

Avancement des travaux sur les silicates de la matière extraterrestre primitive

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Zélia Dionnet

Dan Lévy

+ collaborations étroites Ferenc Borondics, Christophe Sandt, Pierre Vernazza, Jérôme Aléon, Serge Dellanegra

Analytical sequence: from less to more destructive techniques

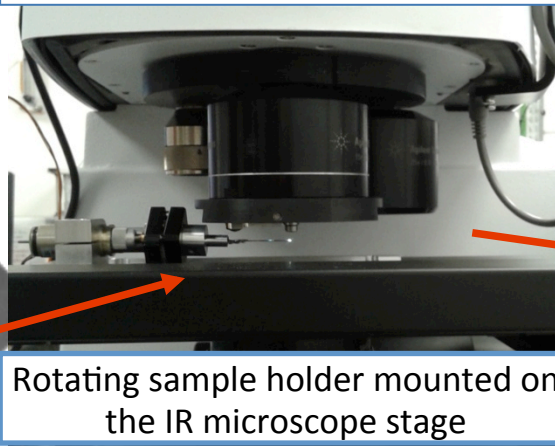
**μ -Vis, μ -FTIR
 μ -Raman imaging**

Aléon-Toppani et al.
2017, in prep

Needle with
meteorite grain

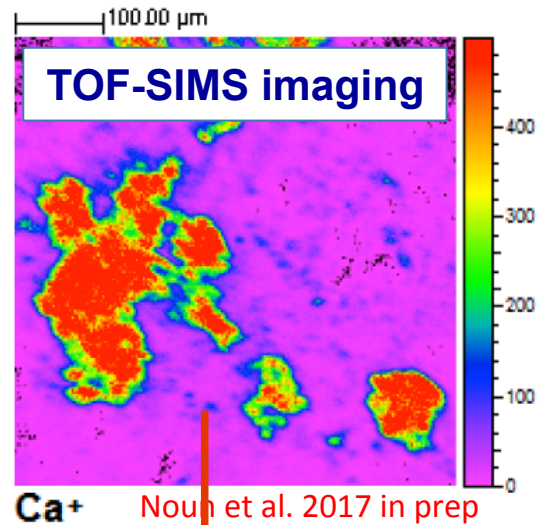
10 μ m

**Synchrotron μ Tomo-X
 μ Tomo-IR (2 in the world!)**



Rotating sample holder mounted on
the IR microscope stage

Dionnet et al. 2017 in prep

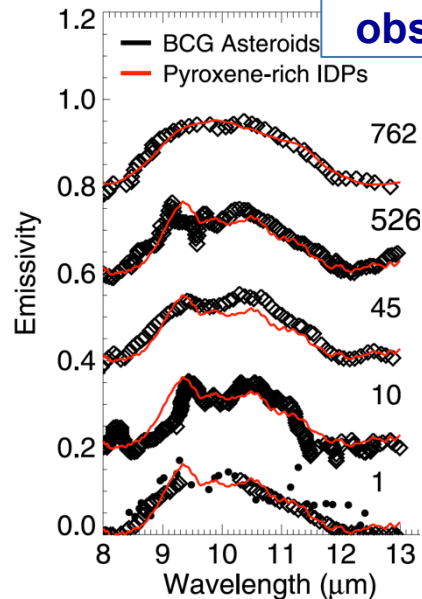


FIB preparations



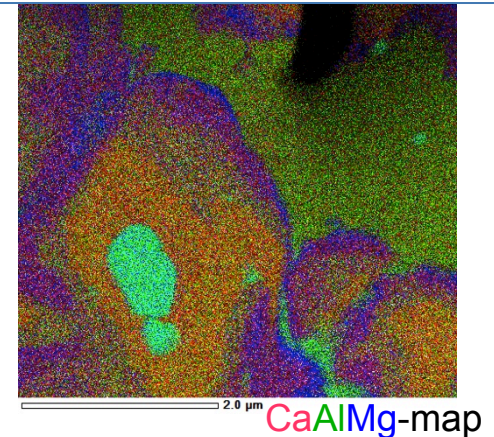
**Clean room
preparations**

**Compare with
observations**



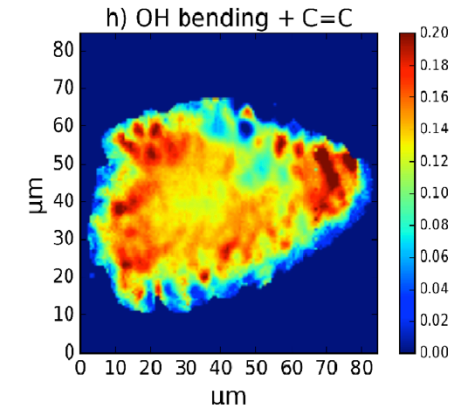
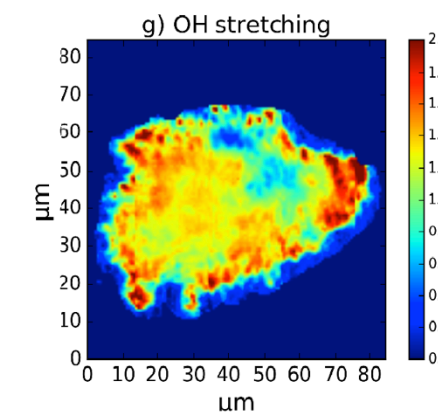
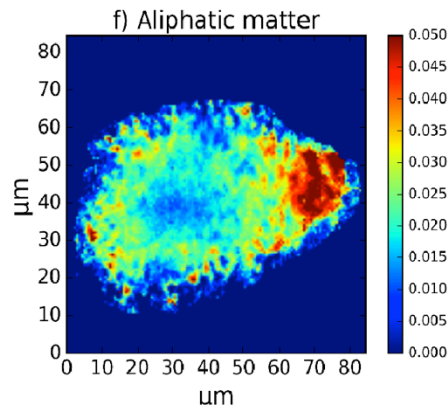
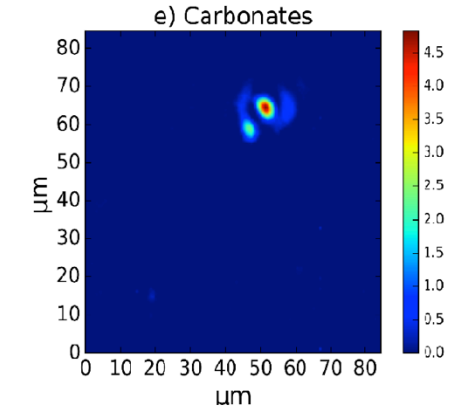
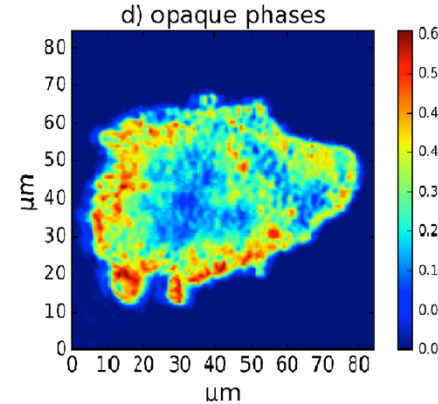
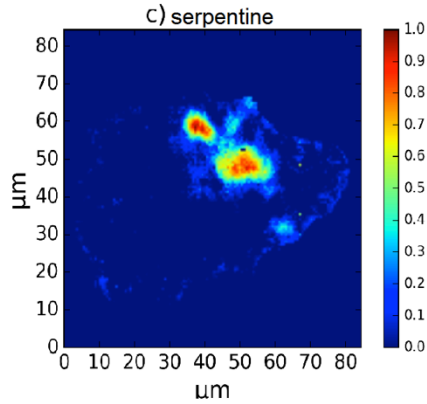
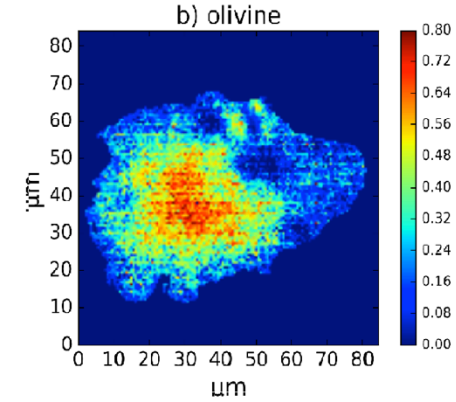
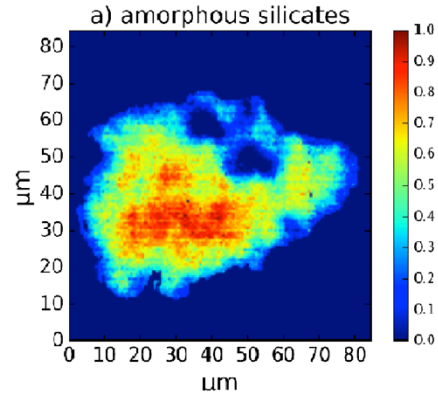
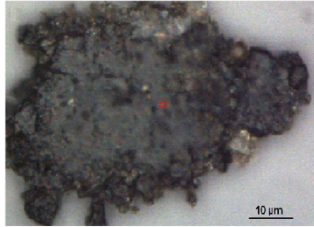
Vernazza et
al. 2015,
2017

STEM chemical mapping



Aléon-Toppani et
al. 2017 in prep

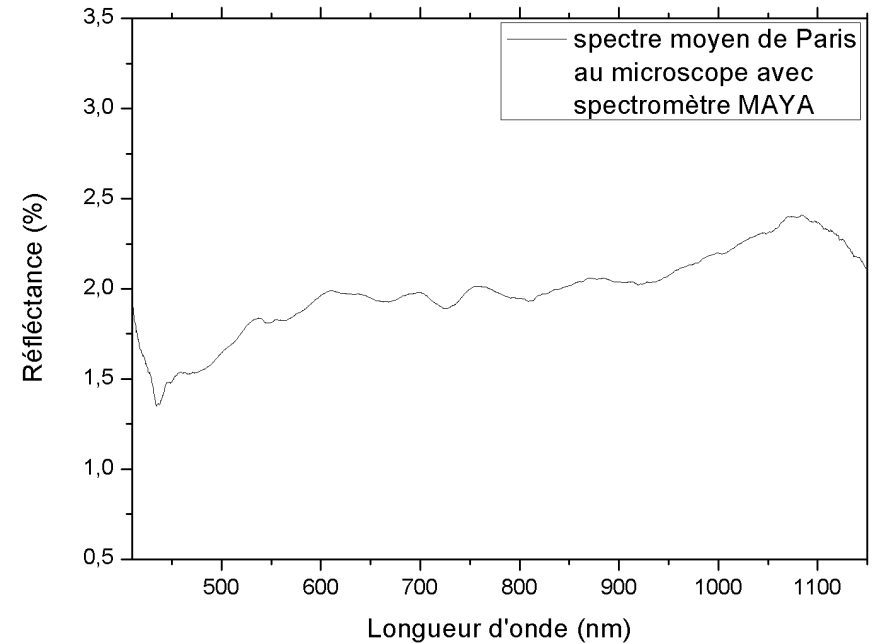
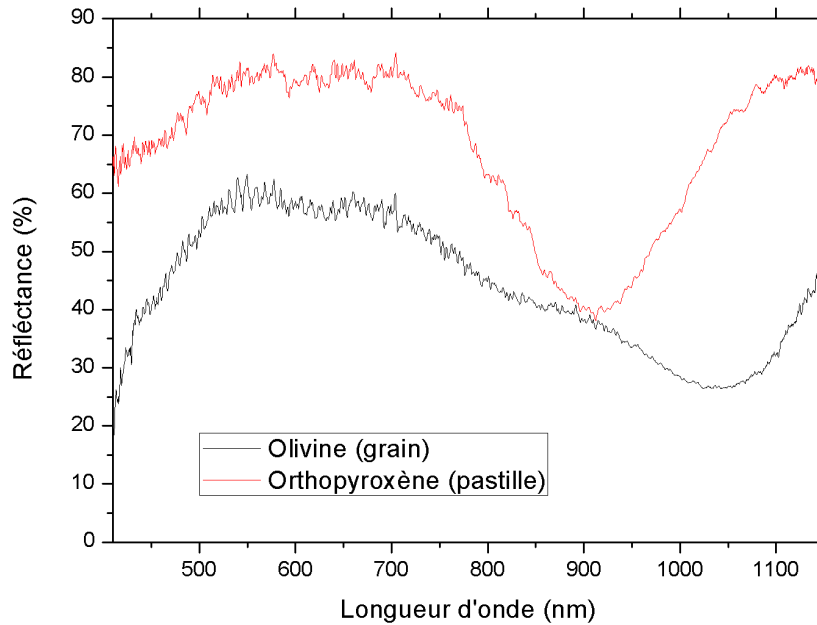
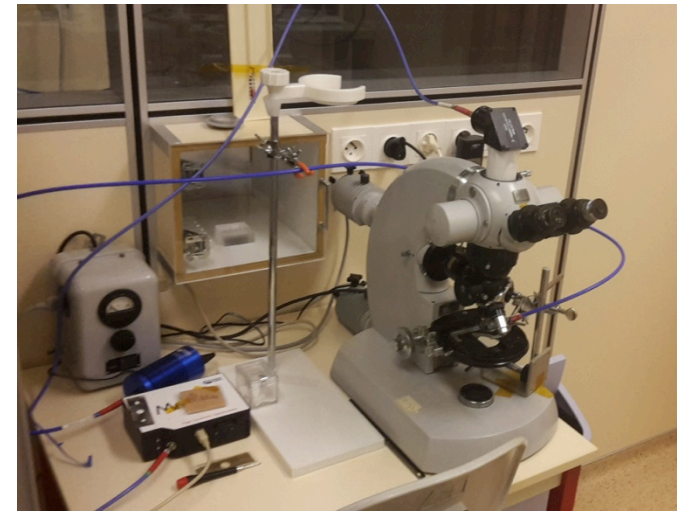
Cartographie FPA sur des échantillons de Paris



Cartographie IR très rapide: lien silicate /Mo

Avancées sur les IDPs

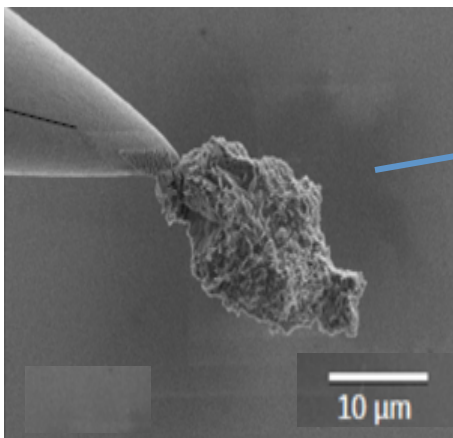
- 20 IDPs reçues
- Développement de la microscopie VIS/NIS en salle blanche (présélection des IDPS et comparaison avec les surfaces astéroïdales)



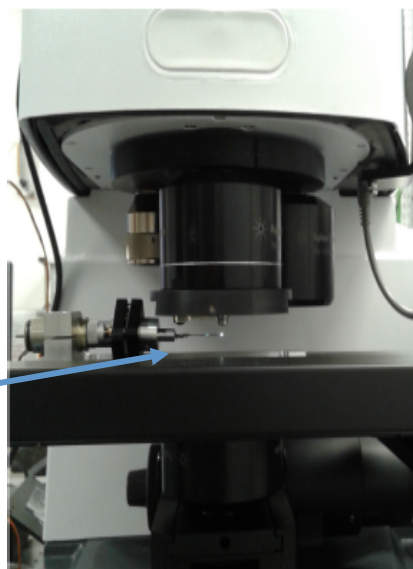
Achat du nouveau microscope en cours (mesure VIS/NIS/reconstruction 3D/micromanipulation)

Micro-tomographie FTIR

Aiguille avec un grain
de météorite

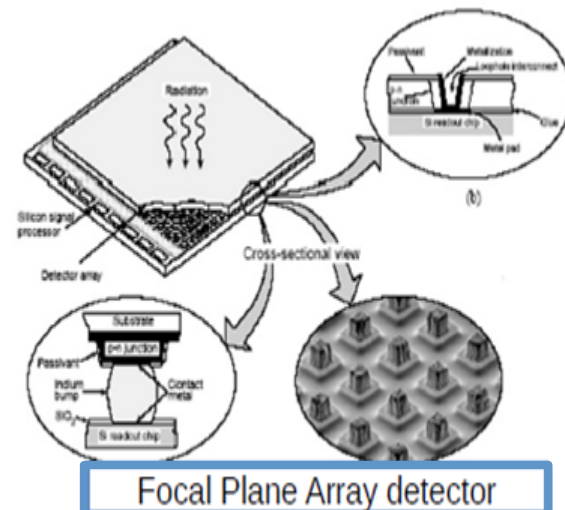


FIB preparation



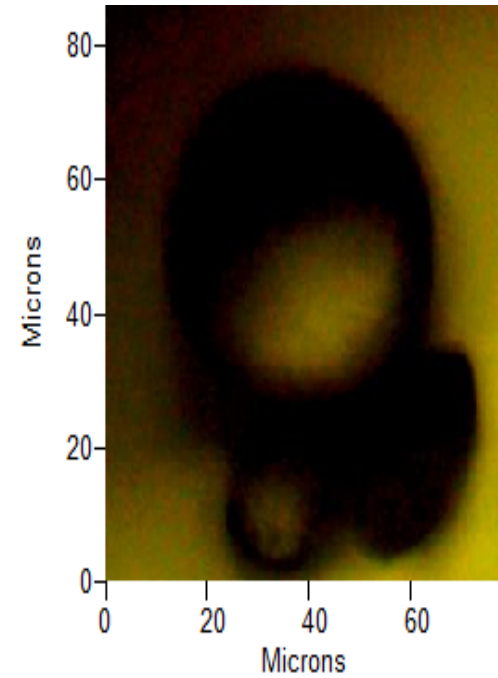
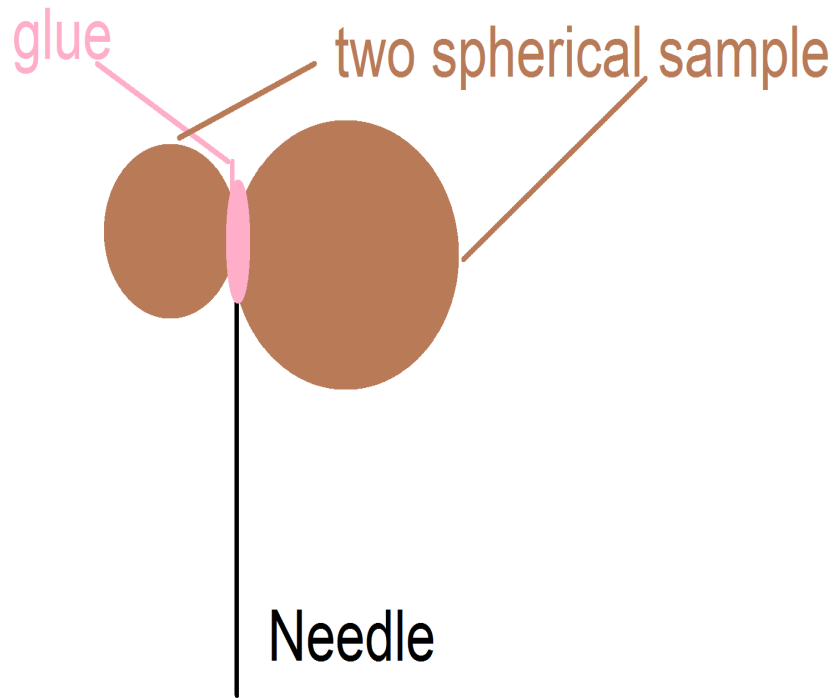
Coupled with a motor

Signal IR



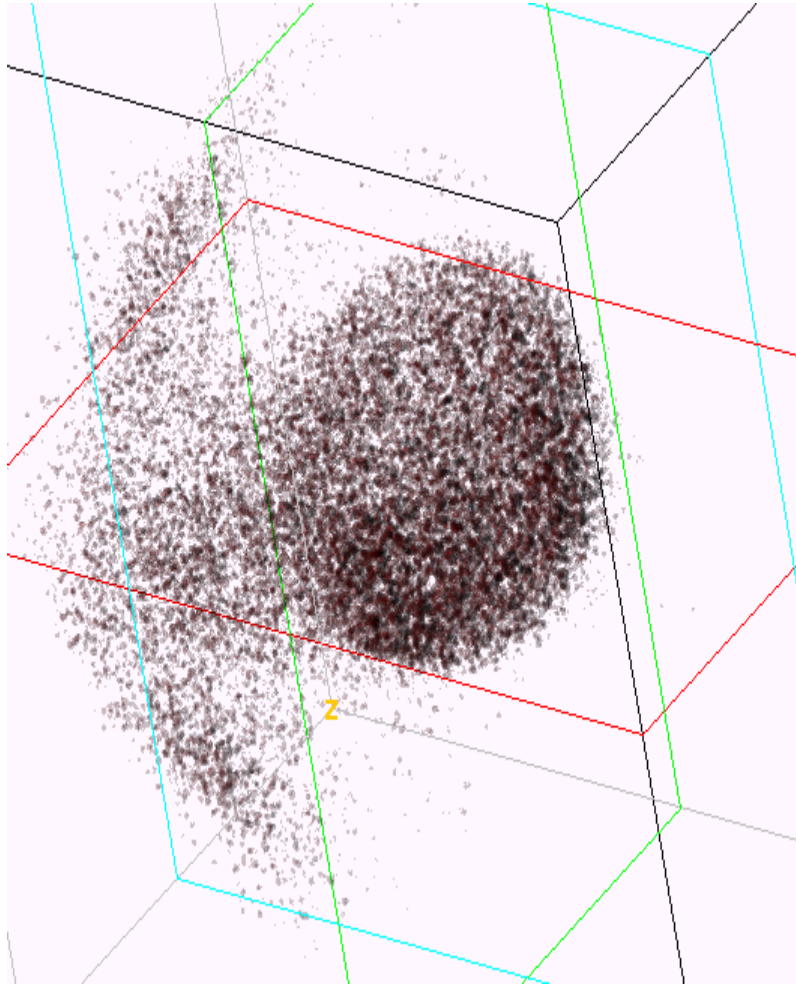
Spherical standard of Silica

-> reconstruction of the differences phases

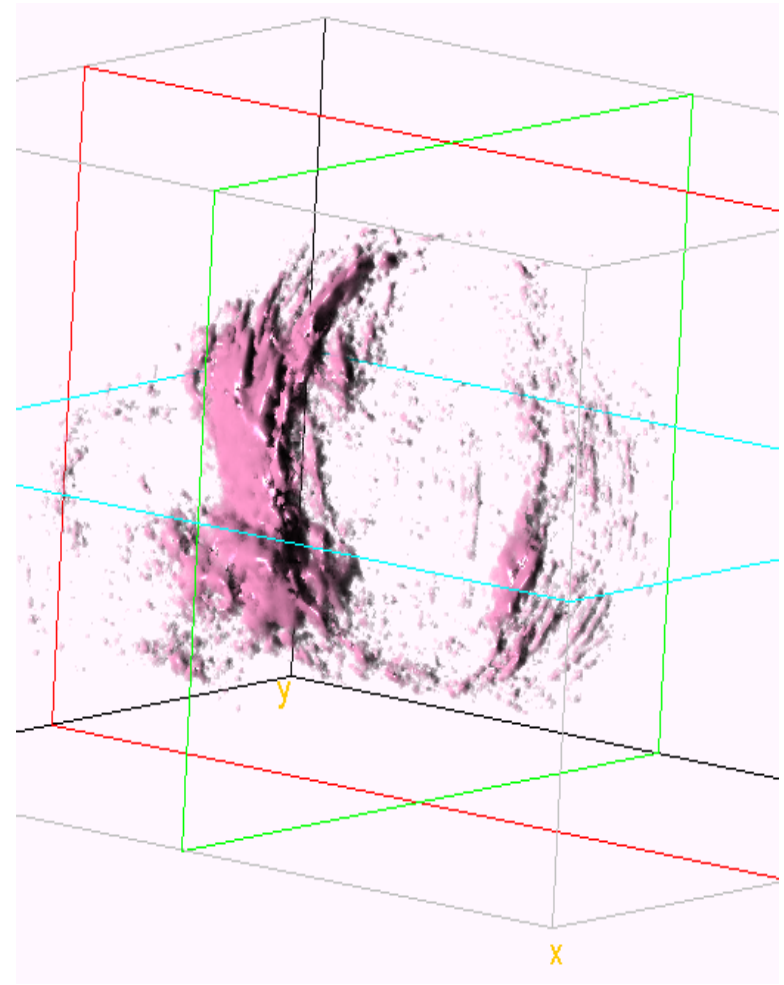


Spherical standard of Silica

-> reconstruction of the differences phases



Silica reconstruction

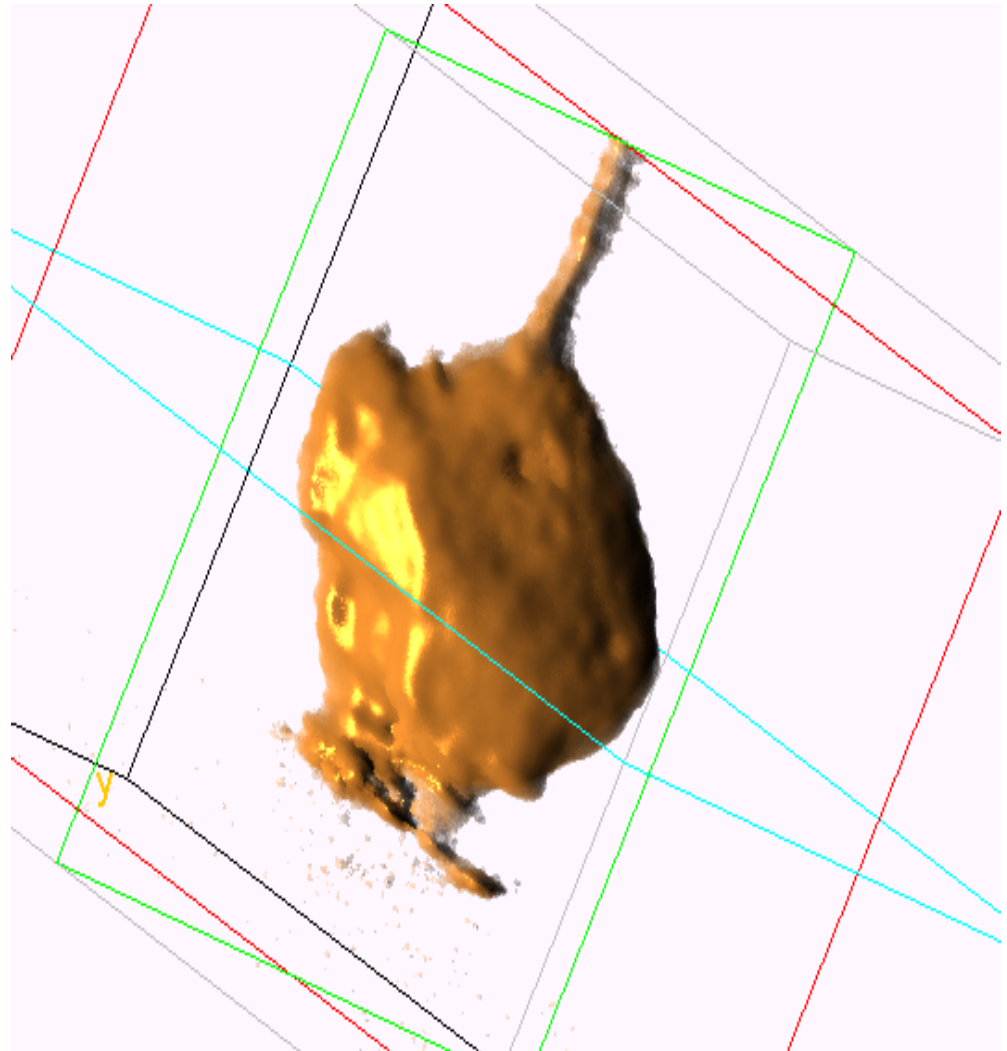
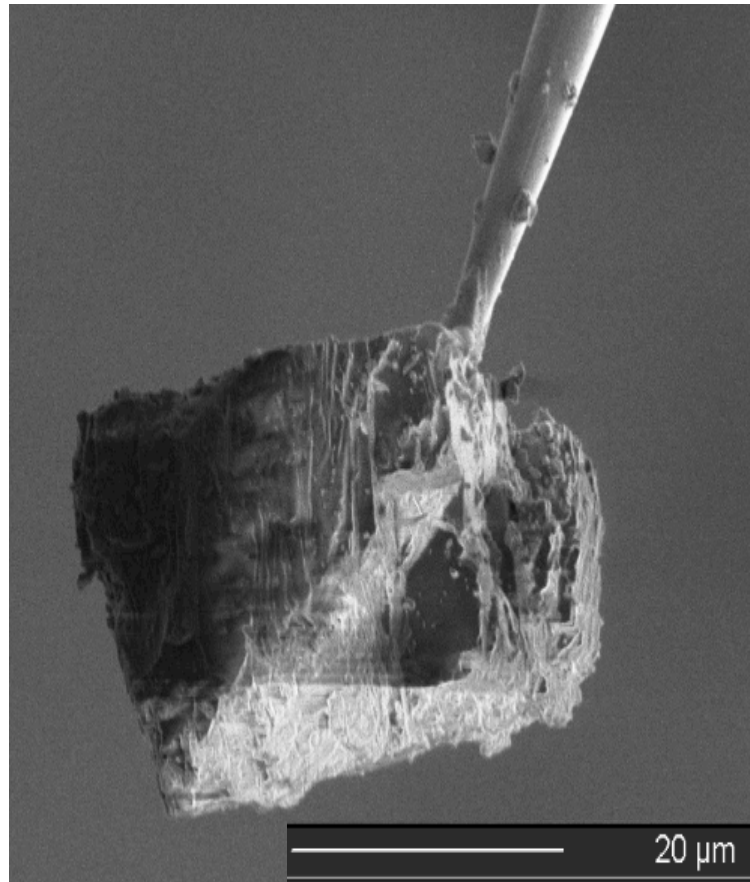


CH band reconstruction : glue

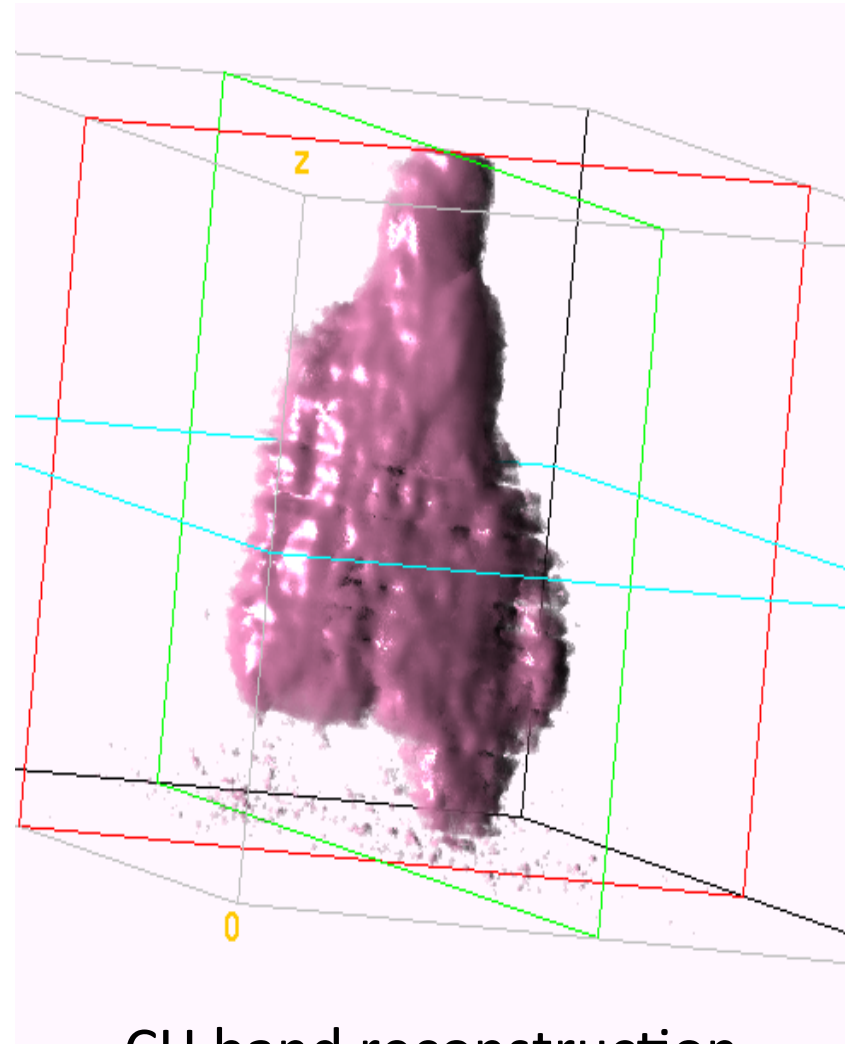
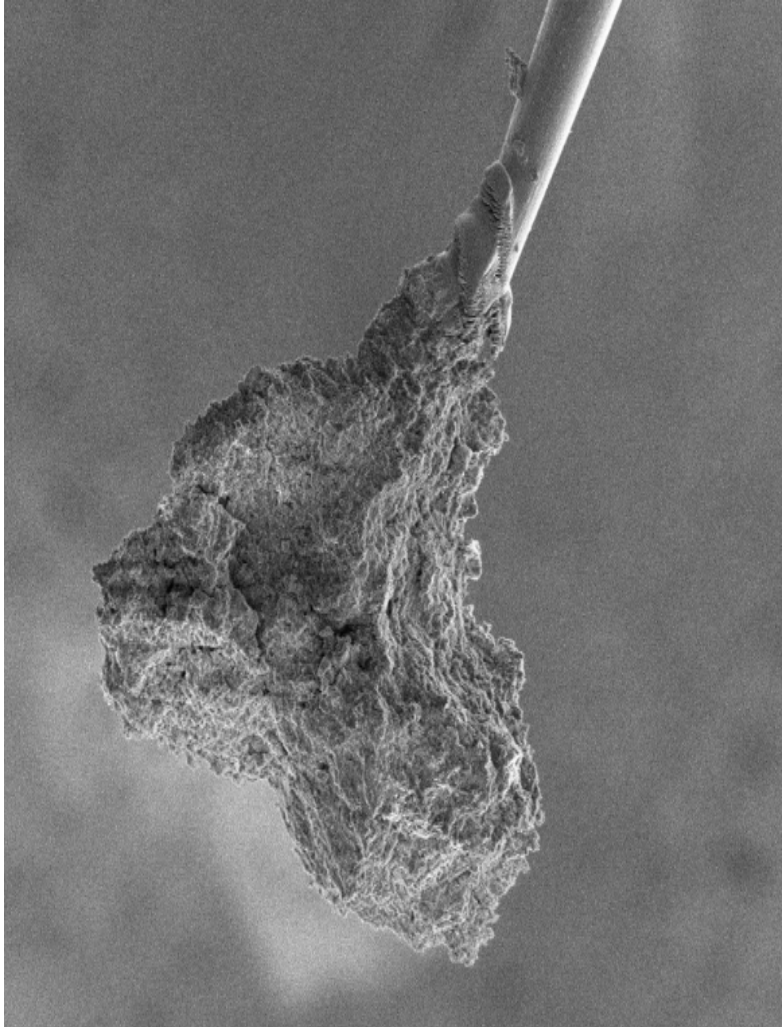
-> able to separate and reconstruct differences phases

Reconstruction of the Calcite

-> Case of an homogeneous standard



First reconstruction of the Paris meteorite



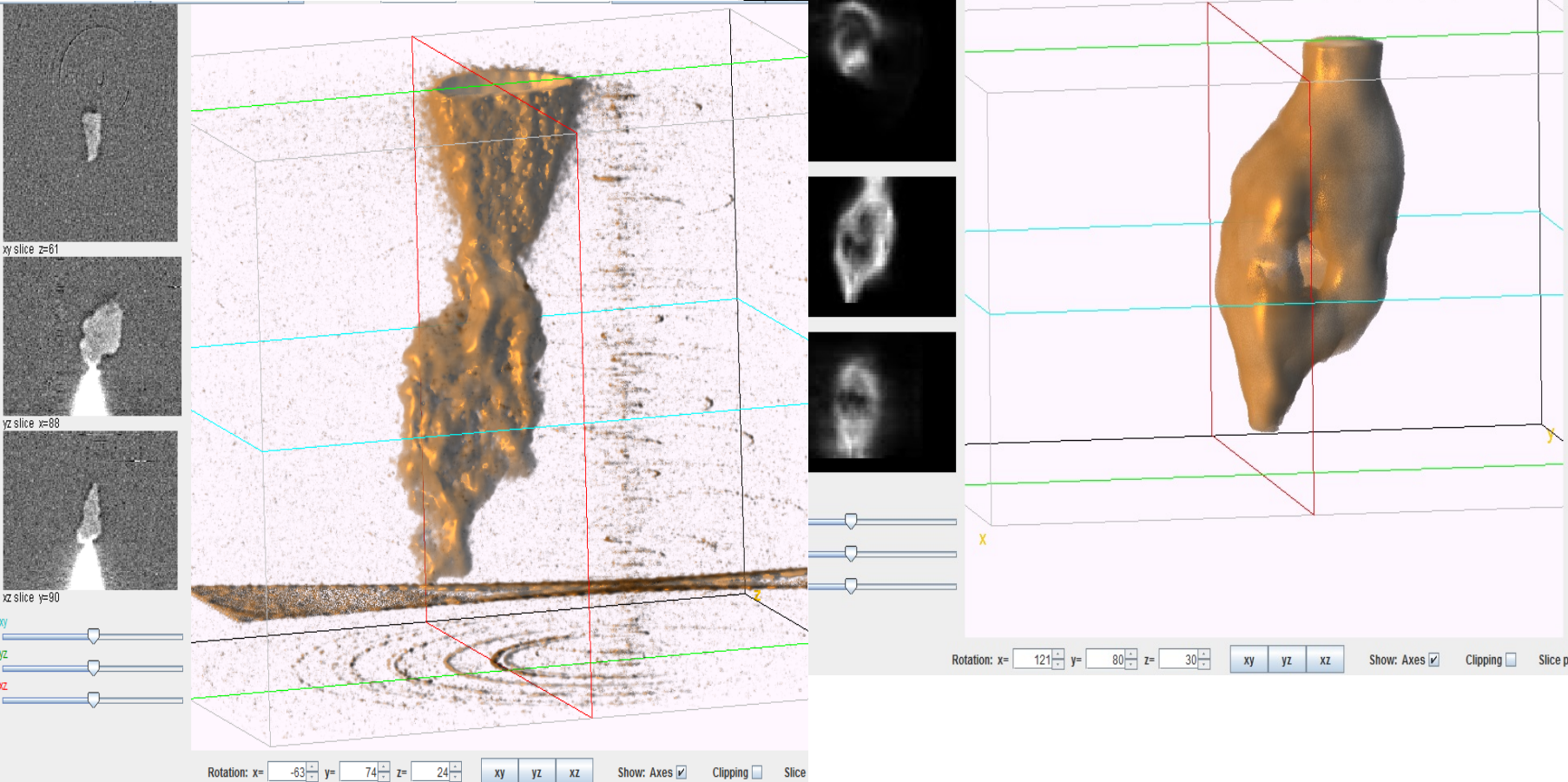
CH band reconstruction

Couplage avec la micro-tomographie X

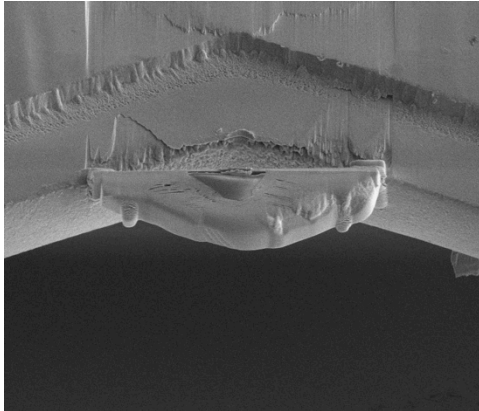
Ligne Psiche/SOLEIL

Standard + complémentarité pour une meilleure info

À 17 KeV

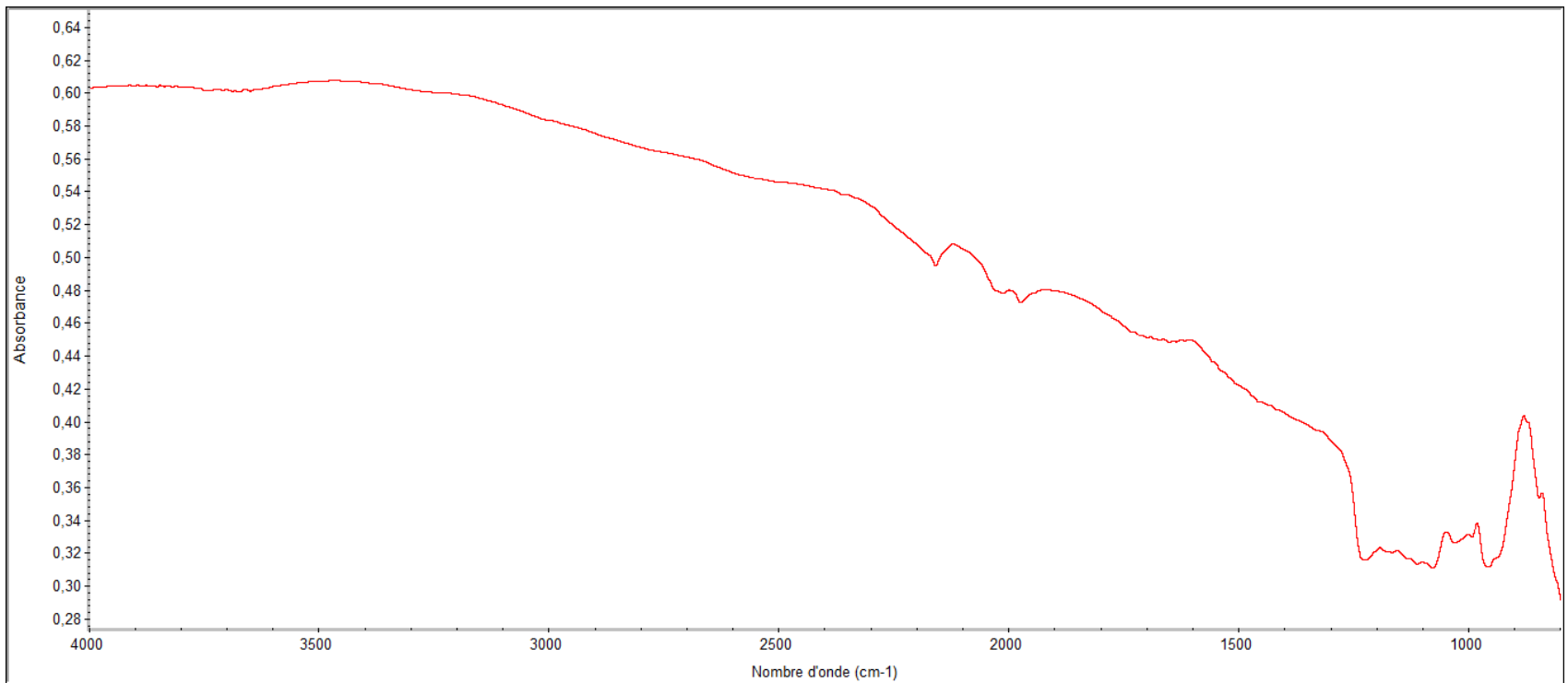


IR spectroscopy on FIB section

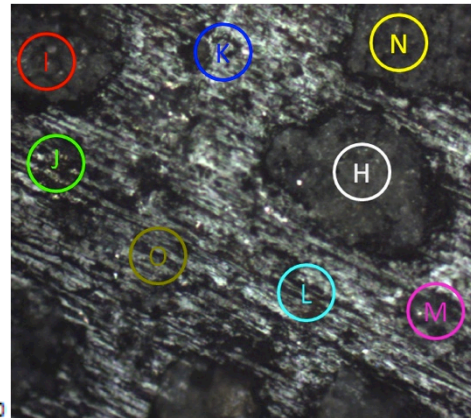
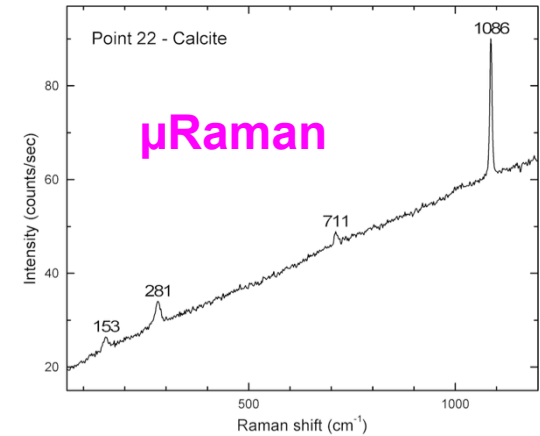
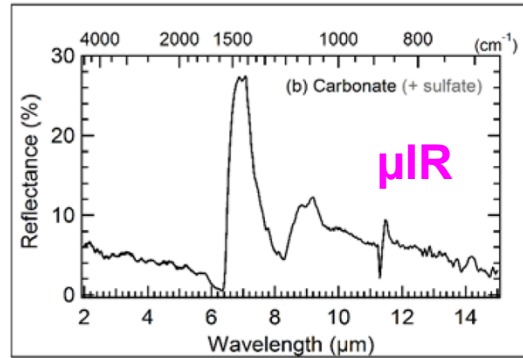
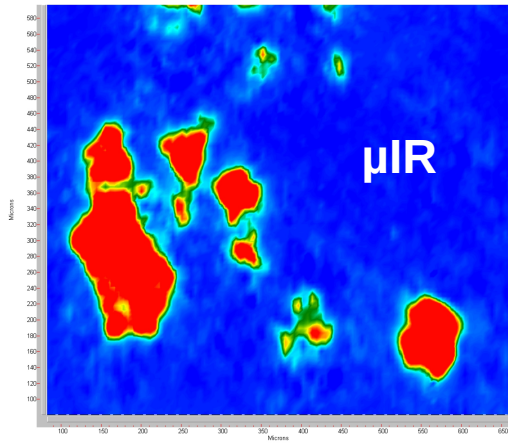


1 micron slice
for IR and
Raman
spectroscopy

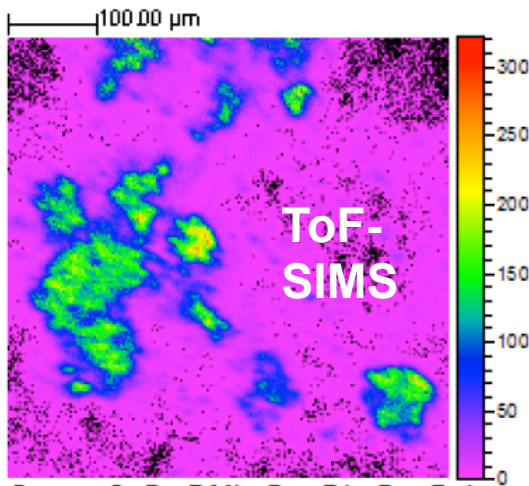
E-Beam	Det	Mag	FWD	Spot	Tilt	HFV	10 μ m
5.00 kV	SED	5.00 kX	4.931	3	59.0°	60.8 μ m	I.E.M.N



Exemple multi-analyses : couplage μ IR – ToF-SIMS



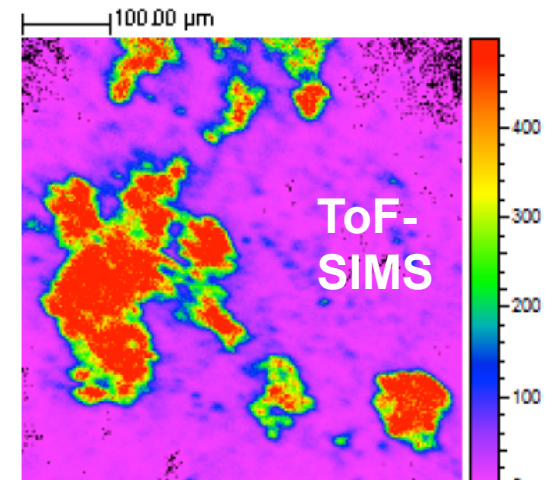
Noun et al. 2017



Sum of: CaOH^+ , Ca_2O^+ , Ca_2O_2^+ ,
 $\text{Ca}_2\text{O}_2\text{H}^+$, $\text{Ca}_3\text{O}_3\text{H}^+$, $\text{Ca}_4\text{O}_4\text{H}^+$

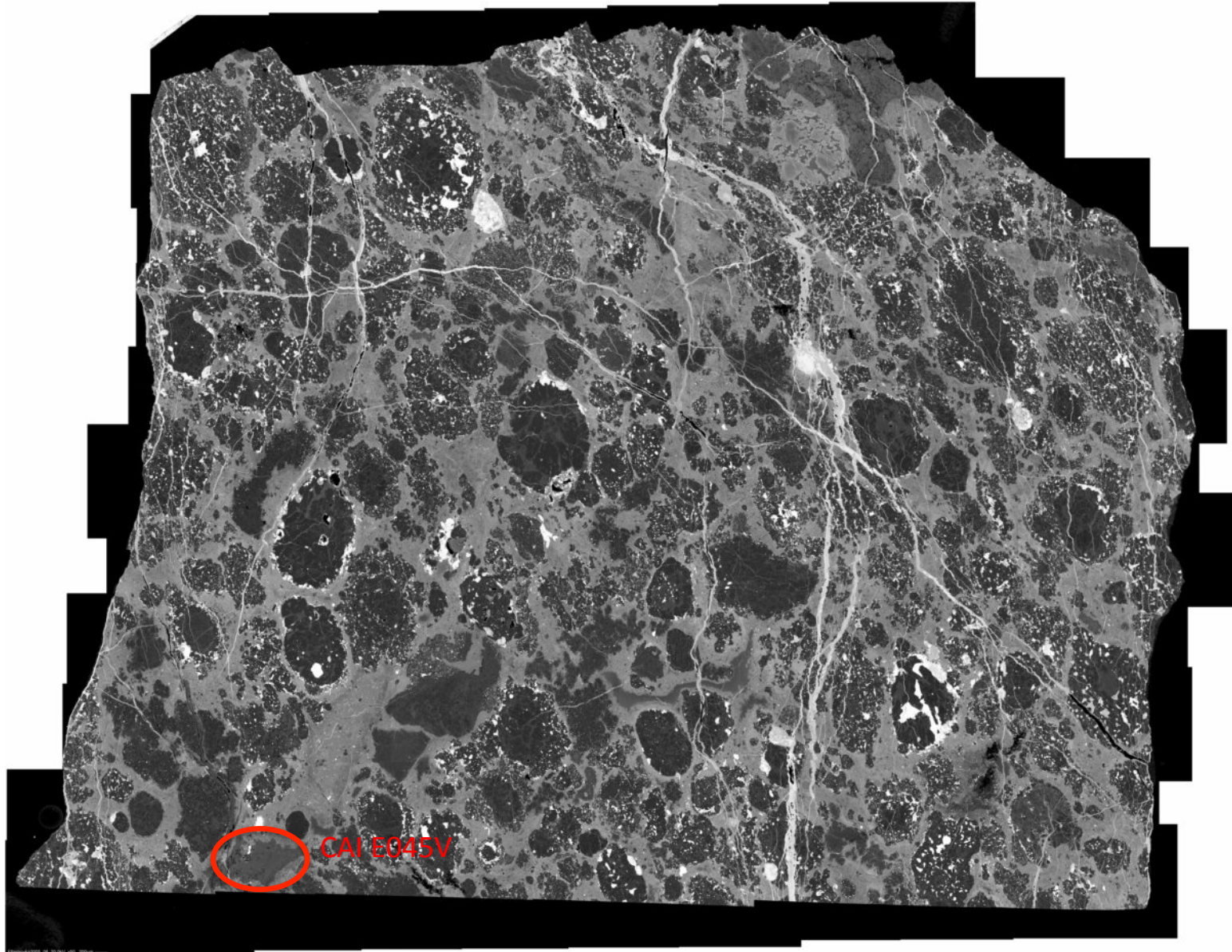
Paris meteorite

Collaboration
S. DellaNegra
(IPNO)

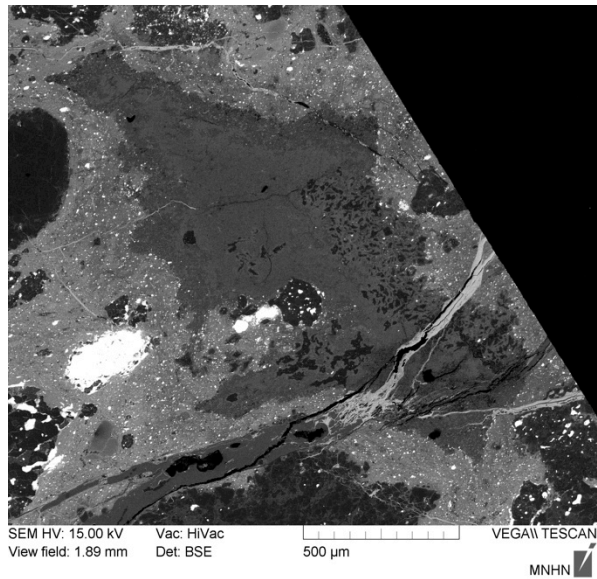


Ca⁺

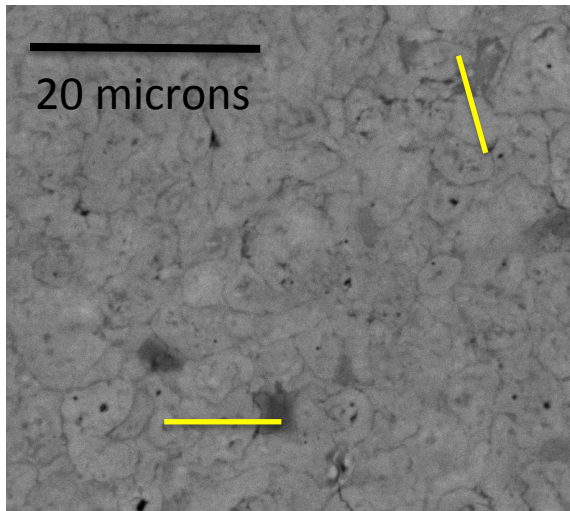
Météorite CV3 Efremovka



Etude des inclusions réfractaires: étude des CAIs « primitives »

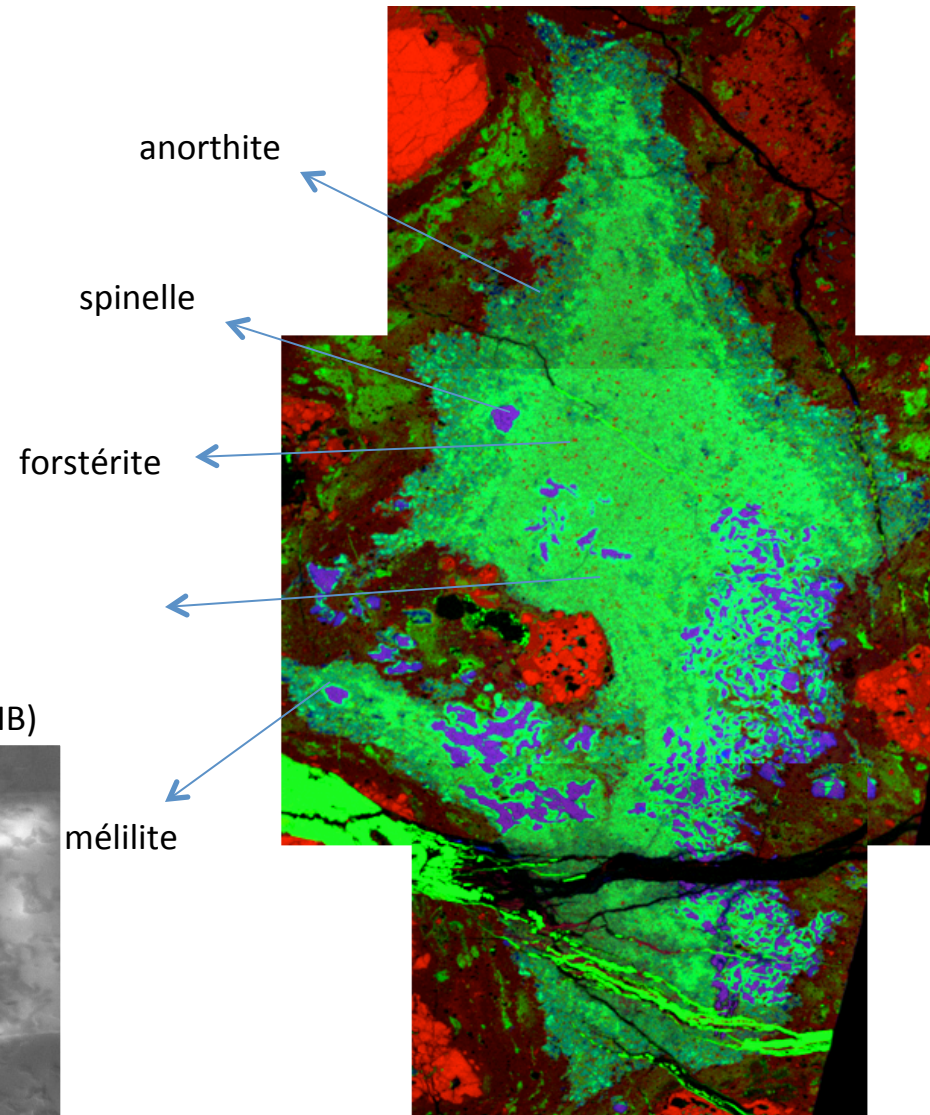
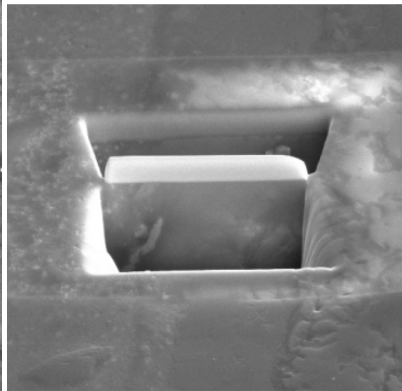


CAI E045-V d'Efremovka



Cœur à grains fins riches en pyroxènes

Section ultramince (FIB)

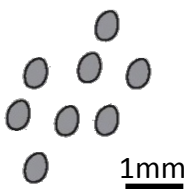


Cartographie RGB MgCaAl de l'inclusion E045-V

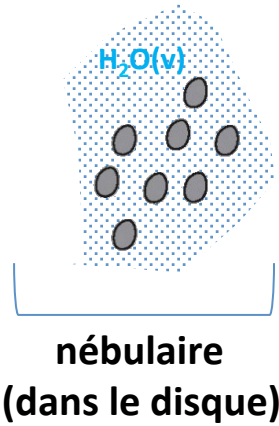
Recherche des traces de l'eau dans les CAIs: enregistrement des volatils du disque interne

2 modèles d'altération possibles

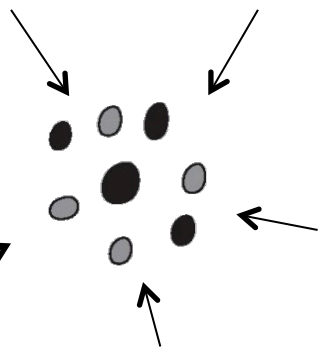
1. Formation CAI



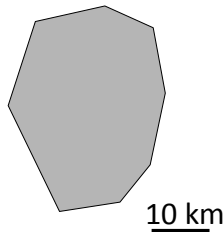
2. Altération



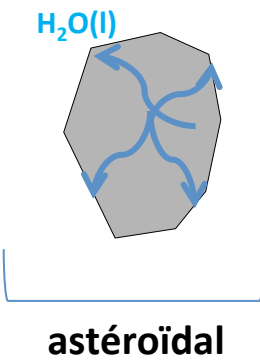
3. Accrétion



4. Astéroïde

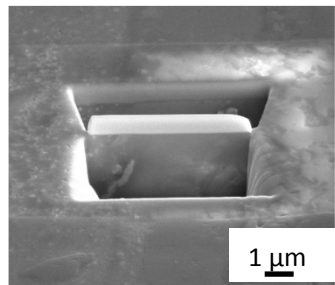


5. Altération



Phases d'altération nébulaires ou astéroïdales ?

Couplage de 3 techniques différentes pour en apprendre plus sur l'eau du disque interne



Section ultramince

Synchrotron
Spectroscopie
Infra Rouge



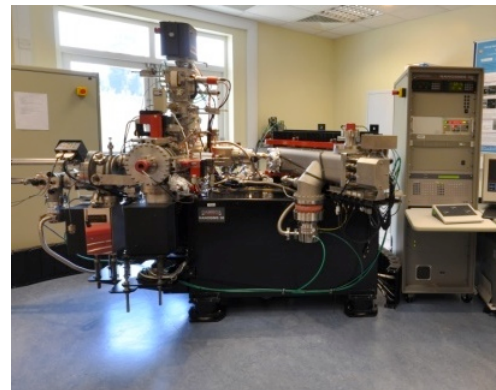
→ Présence et forme
moléculaire de l'eau

Microscope
électronique
à transmission



→ **minéralogie** et
texture des phases
d'altération

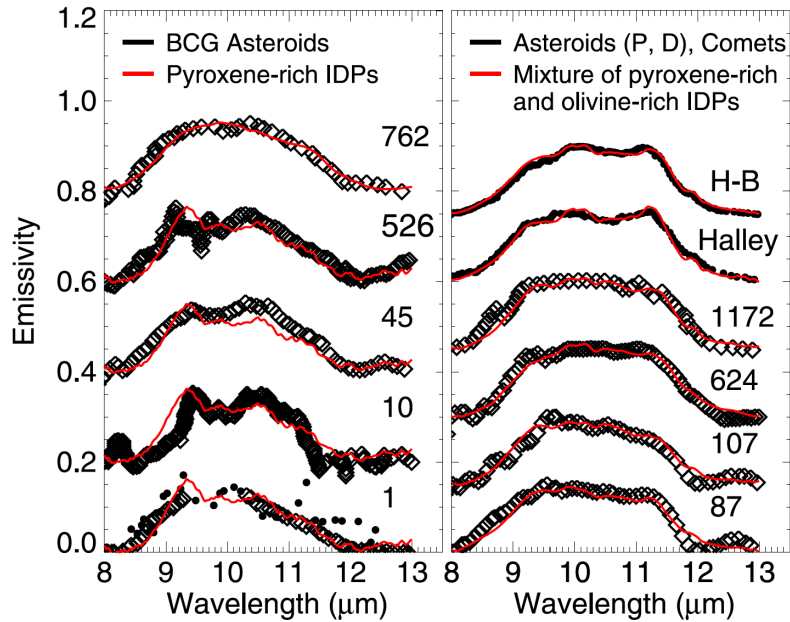
NanoSIMS



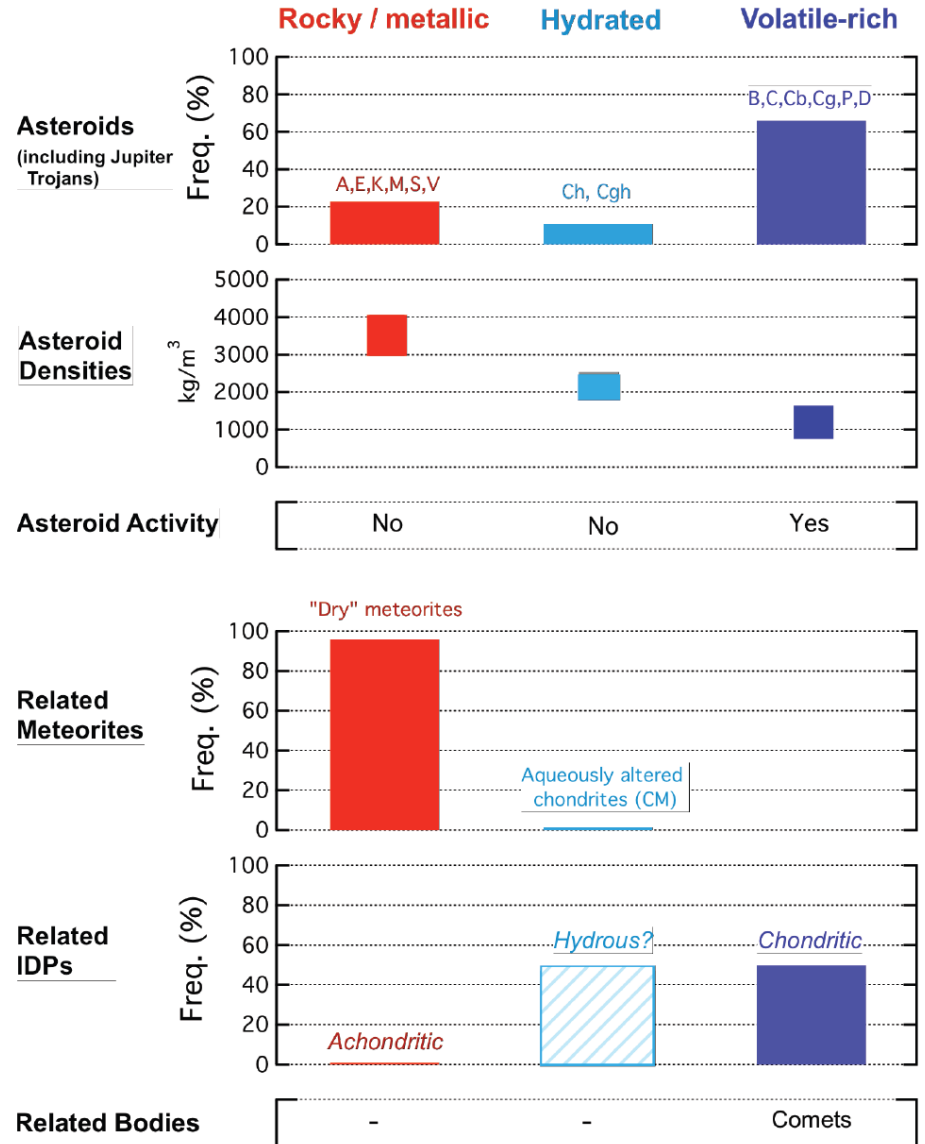
→ Signature **isotopique**
de l'eau

Comparaison spectrale IDPs - astéroïdes

Anhydrous interplanetary dust particles from icy asteroids

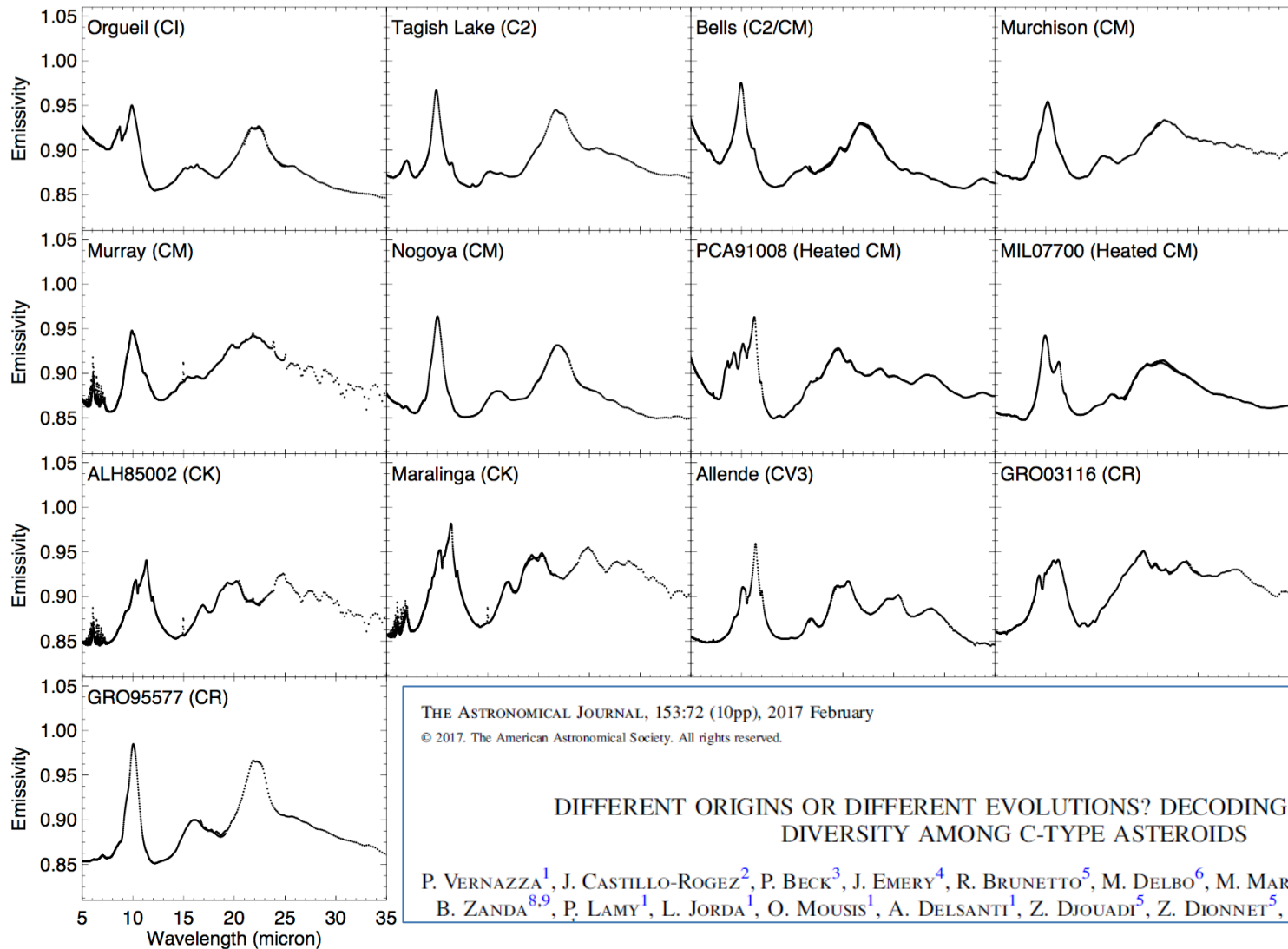


Merouane et al. 2014,
Vernazza et al. 2015



Comparaison spectrale météorites - astéroïdes

Spectres FIR mesurés à SMIS-SOLEIL



THE ASTRONOMICAL JOURNAL, 153:72 (10pp), 2017 February
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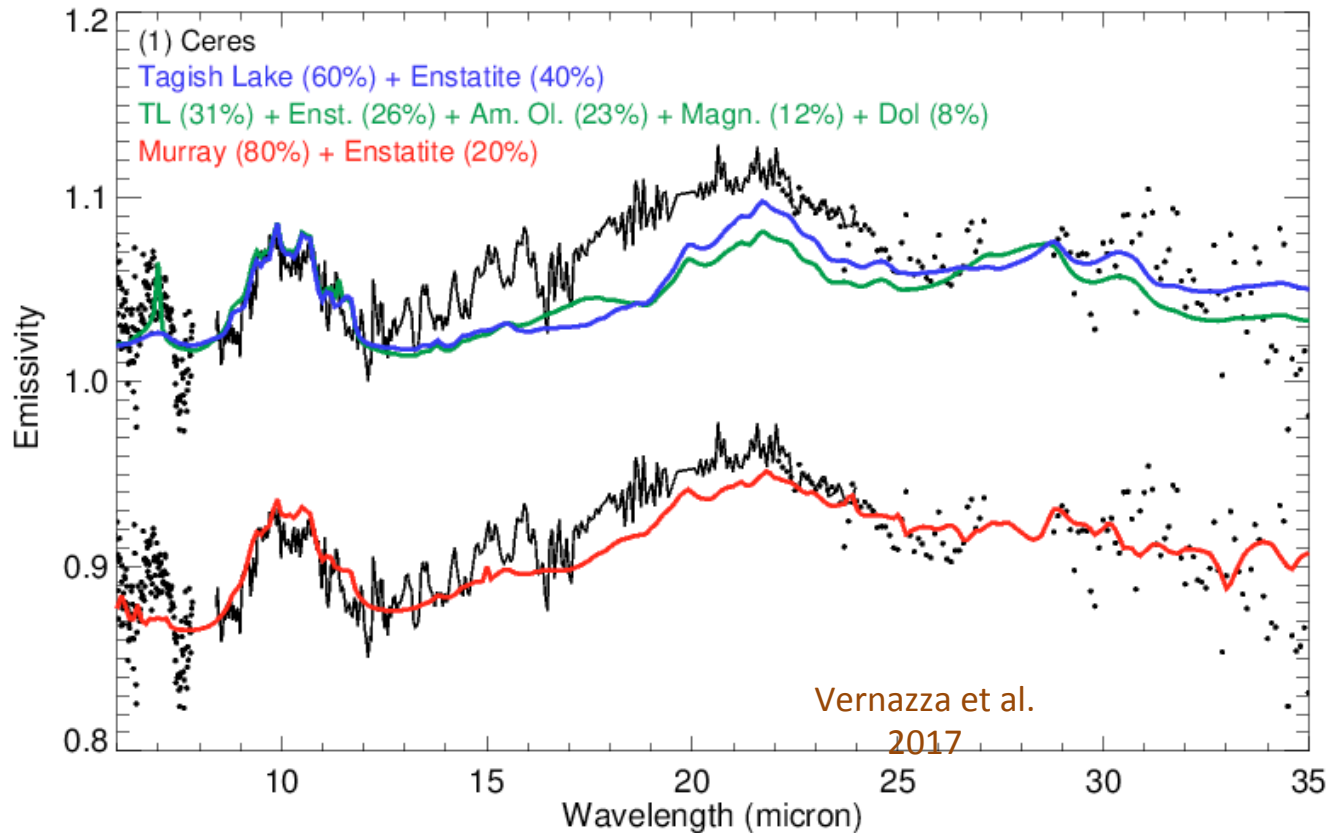
doi:10.3847/1538-3881/153/2/72



DIFFERENT ORIGINS OR DIFFERENT EVOLUTIONS? DECODING THE SPECTRAL DIVERSITY AMONG C-TYPE ASTEROIDS

P. VERNAZZA¹, J. CASTILLO-ROGEZ², P. BECK³, J. EMERY⁴, R. BRUNETTO⁵, M. DELBO⁶, M. MARSSET¹, F. MARCHIS⁷, O. GROUSSIN¹, B. ZANDA^{8,9}, P. LAMY¹, L. JORDA¹, O. MOUSIS¹, A. DELSANTI¹, Z. DJOUADI⁵, Z. DIONNET⁵, F. BORONDICS¹⁰, AND B. CARRY⁶

Application aux observations



IDP fluxes in this region amount to $4E-5$ particles/m²*s (Grün et al. 2001)

→ a square millimeter is impacted by about $\sim 1E3$ particles over $\sim 1E6$ years.

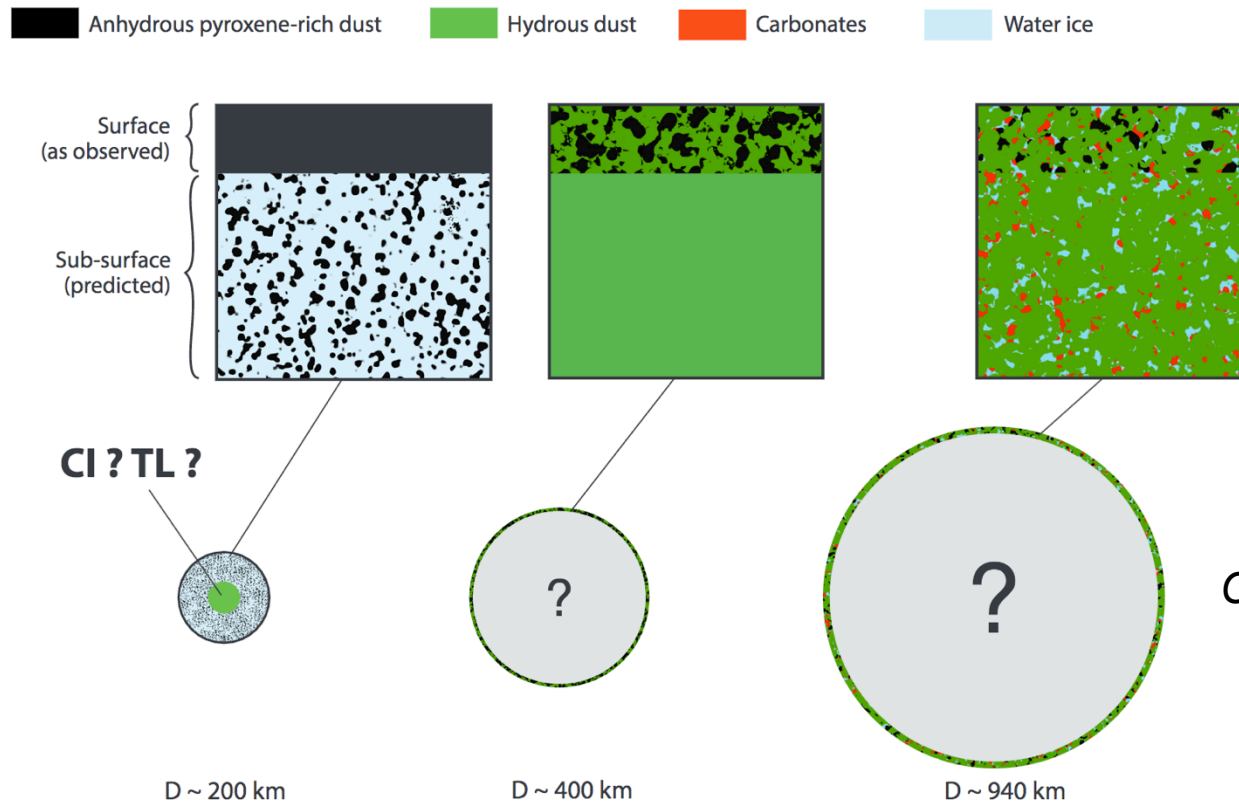
The Themis family (outer main belt) has composition compatible with pyroxene-rich IDPs.

A recent break up (<10 Myrs) has led to the formation of the Beagle family at a = 3.157 AU.

Spitzer observations and numerical modeling showed that the Beagle family is the most likely source of the α dust band (Nesvorny et al. 2008).

We suggest an exogenous origin for this dust.

Différentes origines et/ou évolutions pour les astéroïdes



→ participation à demande JWST GTO NIRCcam (P.I. J. Stansberry)

→ participation à demande JWST DD ERS NIRSspec & MIRI (P.I. P. Vernazza)

Prochaines étapes

- Better separation of the different phases for the meteorite
- Analyses of the same 7 samples with X-ray tomography
- 5 news samples of the Itokawa asteroids