



Etude de la matière organique des échantillons de l'astéroïde Ryugu par nanospectroscopie IR

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A. Dazzi, A. Deniset-Besseau, J. Duprat, Y. Kebukawa, H. Yabuta, ...
C. Sandt, F. Borondics et al.**

(ICP, ISMO, IJCLab, IMPMC-MNHN, SOLEIL, ...)

Mathurin et al. Astron. Astrophys. 2004
<https://doi.org/10.1051/0004-6361/202347435>

<https://www.in2p3.cnrs.fr/fr/cnrsinfo/lin2p3-participe-lanalyse-dun-echantillon-de-lasteroide-ryugu>

<https://www.inc.cnrs.fr/fr/cnrsinfo/la-nano-spectroscopie-infrarouge-revele-une-partie-des-secrets-de-lasteroide-ryugu>

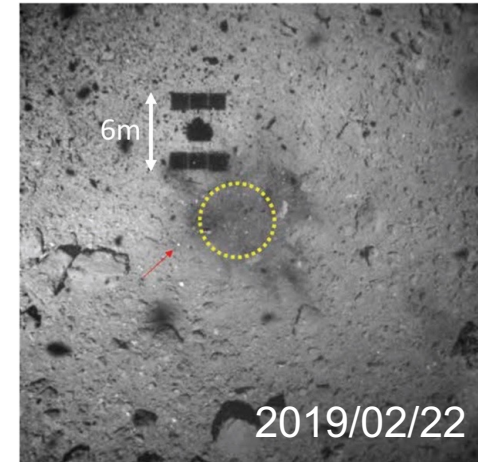


Hayabusa2

- Asteroid Ryugu. Type Cb
- 2 touchdowns completed
 - Feb. 22, 2019 1st touchdown and sample collection
 - Apr. 3-6, 2019 SCI (small Carry-on Impactor)
 - Jul. 11, 2019 2nd touchdown and sample collection
 - => **Sample return Dec. 2020**
- Curation => July 2021
- Initial Analyses July 2021-July 2022
 - 6 sub-teams incl. **Coarse-grain mineralogy ("Stone")** (Leader Tomoki Nakamura); **Insoluble Organic Matter ("IOM")** (Leader Hikaru Yabuta)



Hayabusa2@ Ryugu



Tamatebako (treasure box)

(Credit :JAXA, University of Tokyo, Kochi University, Rikkyo University, Nagoya University, Chiba Institute of Technology, Meiji University, University of Aizu, AIST)

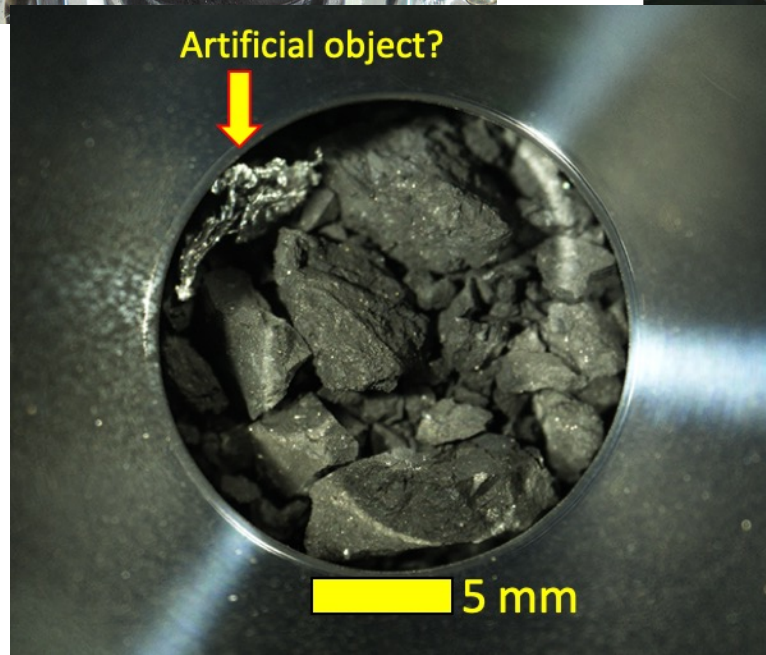
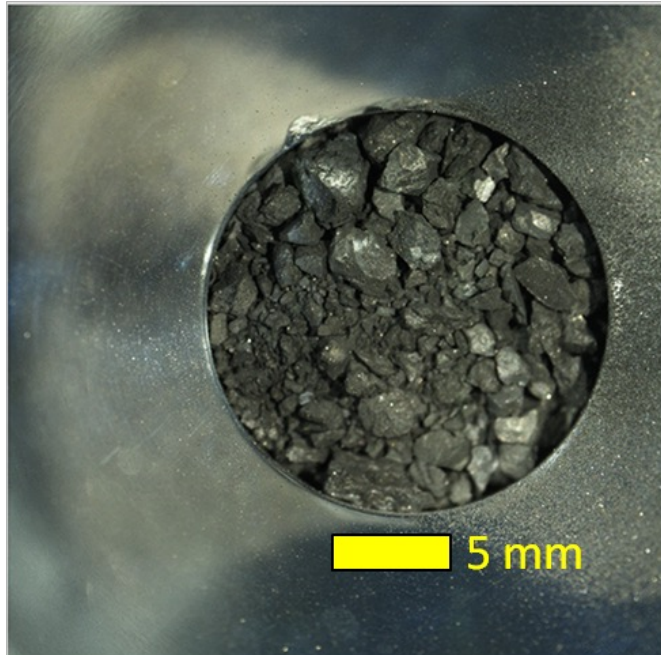
Hayabusa2 : capsule recovery (dec 6, 2020)



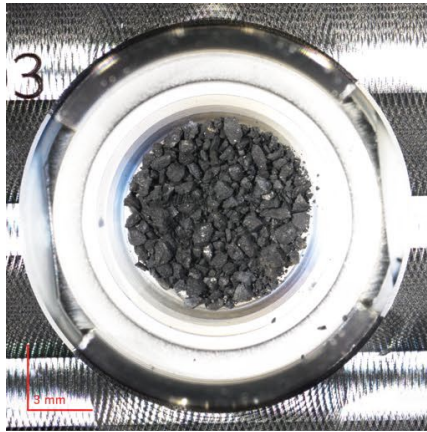
Hayabusa2 : sample containers



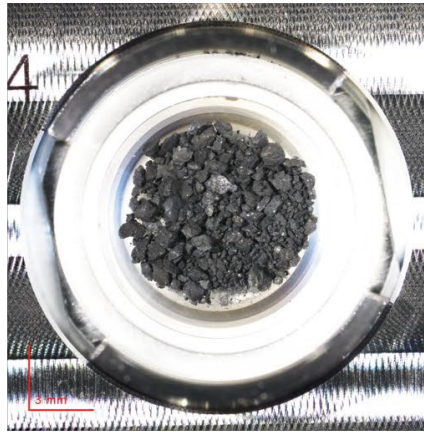
A室開封後の画像



Samples of Ryugu



A0106 (38.4 mg)



A0107 (31.0 mg)



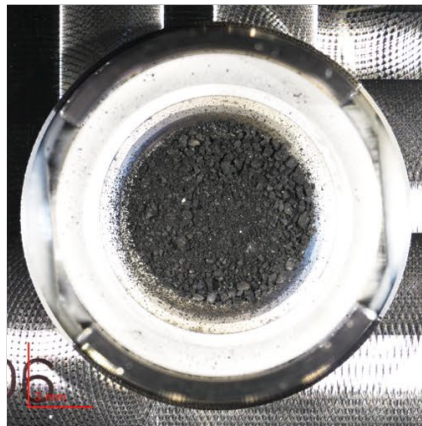
A0040 (3.0 mg)



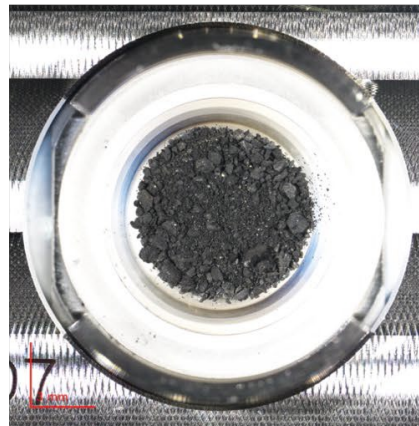
A0058 (3.3 mg)



A0094 (1.8 mg)



C0107 (38.8 mg)



C0108 (33.0 mg)



C0002 (93.5 mg)

Meteorites

- From the asteroid belt located between Mars and Jupiter (and also Lunar and Martian meteorites)
- Samples of macroscopic sizes (cm or more...)
- Variety of types, from « unchanged » to « largely processed » in the asteroid parent body (heat – aqueous alteration)

Carbonaceous chondrites

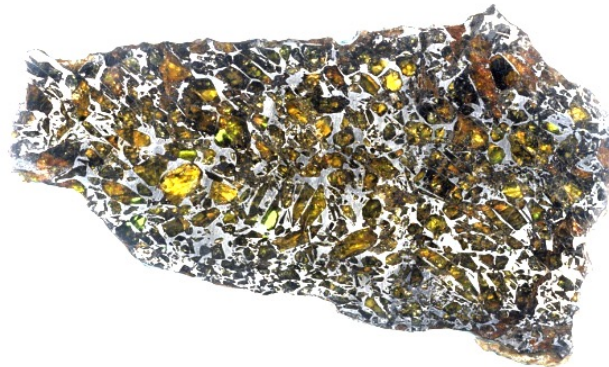
Orgueil



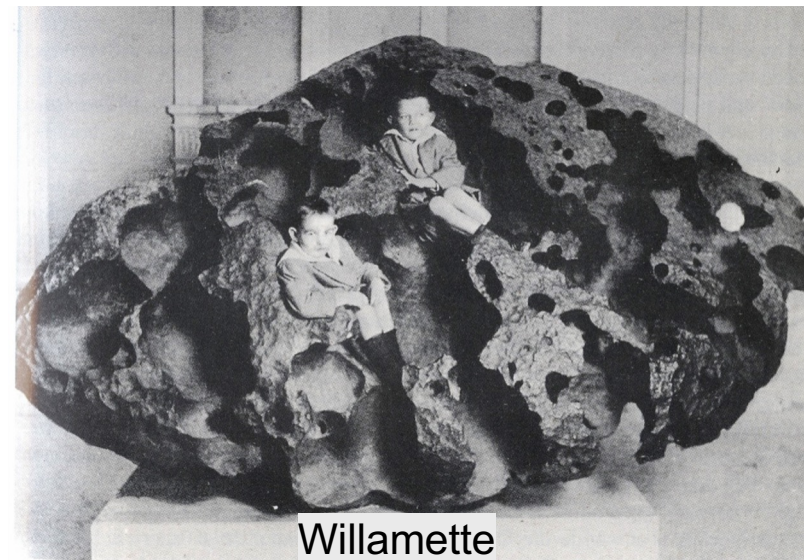
Allende



Stony-iron meteorite



Iron meteorite



Willamette

Iron meteorite



Cabin Creek

Comparison of Ryugu and meteorites

Ryugu



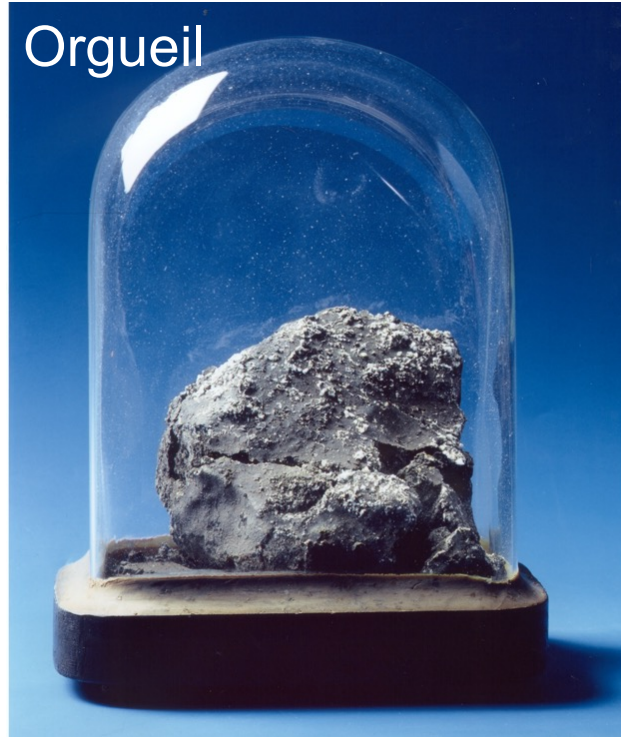
A0058 (3.3 mg)



C0002 (93.5 mg)

Yokoyama+2023

Orgueil

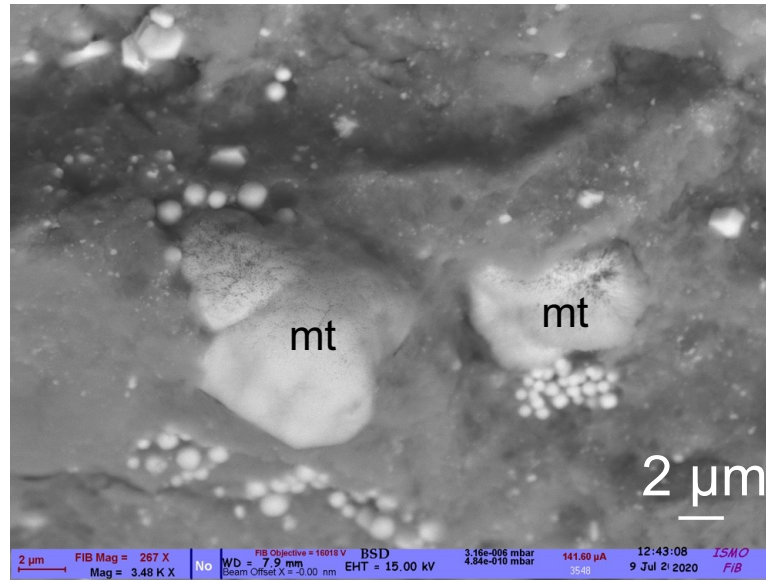
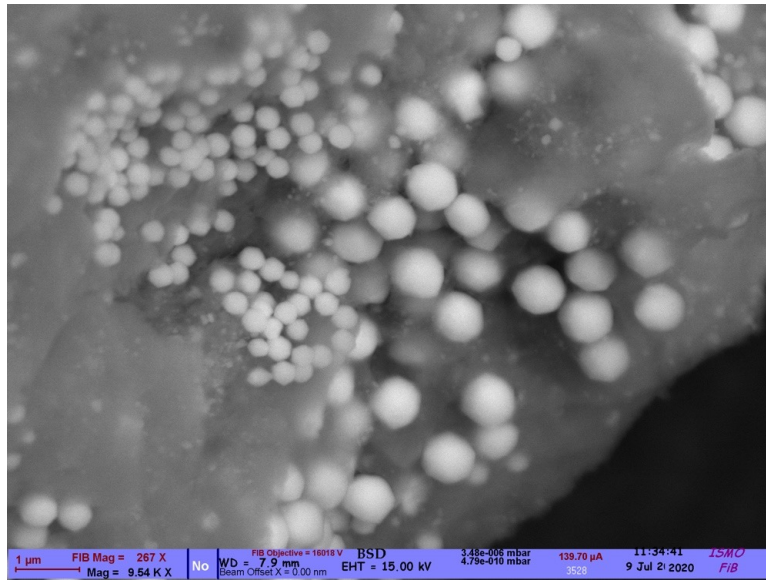
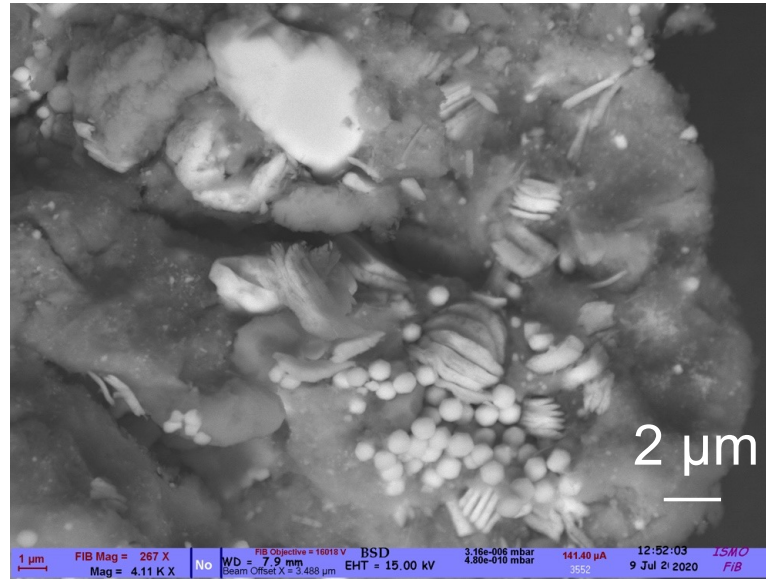
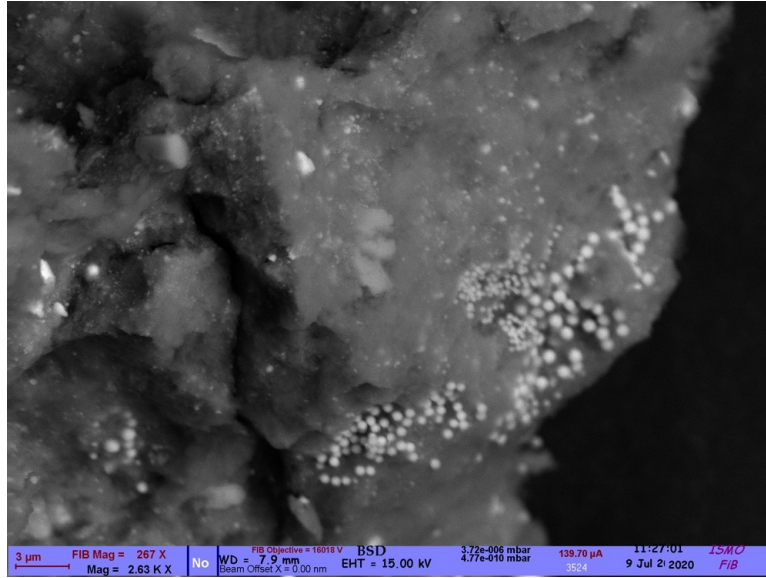


Eunostos - commons.wikimedia.org

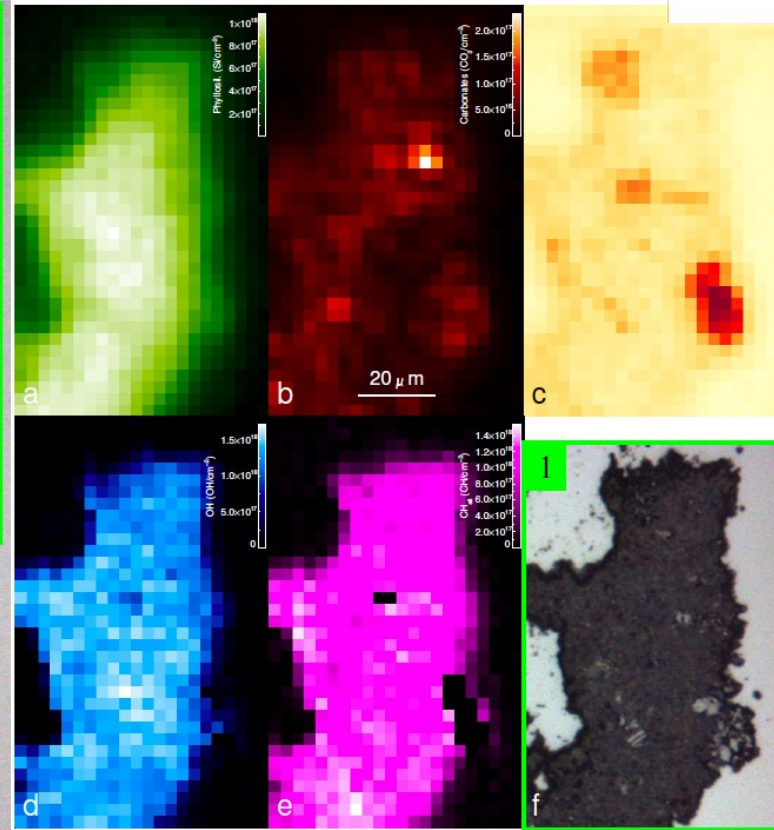
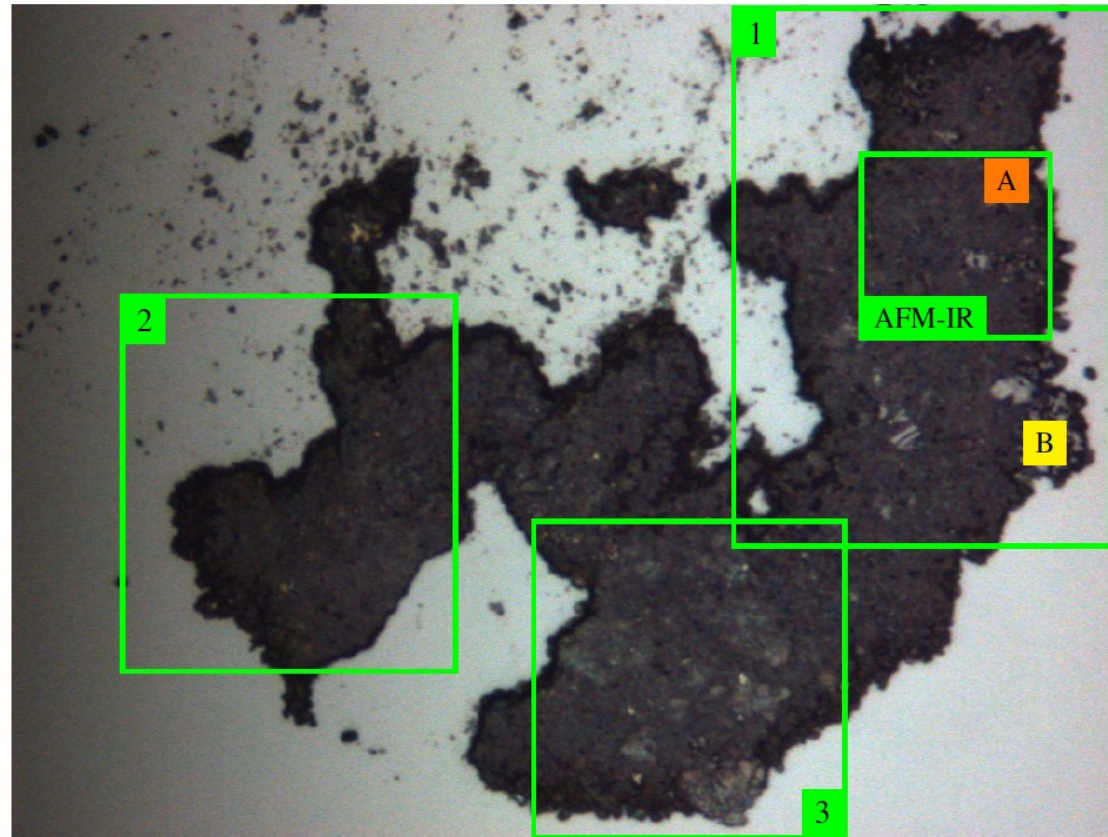
- Similarity of Ryugu and « CI » carbonaceous chondrites, e.g. Orgueil
- Mineralogy altered by water (« clay »), but the most pristine chemical composition

C0002-FC016

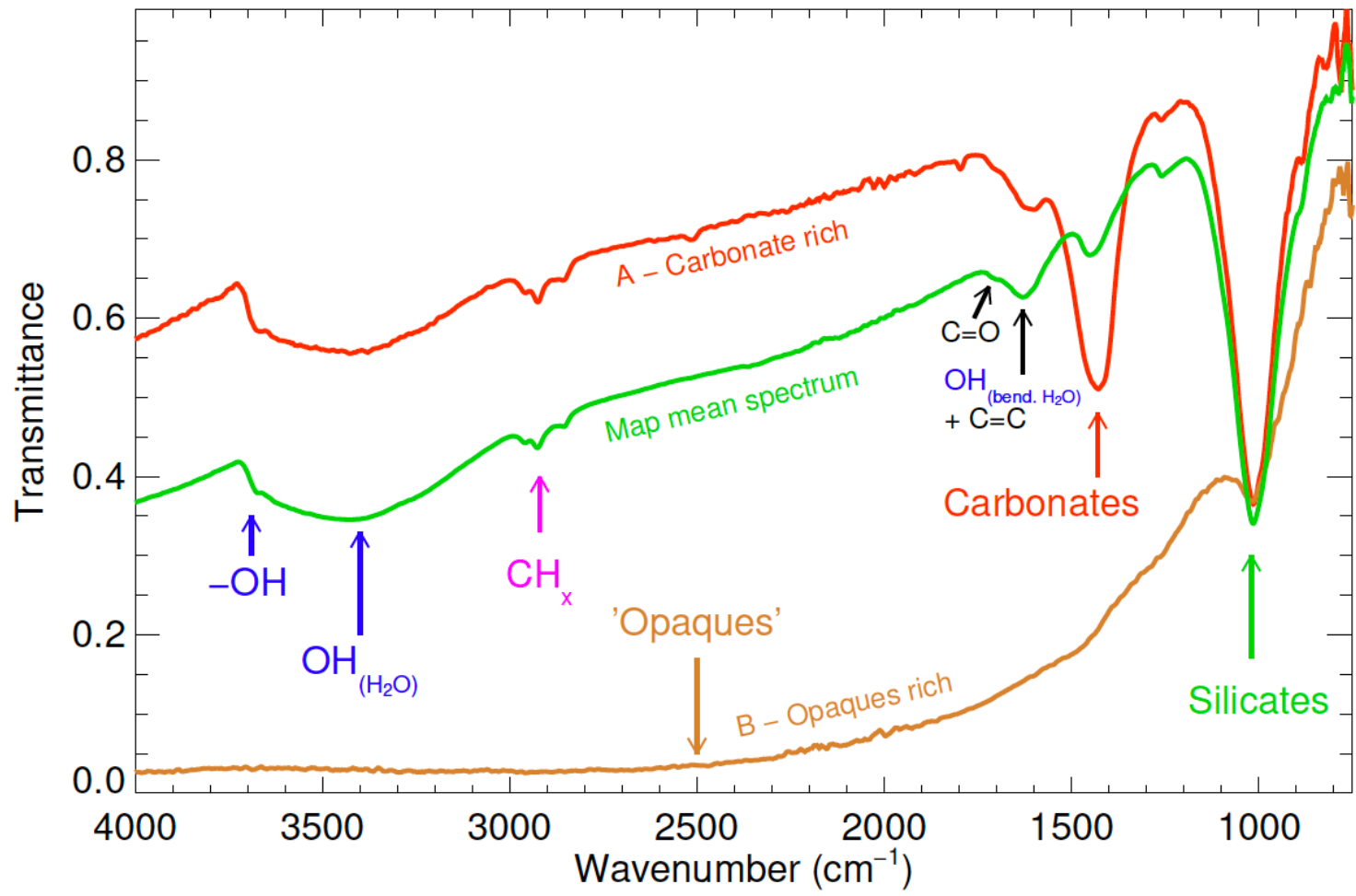
RYUGU



FTIR microscopy (μm level)



FTIR microscopy



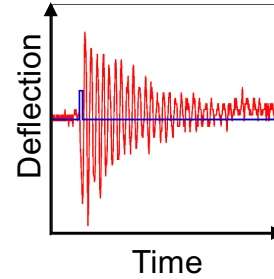
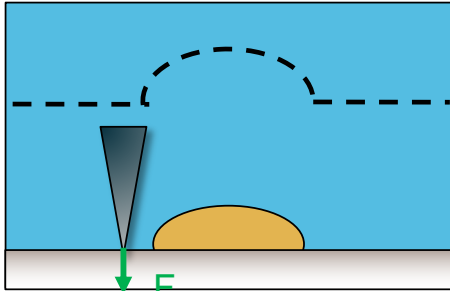
Dartois+2023

RYUGU

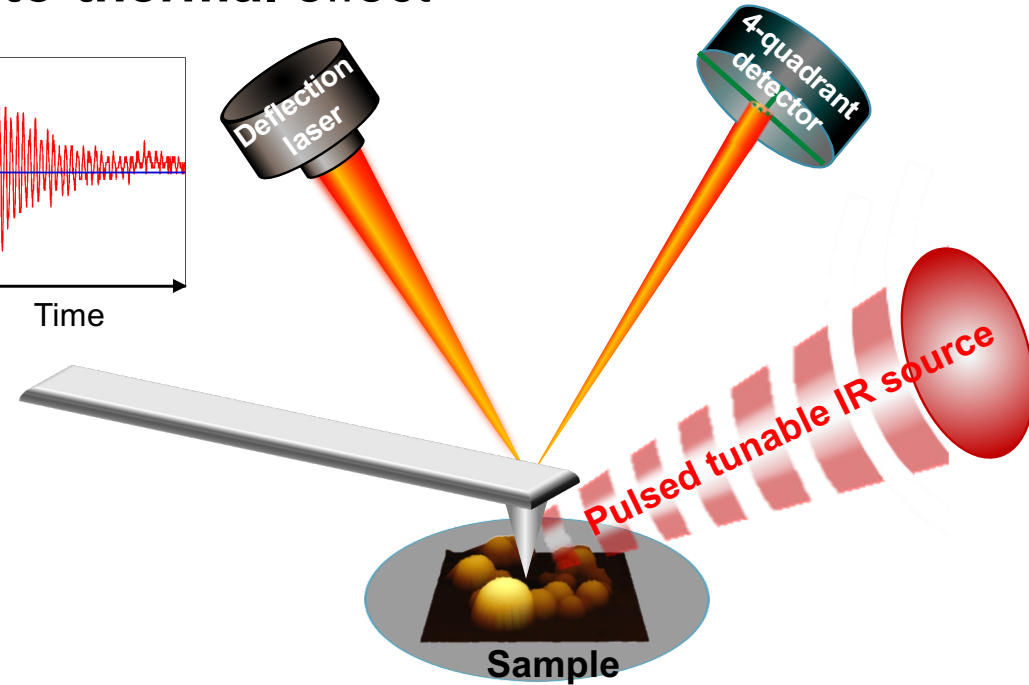
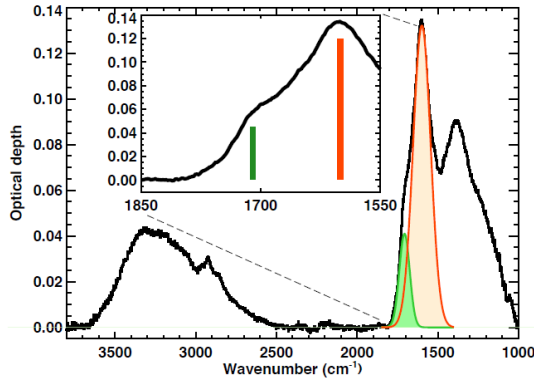
IR Nanospectroscopy AFM-IR

- AFM-IR = IR absorption detection using photo-thermal effect

AFM



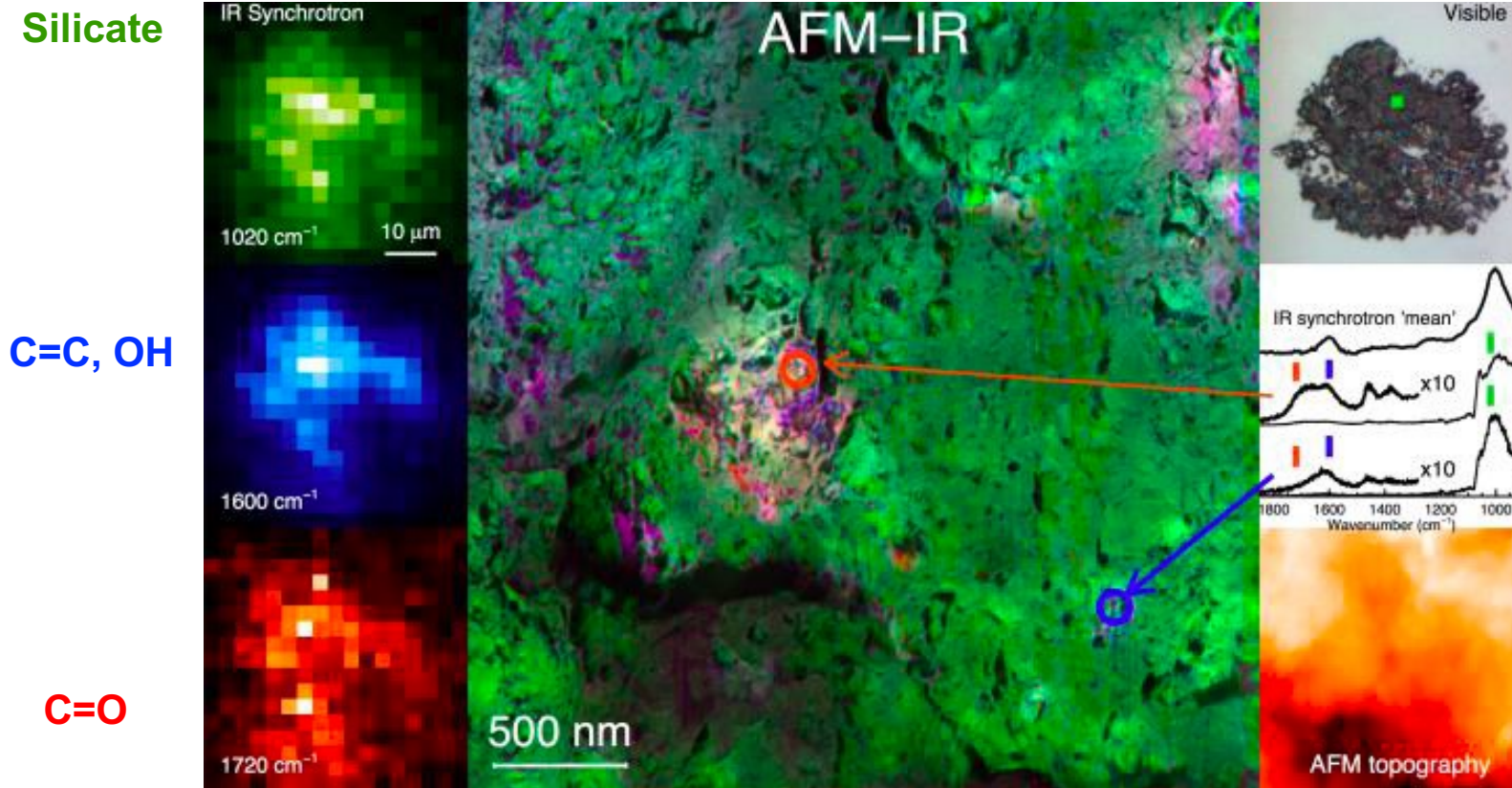
IR



A. Dazzi et al., *Journal of Applied Physics* 2010

→ Lateral resolution fixed by tip dimension (~ tens of nm)

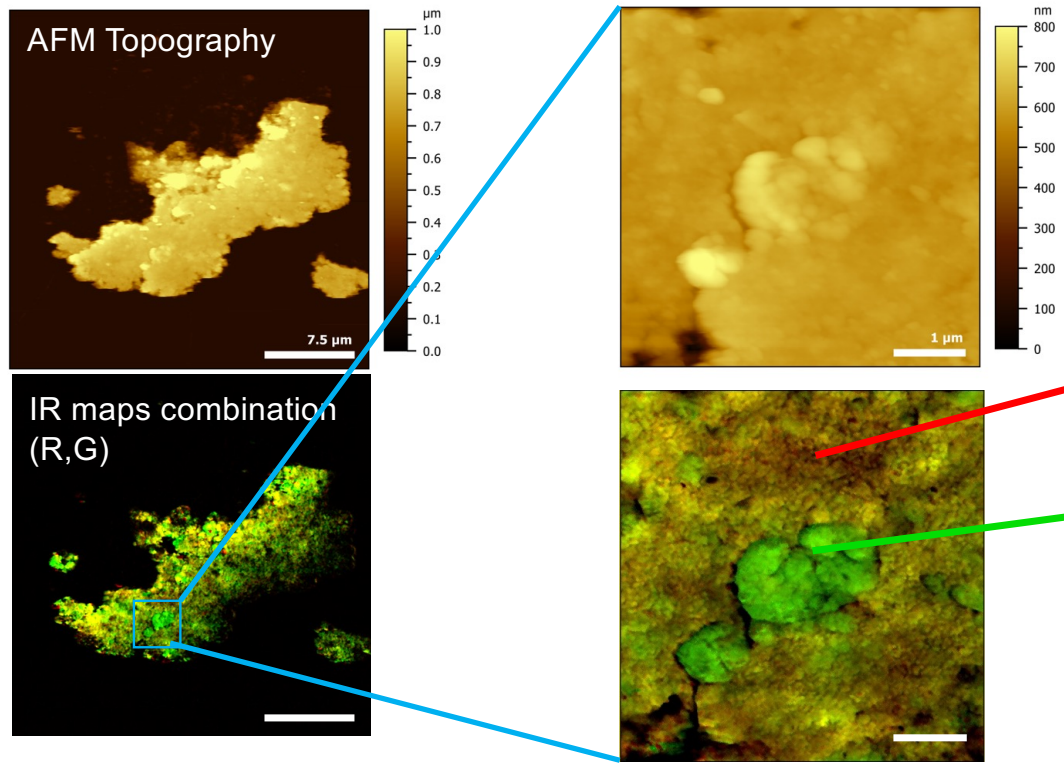
IconIR System : resolution ~50 nm



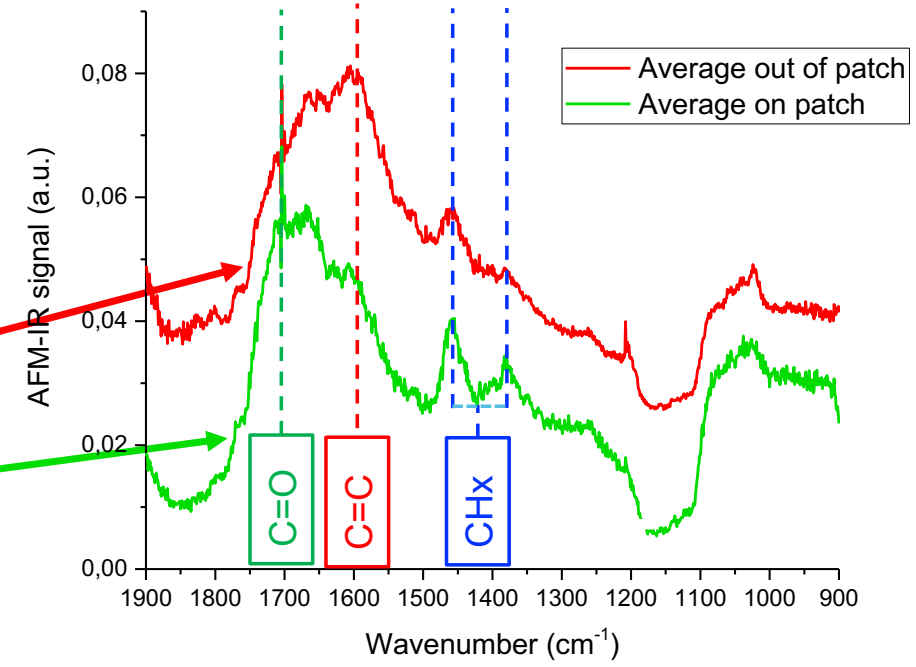
Mathurin+2022, 2024
Yabuta+2023

- Diffuse organic matter
- organic patches at the nanoscale

IconIR System : resolution ~ 50 nm



Average of hundreds of spectra

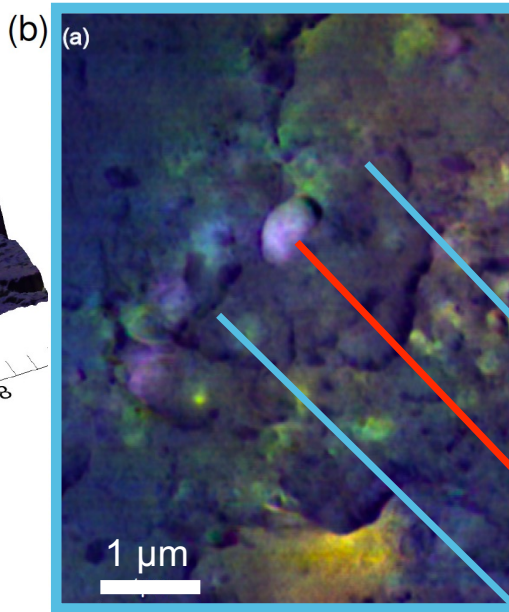
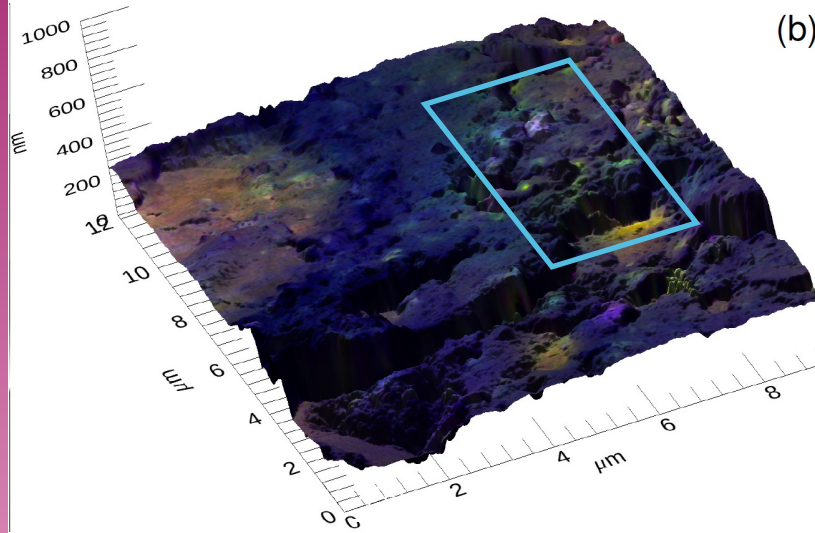


Mathurin+2024

RYUGU - IOM

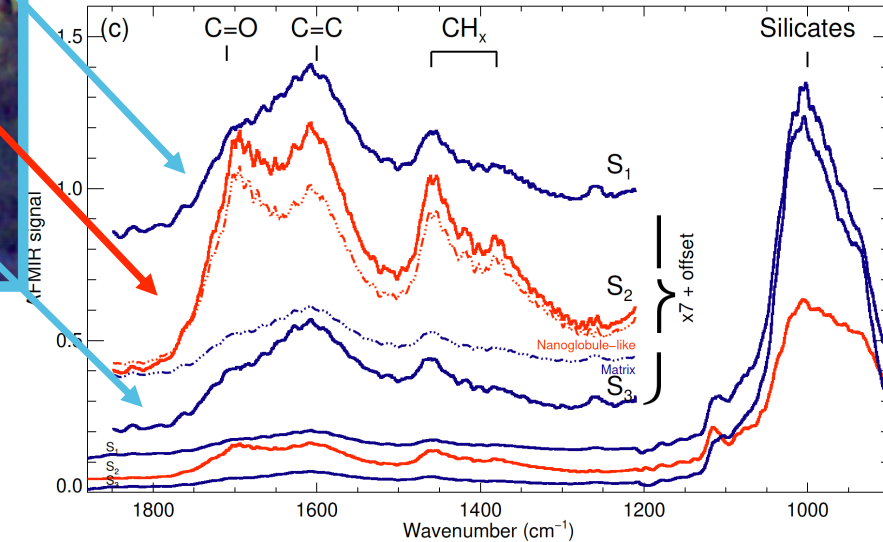
- Bulk IOM organics : C=C rich, some CHx
- Organic patches ("nanoglobules") : C=O & CHx rich

Ryugu nanoglobules AFM-IR spectra



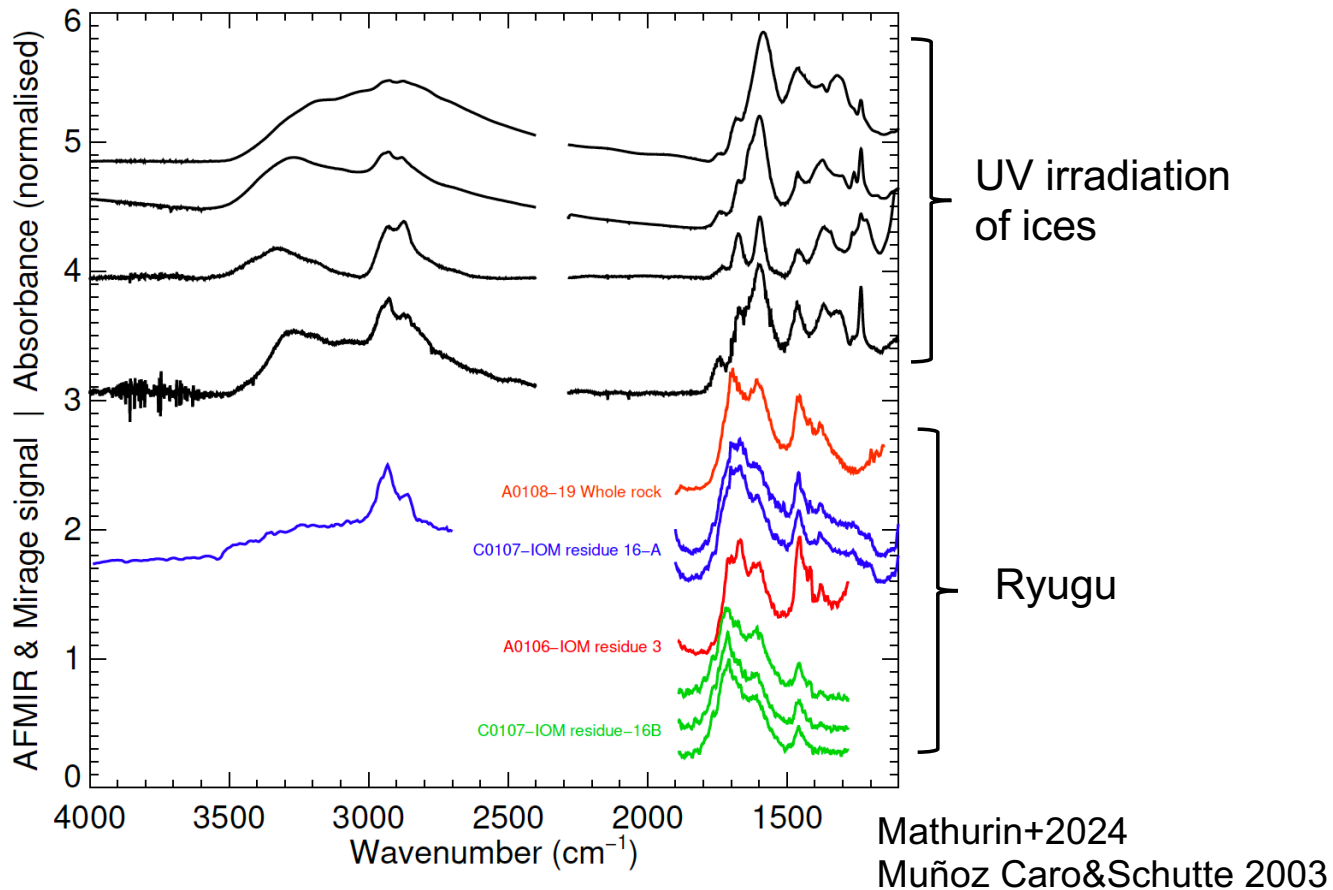
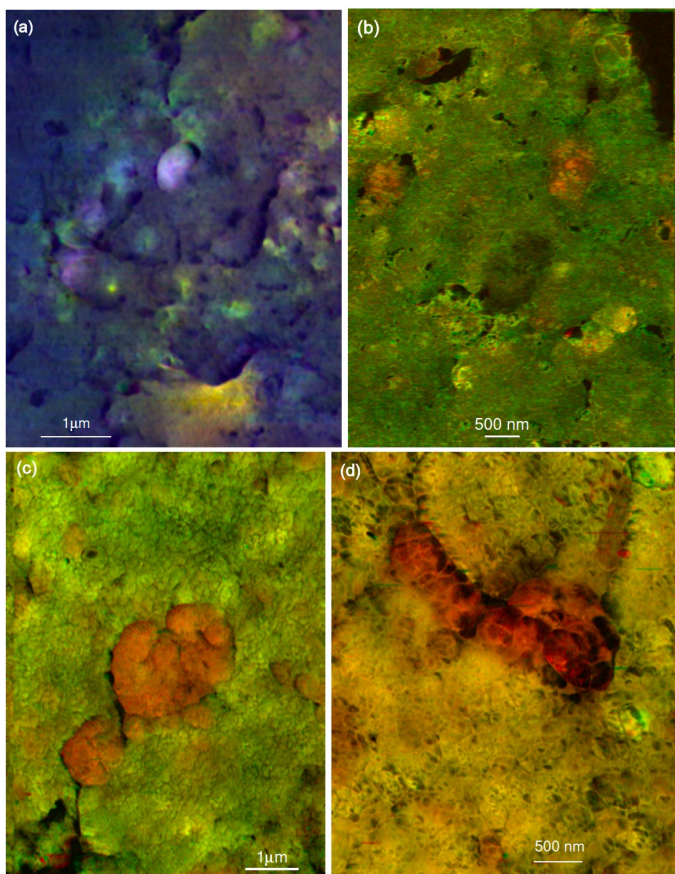
- Nanoglobules are also found in all types of carbonaceous chondrites IOM De Gregorio+2013

- Nanoglobules are rich in C=O and CH_x compared to the diffuse organic matter
- Origin/formation of nanoglobules?



Formation of Ryugu organic nanoglobules?

RYUGU



- Formation by irradiation of ices in the outer regions of the protoplanetary disk?

Summary

- Ryugu contains a few wt% of carbon
- N/C ratio compatible with that of carbonaceous chondrites
- Several phases:
 - Diffuse organic matter
 - Organic inclusions in the matrix (incl. Nanoglobules)
- AFM-IR analysis allows to measure the composition of individual nanoglobules at the ~ 50 nm scale
 - Nanoglobules rich in C=O and CH_x compared to the diffuse organic matter
- Formation of nanoglobules by irradiation (UV) of ices in the outer regions of the protoplanetary disk?



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