

INTERNATIONAL SYMPOSIUM AND WORKSHOP ON ASTROCHEMISTRY

Understanding extraterrestrial molecular complexity
through experiments, observations and models

JULY 3rd – 8th, 2016
CAMPINAS, SP, BRAZIL

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Triggering photochemical processes in frozen extraterrestrial worlds by soft X-rays

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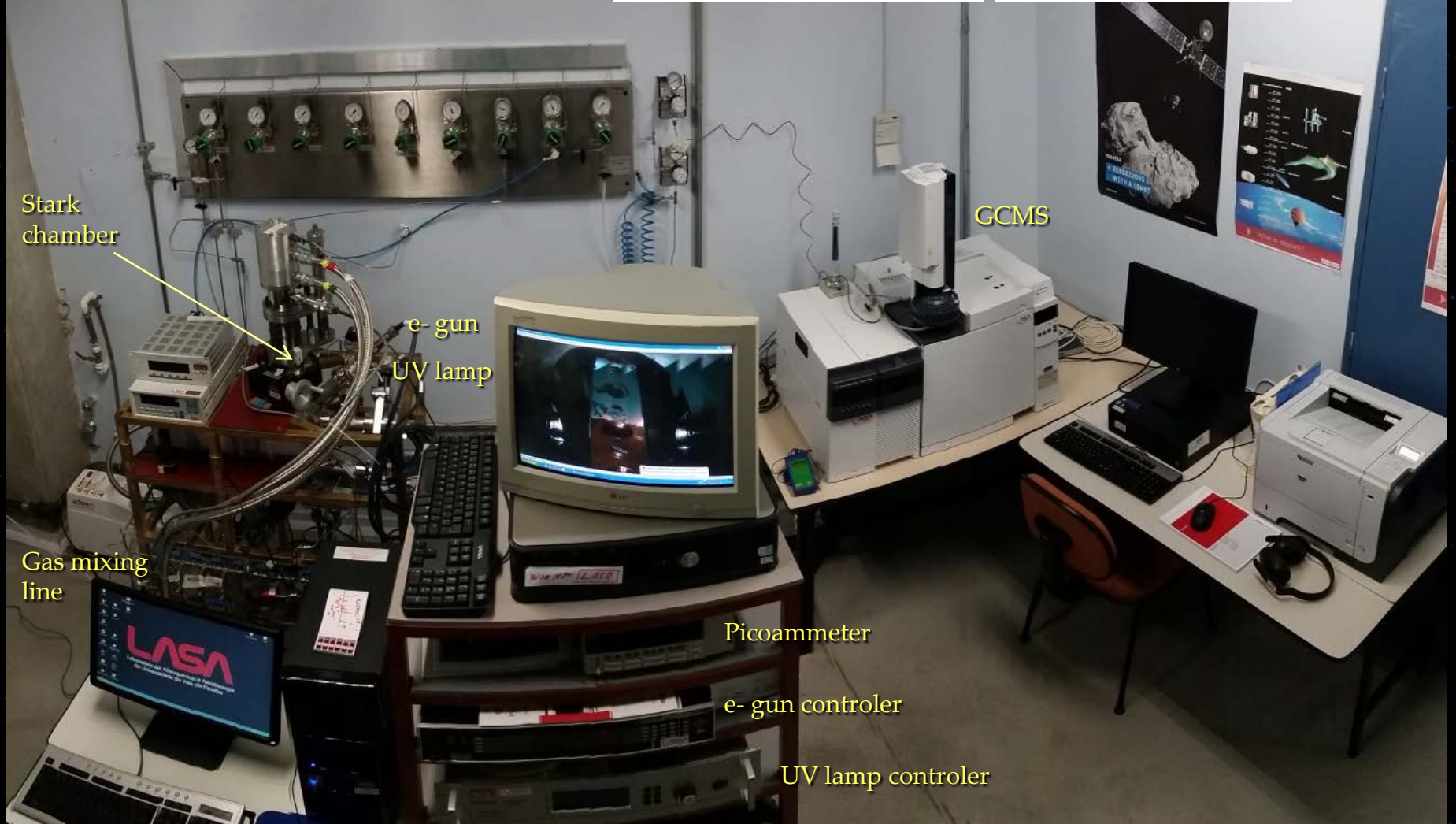
- 39 undergrad Courses (4000 students)
- 3 PhD programs
(Physics and Astronomy; CAPES N4)
- 6 Master programs
- 23 Lato-Sensu programs



Research Institute (IP&D)



The Lab



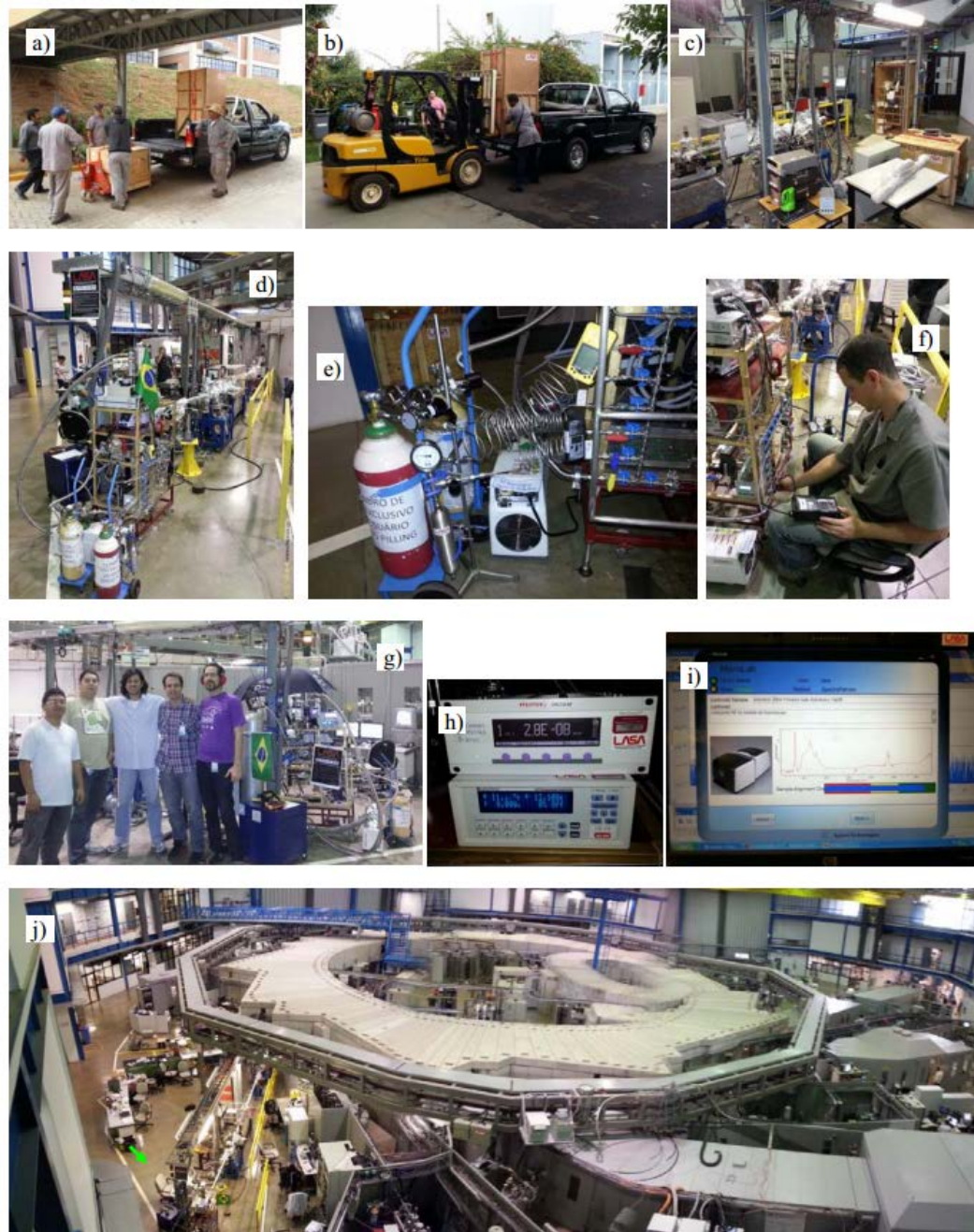
Sponsors and acknowledgments:

The experiment

Goal: Solar System frozen moons
(Titan, Europa, Enceladus)

Technique: UHV, FTIR, QMS.

The measurements were performed inside a high vacuum chamber (Stark) from the Astrochemistry and Astrobiology Univap's labs (LASA) coupled to SGM beamline at the Brazilian Synchrotron light Source LNLS/CNPEM.



Legenda: a) Acondicionamento da câmara STARK para seu transporte para realização de experimentos no LNLS em Campinas, SP; b) Chegada dos equipamentos no LNLS; c) Desempacotamento da câmara STARK dentro do Hall experimental do LNLS; d) Câmara STARK montada na linha SGM do LNLS pronta para início dos experimentos; e) Cilindros de amostras e detectores de gases do LASA acoplados a câmara STARK; f) Teste da linha de gás da câmara STARK; g) Equipe do LASA realizando os experimentos no LNLS; h) Eletrônica dos controladores de pressão e temperatura da câmara

The gas samples were deposited onto a ZnSe substrate at 13 K and then heated (when was the case) to specific temperatures to be irradiated. *In-situ* analysis were performed by a Fourier transform infrared (FTIR) spectrometer at different photon fluences. Cross section, photolysis yield and half-lives of the produced species were quantified.

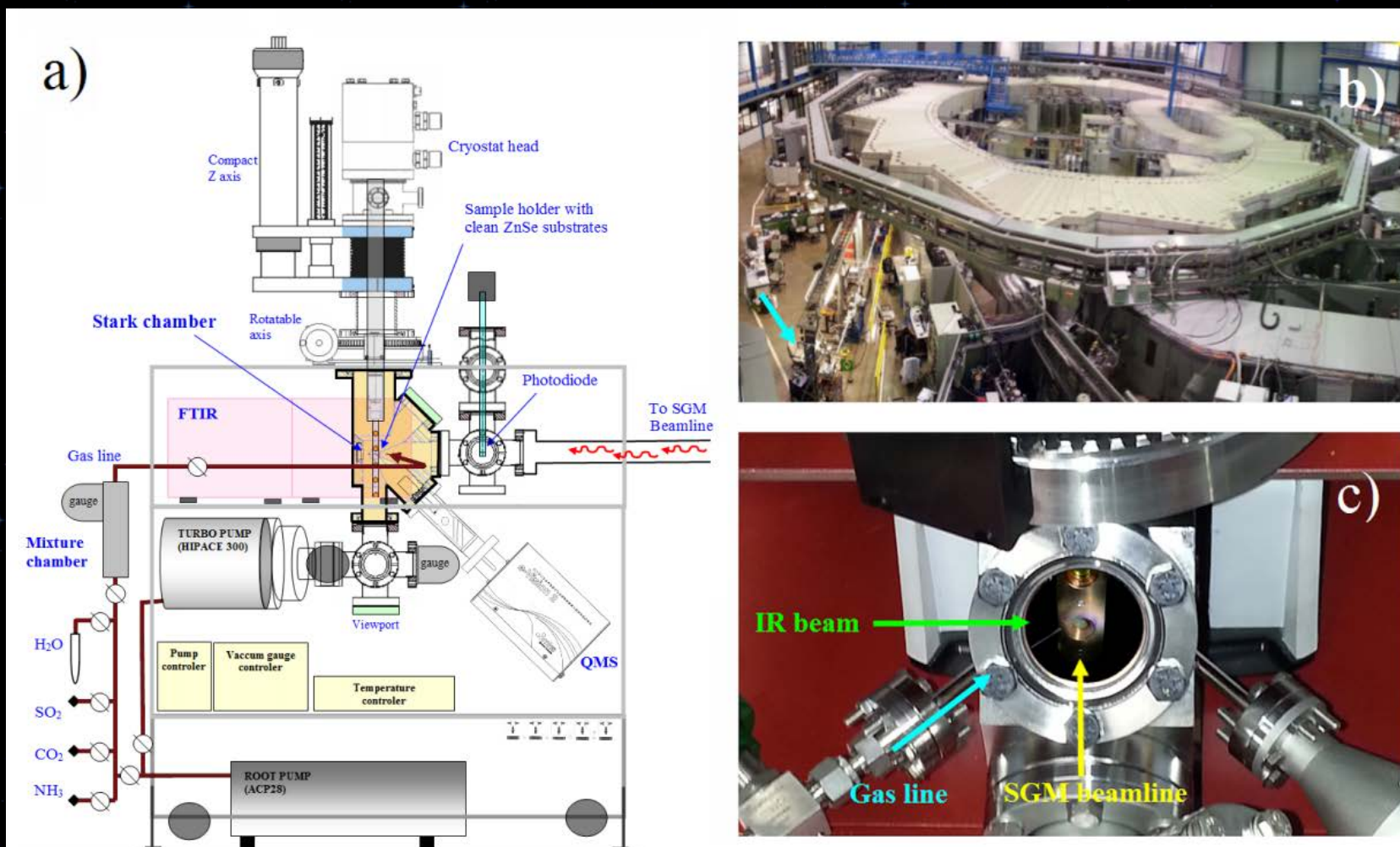
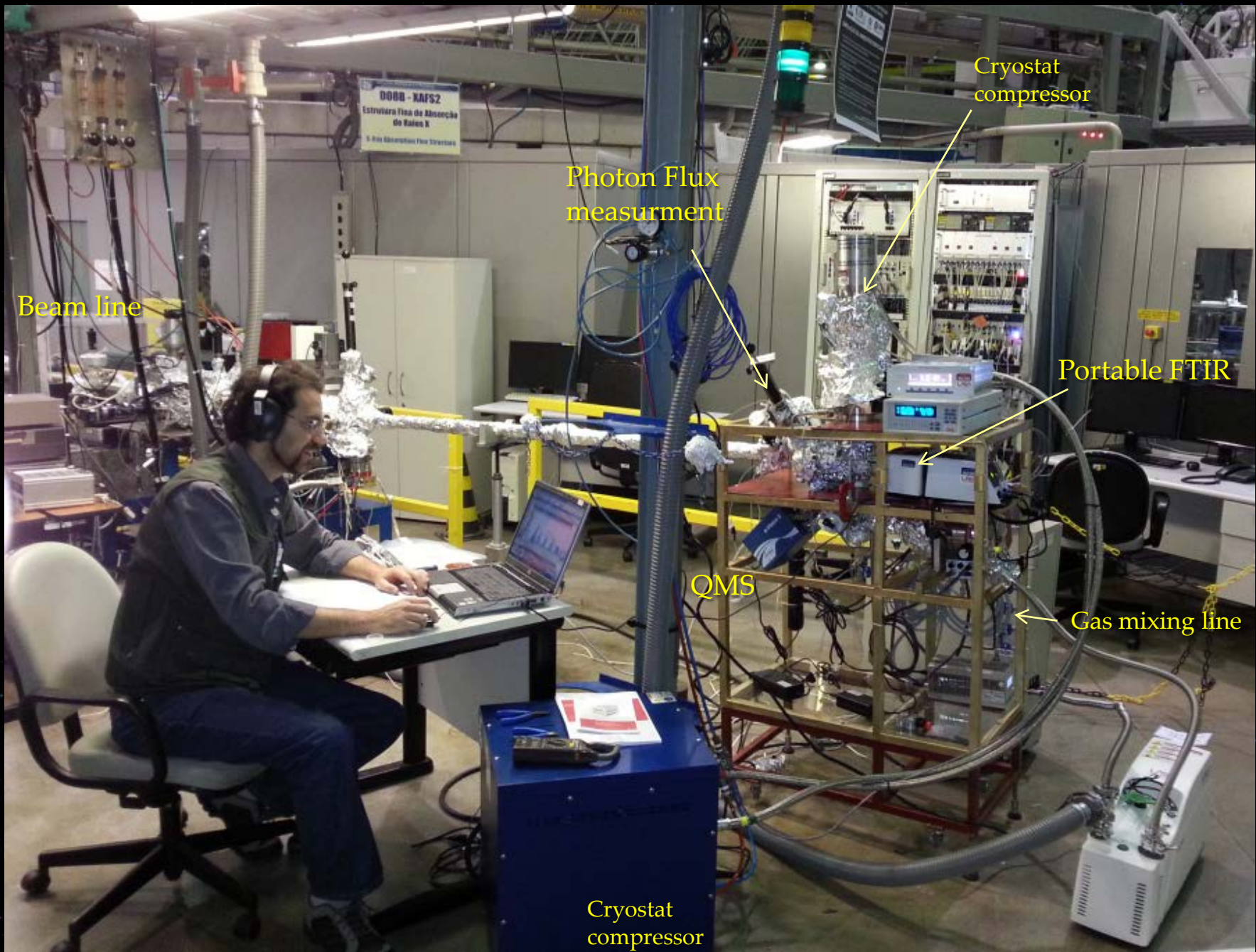


Figure 1. a) Diagram of the experimental setup (Stark chamber). b) Picture of the experimental hall of the Brazilian synchrotron source (LNLS) with the experimental chamber coupled at the SGM beam line (arrow). c) Picture showing the Europa surface analog inside the chamber ready to be irradiated by synchrotron light.



Beam line

Photon Flux
measurement

Cryostat
compressor

Portable FTIR

OMS

Gas mixing line

Cryostat
compressor

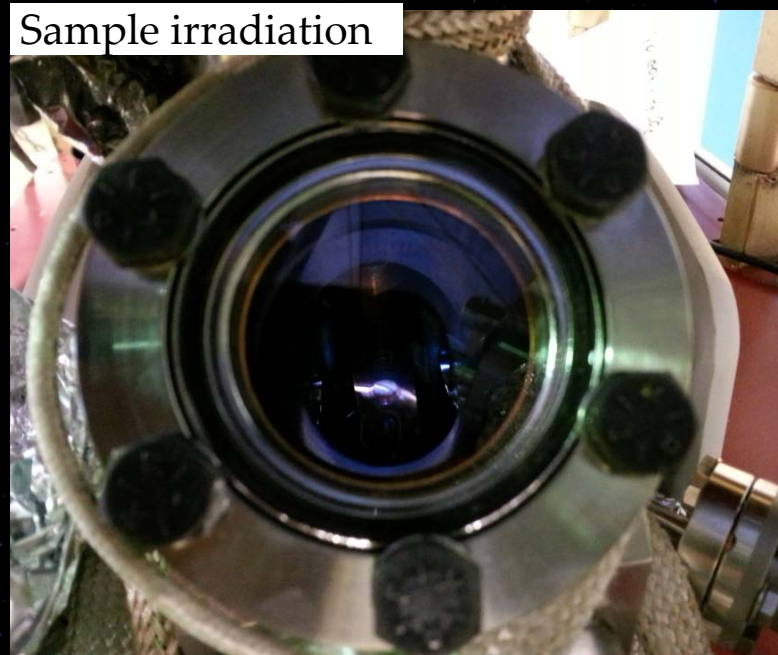
SGM beamline with Stark chamber coupled



Sample preparation



Sample irradiation



Gas mixing line

Heater controller

The simulated objects

Titan

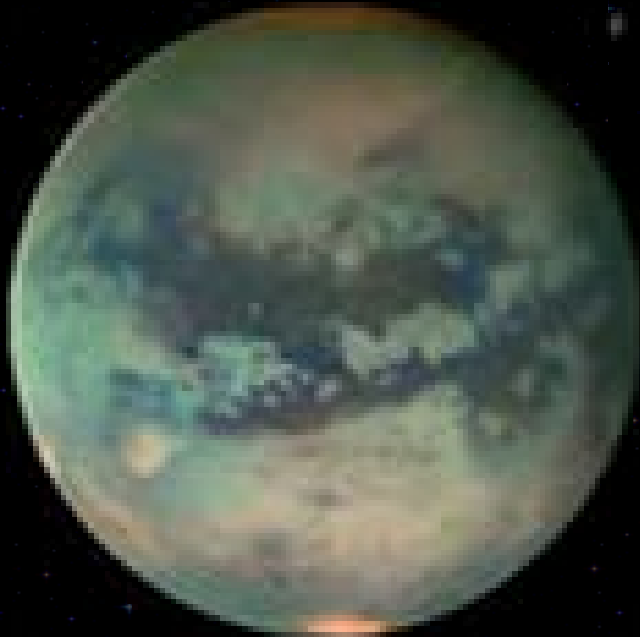
Aerosols (upper atmosphere)

$\text{N}_2:\text{CH}_4$ (19:1)

Produced at 12K

Irradiated at 12K

Fredson's PhD thesis.



Enceladus

Surface (Equator 80K, Pole 20K)

$\text{H}_2\text{O}:\text{CO}_2:\text{CH}_4:\text{NH}_3$ (10:1:1:1)

Produced at 12K

Irradiated at 50 e 80 K

Bergantini's PhD Thesis.



Europa

Surface (Equator 90K, Pole 50K)

$\text{H}_2\text{O}:\text{CO}_2:\text{NH}_3:\text{SO}_2$ (10:1:1:1)

Produced at 12K

Irradiated at 50 e 90 K

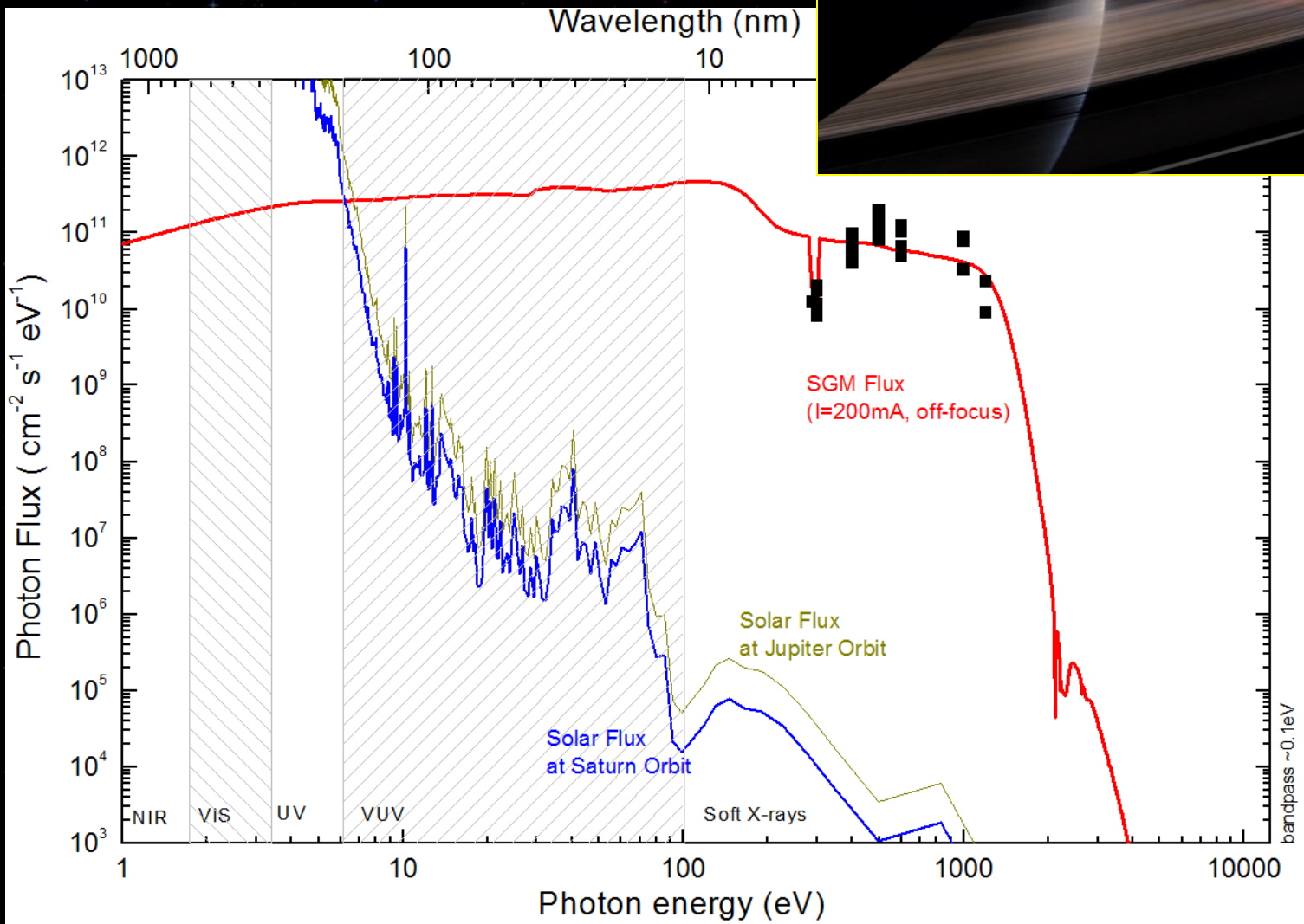
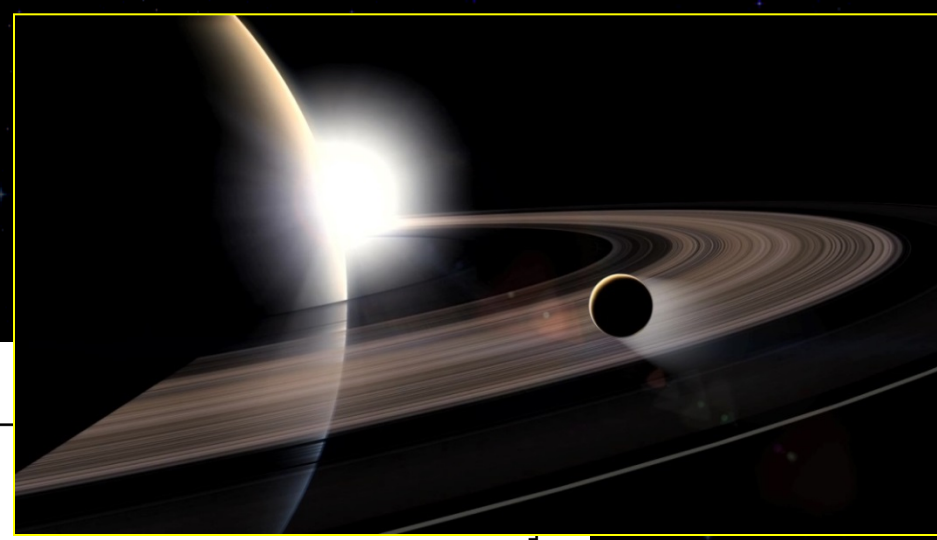
Pilling et al 2015, APJ.



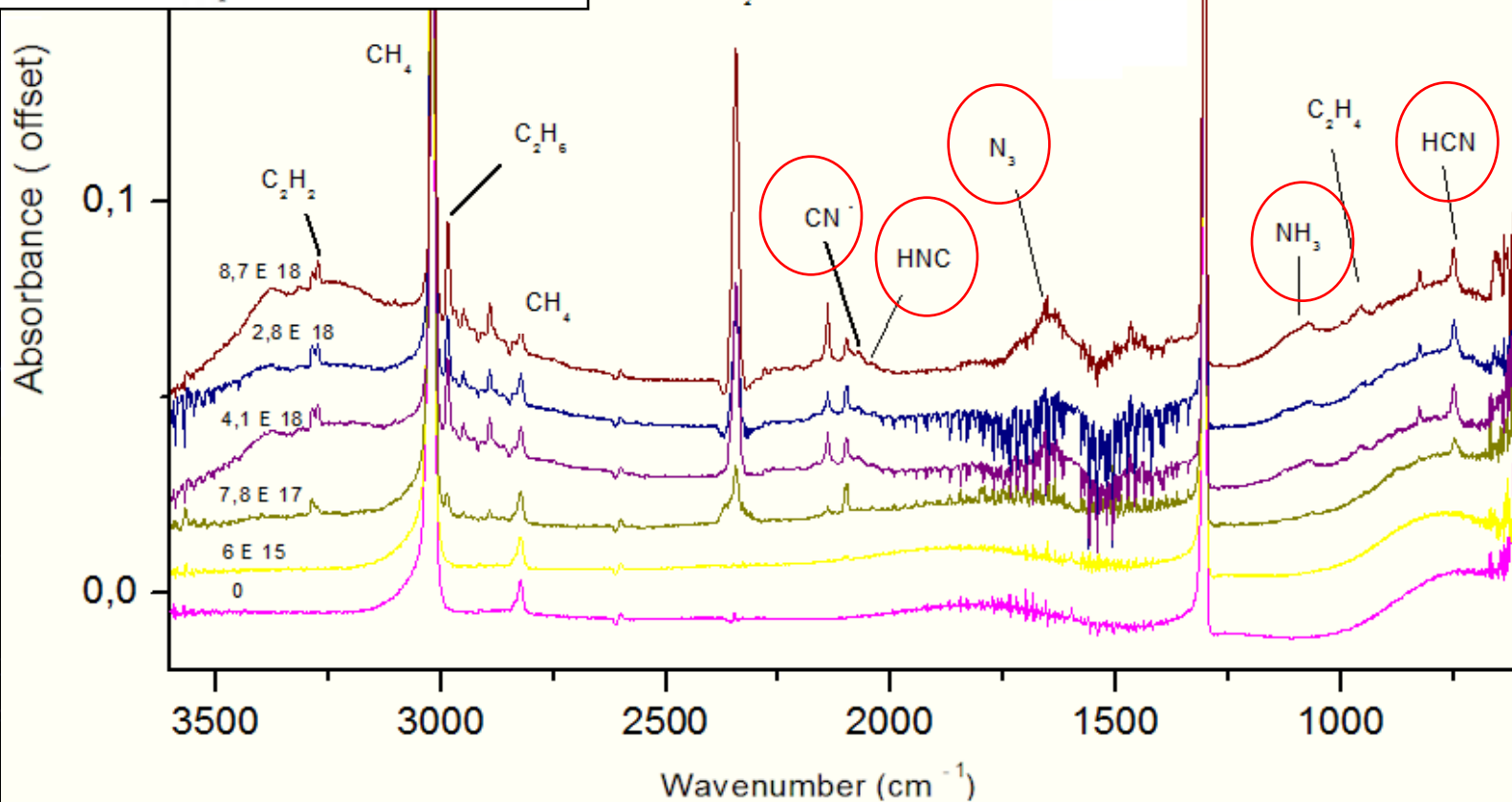
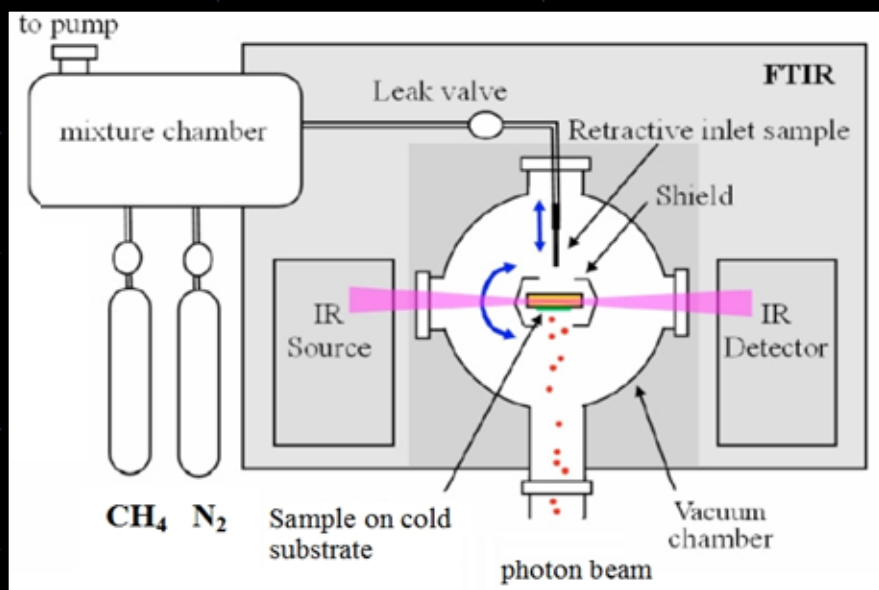
The radiation field

Flux (6-2000 eV) $\sim 1 \times 10^{14}$ photons $\text{cm}^{-2} \text{s}^{-1}$

Sample of Energy delivered :
1 min (SMG) \sim 6 days (Jupiter) \sim 40 days (Saturn)



Selected results: Titan (aerosol)



Highlight: Adenine production in Titan aerosol analogs by X-rays

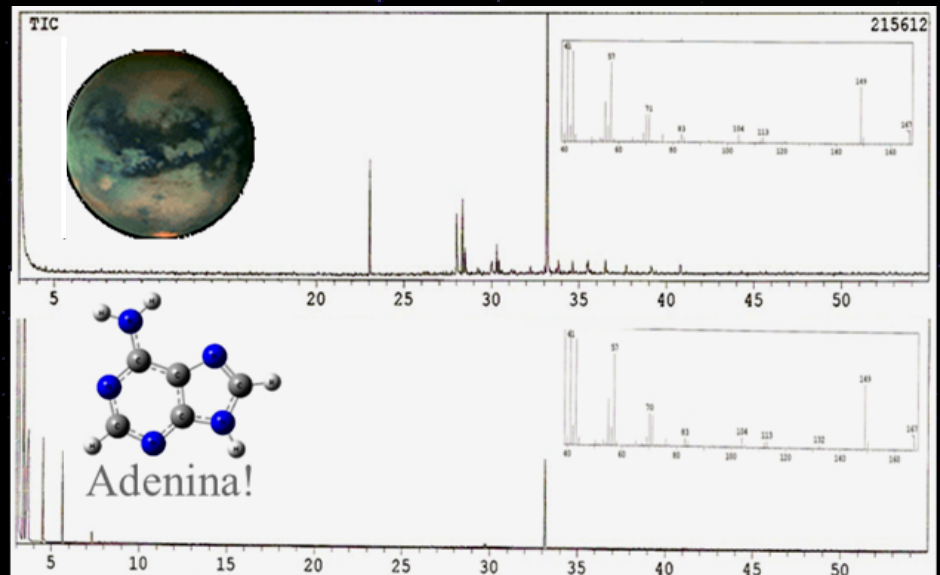
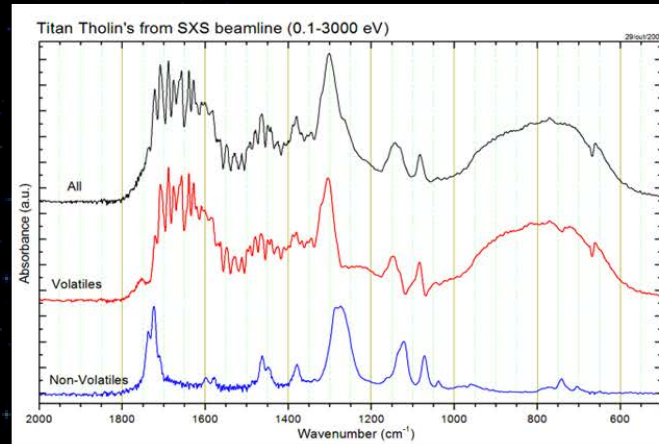
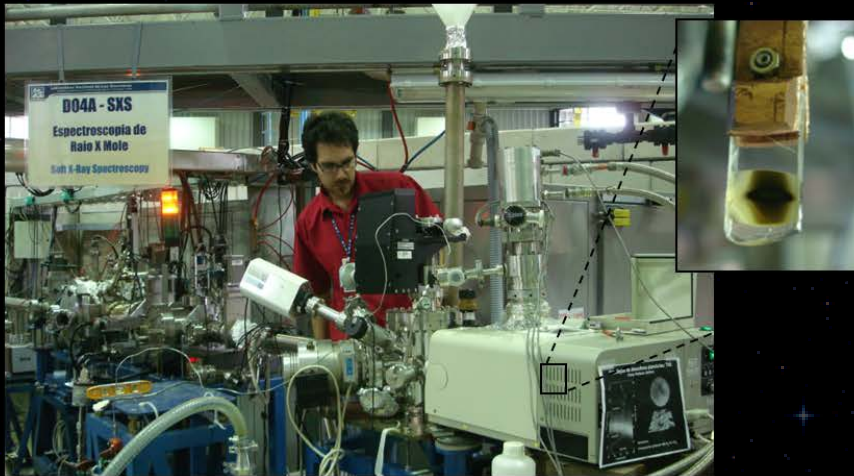
LNLS, SXS Beamline (White beam. 0.1-3 keV)

~ 72h exposure time

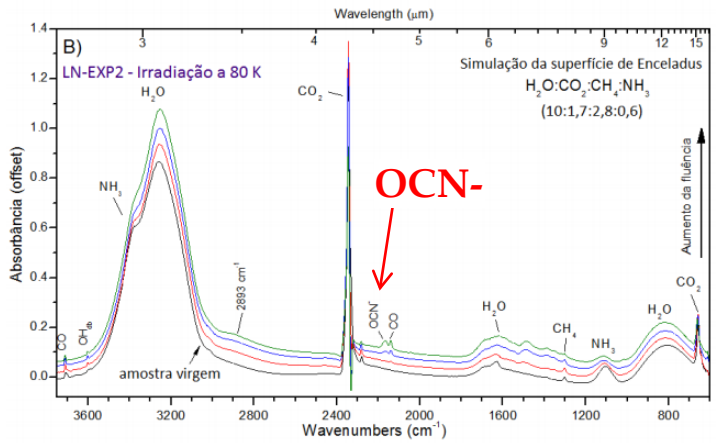
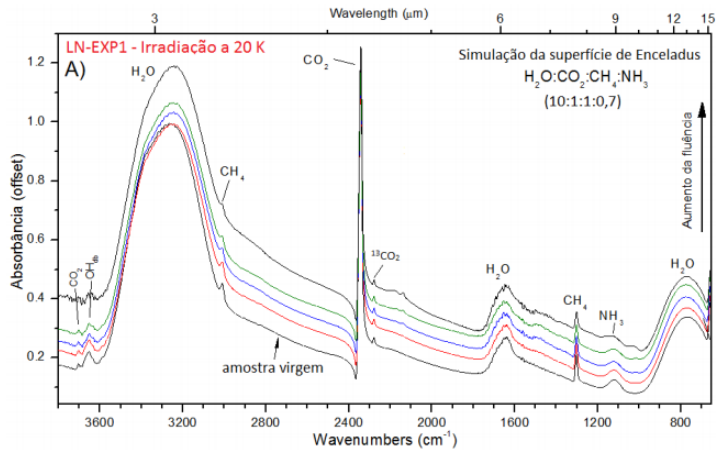
Sample: N₂:CH₄ (19:1) at 10 K

Analysis: FTIR and QMS in-situ;
RMN and GCMS ex-situ.

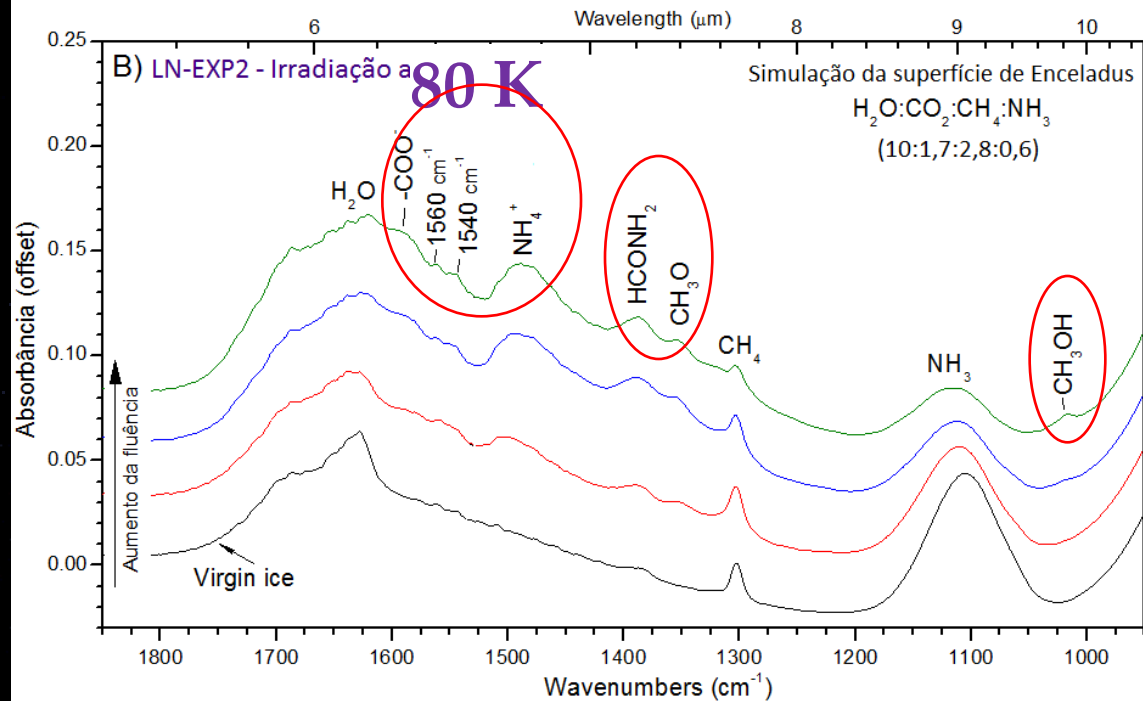
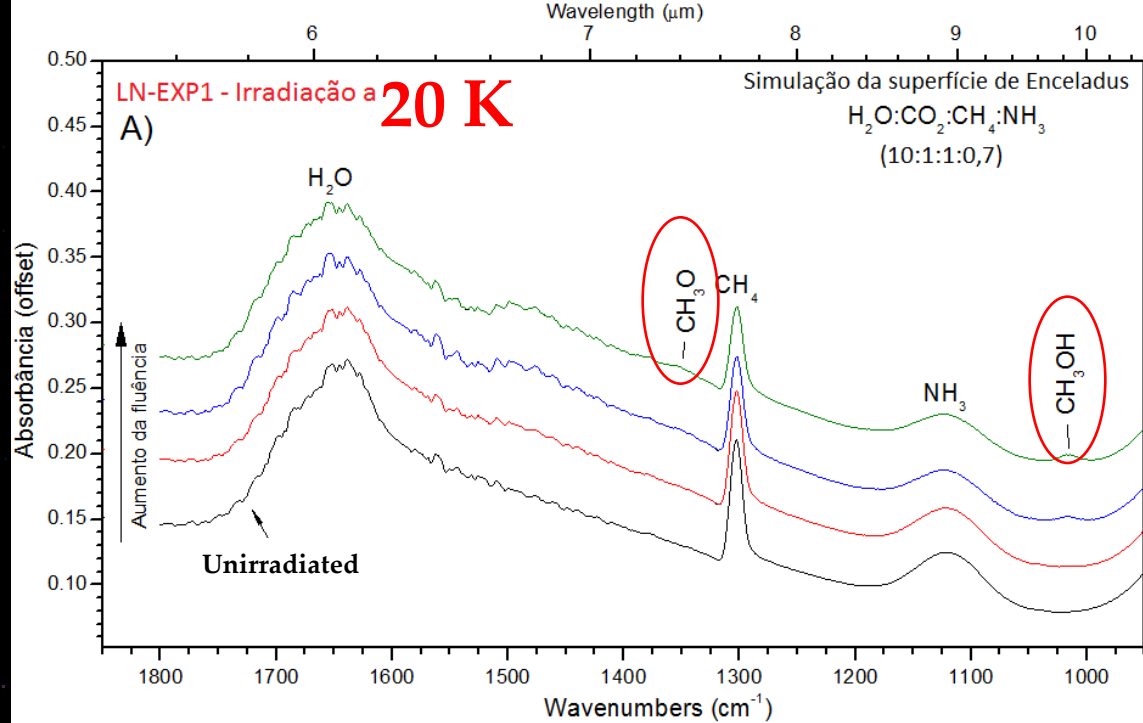
Adenine formation mainly via secondary electrons!



Selected results: Enceladus

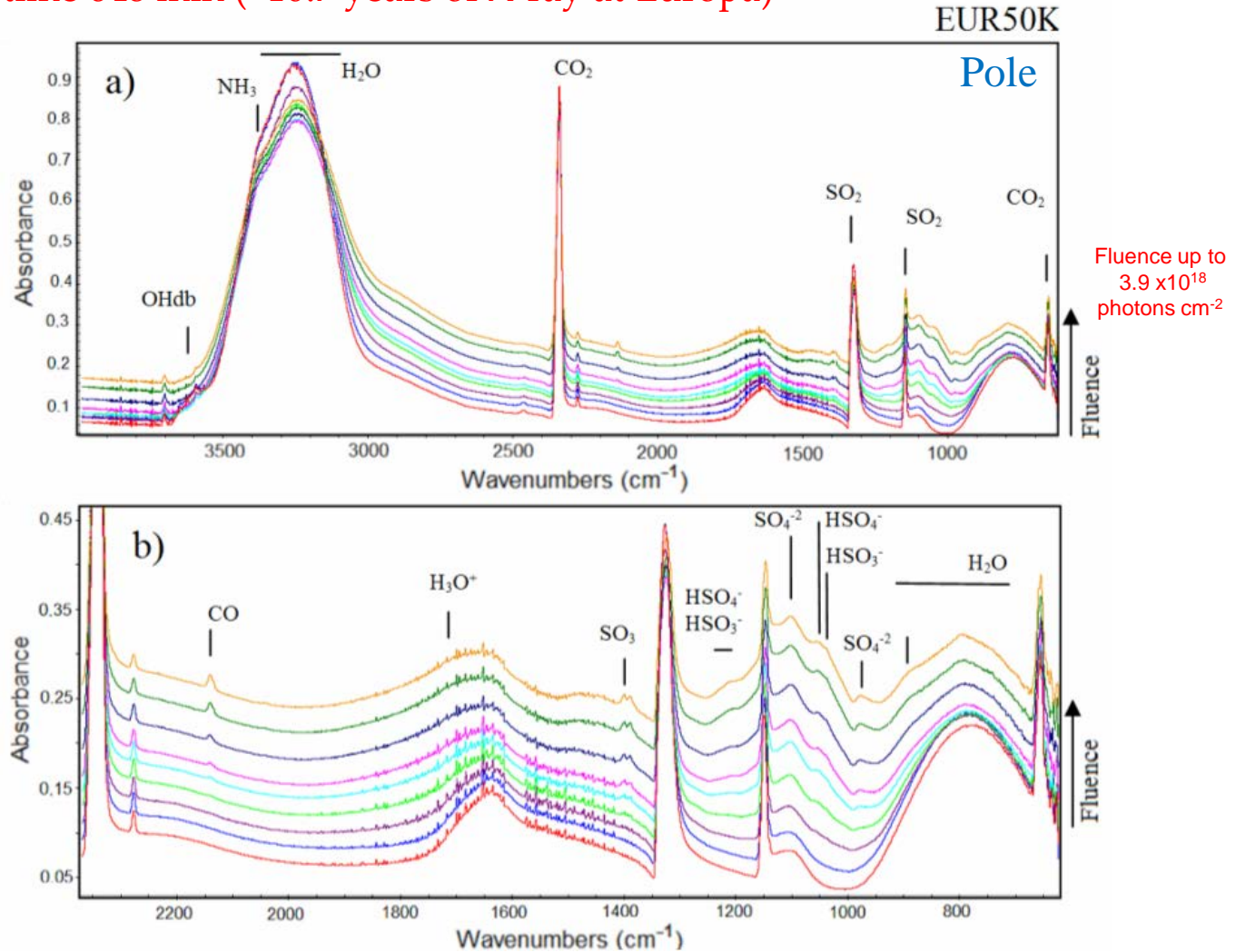


Pilling and Bergantini, APJ, in preparation.



Selected results: Europa

Total time 648 min (~10.7 years of X-ray at Europa)



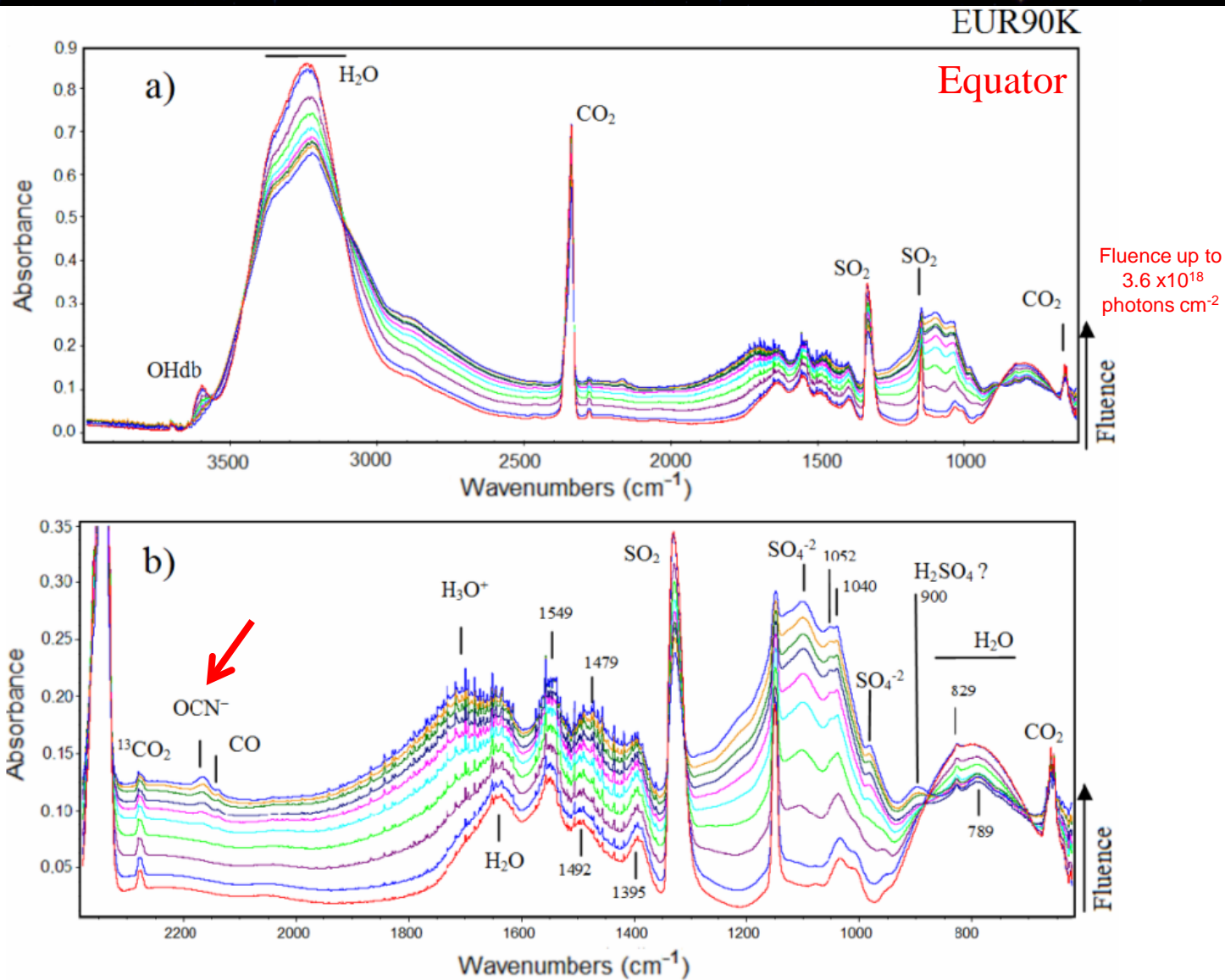
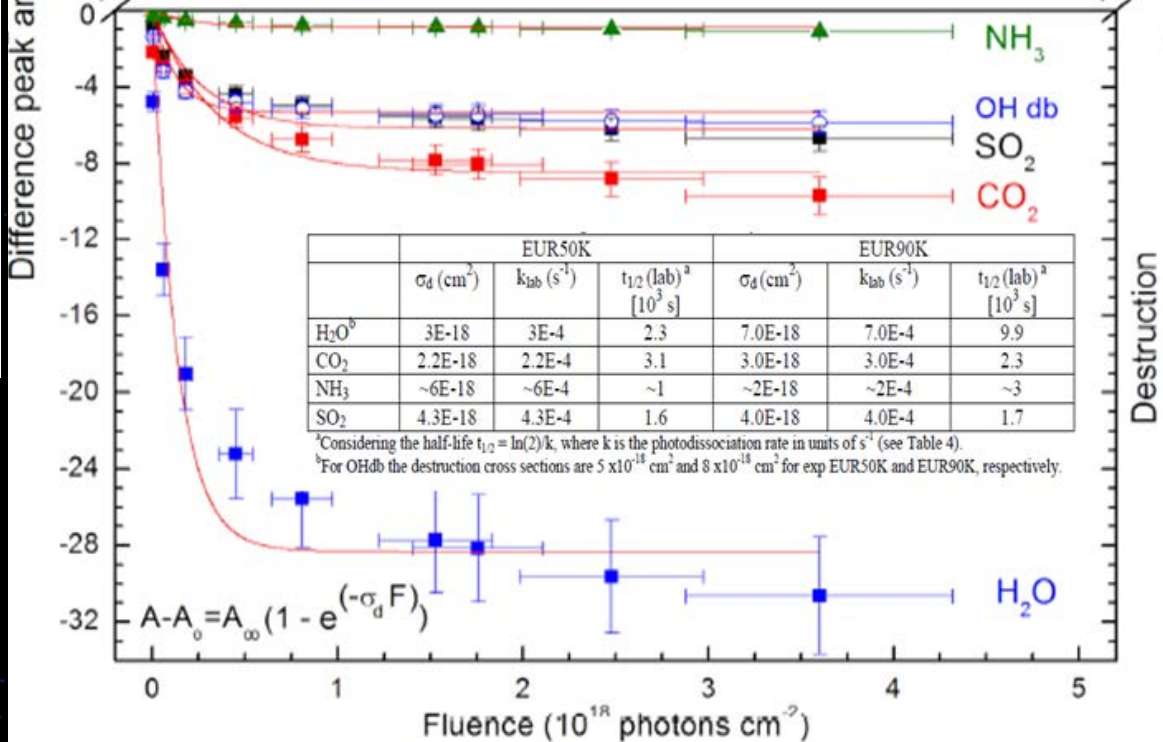
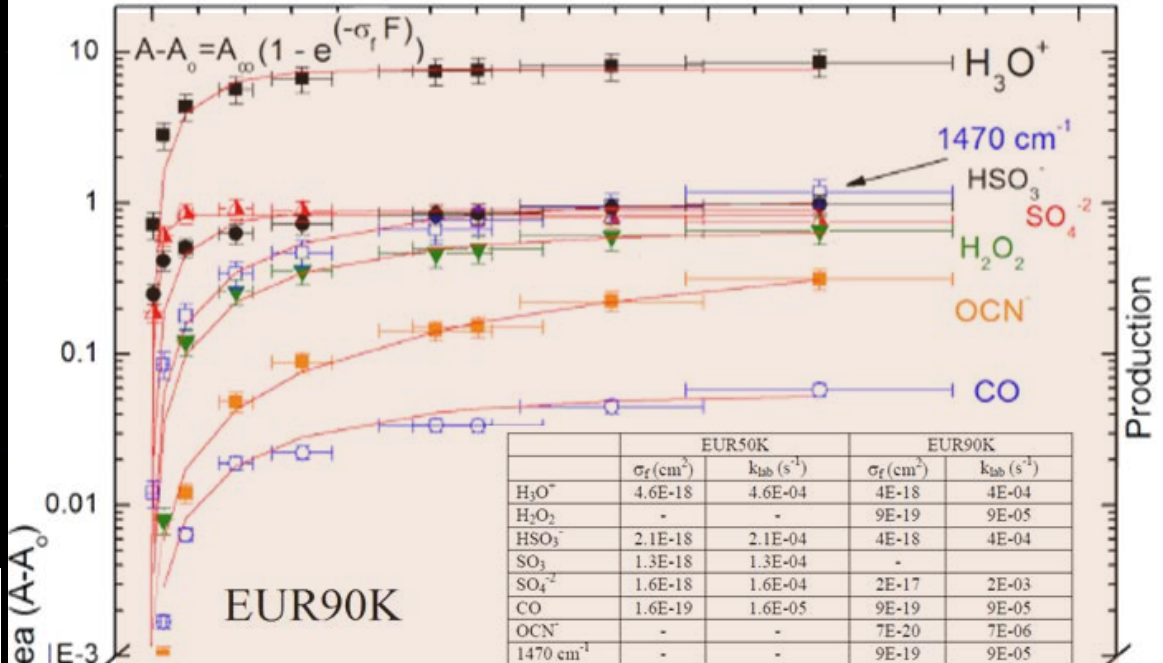
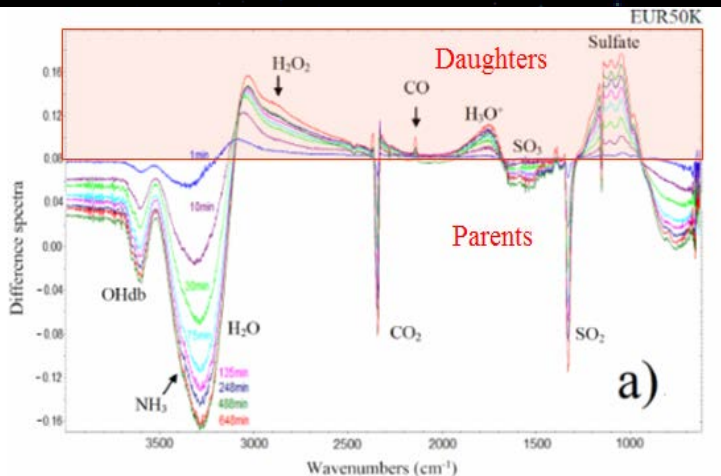


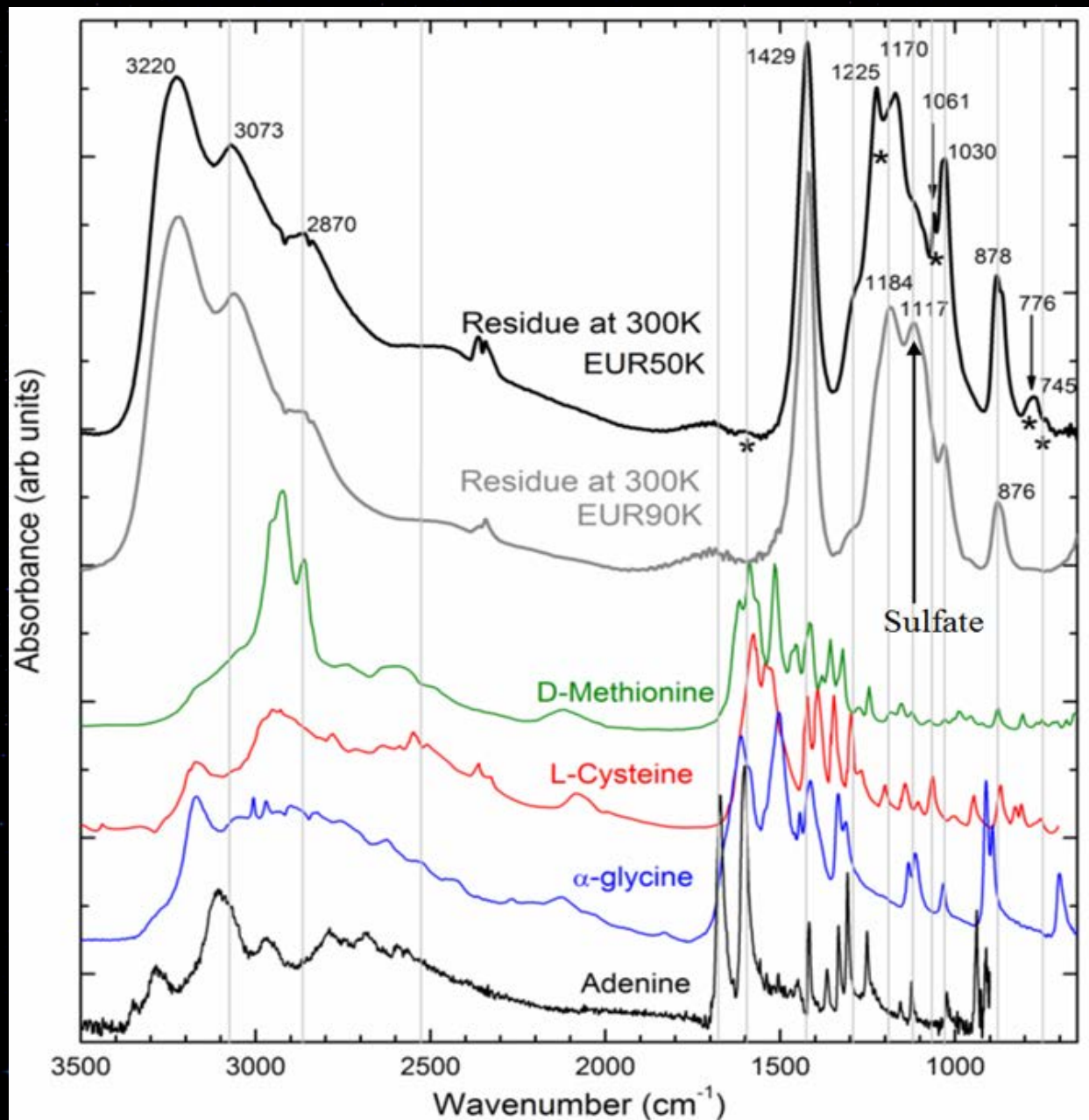
Figure 6 - a) Evolution of infrared spectrum of Europa analog at 90 K (equatorial regions) during the irradiation employing VUV and soft X-rays. The bottom spectrum is the unirradiated ice and the uppermost spectrum is the one obtained at the highest photon fluence. b) Expanded view from 2380 to 610 cm⁻¹. Each spectrum has an offset for better visualization.

Absolute formation and dissociation cross sections

Photodissociation rates and half lives



Tentative identifications by FTIR of biomolecules in the residues after heating.



Pole

Equator

Thank you for your attention 

Acknowledgments: FAPESP (JP 2009-18304-0) , CNPq, UNIVAP, LNILS and INCT-A

