Photochemistry on the International Space Station: a study of the effects of the solar electromagnetic radiation on organic refractory samples

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Photochemistry on the International Space Station: a study of the effects of the solar electromagnetic radiation on organic refractory samples

Plan of this presentation:

- Astrophysical / Astrobiological Framework
- **P**hotochemistry on the **S**pace **S**tation (**PSS**) Experiment
- Procedure of Sample Preparation
- Analysis of the Organic Residues
- State of Art of the PSS Experiment

Physical-chemical processes in the interplanetary space

Contents:

Trans Neptunian Objects (TNOs)

Cold satellites of giant planets

Comets in the Oort cloud

} Objects covered by ices (H_2O, N_2, CH_4, CO, CO_2, C_2H_6...)

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↓

Exposition to the ultraviolet and ion irradiation

↓

chemical rearrangement of the molecular bonds and the formation of new molecular species

↓

Formation of refractory organic residues (laboratory evidences)

Physical-chemical processes in the interplanetary space

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↓

Exposition to the ultraviolet and ion irradiation

↓

chemical rearrangement of the molecular bonds and the formation of new molecular species

↓

Formation of refractory organic residues (laboratory evidences)

←

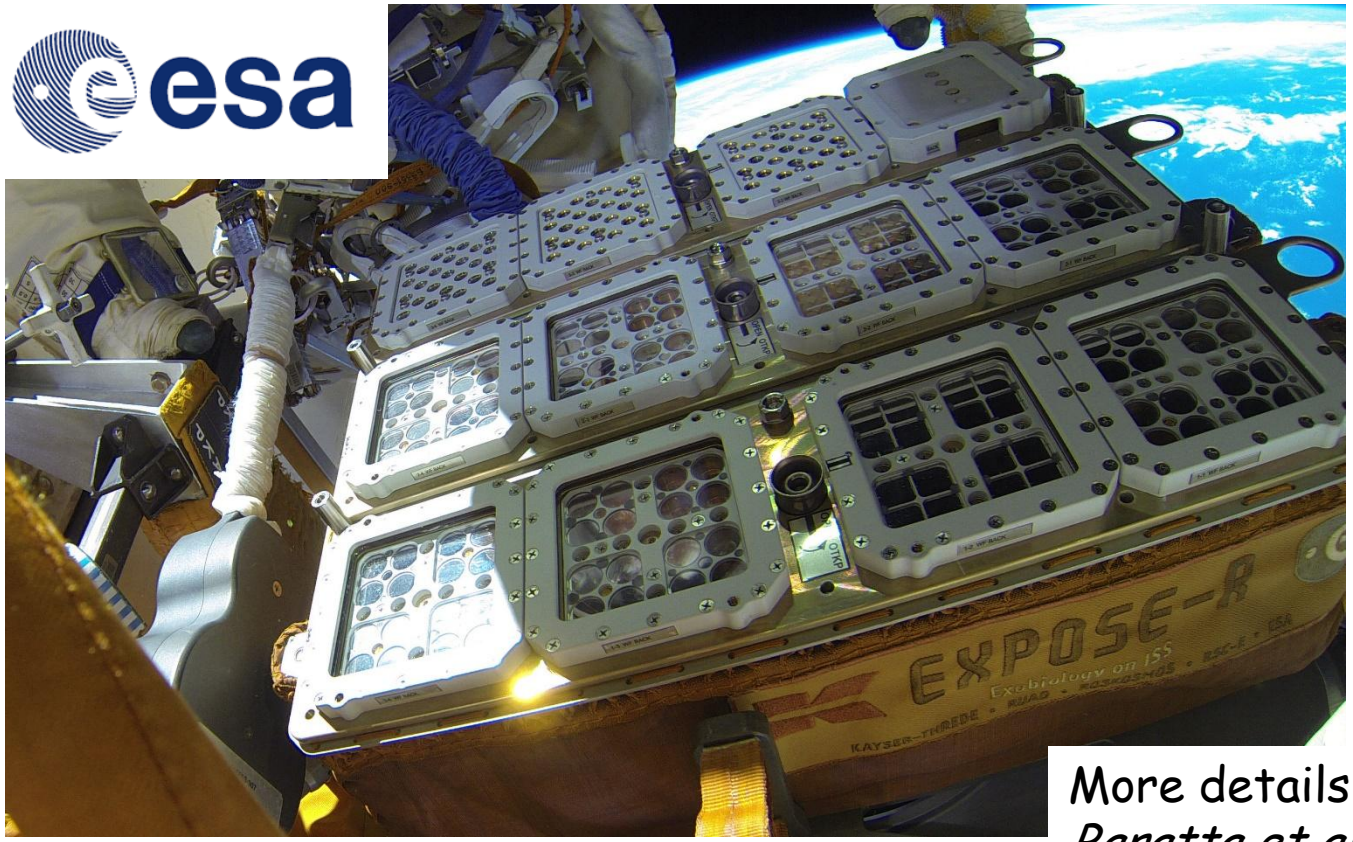
In the proximity of the Sun (~ 3 AU), comets deliver these organic residues. Travelling through interplanetary medium, they are further exposed to the radiation.

Could they contribute to the bio-chemical evolution of the Earth??

Photochemistry on the Space Station (PSS) Experiment

Contents:

Several organic compounds and mixtures housed in the International Space Station and exposed, for 12-18 months, to the unfiltered solar electromagnetic spectrum



More details in:
Baratta et al., 2015

Launch : July 23, 2014
Exposition: from October 2014, for 12-18 months

Photochemistry on the Space Station (PSS) Experiment

Contents:

Contribution of the LASp – Catania:

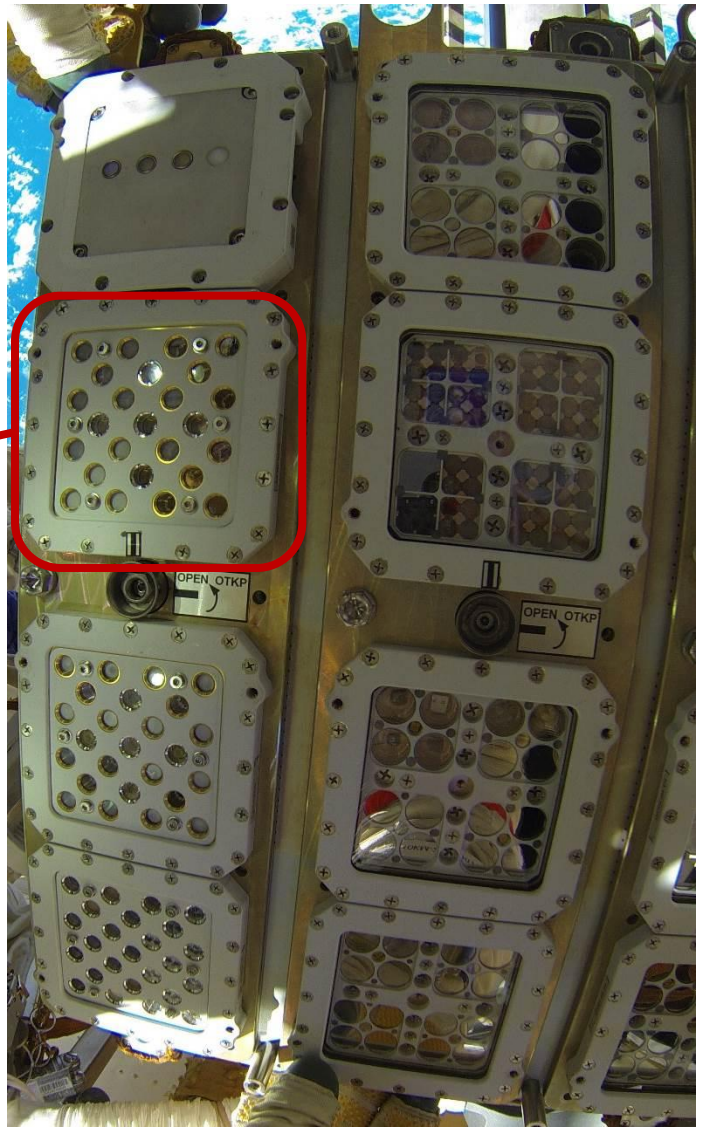
#10 190 nm thick
#10 130 nm thick
#10 65 nm thick

} **30 organic samples on MgF_2 windows**

For each thickness :

4 are flying on board of the ISS:

2 exposed + **2** kept inside



Photochemistry on the Space Station (PSS) Experiment

Contents:

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#10 190 nm thick
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30 organic samples on MgF_2 windows

For each thickness :

4 are flying on board of the ISS:

2 exposed + **2** kept inside

6 were sent to the ESA laboratories
(DLR facility in Cologne)

2 in vacuum and same T variations as the ISS exposed ones
2 in vacuum and at room temperature
2 exposed to visible - near UV electromagnetic radiation

Photochemistry on the Space Station (PSS) Experiment

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Contribution of the LASp – Catania:

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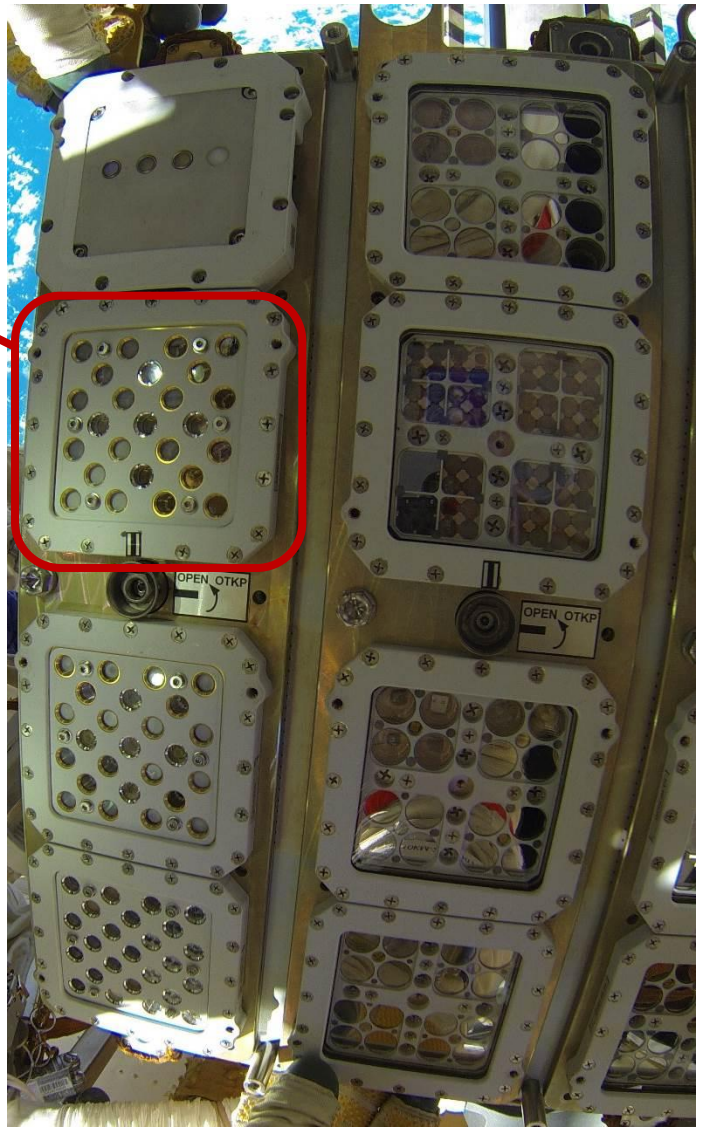


OUR AIM

We already investigated (in the laboratory) the effects of the ion irradiation on the organic residues (*Palumbo et al, 2004*)

Now we want to study the effects of the solar UV photons on the organic residues by comparing them with the residues exposed to Lyman-alpha photons in our laboratory.

Samples' Preparation (3 steps)

Contents:

1) Deposition of the frozen gas

N_2 : CH_4 : CO @ 16 K

icy mixture representative in the outer Solar System
(*Owen et al, 1993*)

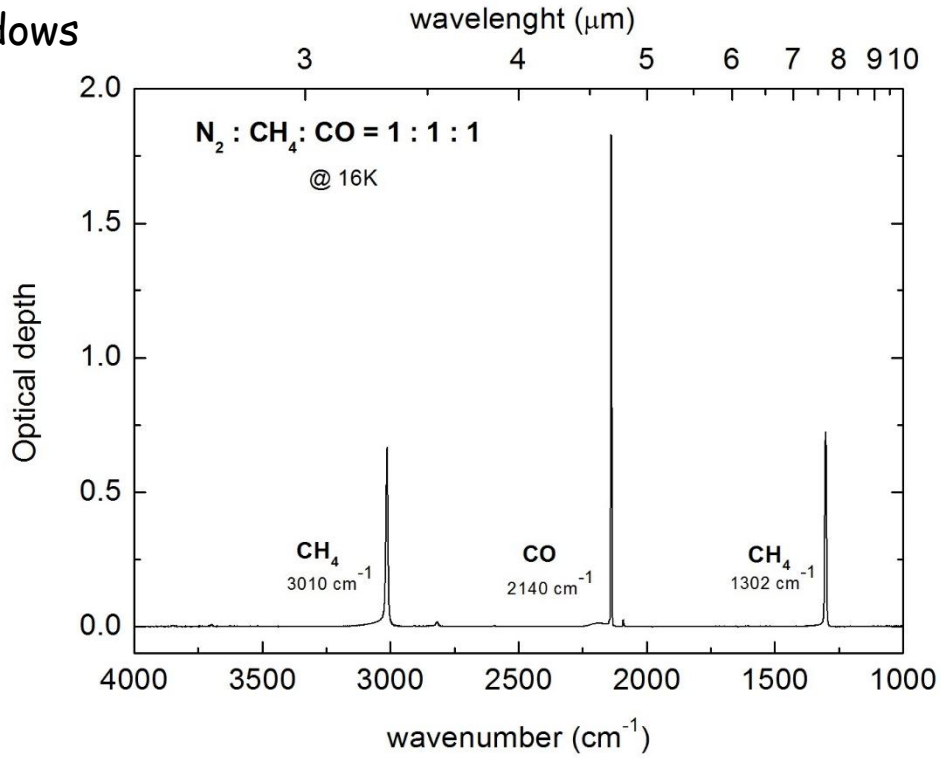
Sample substrate: MgF_2 windows

IR bands:

Nitrogen (N_2):
no IR active band

Methane (CH_4):
1302 cm^{-1} & 3010 cm^{-1}

Carbon monoxide (CO):
2140 cm^{-1}



Samples' Preparation (3 steps)

Contents:

1) Deposition of the frozen gas

$N_2 : CH_4 : CO$ @ 16 K

2) Ion irradiation of the frozen gas

$(N_2 : CH_4 : CO)$ + 200 keV He^+

energy received by each of the 30 samples:
(110±5) eV/16u

↓

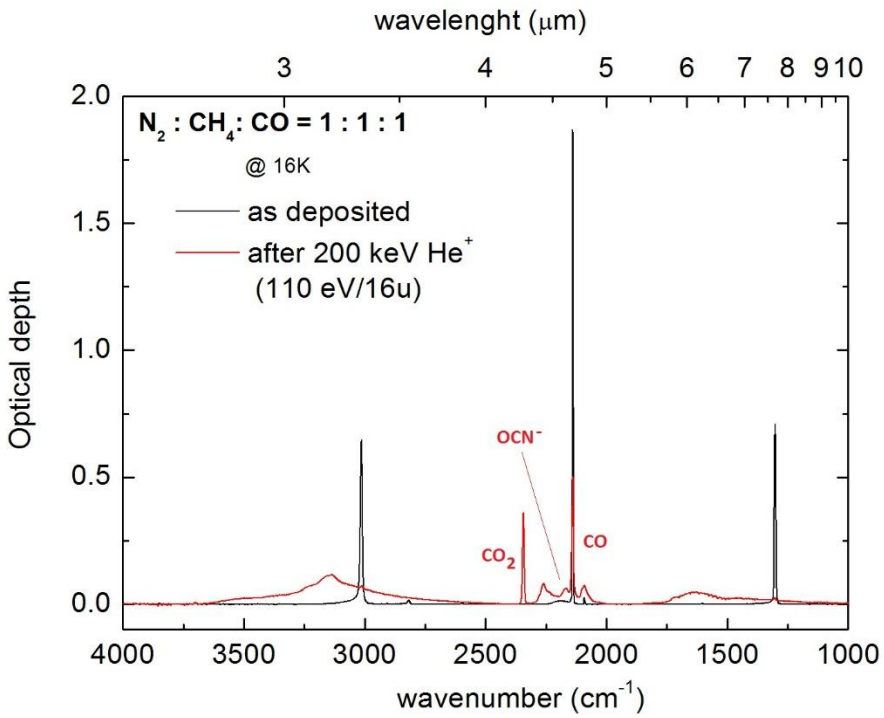
Ion dose suffered by the external layers of the comets and TNOs according to *Strazzulla & Johnson, 1991*

IR bands (after irradiation):

Carbon dioxide (CO_2):
2340 cm^{-1}

Cyanate ion (OCN^-):
2167 cm^{-1}

……



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1) Deposition of the frozen gas

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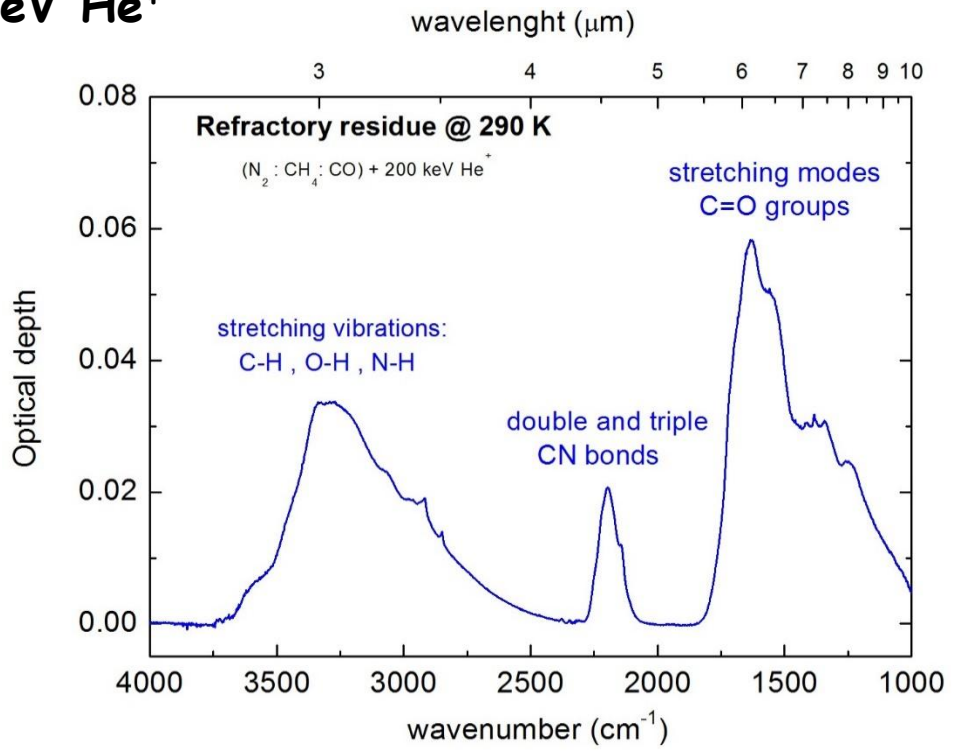
$(N_2 : CH_4 : CO)$ + 200 keV He^+

3) Sample gently warmed up to room temperature

Refractory organic residue rich in:

- CH groups
- NH groups
- OH groups
- CN groups



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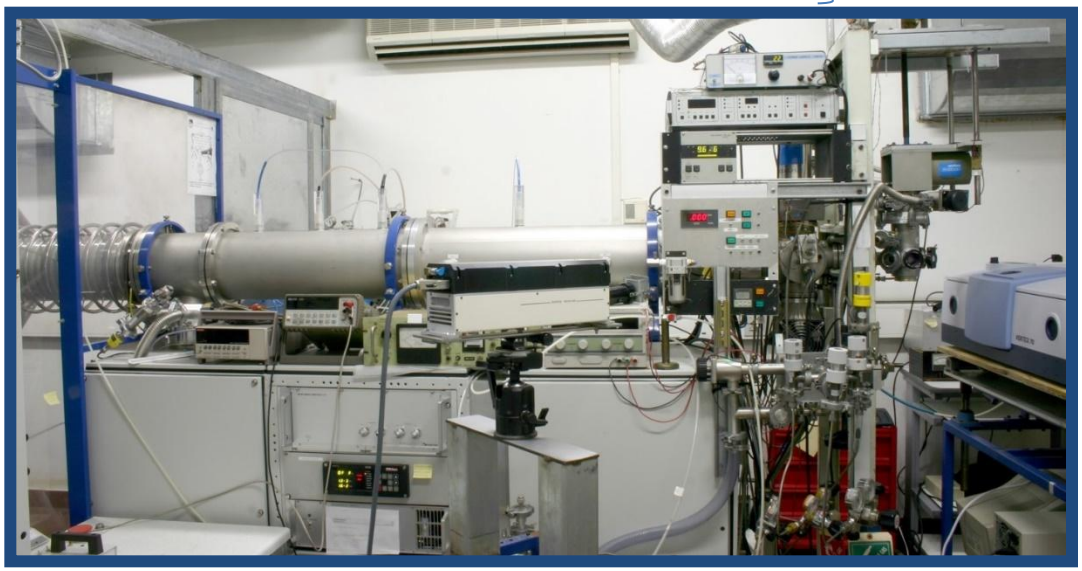
Totally performed in the astrophysical laboratory of Catania



"***L****aboratorio di* ***A****strofisica* ***Sp****erimentale*"

LASp

Samples' Preparation (3 steps)

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$(N_2 : CH_4 : CO)$ + 200 keV He^+

3) Sample gently warmed up to room temperature

Totally performed in the astrophysical laboratory of Catania

In addition to the 30 samples for the PSS project, we have produced similar ones in order to…

- Simulate, in our laboratory, the solar vacuum UV irradiation on the refractory residues

- Study the temporal (natural) evolution of the organic residues stored in our laboratory at room temperature and pressure

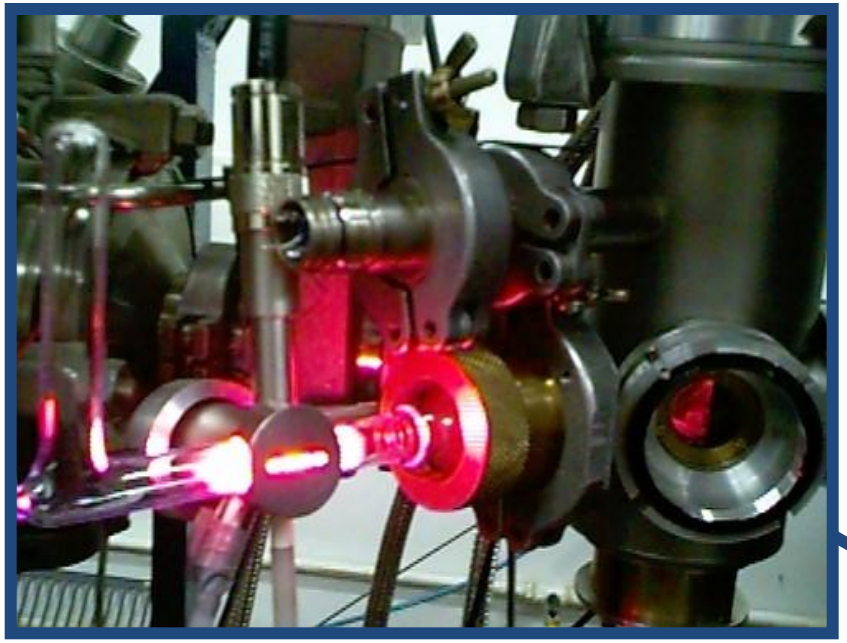
Analysis on the Organic Residues

- WORK STILL IN PROGRESS -

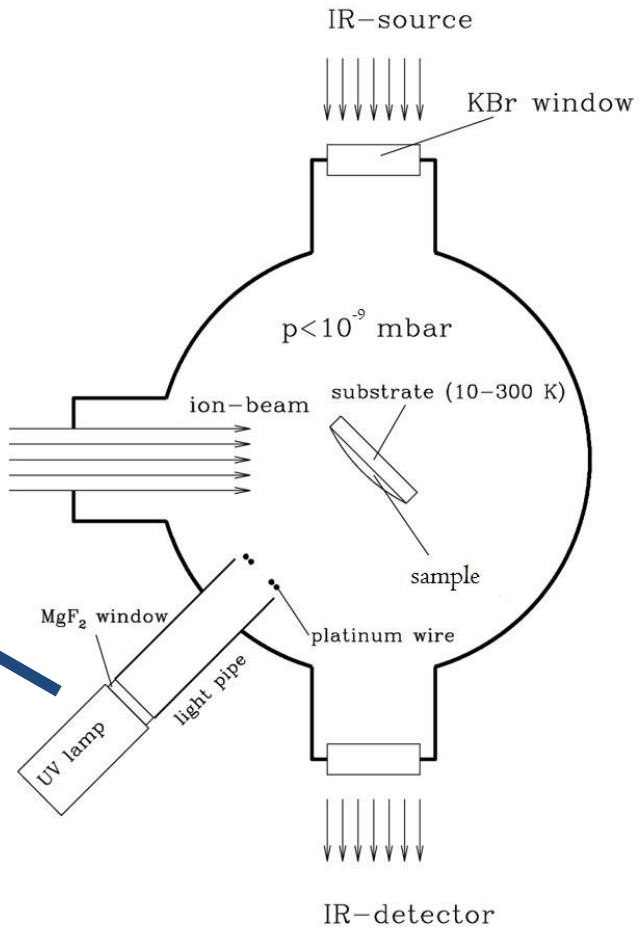
Contents:

• Laboratory UV irradiation of the refractory residues →

UV lamp already mounted. Ready to start!



10.2 eV Lyman-alpha photons



Analysis on the Organic Residues

- WORK STILL IN PROGRESS -

Contents:

• Laboratory UV irradiation of the refractory residues → **UV lamp already mounted. Ready to start!**

• Study the temporal evolution of the organic residues stored in our laboratory at room temperature and pressure → **A preliminary analysis is ready!**

↓

• Collection of several IR spectra in a time frame of about 600 days

• Investigation how the intensity of the bands naturally evolve over time

Analysis on the Organic Residues

- WORK STILL IN PROGRESS -

Contents:

• Laboratory UV irradiation of the refractory residues → **UV lamp already mounted. Ready to start!**

• Study the temporal evolution of the organic residues stored in our laboratory at room temperature and pressure → **A preliminary analysis is ready!**

• **Collection of several IR spectra in a time frame of about 600 days**

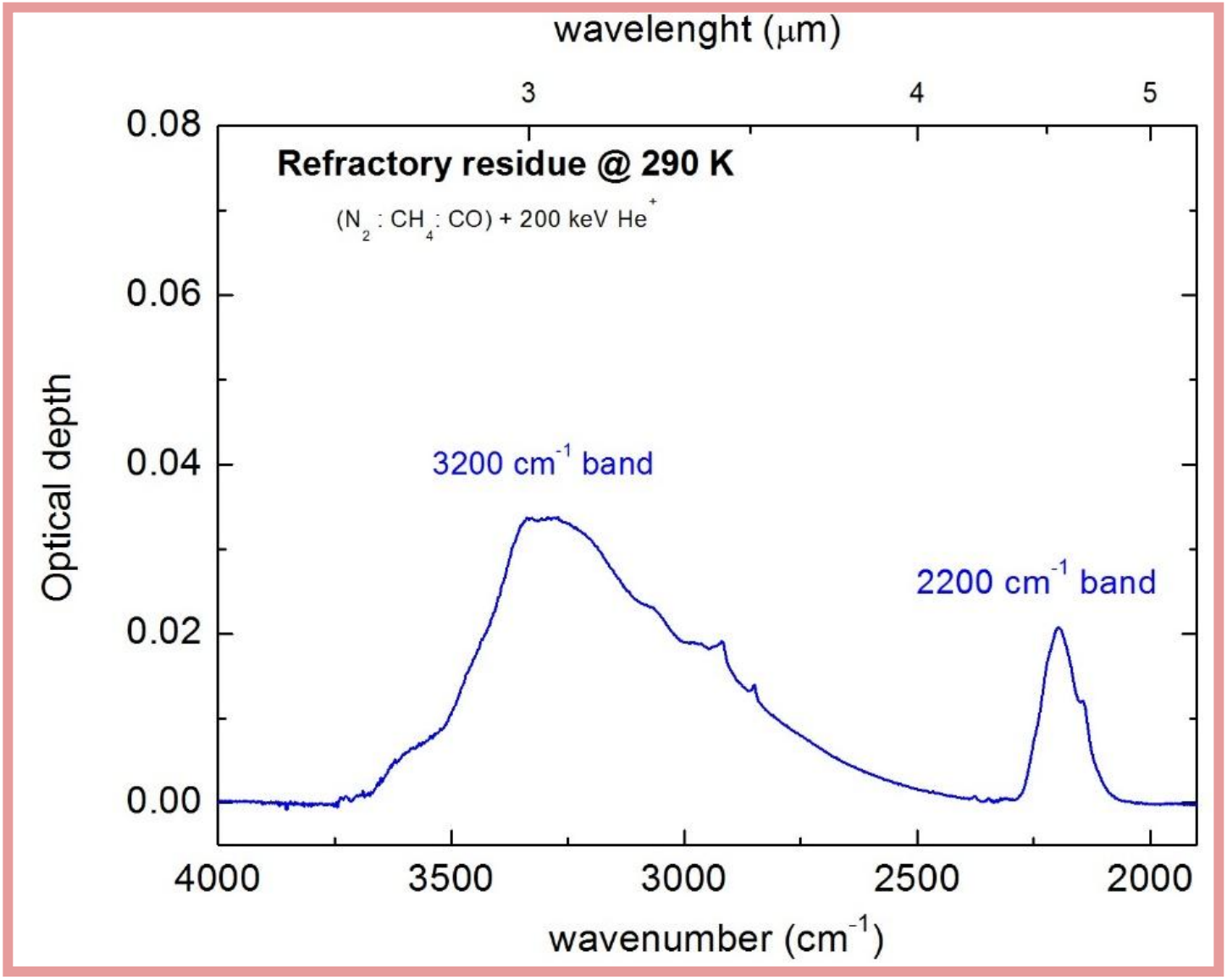
• **Investigation how the intensity of the bands naturally evolve over time**

IMPORTANCE

To disentangle the effects of the solar radiation from the natural degradation.

Temporal evolution of the Organic Residues

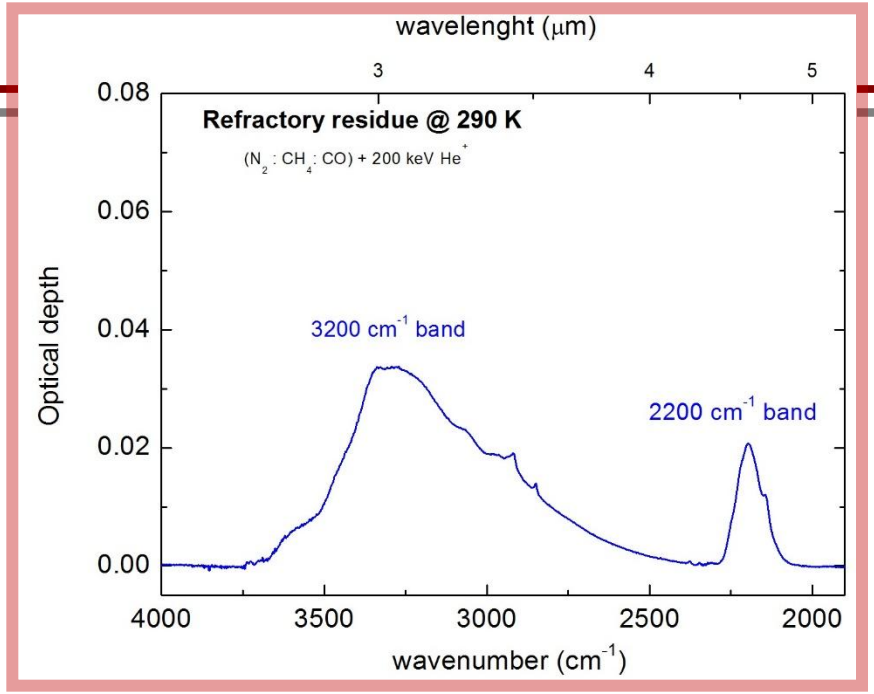
Contents:



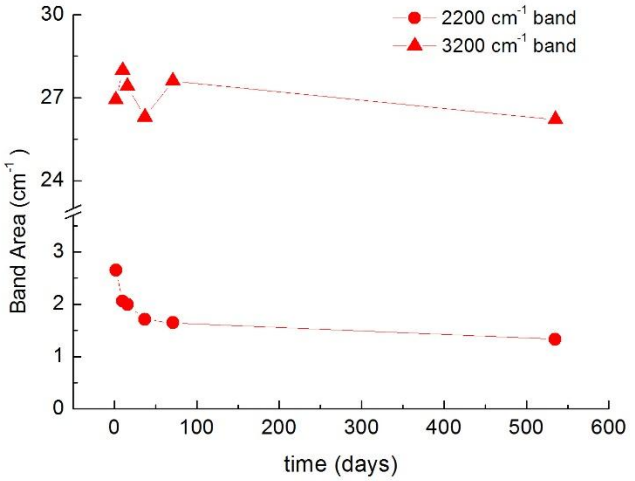
Temporal evolution of the Organic Residues

Contents:

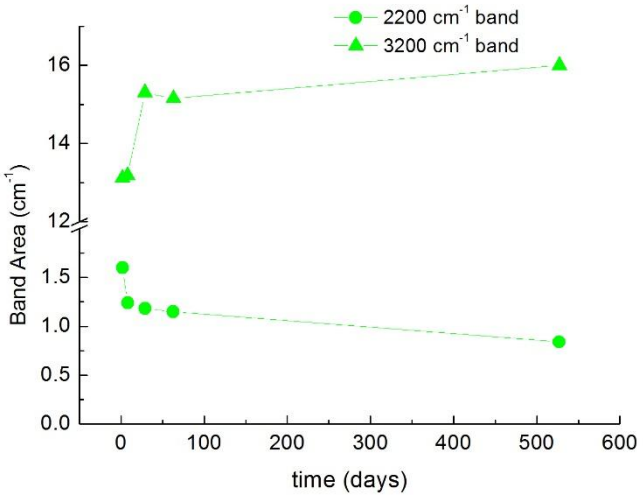
- ASTROPHYSICAL / ASTROBIOLOGICAL FRAMEWORK
- PSS EXPERIMENT
- PROCEDURE OF SAMPLE PREPARATION
- **ANALYSIS ON THE ORGANIC RESIDUES**
- STATE OF THE ART OF THE PSS EXPERIMENT



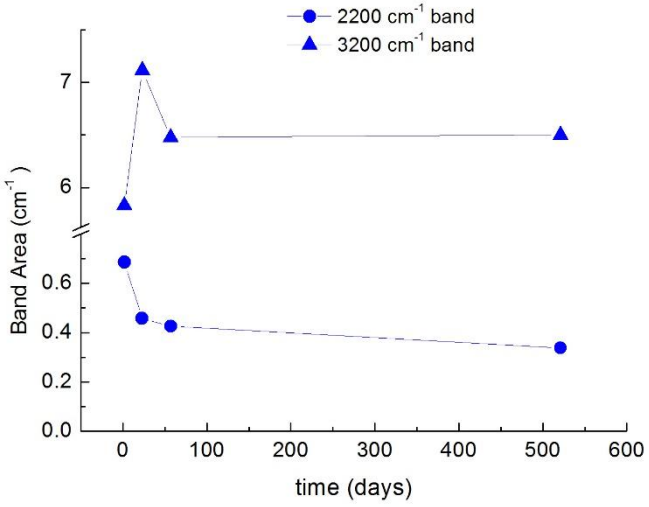
initial sample thickness: 190 nm



initial sample thickness: 130 nm



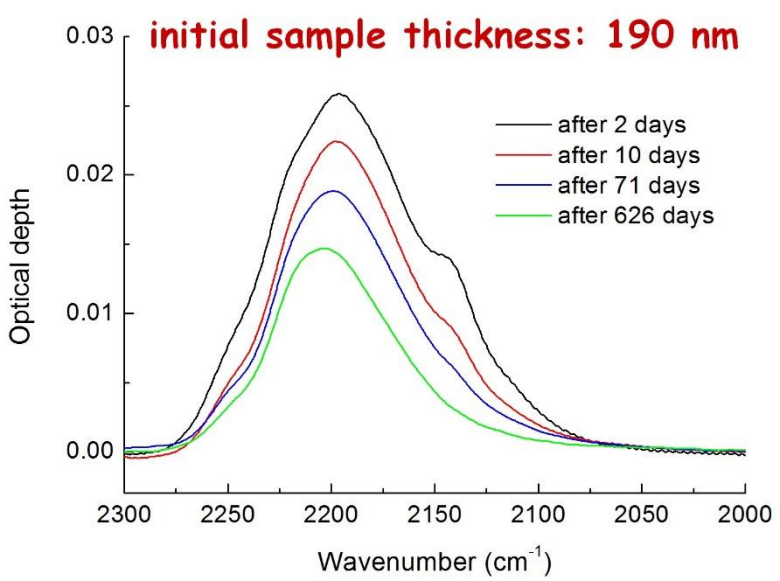
initial sample thickness: 65 nm

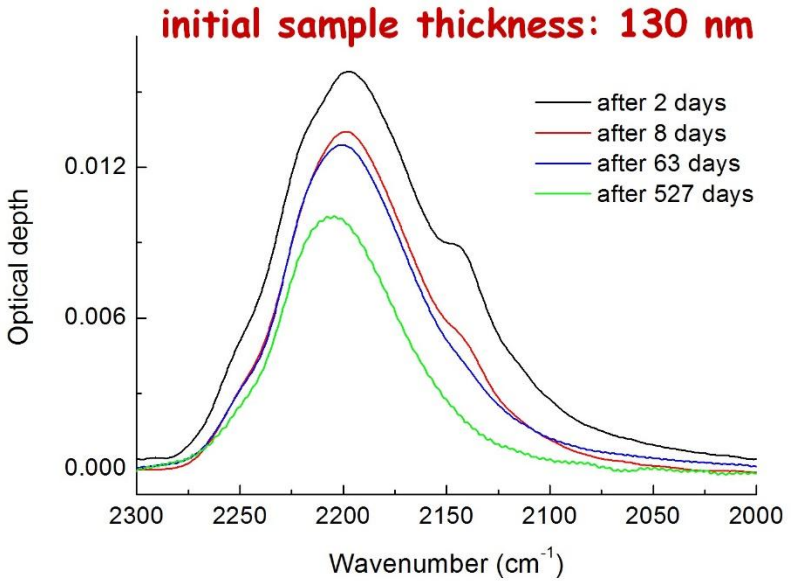


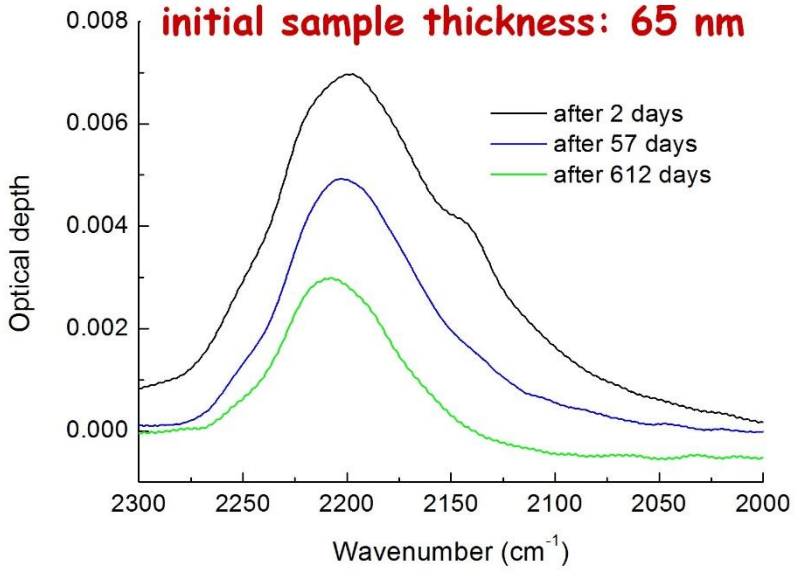
Temporal evolution of the Organic Residues

- multi-peaked band (2200 cm^{-1}) -

Contents:



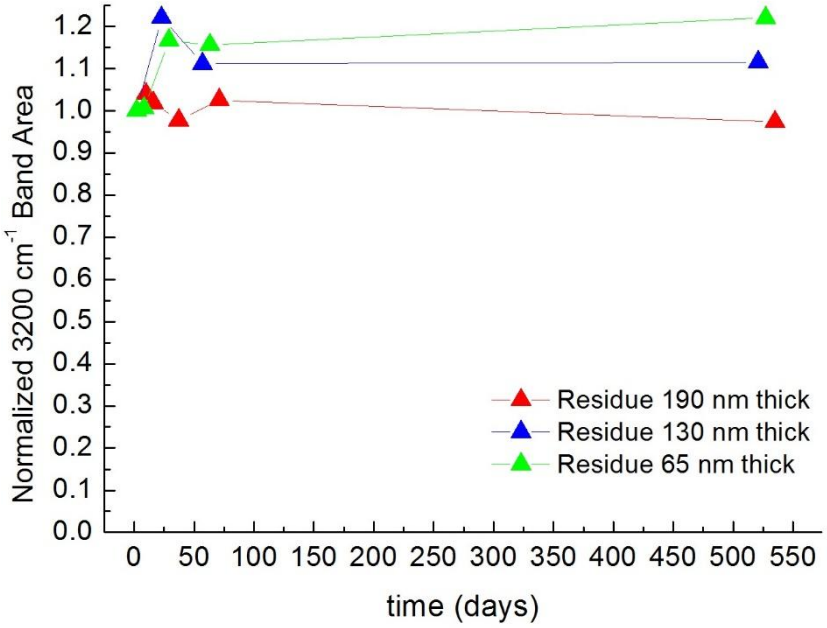




Temporal evolution of the Organic Residues

- 2200 cm^{-1} and 3200 cm^{-1} bands-

Contents:

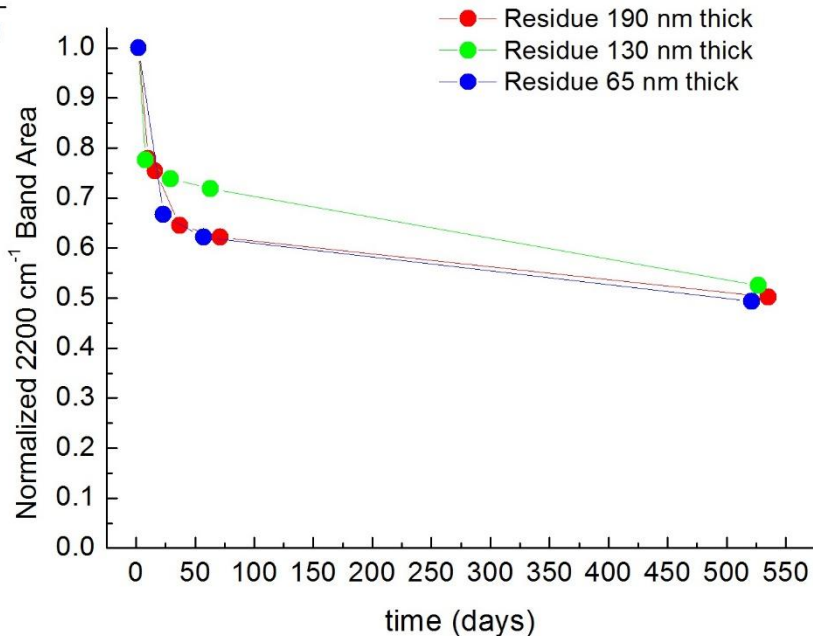


3200 cm^{-1} band:

only little variations over the time.
The intensity variations do not show a clear trend.

2200 cm^{-1} band:

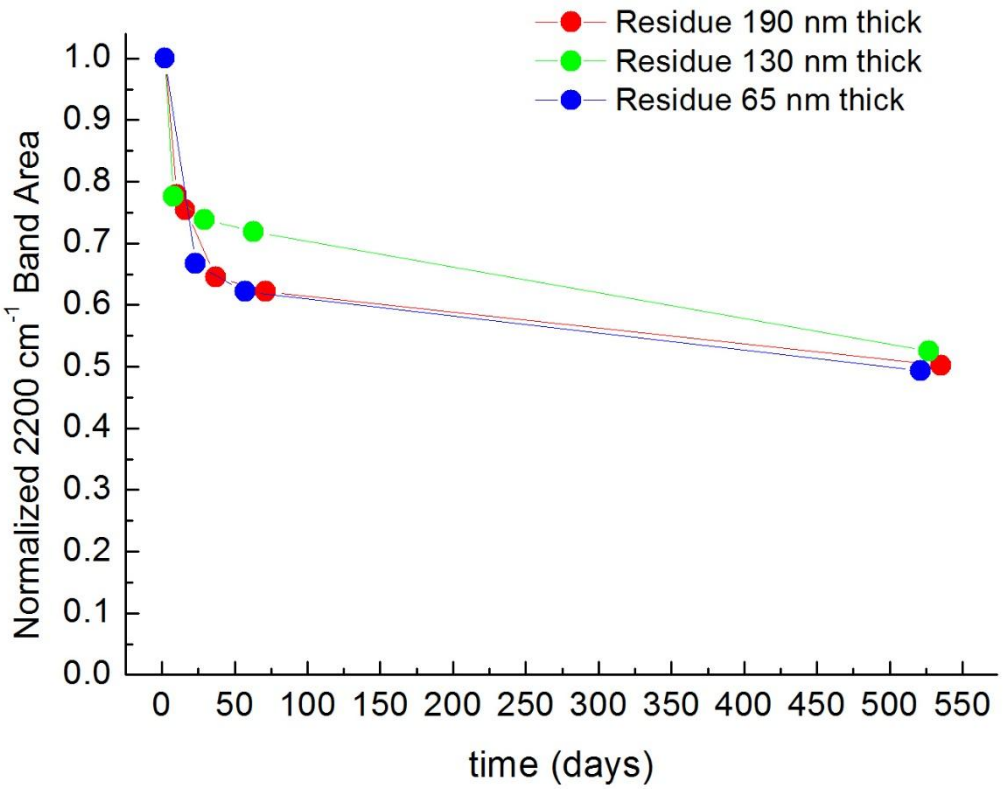
clear, gradual reduction in intensity over time.



Temporal evolution of the Organic Residues

- multi-peaked band (2200 cm^{-1}) -

Contents:



For all the sample thickness, the 2200 cm^{-1} band decays over time. However, we need further data to conclude if :

- **the band is going to become stable**

OR

- **the band is going to disappear**

Take-home message

- **Our organic samples are flying on bord to the ISS since July 2014 and they will come back on March 2016**
- **We are ready to begin the UV irradiation of the refractory residues in our laboratory**
- **We need to collect further spectra to conclude if the 2200 cm^{-1} band naturally disappears over the time or not**
- **In any case, the other bands in our refractory samples do not show natural degradation over time**
- **We have planned to study the temporal evolution of our samples storing them at lower temperature (~70 K)**

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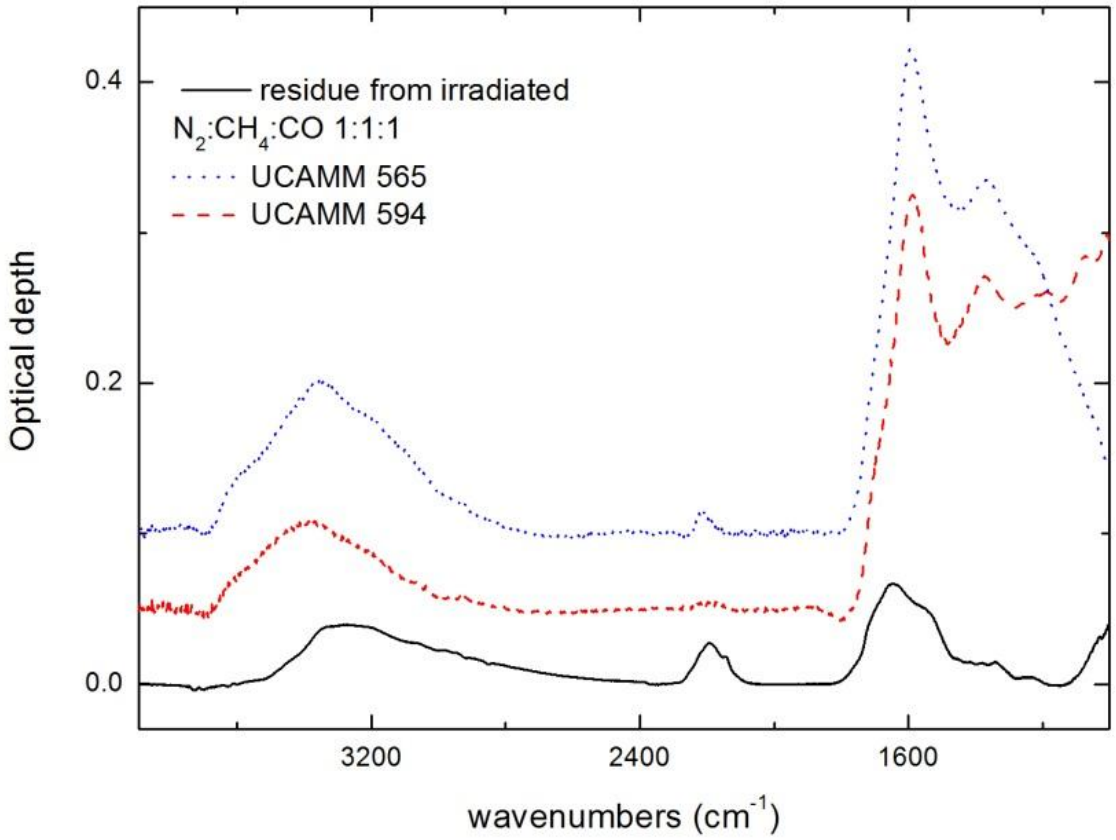
Thank you for your attention!

Goal of the experiment

To better clarify the goal of the experiment, we show a comparison of the IR spectra of one of our residue with those of two ultracarbonaceous Antarctic meteorites (Dartois et al.,2013) thought to have been originated in the outer solar system



No fit, but similar bands!

Photochemistry on the Space Station (PSS) Experiment

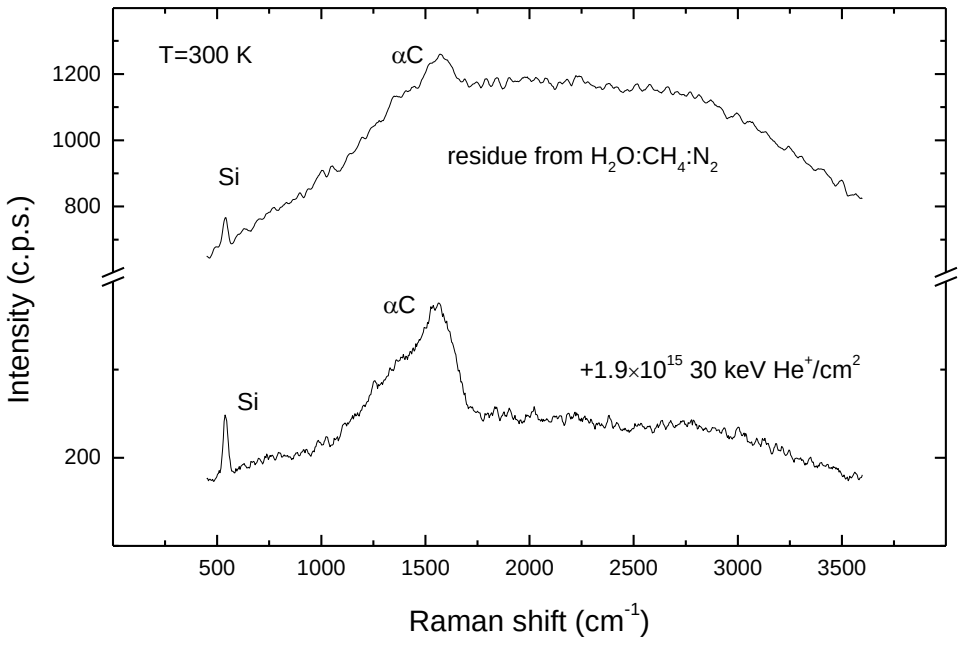
Contribution of the LASp – Catania:

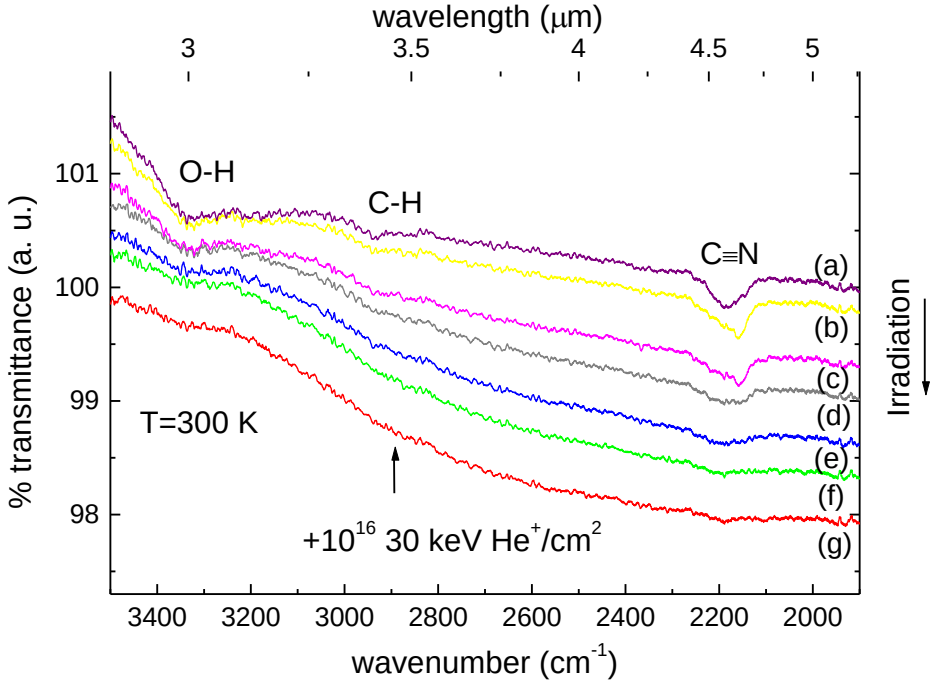
#10 190 nm thick
#10 130 nm thick
#10 65 nm thick

} **30 organic samples on MgF_2 windows**

We already investigated (in the laboratory) the effects of the ion irradiation on the organic residues: the intensity of all infrared absorption features decreases.

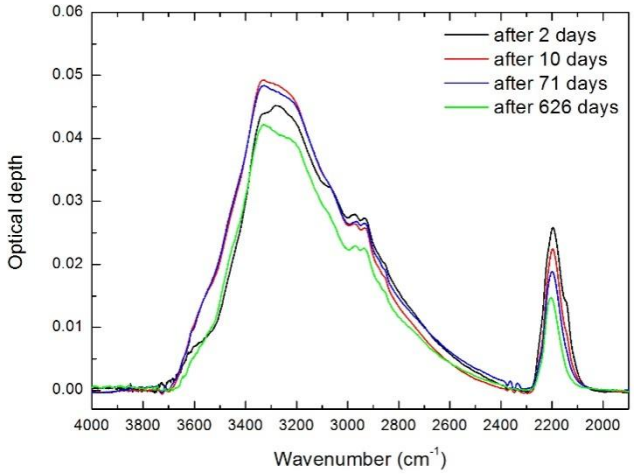
Raman spectroscopy shows that ion irradiation causes a modification of the structure of the samples which evolve towards an amorphous carbon. (Palumbo et al, 2004)



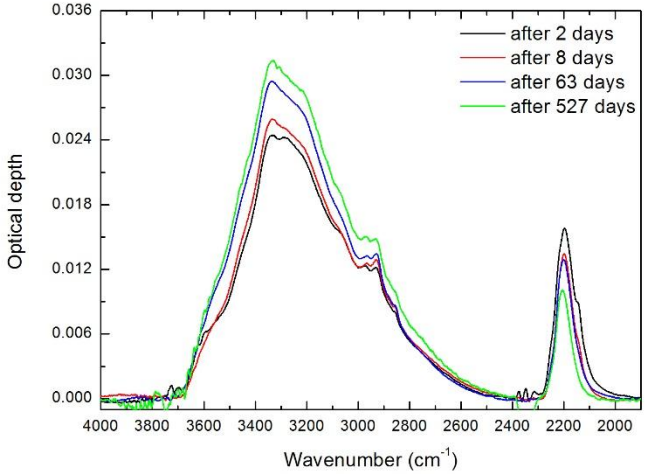


Temporal evolution of the Organic Residues

initial sample thickness: 190 nm



initial sample thickness: 130 nm



initial sample thickness: 65 nm