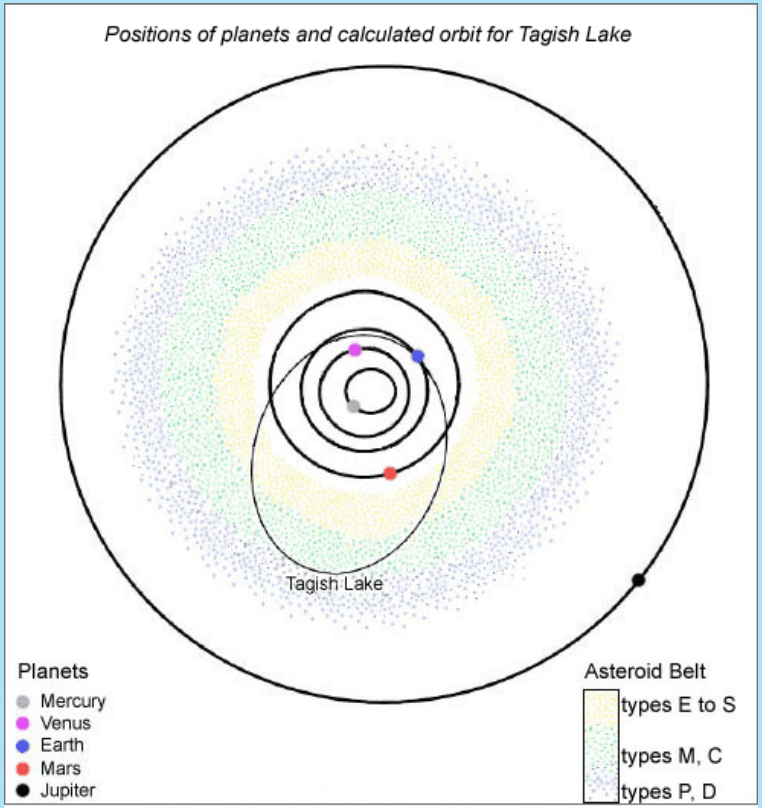
Meteorites & Antarctica

Antarctic Meteorite Research

PI : R. Harvey, US



Most meteorites are coming from the asteroid belt between Mars and Jupiter



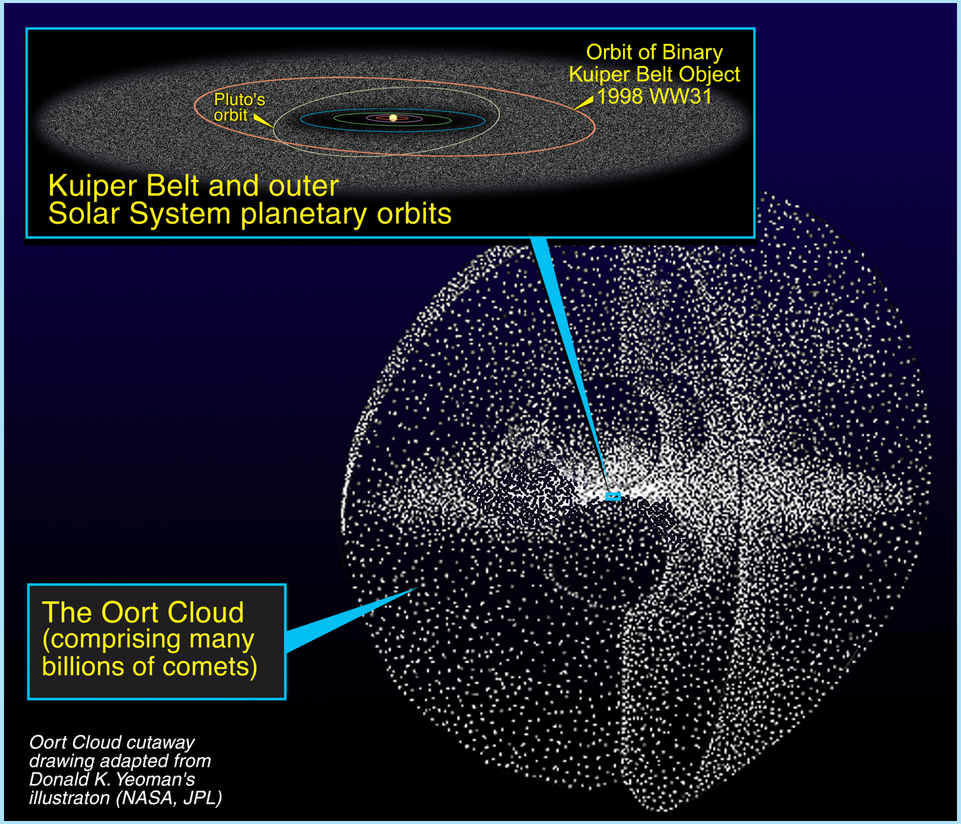
(PSRD graphic based on Brown *et al.*, 2000, *Science*, v.290, p.321.)

Brown et al. Science 2000

They are sampling a restricted part of **the inner solar system**

The comets

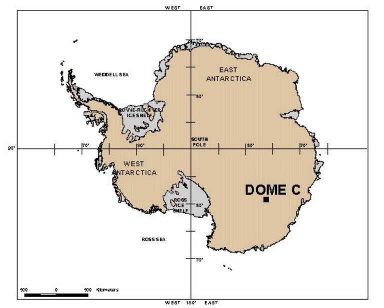
dust from the outer solar system



Sun-Earth : **1 AU** = 10^9 km

Kuiper belt : 70 AU

Oort Cloud : 50-100 10^3 AU



The **unique advantages** of Central Antarctica Regions for Extraterrestrial Dust research

* Dome C is **extremely preserved from terrestrial dust contamination** within the MMs size range [d > 50μm] :

- 1100 kms from the coasts of Adélie Land, 3200 m in altitude
- The dominant wind blowing from centre to coast
- The surface snow is separated from the bedrock by more 3,5 km of ice

-> a **high ET/T ratio** is expected, search for **new objects**

* Dome C **snow stays at low temperature** thought the year **(-70° < T<-20°)**

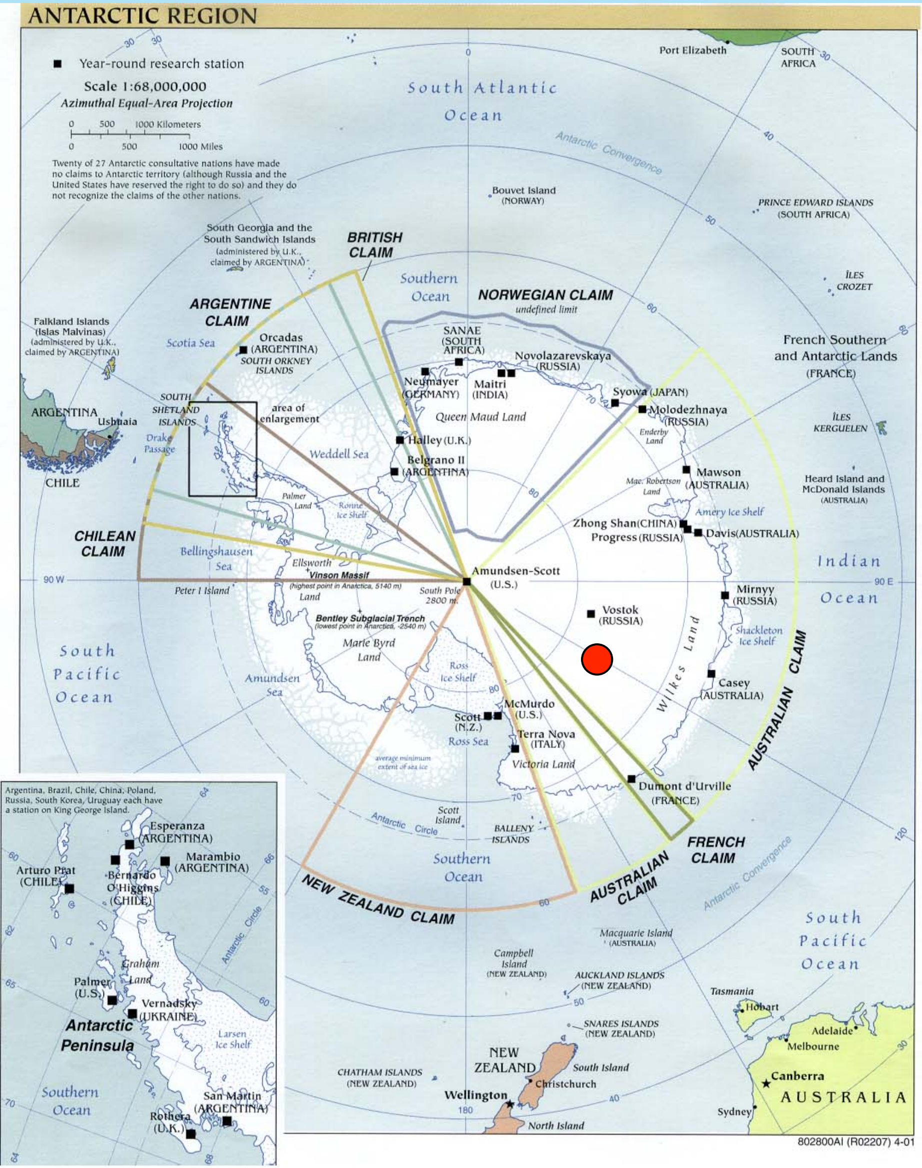
-> **unique condition of preservation from terrestrial weathering** are expected

- Dome C has **very low and regular precipitation rate :**

-> recover micrometeorites from **reasonable volume of snow** (few m^3)
-> measure a **FLUX of ET particles/m^2/year**
-> search for **variations in intensity/composition of the flux** in the last century

Duprat et al. *EAS series 2005*.

The polar Instituts (IPEV / PNRA)



Le Programme
« Micrométéorites @ Dôme C »

Dôme C, Janvier 2000

Neige de surface

(0-80 cm) @ 3 km du camp

Dôme C, Janvier 2002

Tranchée 3-4 mètres

V = 11 m^3

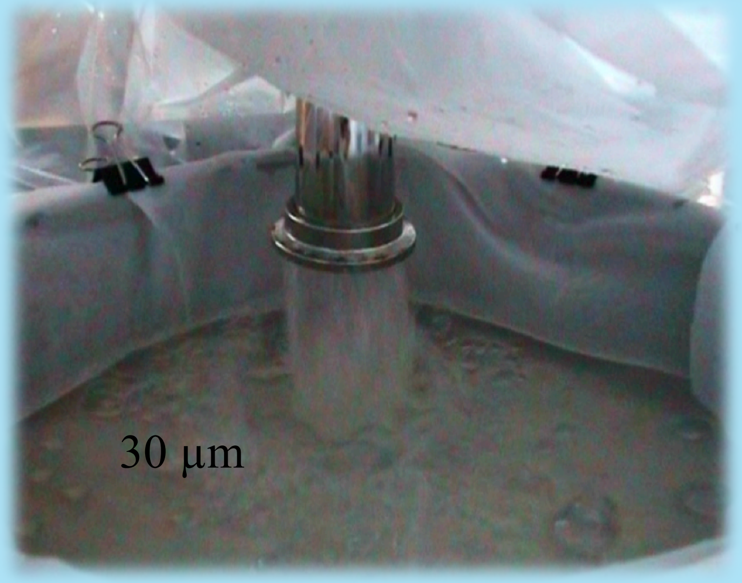
Dôme C, Janvier 2006-2014

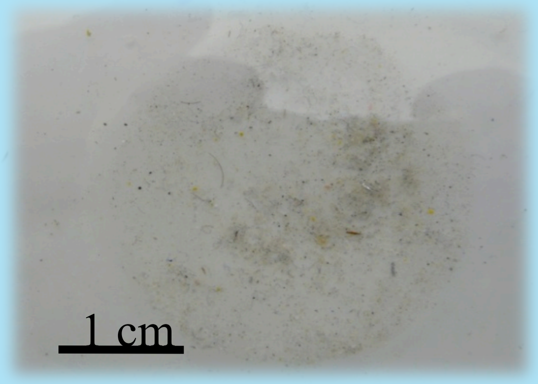
Tranchée 4-5 mètres

V = 25 m^3

The melting/sieving procedure

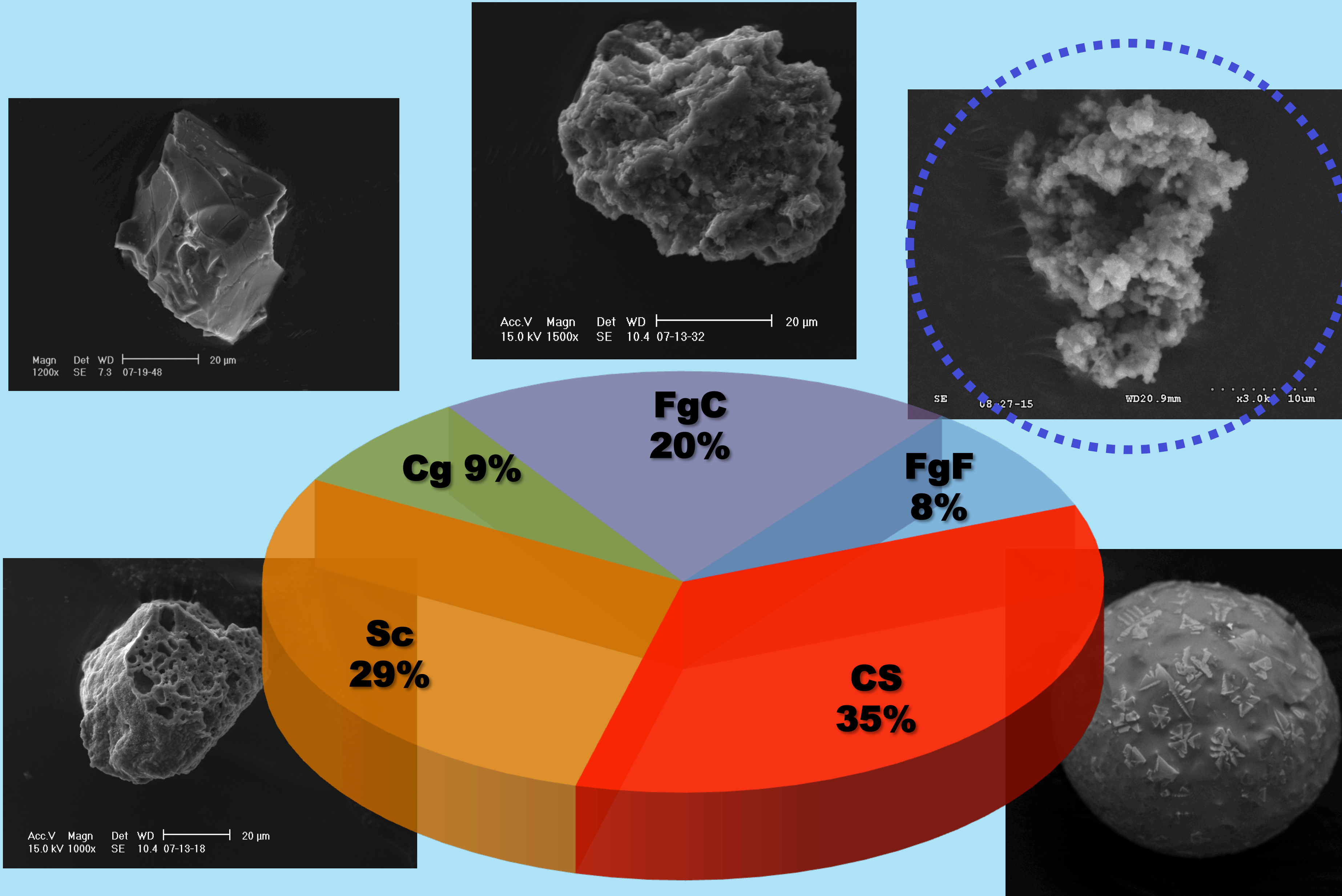
High efficiency double tank stainless steel smelter / 35kW propane boiler



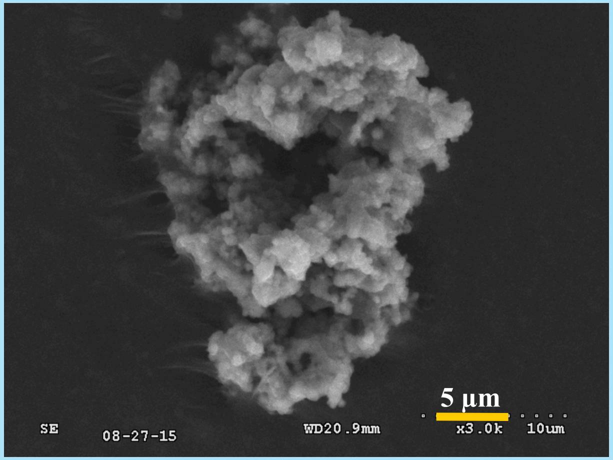


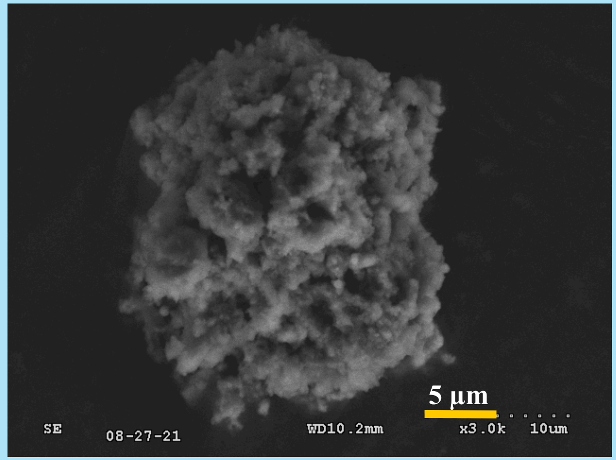
The 30 µm filters are pre-analyzed in a mini-lab to control terrestrial contamination

The CONCORDIA Collection, different types of micrometeorites

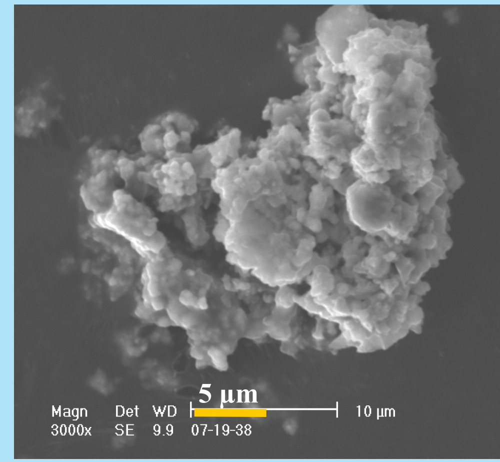


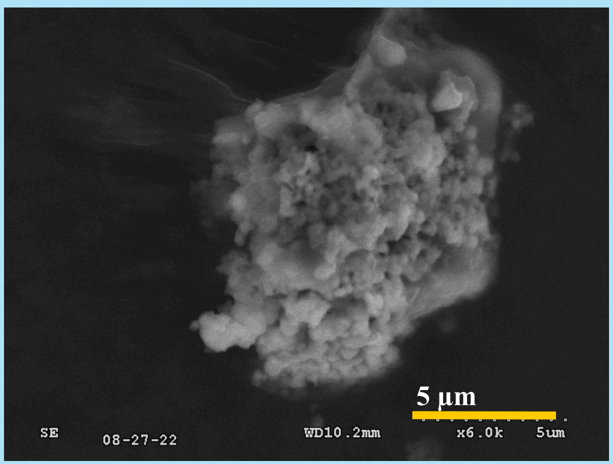
CONCORDIA friable particles

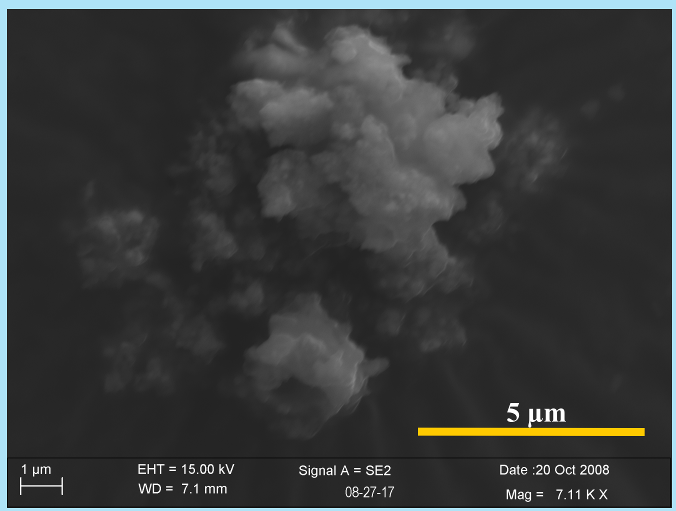


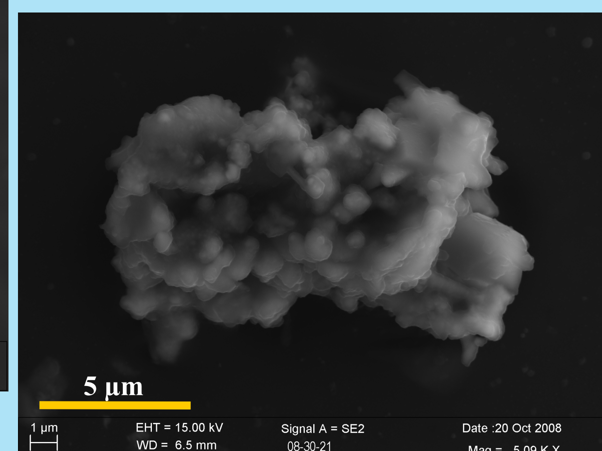


8% of AMMs



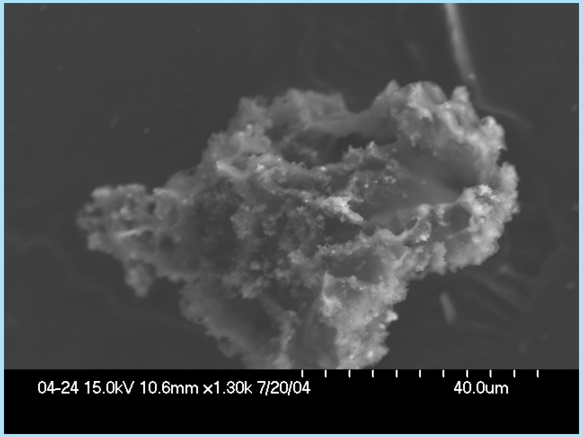


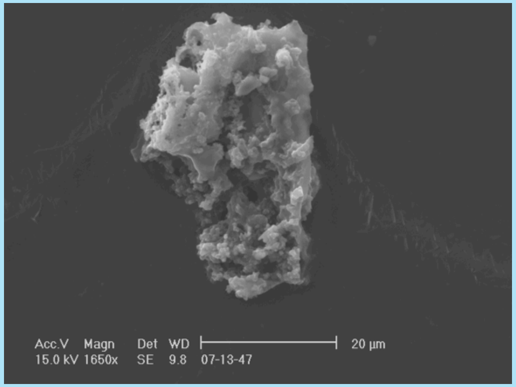


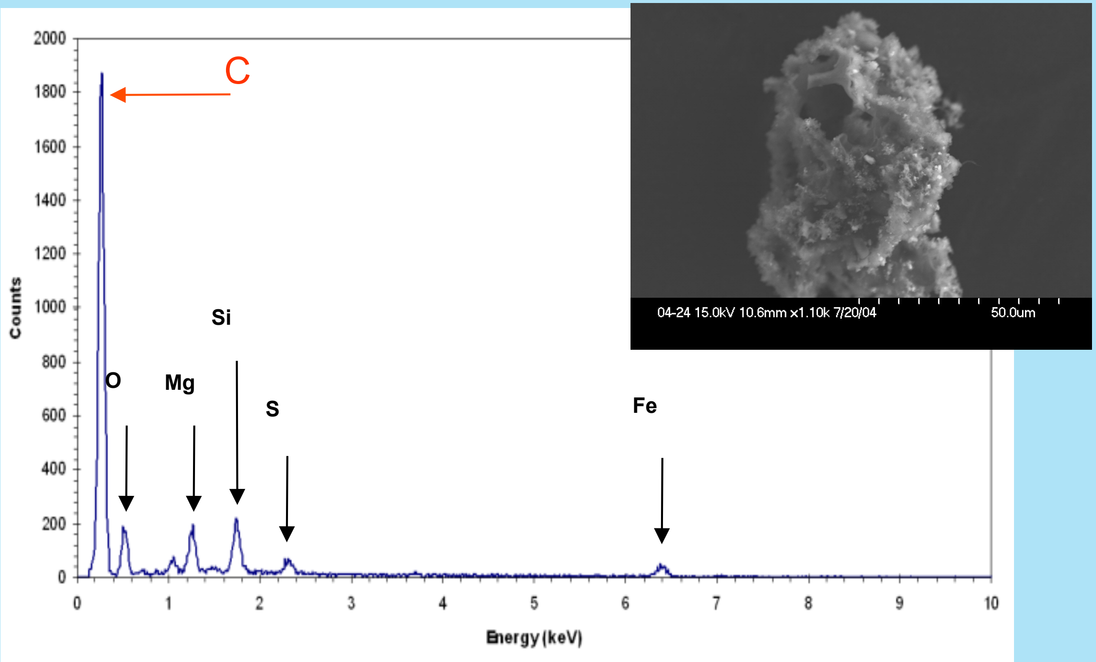


Duprat, Engrand *et al.*, *Adv. Space. Res.* (2007)

UltraCarbonaceous Antarctic MicroMeteorites (UCAMMs)







Dobrica, Engrand et al. LPSC 2008

Among the fine grained particles, some exhibit extremely high carbon content, the UCAMMs.
In UCAMMs, the organic matter represent more than 50 vol%

A new type of extraterrestrial material similar to:

- *CHON* particles (Halley comet) (Kissel et al 1987)
- Rare C-rich IDP (stratospheric collections) (Thomas et al. 1993)

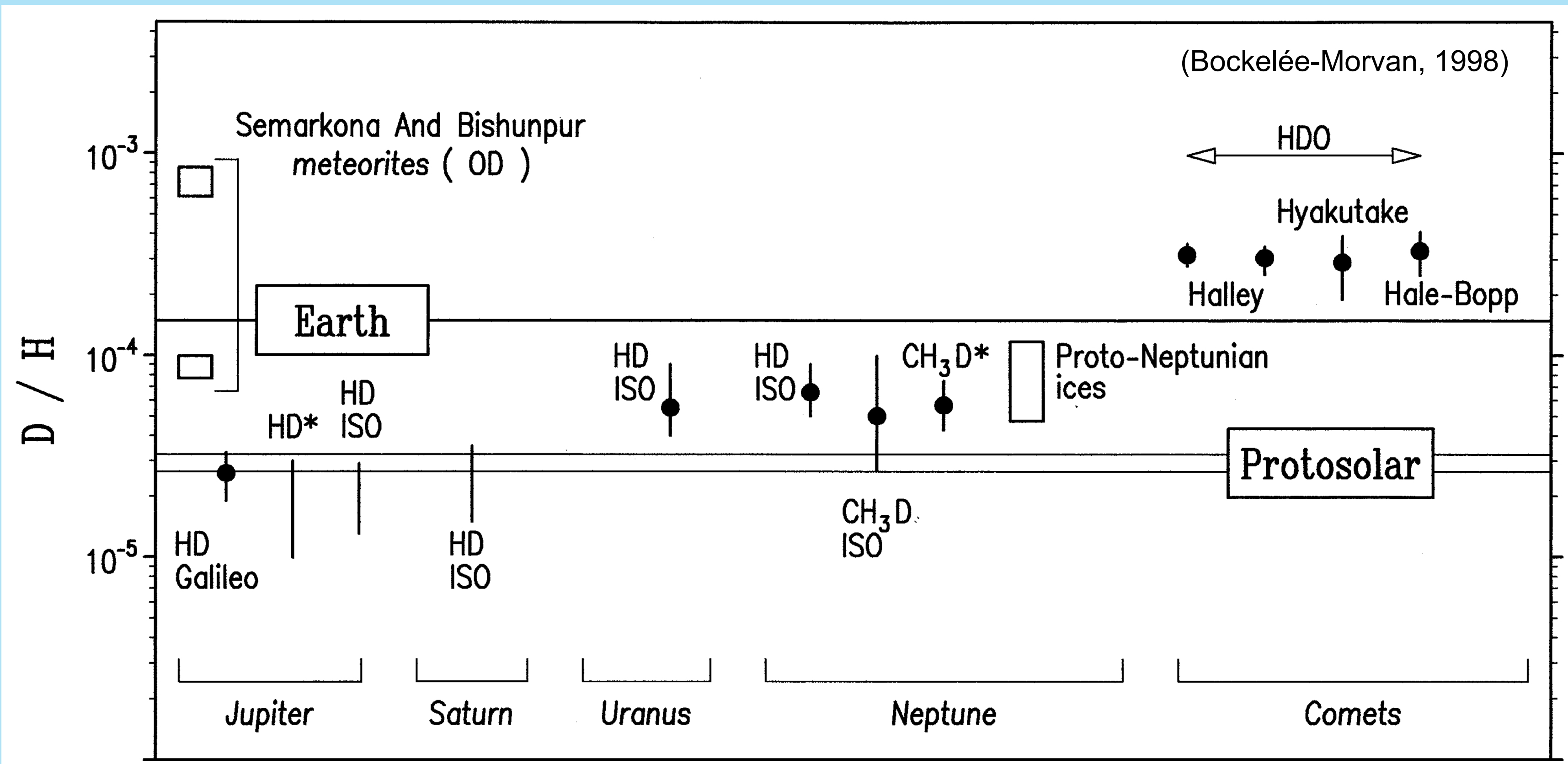
D/H ratios in the solar system

- Protosolar H_2 : D/H ~ 3×10^{-5}
- SMOW H_2O : D/H ~ 15×10^{-5}
- Cometary H_2O : D/H ~ 30×10^{-5}

The origin of the Deuterium excesses

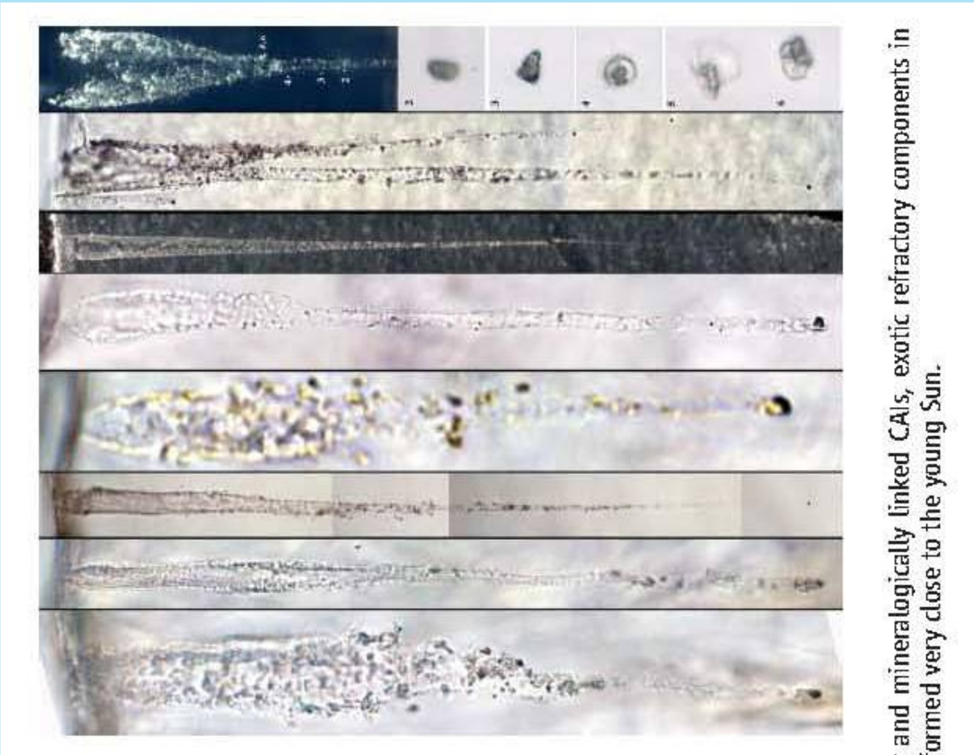
Ion-molecules reactions at low temperature

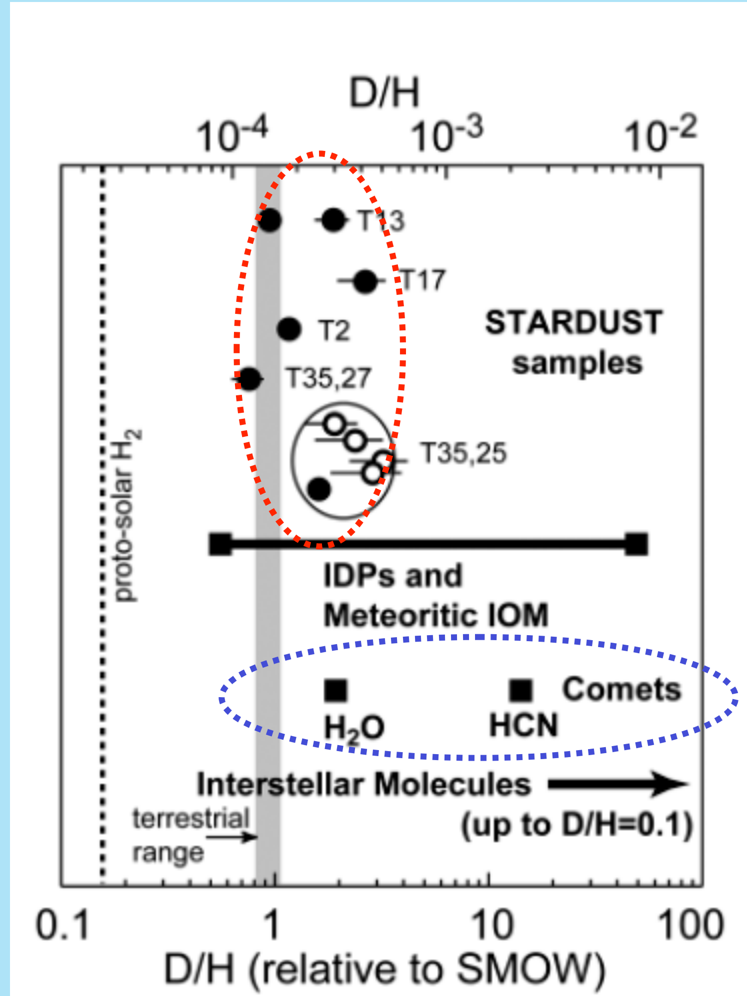
$$H_3^+ + \mathbf{HD} \rightleftharpoons \mathbf{H_2D}^+ + H_2$$



The quest for pristine early solar system material…

D/H of 81P/Wild2 particles (STARDUST data)





McKeegan et al Science 2006

$D/H < 3 \times D/H_{smow}$

- Heterogeneity of the cometary reservoir ?
- Alteration of the particles :
  - heating
  - mixing with aerogel

The D/H in a Jupiter-family comet, different types of comets

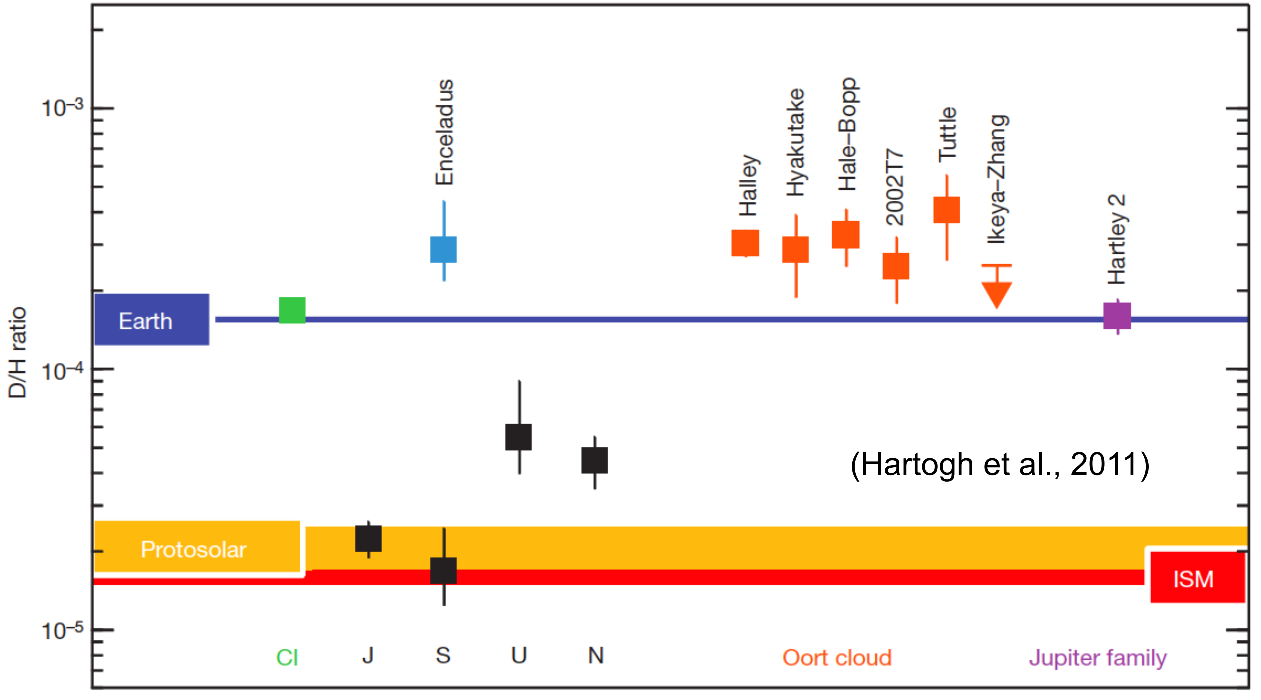
LETTER

Nature 5 octobre 2011

doi:10.1038/nature10519

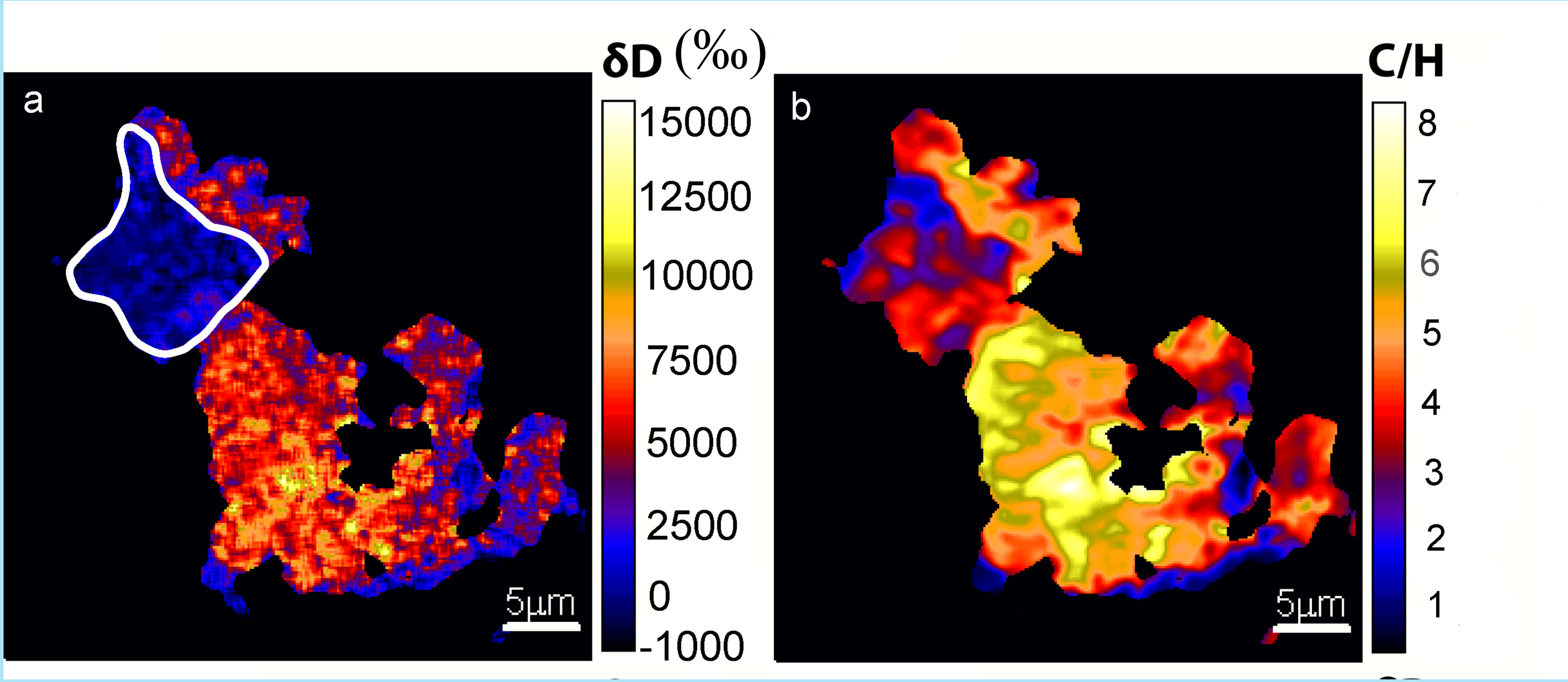
Ocean-like water in the Jupiter-family comet 103P/Hartley 2

Paul Hartogh[1], Dariusz C. Lis[2], Dominique Bockelée-Morvan[3], Miguel de Val-Borro[1], Nicolas Biver[3], Michael Küppers[4], Martin Emprechtinger[2], Edwin A. Bergin[5], Jacques Crovisier[3], Miriam Rengel[1], Raphael Moreno[3], Slawomira Szutowicz[6] & Geoffrey A. Blake[2]



D/H ratios in ultracarbonaceous micrometeorites

Data Nanosims Muséum National Histoire Naturelle

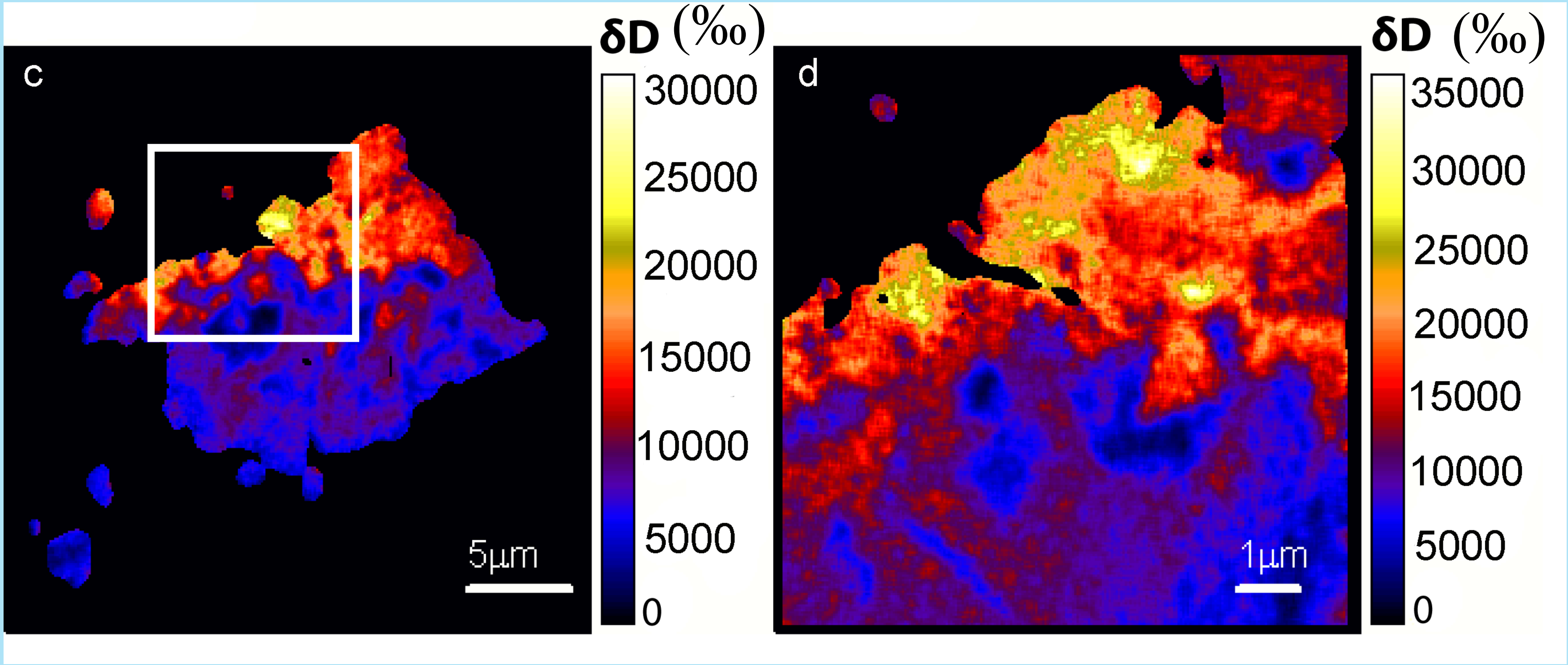


Duprat et al. Science 2010

D/H in a UCAMM fragment (DC06-08-19)

- D/H ~ 10 x D/H_{smow}
- the D excesses are carried by the organic phase

D/H ratios in ultracarbonaceous micrometeorites

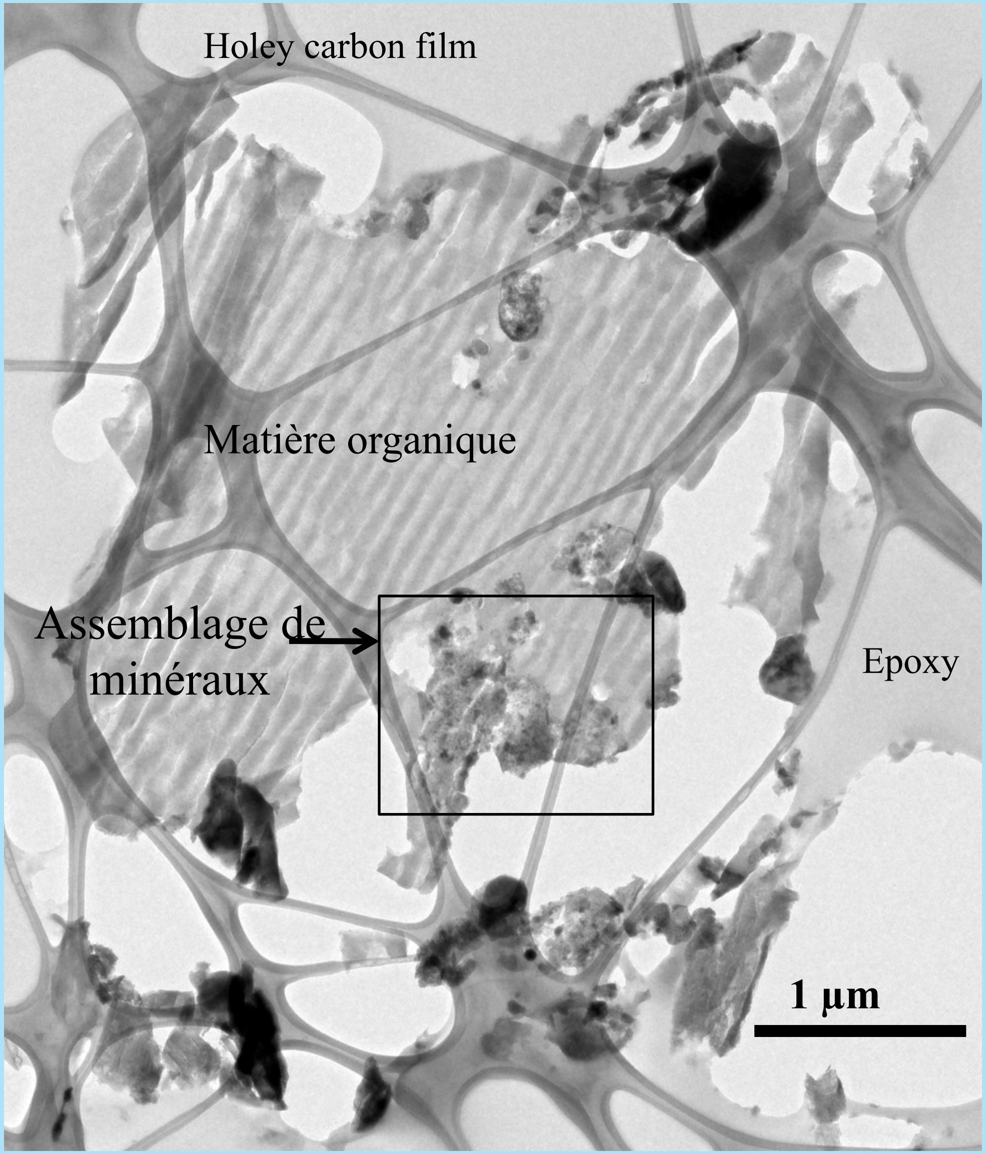


Duprat et al. Science 2010

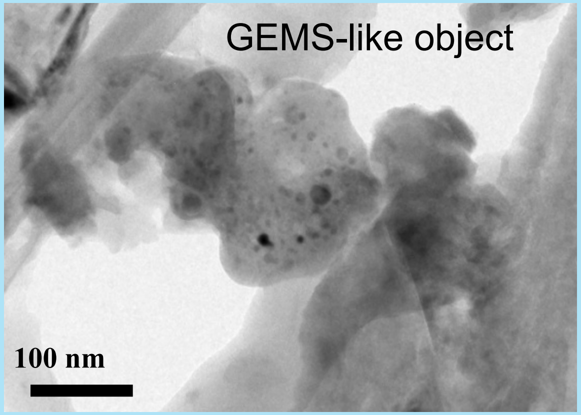
D/H mesuré sur un fragment d'UCAMM (DC06-08-119)

- D/H ~ 10-30 x D/H_{smow}
- D/H extrêmement élevés sur des surfaces étendues (10-100 µm²)

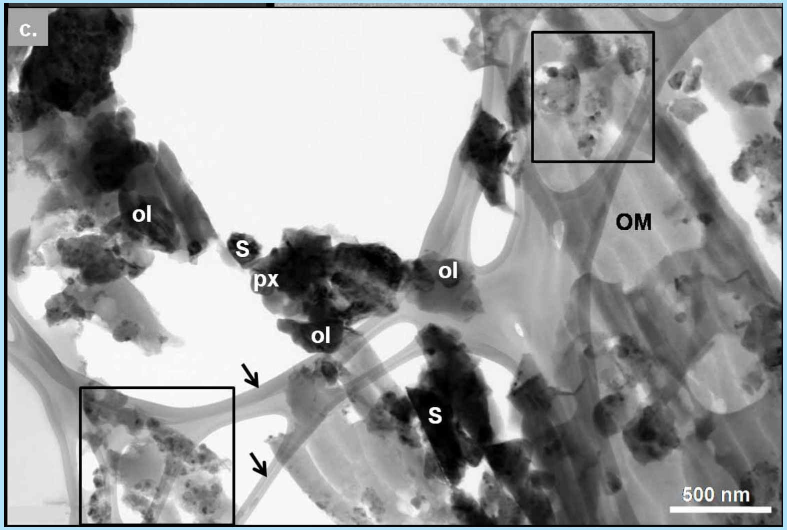
UCAMMs allow to study the intimate association between high (minerals) and low (organics) temperature phases.



Data TEM Univ. Lille (E. Dobrica, C. Engrand, H Leroux)



Amorphous phases



Crystalline phases 50-100 nm

Crystalline phases are typical of protoplanetary disk and similar to that reported in STARDUST samples

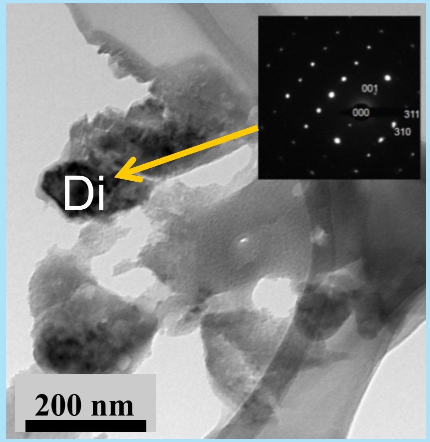
In the ISM

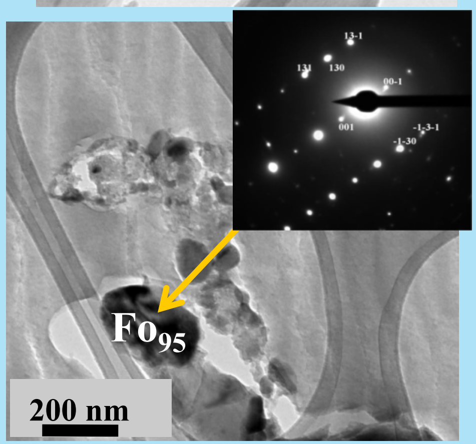
Xtal/Amorphous

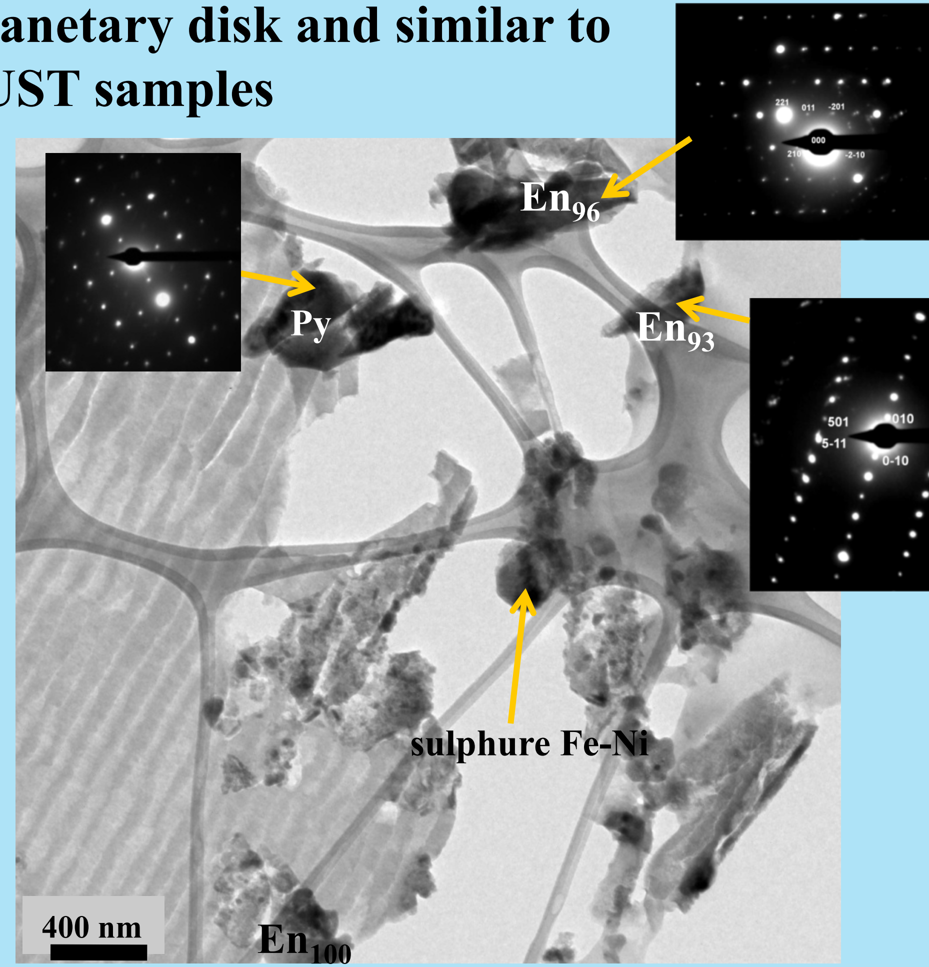
< 2.2 wt%

(Kemper et al. ApJ 2004)

Not at all what is observed in UCAMMs!







Data TEM, Dobrica, Leroux, Engrand

A mixing between high and low temperature materials

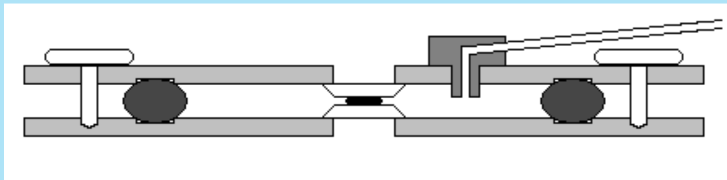
→ confirmation of the radial mixing from inner zones to the comet forming region

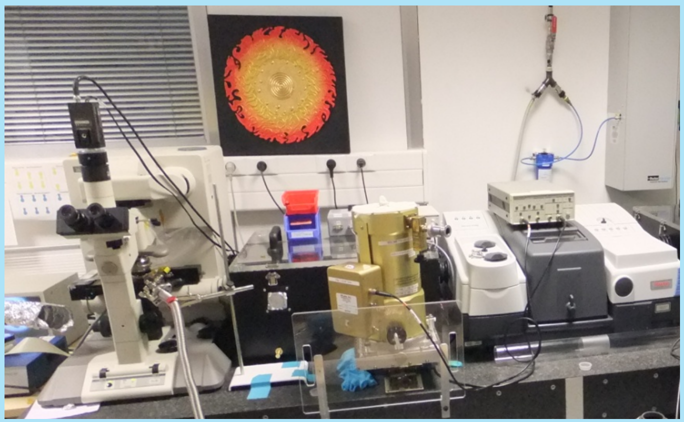
No sign of abnormal interstellar heritage

→ a local origin of the Deuterium excesses in the primitive organic matter, i.e. within the proto-planetary disk itself ?

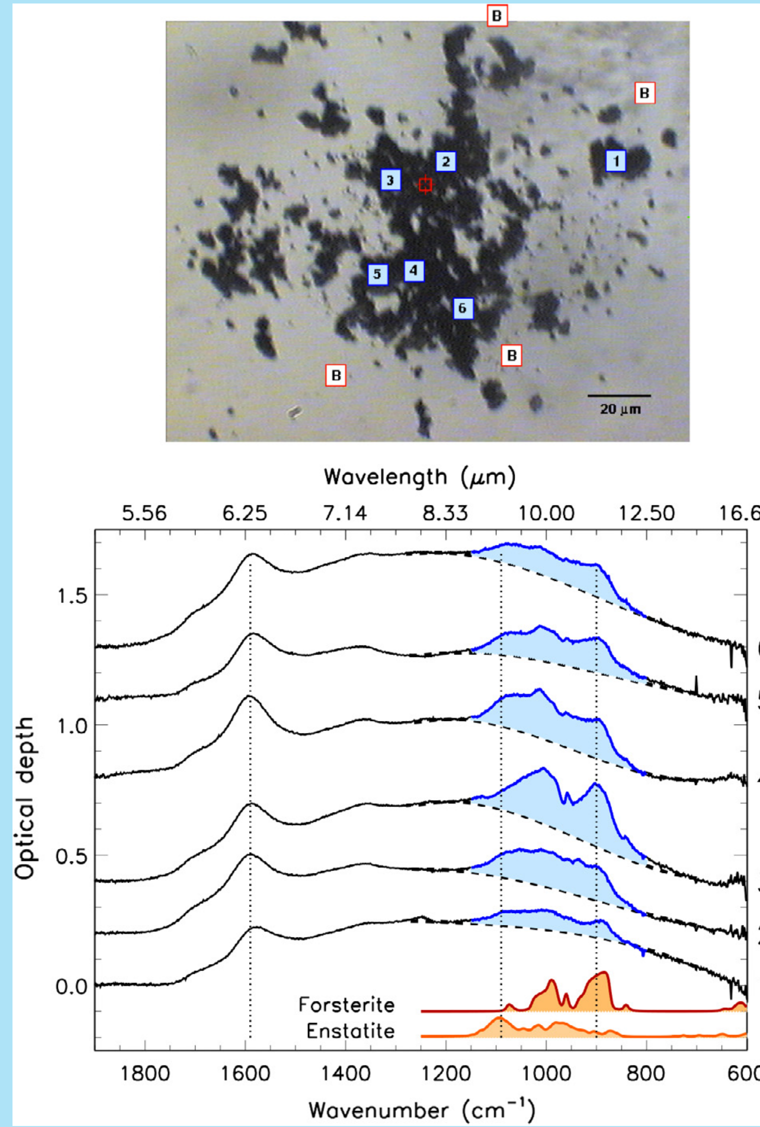
Coupled studies on the same sample

- ✓ Infra-Red transmission microanalyses @ synchrotron SOLEIL
- ✓ Elemental composition : SEM and electronic microprobe



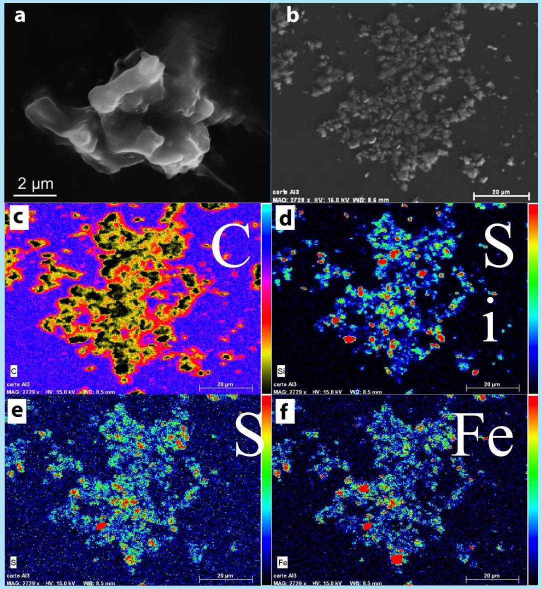


- ✓ Isotopic studies at the Nanosims
  (MNHN, Institut Curie Orsay)

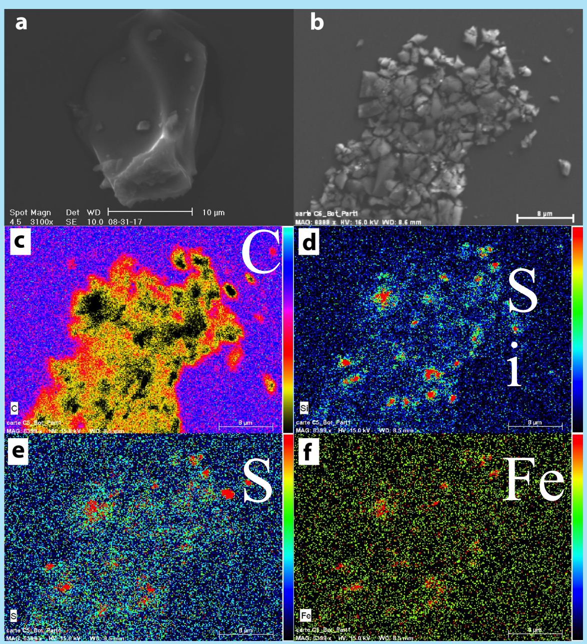


Dartois, Engrand et al. Icarus 2013

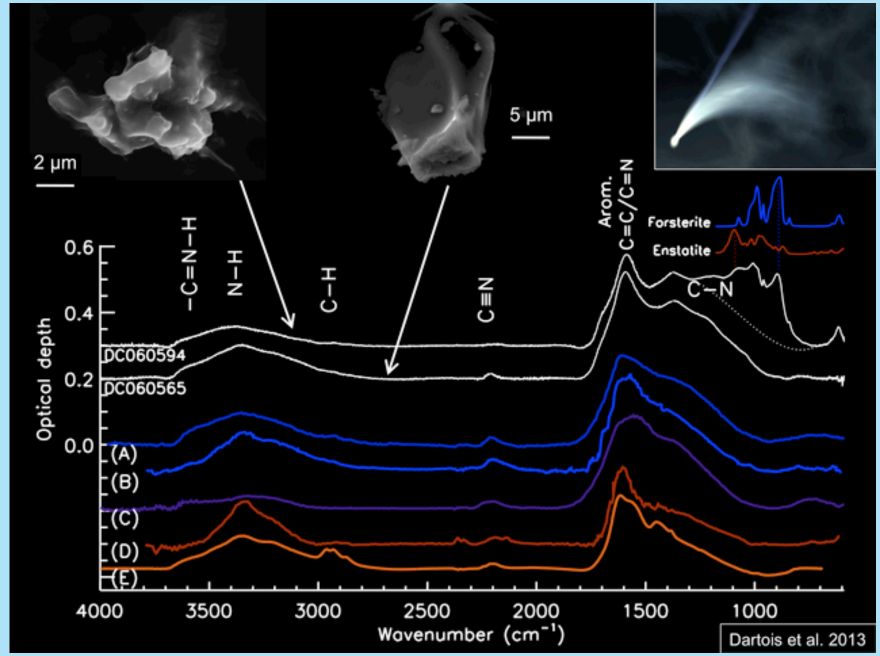
The UCAMM organic matter is nitrogen rich

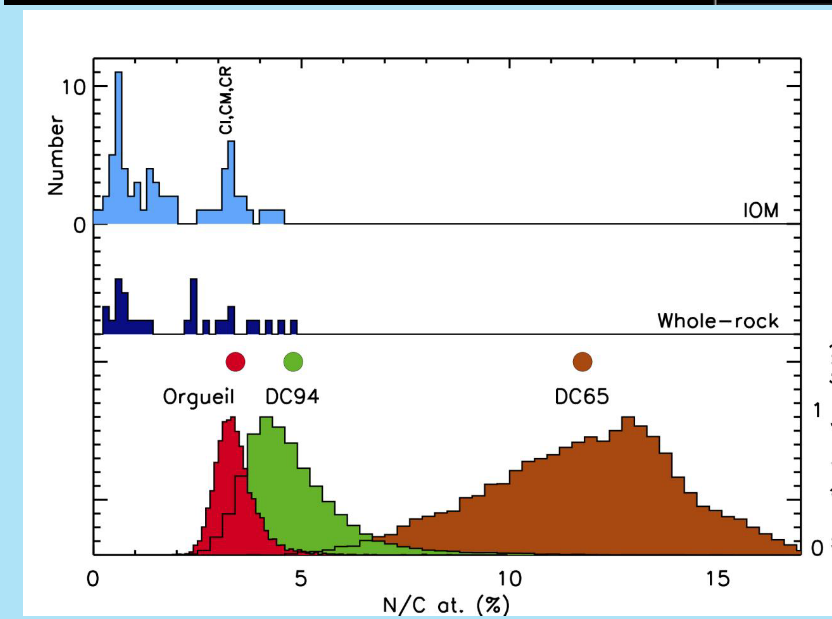


DC06-05-94, mineral rich



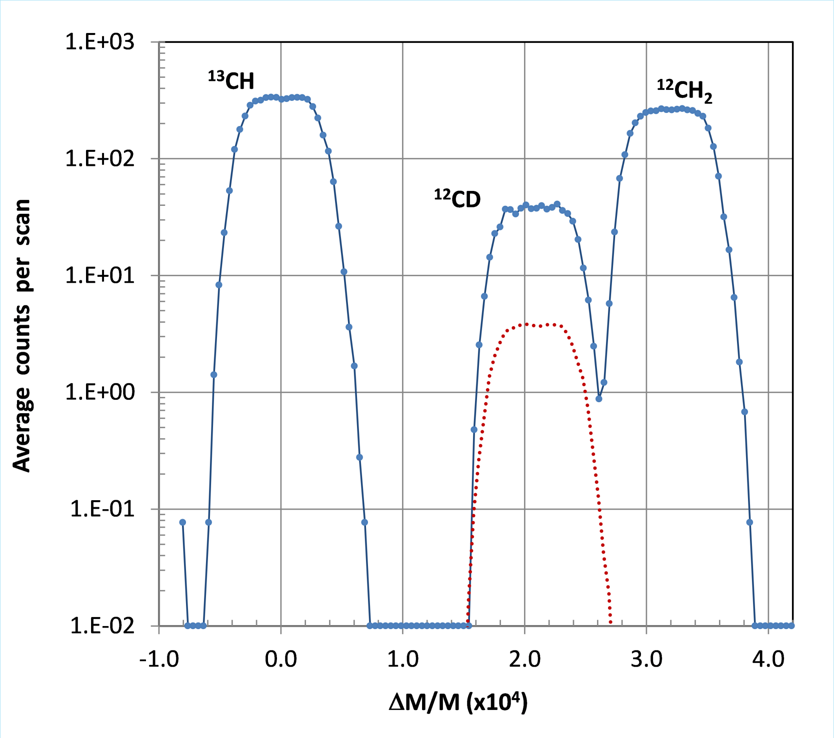
DC06-05-65, mineral poor



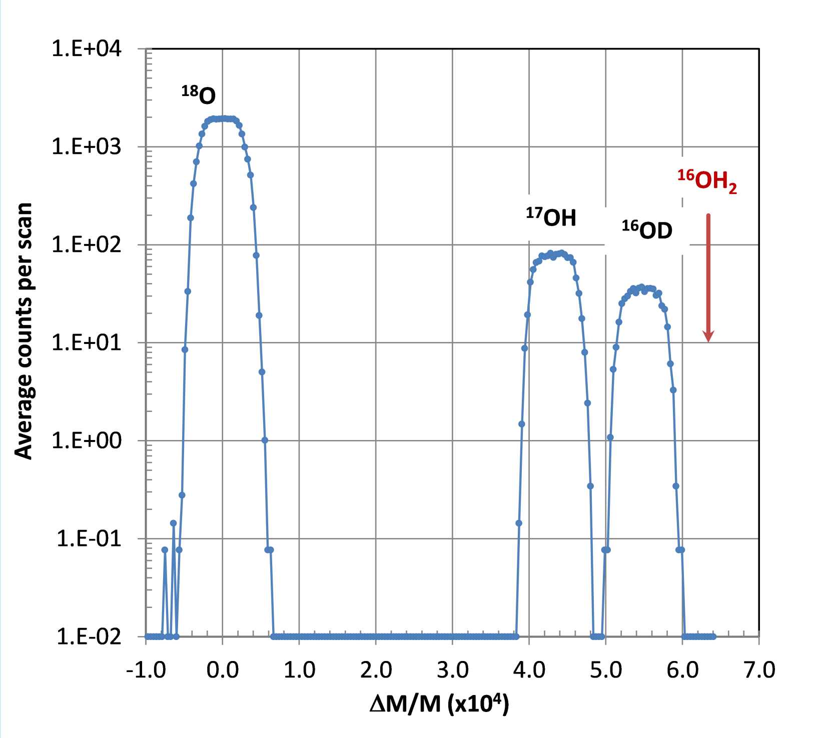


Dartois, Engrand et al. Icarus 2013

Nanosims studies at high mass resolution



Mass spectrum at A=14, 15 scans, on D-rich Polystyrene (10xSMOW), (^{13}C-^{12}CD is used as ΔM/M reference, ^{12}CH-^{12}CH$_2$ 1/8900)



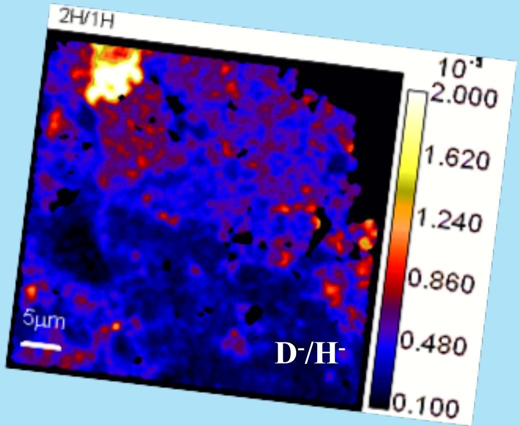
Mass spectrum at A=18, 15 scans, on Goethite, (^{18}O-^{17}OH is used as ΔM/M reference, ^{17}OH-^{16}OD 1/8740)

Improvement performed in 2011-2014 by G. Slodzian on the Nanosims at Institut Curie
(Slodzian et al. *Microscopy & Microanalysis 2014* and *Nanosims workshop MNHN-Paris October 2014)*

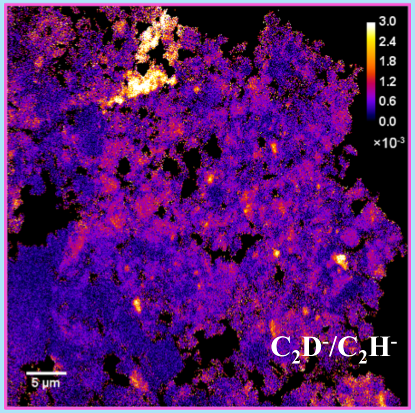
D/H ratios measurements using polyatomic secondary ions :

- Possibility to measure D/H and ^{15}N/^{14}N ratios with the same B field
- Sensitivity to the emitting phase
- Better IMF correction

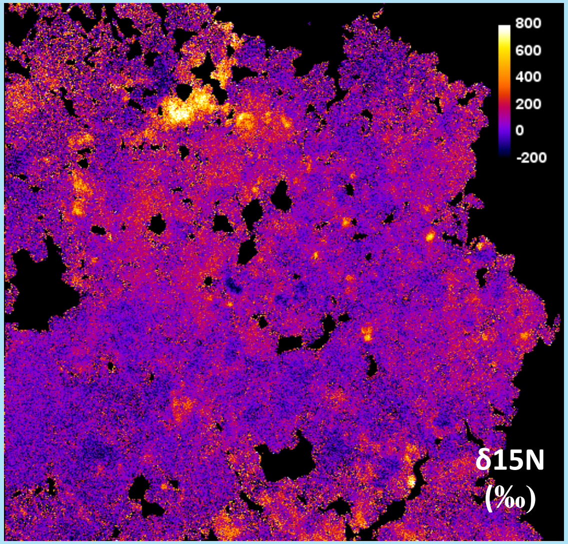
Hydrogen and Nitrogen isotopic measurements on UCAMMs



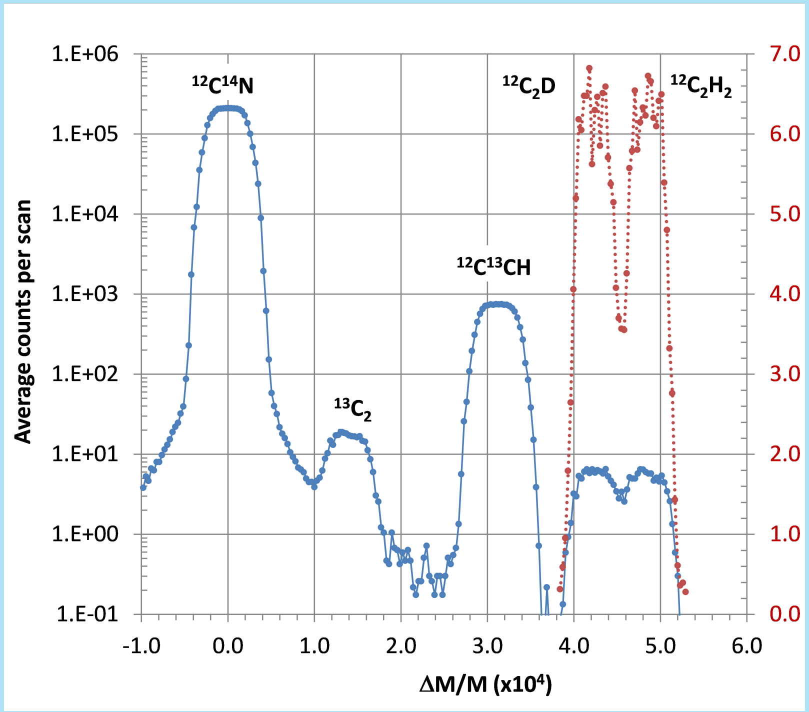
Fcp=22pA,
Low Res, 50x50 µm, (256x256)



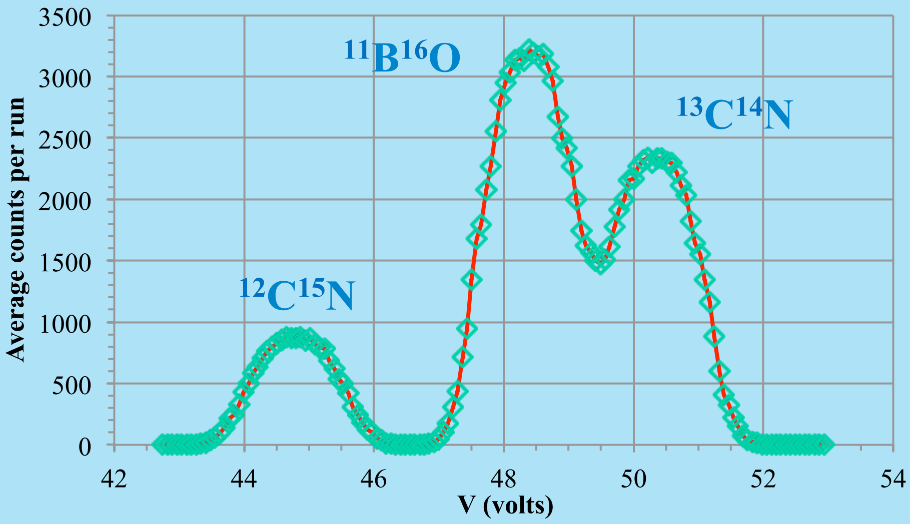
Fcp=11 pA,
High Res, , 50x50 µm (512x512)



Fcp=9.9 pA
High Res, , 50x50 µm (512x512)

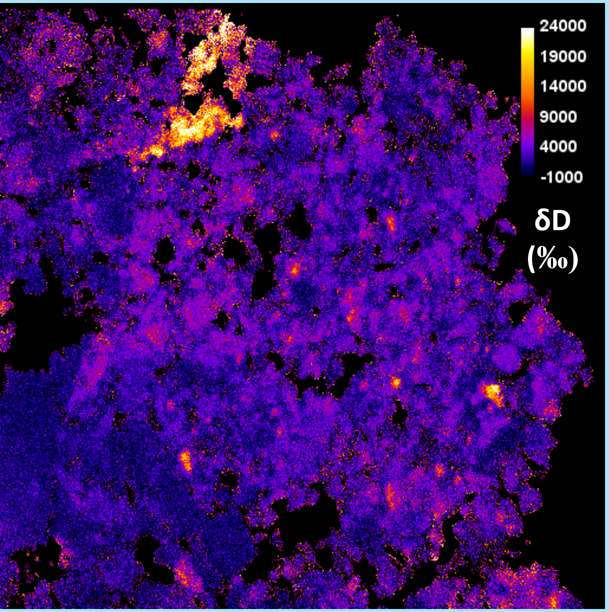


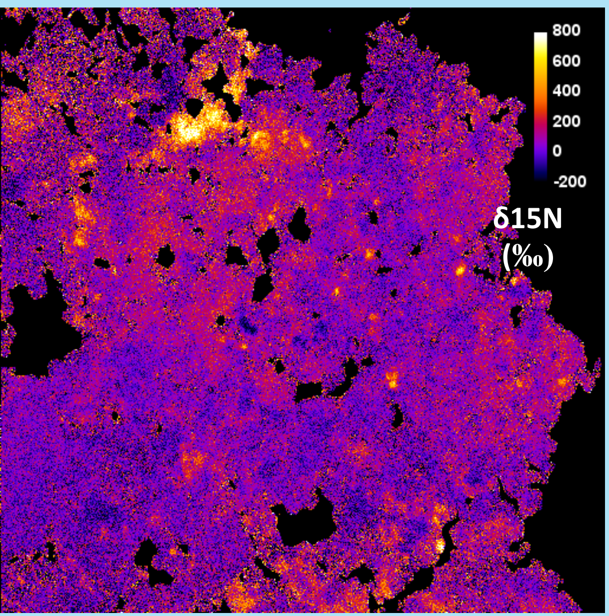
Scan (N=20) at mass A=26 on a Polyacrylonitril (150nm) film,
$^{12}C^{14}N$-$^{12}C^{13}CH$ use as reference, (C_2D-C_2H_2 1/16800)

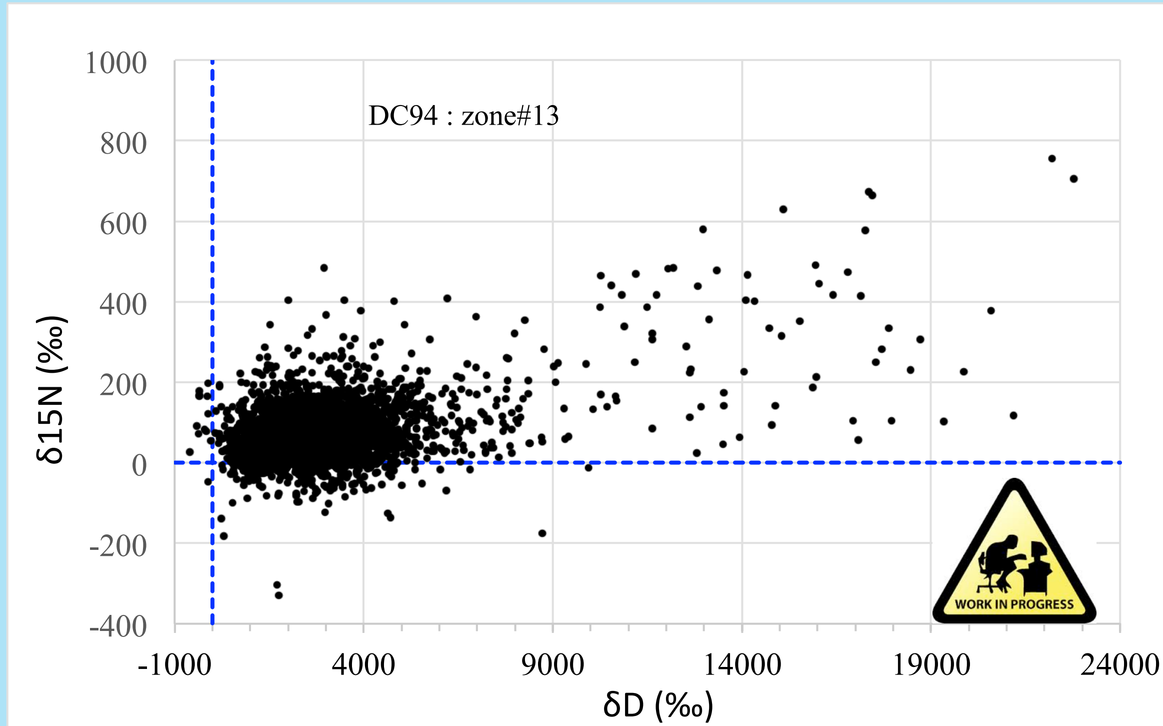


Scan (N=10) at mass A=27 on UCAMM 94
(the built-in instrument voltage were divided by 2)

Spatial correlations between D-rich and ^{15}N-rich phases







Noémie Bardin PhD

UCAMM DC06-05-94 zone # 13
Images size : 50 × 50 µm² (un-smoothed 512 × 512 px).
C_2D/C_2H, Fcp=11 pA, $C^{15}N/C^{14}N$ 30 frames , Fcp=9.9 pA Correlation plot, ROI size : 0.78*0.78 µm² (8*8 px)

Some areas exhibit a correlation between D and ^{15}N excesses but not all.
Still a work in progress…

Conclusion

- ✓ The central regions of the Antarctic continent provide the opportunity to recover **rare and fragile micrometeorites**
- ✓ Ultracarbonaceous Antarctic MicroMeteorites recovered from Dome C and Dome Fuji are most probably **giant cometary grains**
- ✓ **High mass resolution** with the Nanosims allows the use of polyatomic ions (e.g. OD/OH, CD/CH, C_2D/C_2H) for isotopic studies
- ✓ The organic matter from UCAMMS is **N-rich and D-rich** and **is** most probably sampling **material from beyond the nitrogen snow-line**