Upgrade of the Laboratorio di Astrofisica Sperimentale (LASp) at INAF-OACt

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Laboratorio di Astrofisica Sperimentale - Catania

Ion source
200 kV

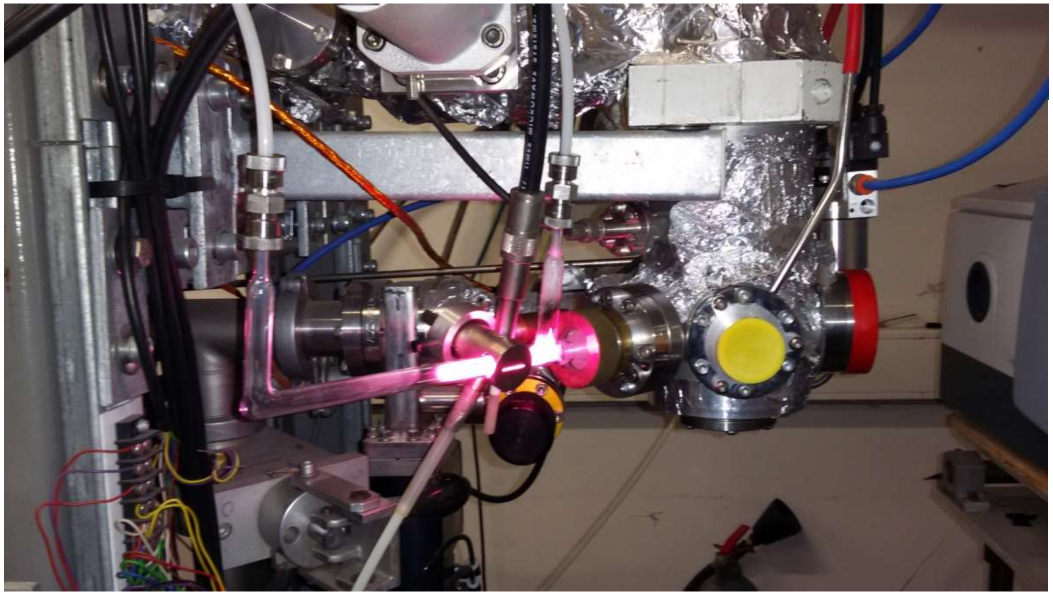
Ion beam line

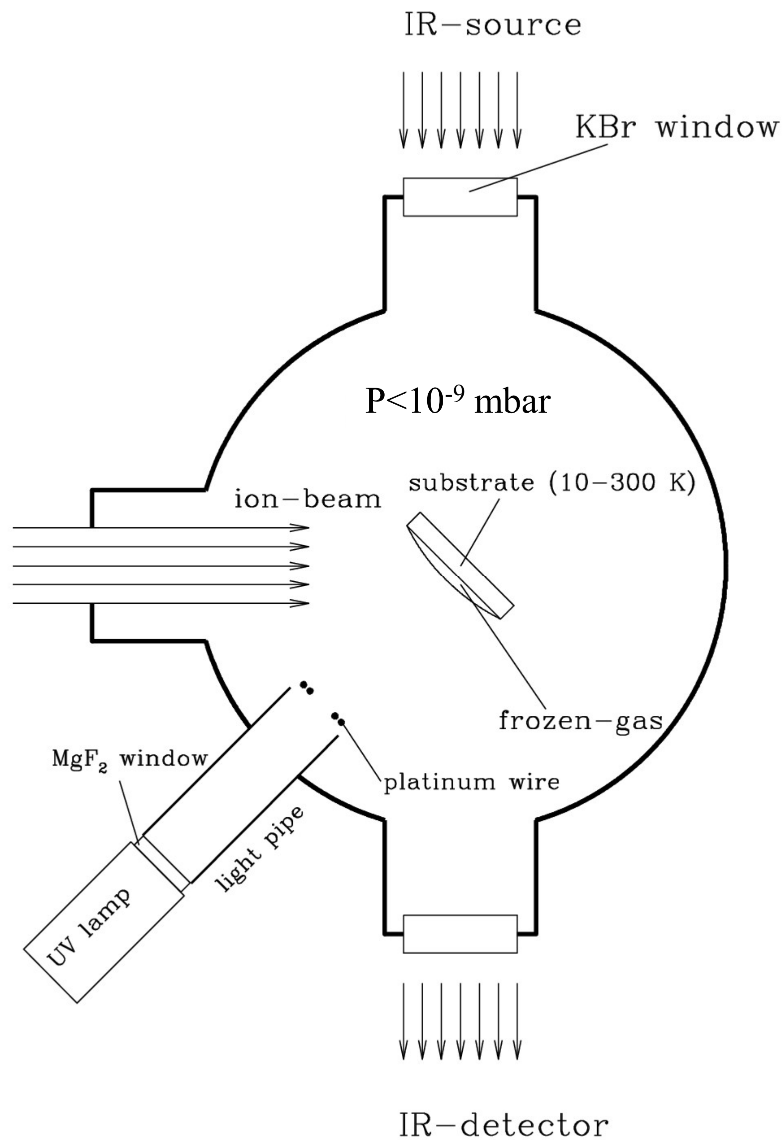
Vacuum chamber
Cryostat

FTIR
spectometer

- Ultra High Vacuum (UHV) chamber ($P<10^{-9}$ mbar)
- Cryostat (15-300 K)
- Ion implanter (Danfysik-200 kV)
- UV lamp (Lyman-alpha)
- FTIR spectrometer
- UV-Vis-NIR spectrometer
- Raman spectrometer

Vacuum chamber





In-situ analysis:

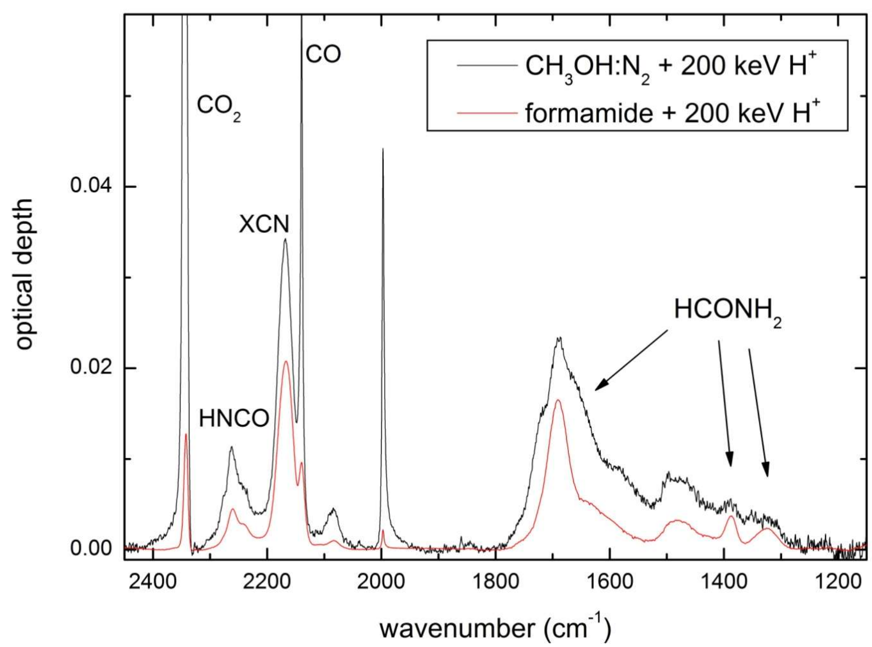
IR spectroscopy

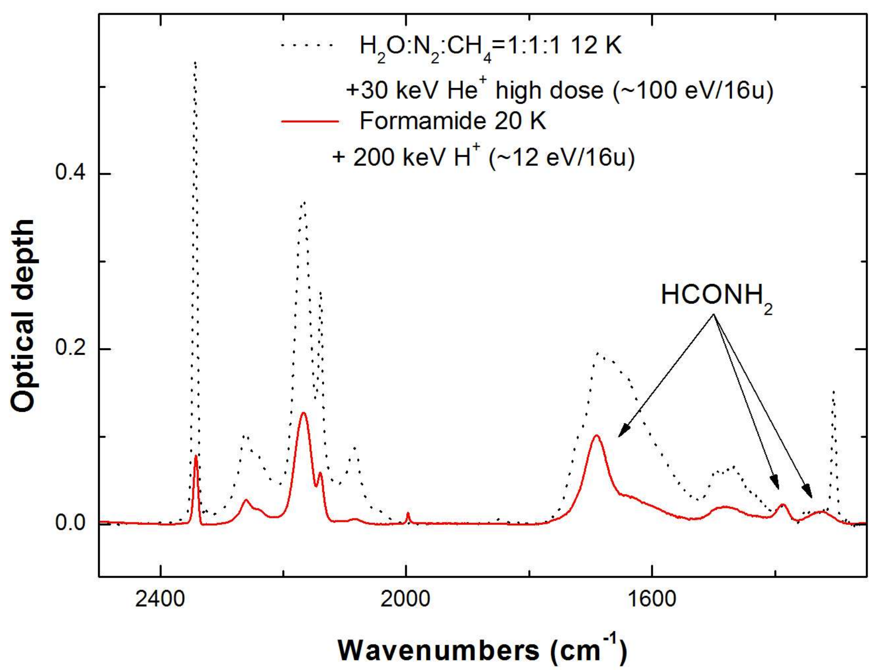
Raman spectroscopy

Formamide (NH_2CHO)

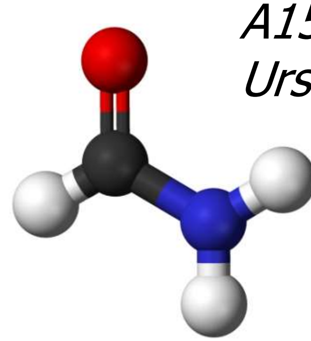
is detected in comets and both in high and low-mass star forming regions
It is relevant for Astrobiology

Peak position cm^{-1}	μm	Assignment
3368	2.97	ν_1 asym. NH_2 stretch
3181	3.14	ν_2 sym. NH_2 stretch
2881	3.47	ν_3 CH stretch
1708	5.85	ν_4 CO stretch
1631	6.13	ν_5 in plane NH_2 scissoring
1388	7.20	ν_6 in plane CH scissoring
1328	7.53	ν_7 CN stretch





Kanuchova et al. 2016, A&A 585, A155;
Urso et al. 2017, PCCP 19, 21759



Present limits

Solid CH_3OH

Species not present before processing

CO	→ 20% w.r.t. CH_3OH
H_2CO	→ 10%
CO_2	→ 6%
CH_4	→ 5%
$HCOOCH_3$	→ 0.2%

It is believed that other more complex species are formed after processing which cannot be detected because their abundance is below the detection limit of IR spectroscopy

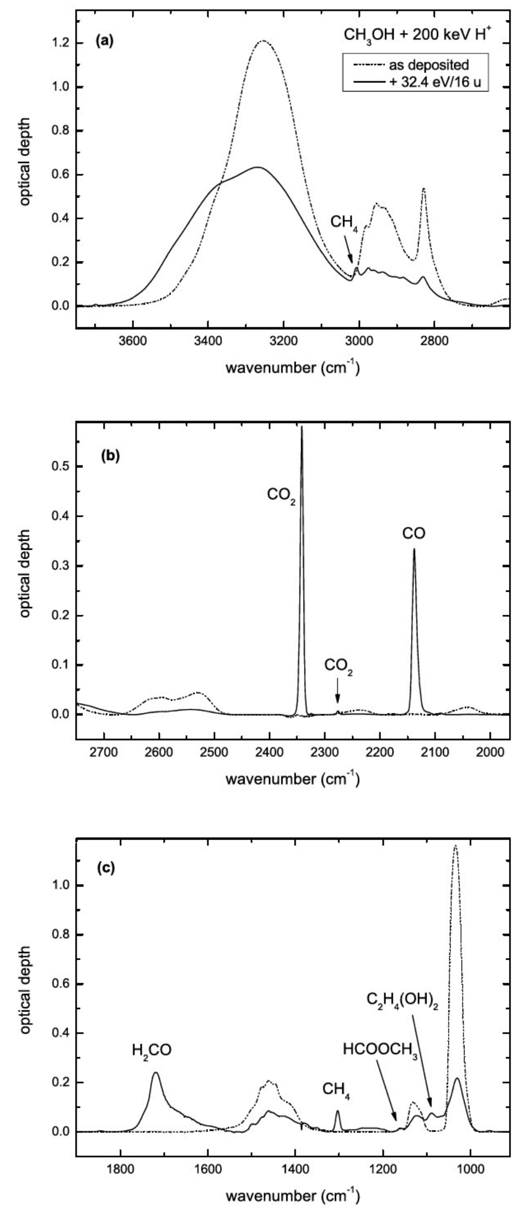


Fig. 8. Infrared spectra of a CH_3OH pure ice as deposited (dotted lines) and after irradiation with 200 keV protons (solid lines) in three different spectral regions from 3700 to 900 cm^{-1} (2.70−11.11 μm).

Modica and Palumbo 2010, A&A 519, A22

New experimental set-up

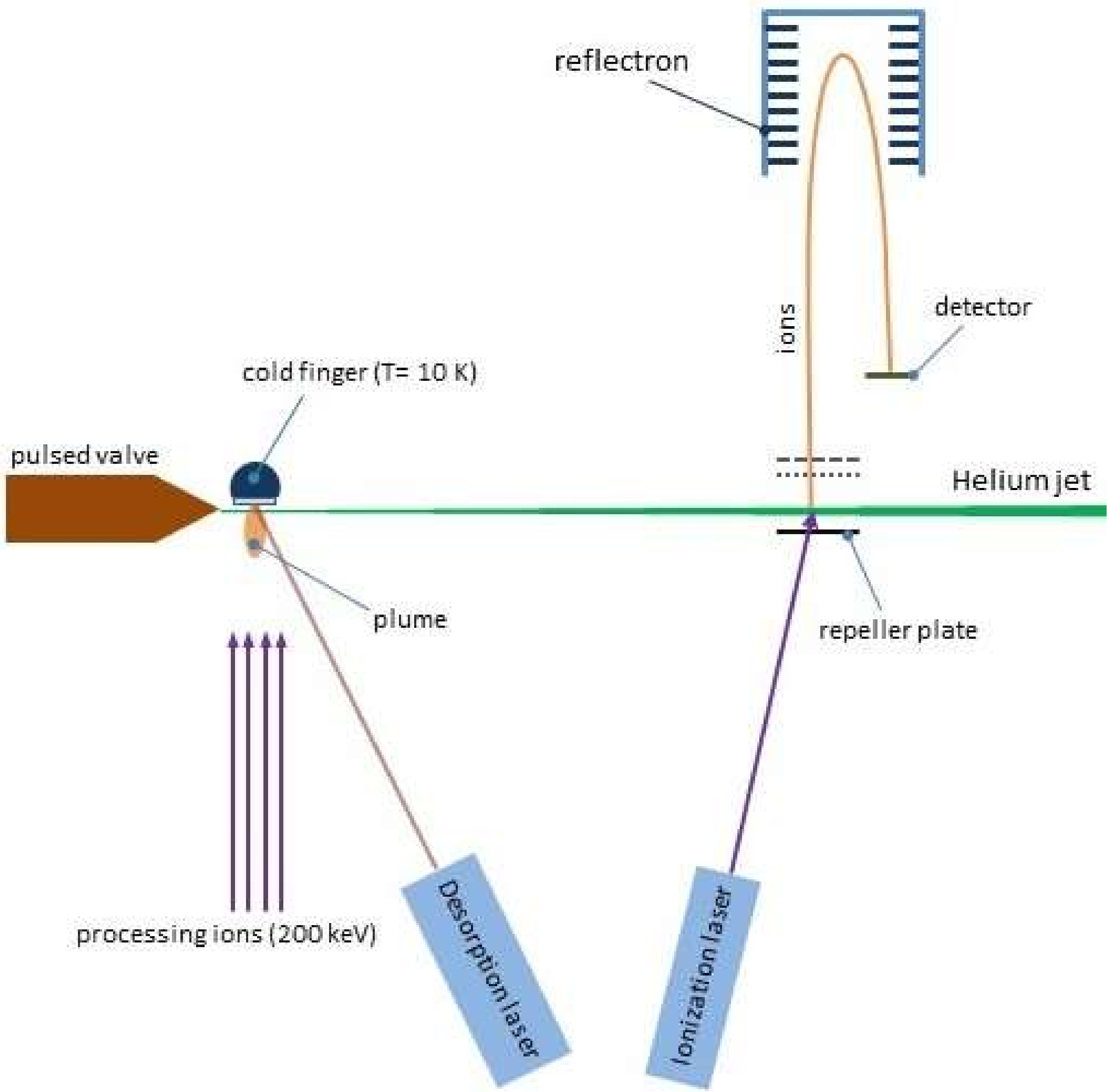
iALMA

➢**Open question:**
What and how many complex molecules are formed in ices in space by energetic processing?

➢**Aim:**
To build up a new and original experimental set-up that will detect molecules formed after energetic ion bombardment of simple ices, using a combination of laser desorption, He jet cooling and VUV-UV-tunable photo-ionization followed by high resolution mass-spectrometric analysis.

➢**Gain:**
Present relative sensitivity (i.e. IR spectroscopy) ~10^{-3} (column density)
Expected relative sensitivity ~ 10^{-7} (mass abundance)

Laser desorption – laser ionization TOF – MS (jet cooling configuration)



Jet cooling effects:

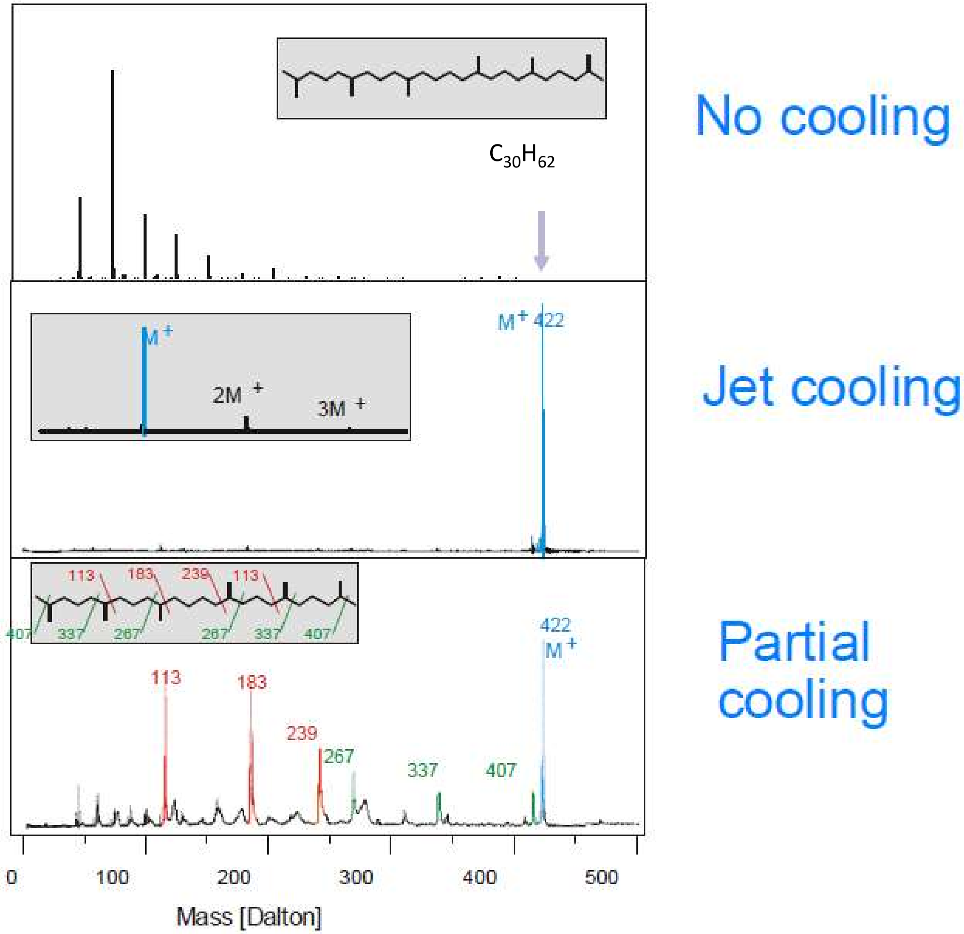
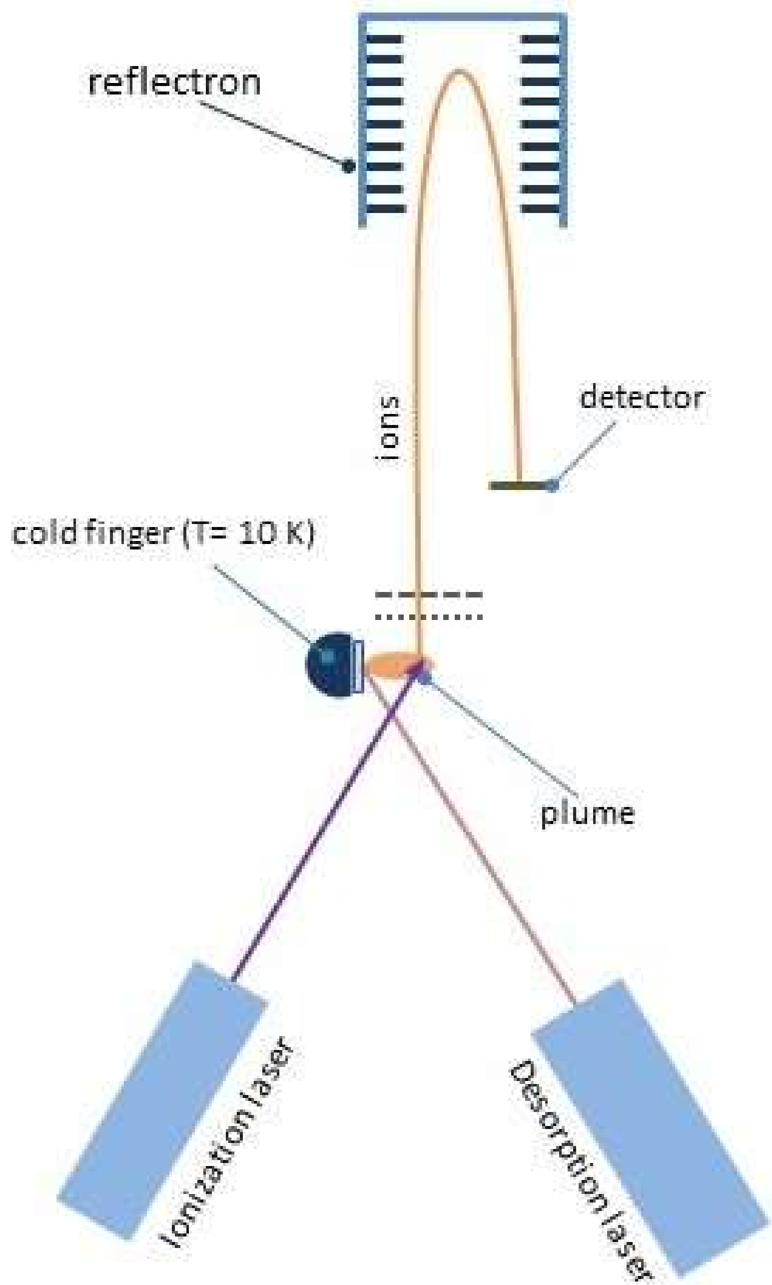


Figure 2: 125 nm single photon ionization of laser desorbed squalene with different degrees of jet-cooling

.... but sensitivity may be relatively low

MALDI TOF (plume configuration)



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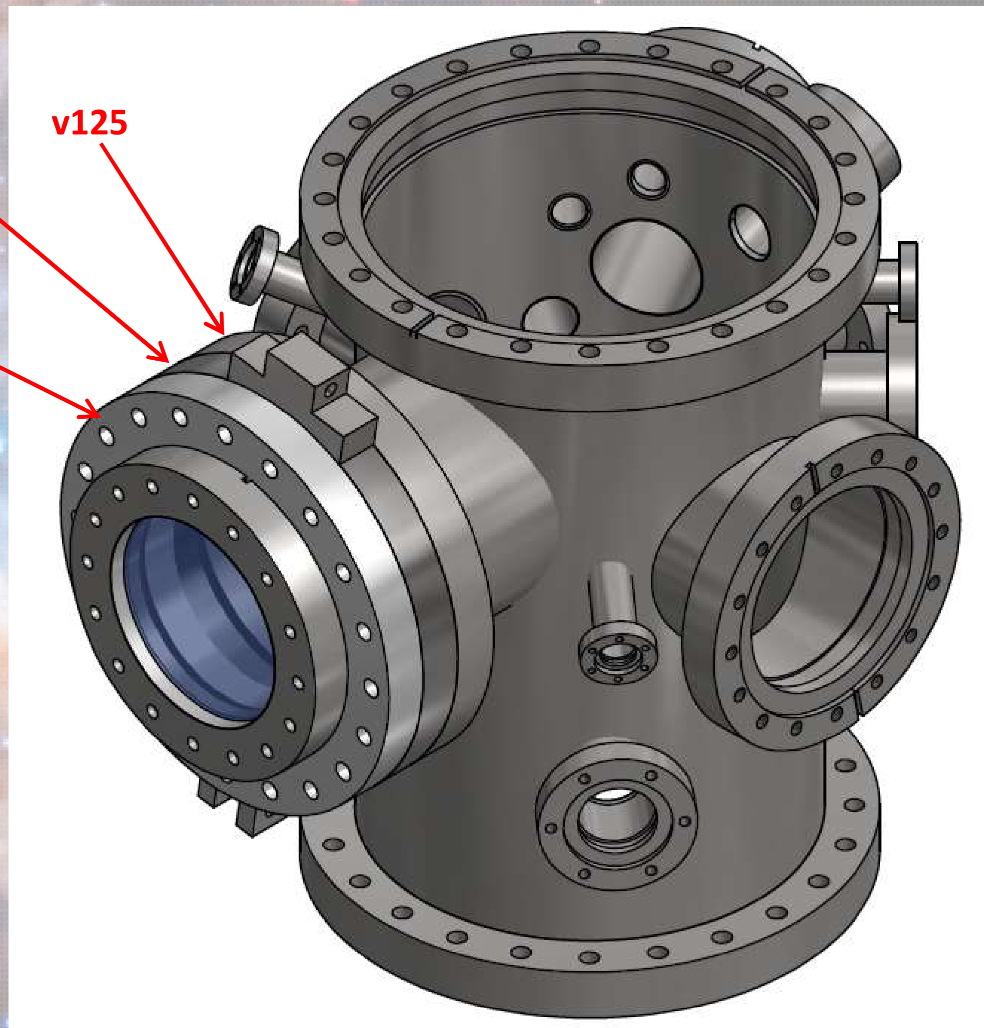
Mechanical engineering :
New UHV Chamber

Quick access door

v125

Zero length reducer 125CF/100CF



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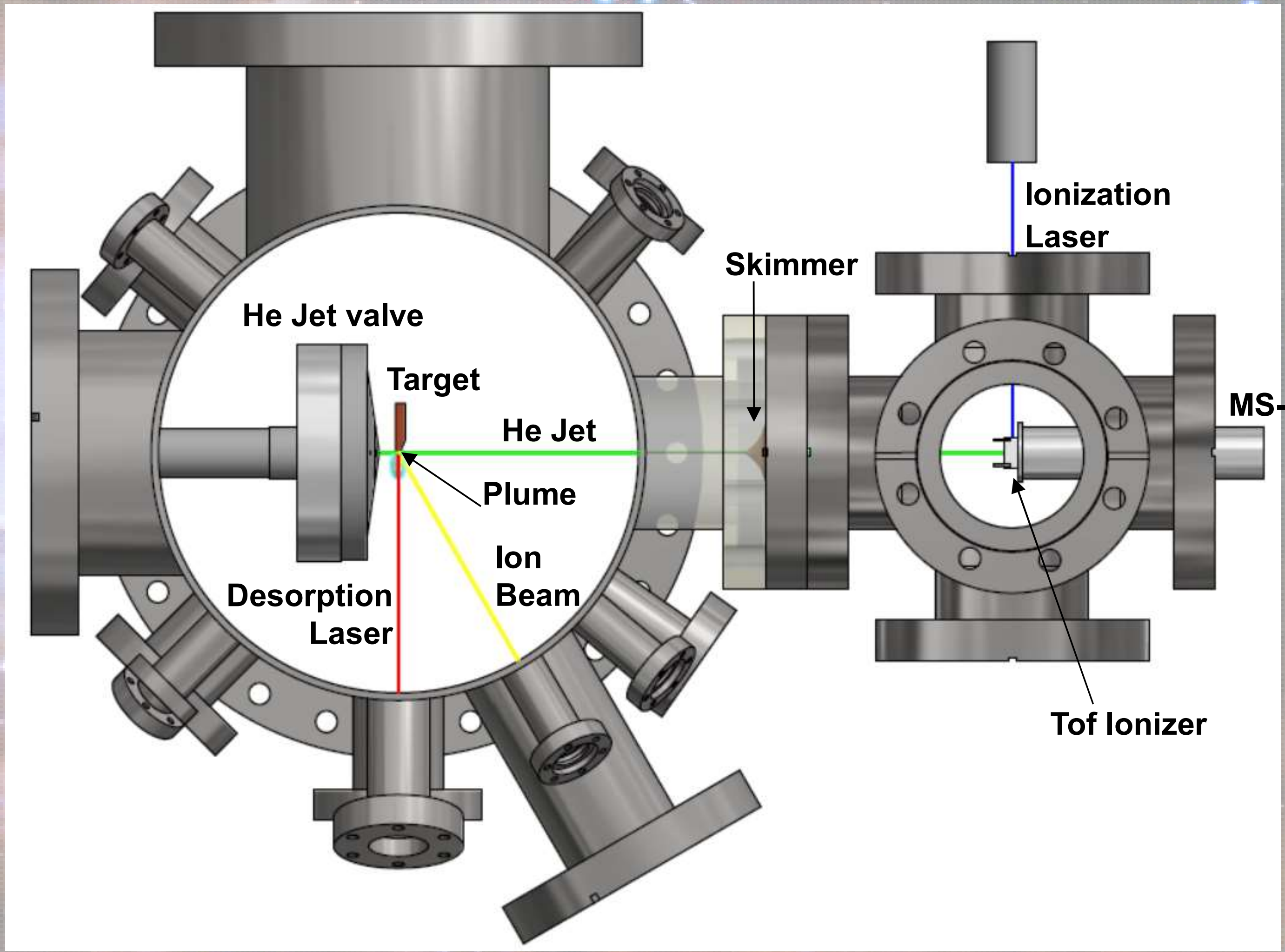
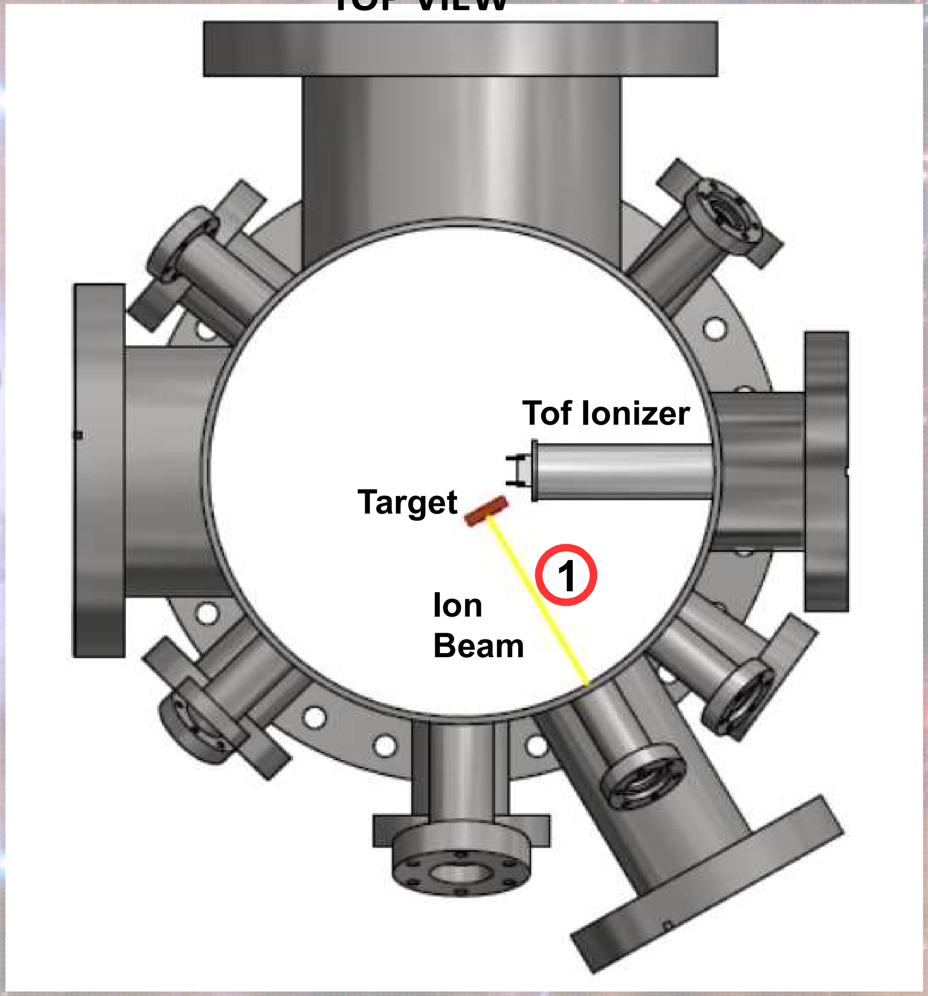
Working configuration
- Molecular Beam Mode -

TOP VIEW



Working configuration
- Plume Mode -

TOP VIEW



0. Ice deposited
1. Processed sample
2. Desorption laser
3. Plume → ionizer
4. Ionization laser
5. Analysis

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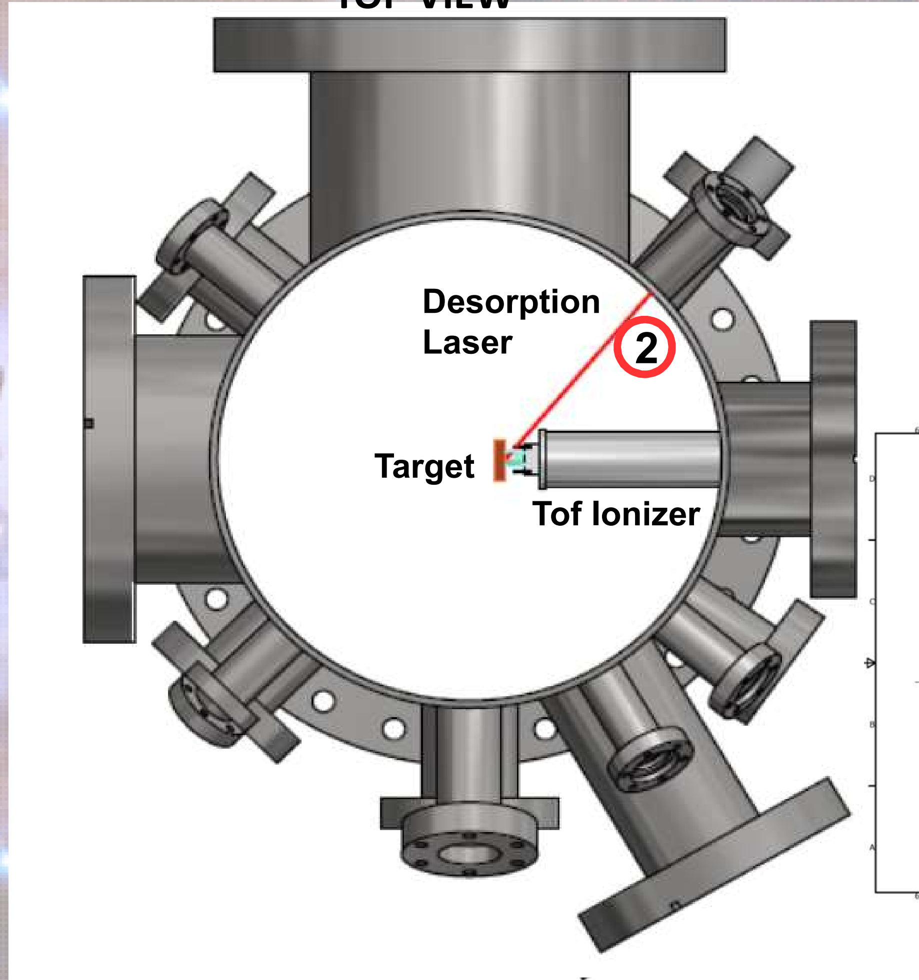
Working configuration
- Plume Mode -

TOP VIEW



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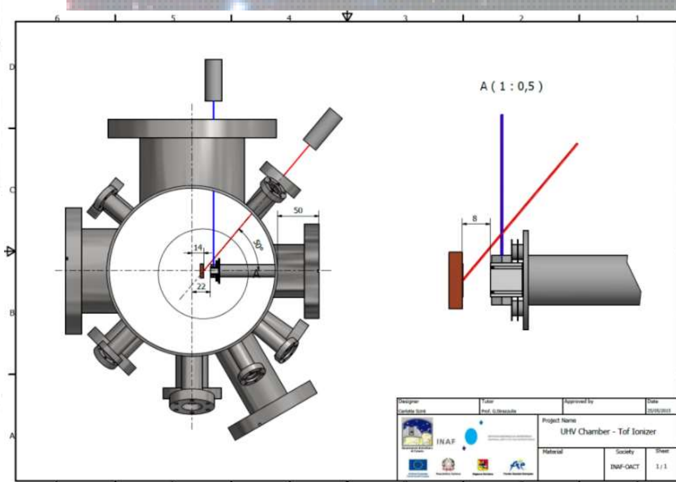
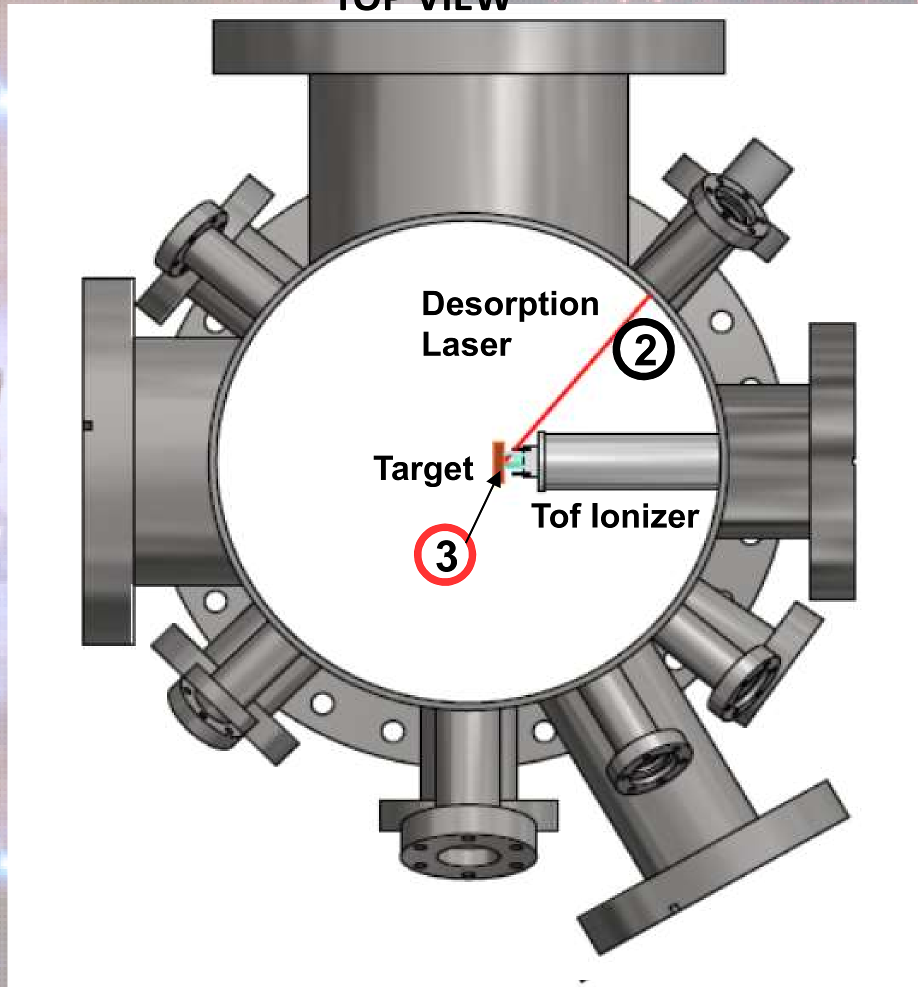


Working configuration
- Plume Mode -

TOP VIEW



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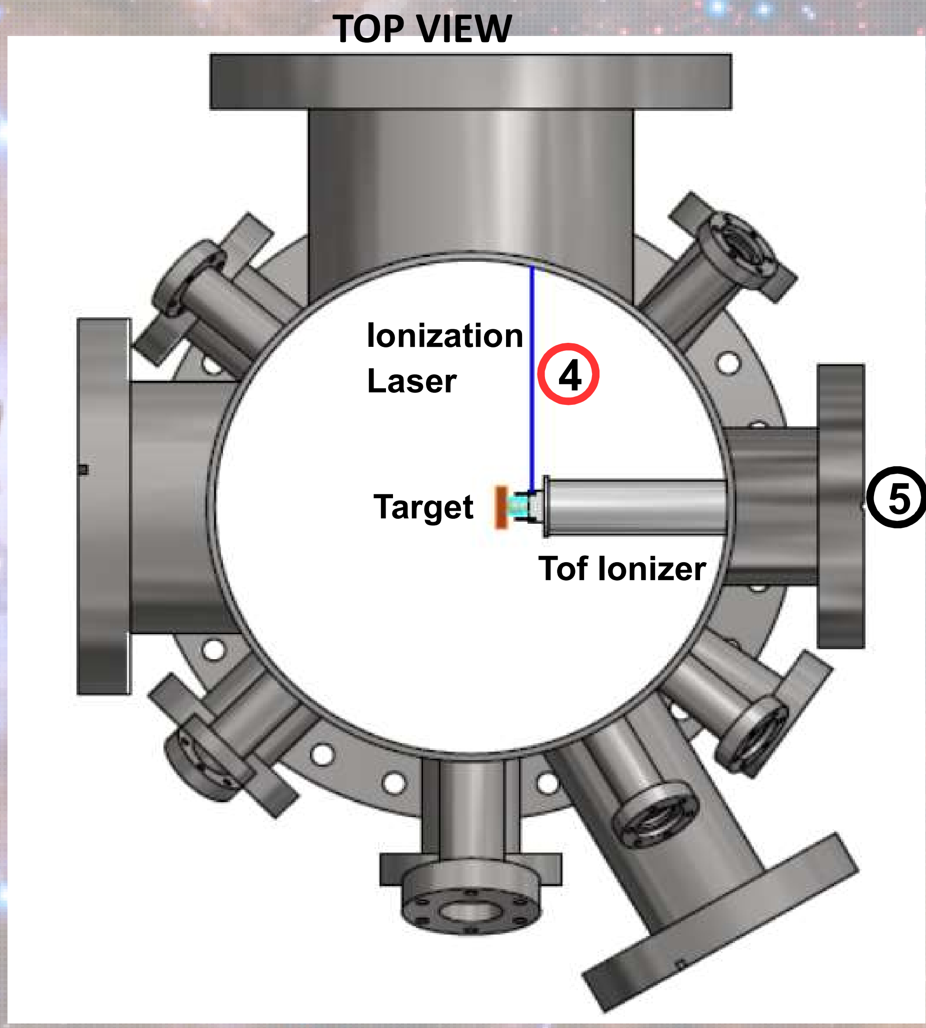

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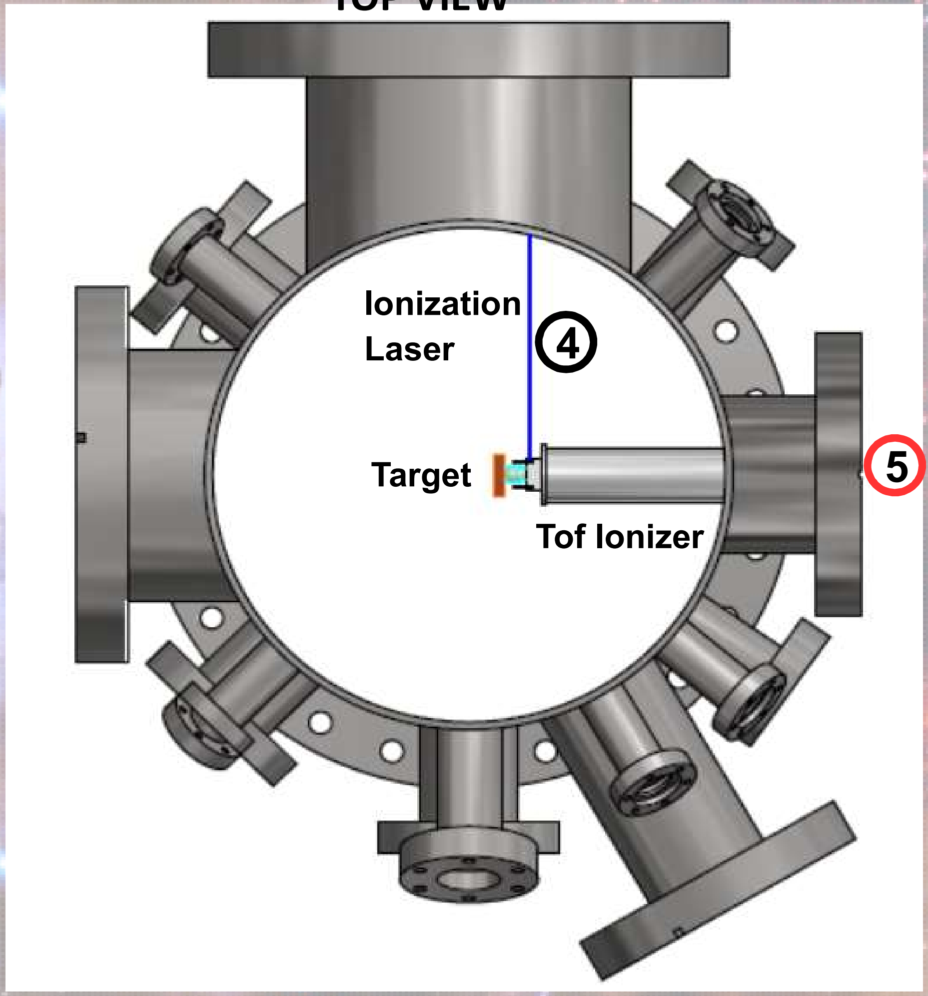
Working configuration
- Plume Mode -

TOP VIEW



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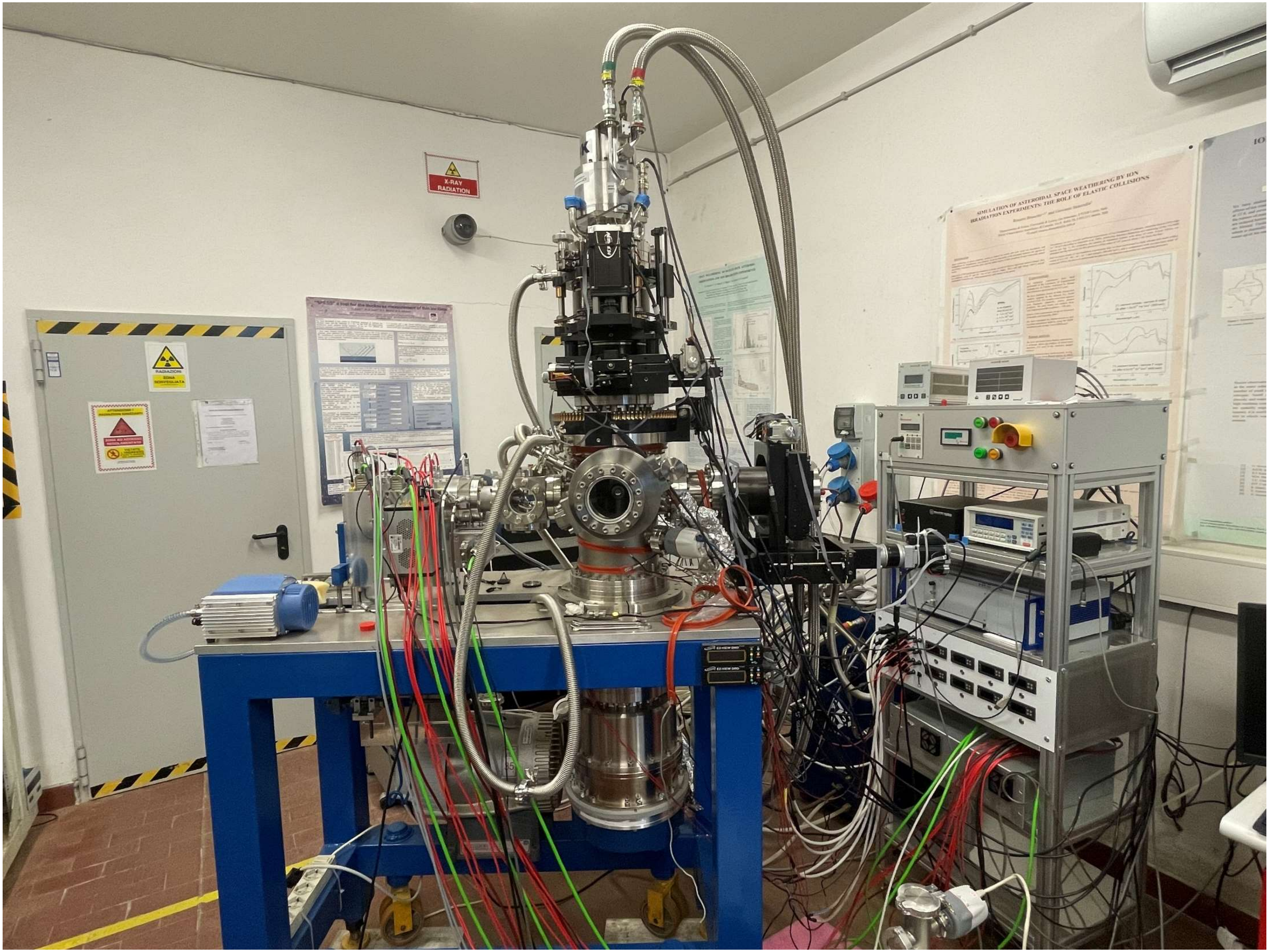
4. Ionization laser

5. Analysis


X-RAY
RADIATION
RADIAZIONI
ZONA SORVEGLIATA
SIMULATION OF ASTEROIDAL SPACE WEATHERING BY ION IRRADIATION EXPERIMENTS: THE ROLE OF ELASTIC COLLISIONS

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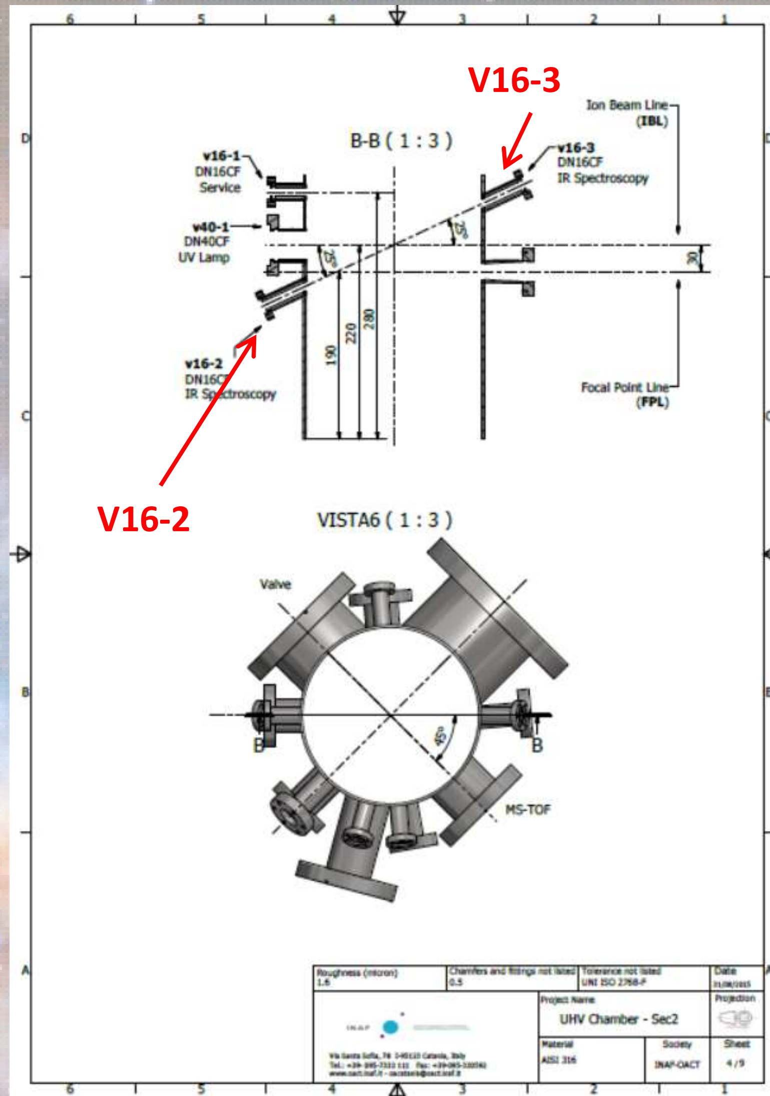

We plan to acquire an optical fibers IR spectrometer for the new experimental set up

Although MIR spectroscopy is far less sensitive than TOF-MS, it can give valuable information on the comprehensive chemistry induced by the energetic processing.

Column densities of major products derived by IR spectroscopy can be used to quantitatively calibrate the far less abundant complex molecules detected by TOF-MS

Acknowledgments

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Osservatorio Astrofisico di Catania

esa

ASI

iALMA

REGIONE SICILIA

Genesis-SKA

Vamos Seguro

cost

EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

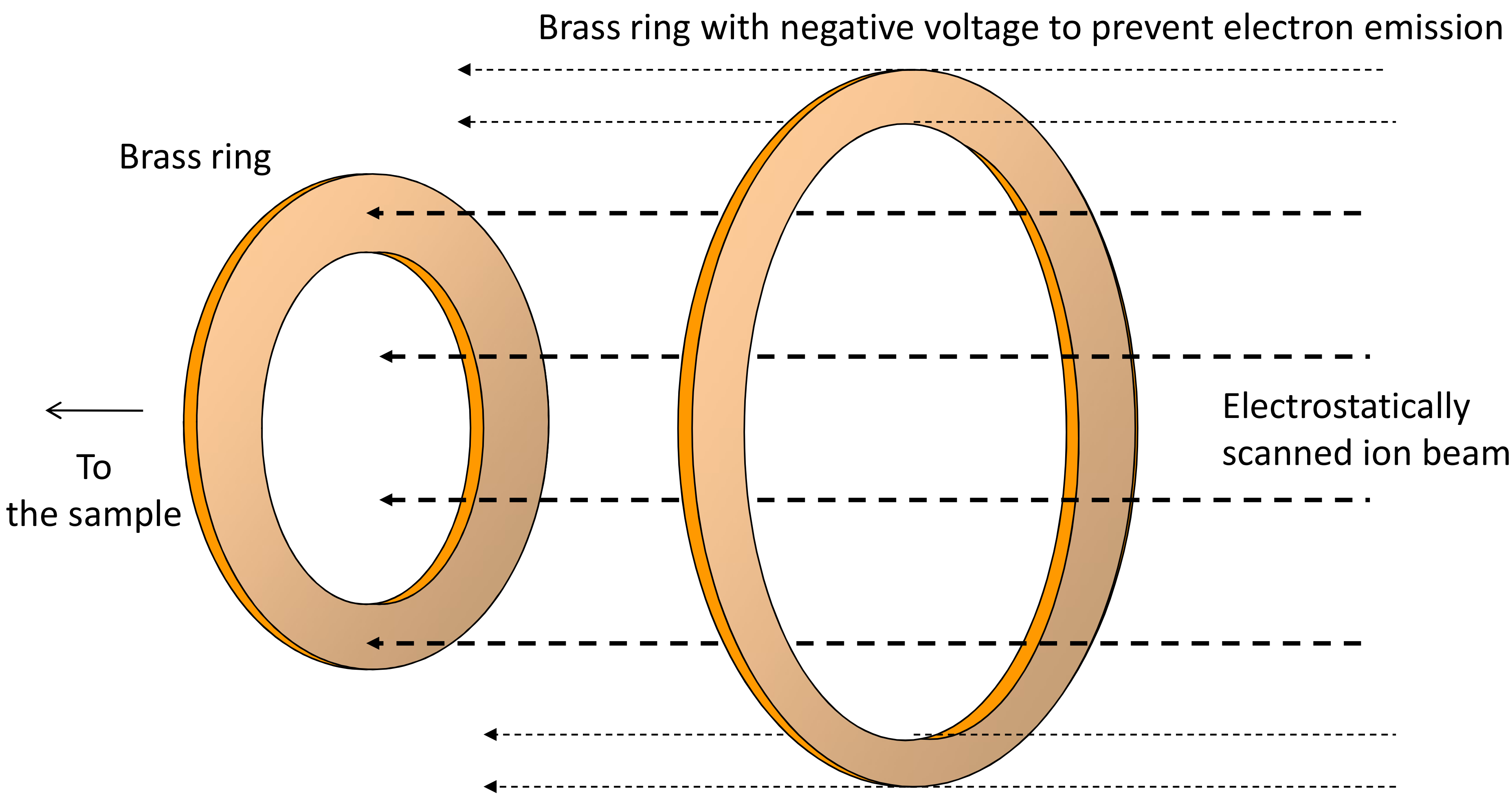
LASSIE

MIUR PRIN

VAMDC

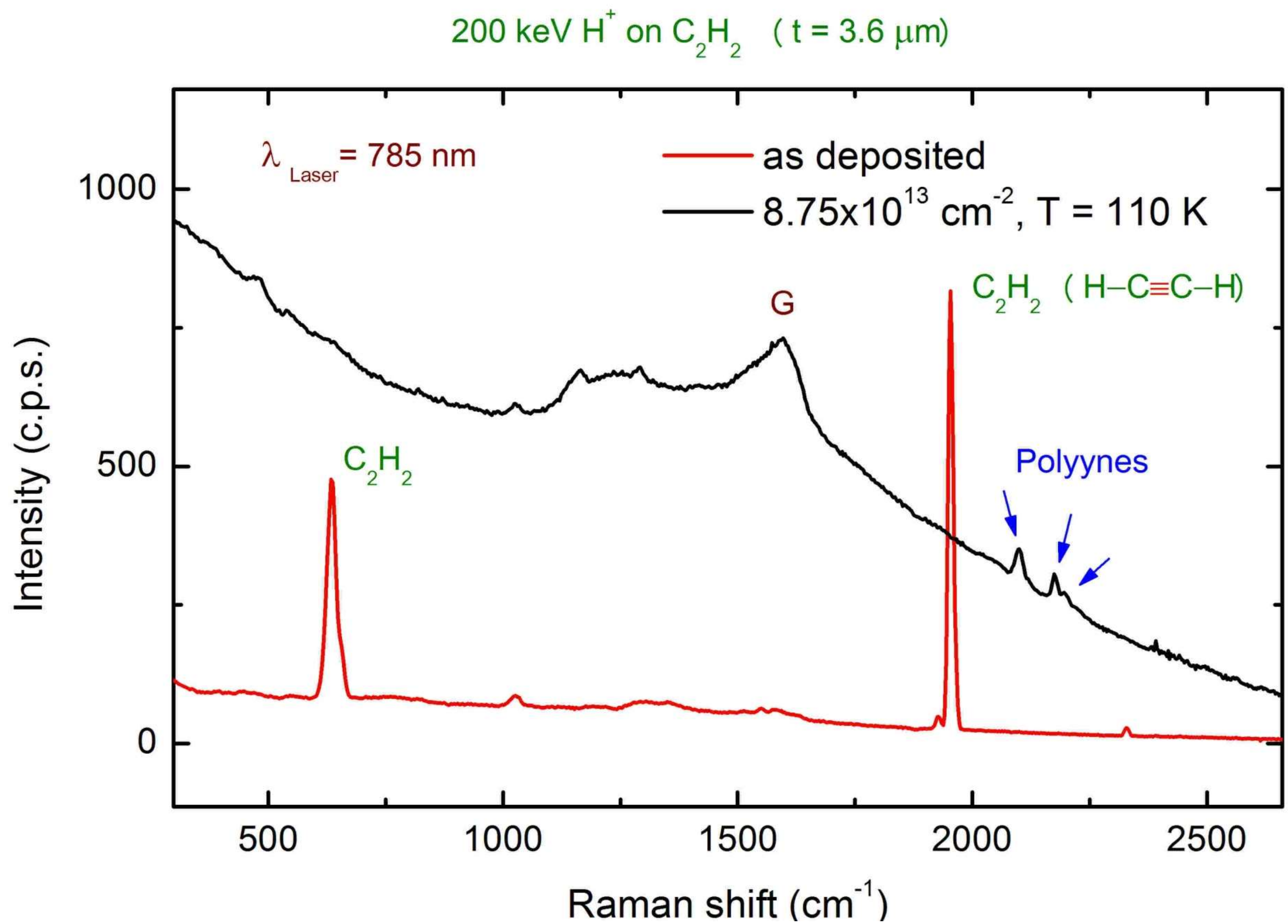
Virtual Atomic and Molecular Data Centre

Ion current measurement during irradiation



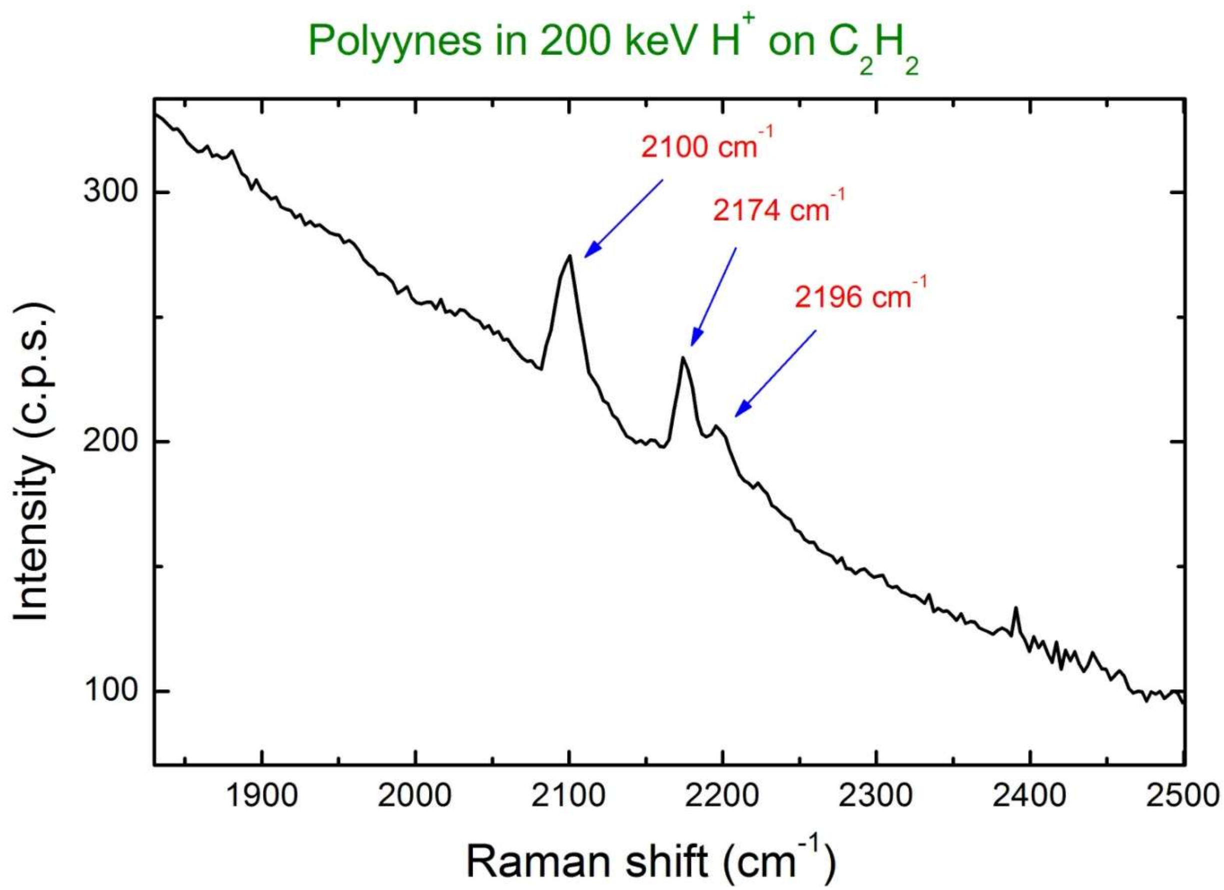
The area of the brass ring is equal to the area of the hole.
The number of ions passing through the brass ring is equal to the number that hit the ring.

Formation of carbon chains



Compagnini et al. 2009, Carbon 47, 1605

Formation of carbon chains



Based on peak position

chains involved should contain 8-12 carbon atoms

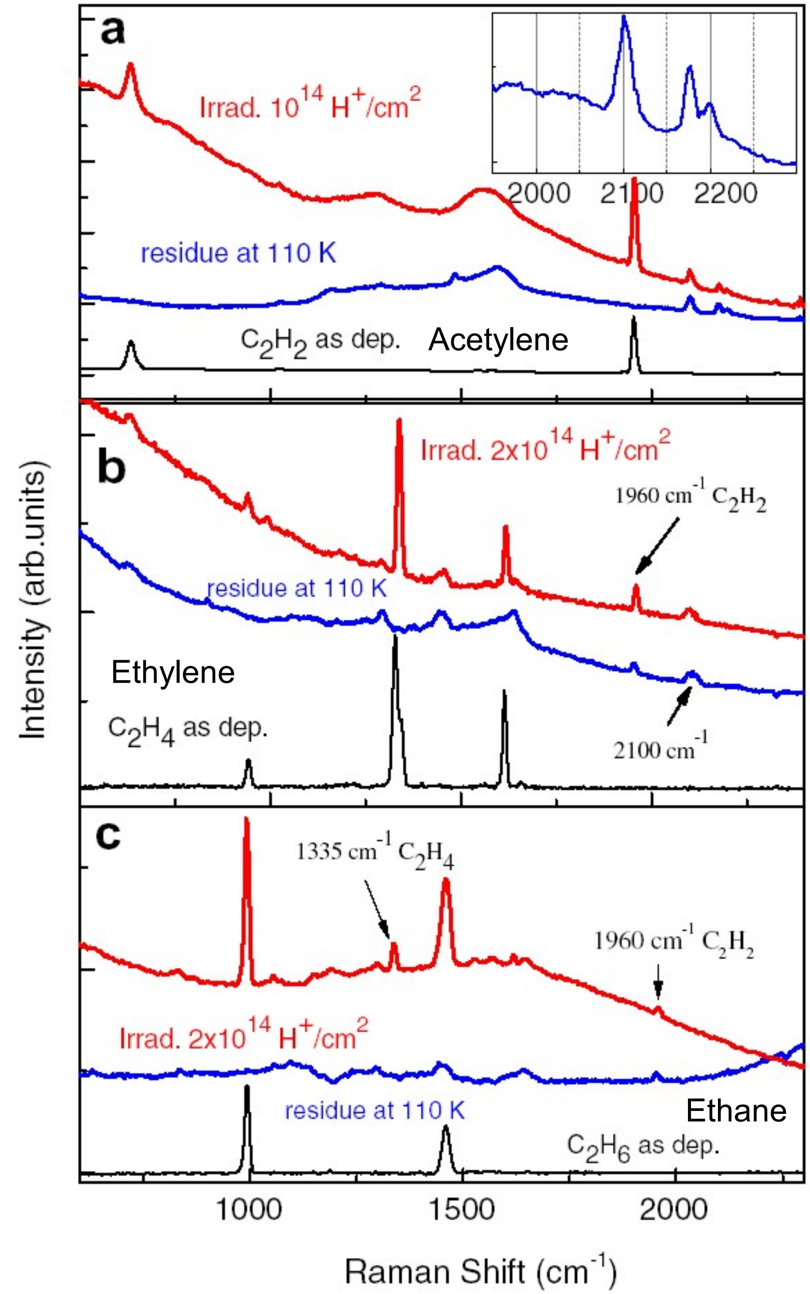
Compagnini et al. 2009, Carbon 47, 1605

Formation of carbon chains

$$C_2H_2 \overset{irrad.}{\longrightarrow} R{-}(C{\equiv}C)_n{-}R$$

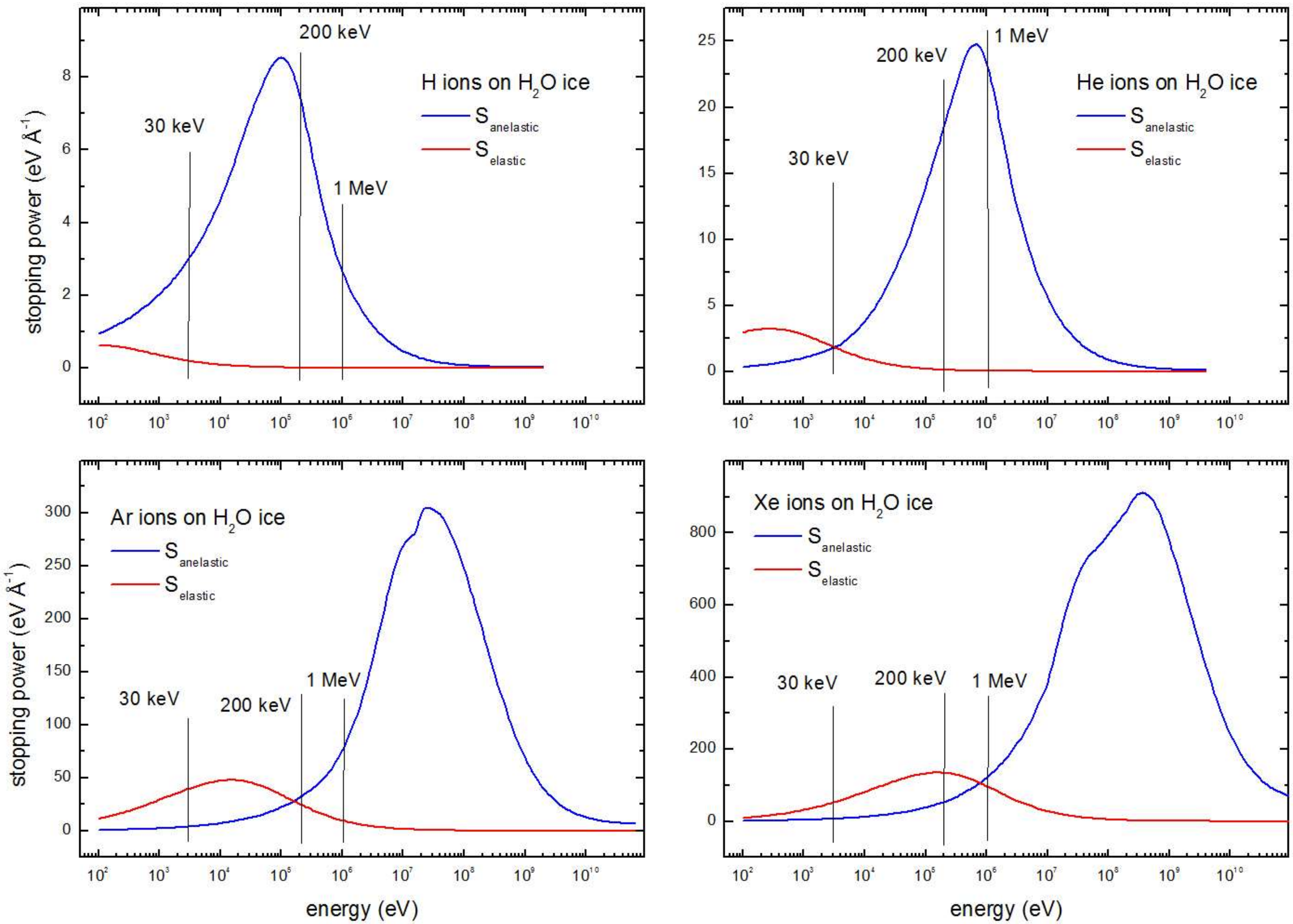
$$C_2H_4 \overset{irrad.}{\longrightarrow} C_2H_2 + R{-}(C{\equiv}C)_n{-}R$$

$$C_2H_6 \overset{irrad.}{\longrightarrow} C_2H_4 + C_2H_2 + R{-}(C{\equiv}C)_n{-}R$$



Compagnini et al. 2009, Carbon 47, 1605

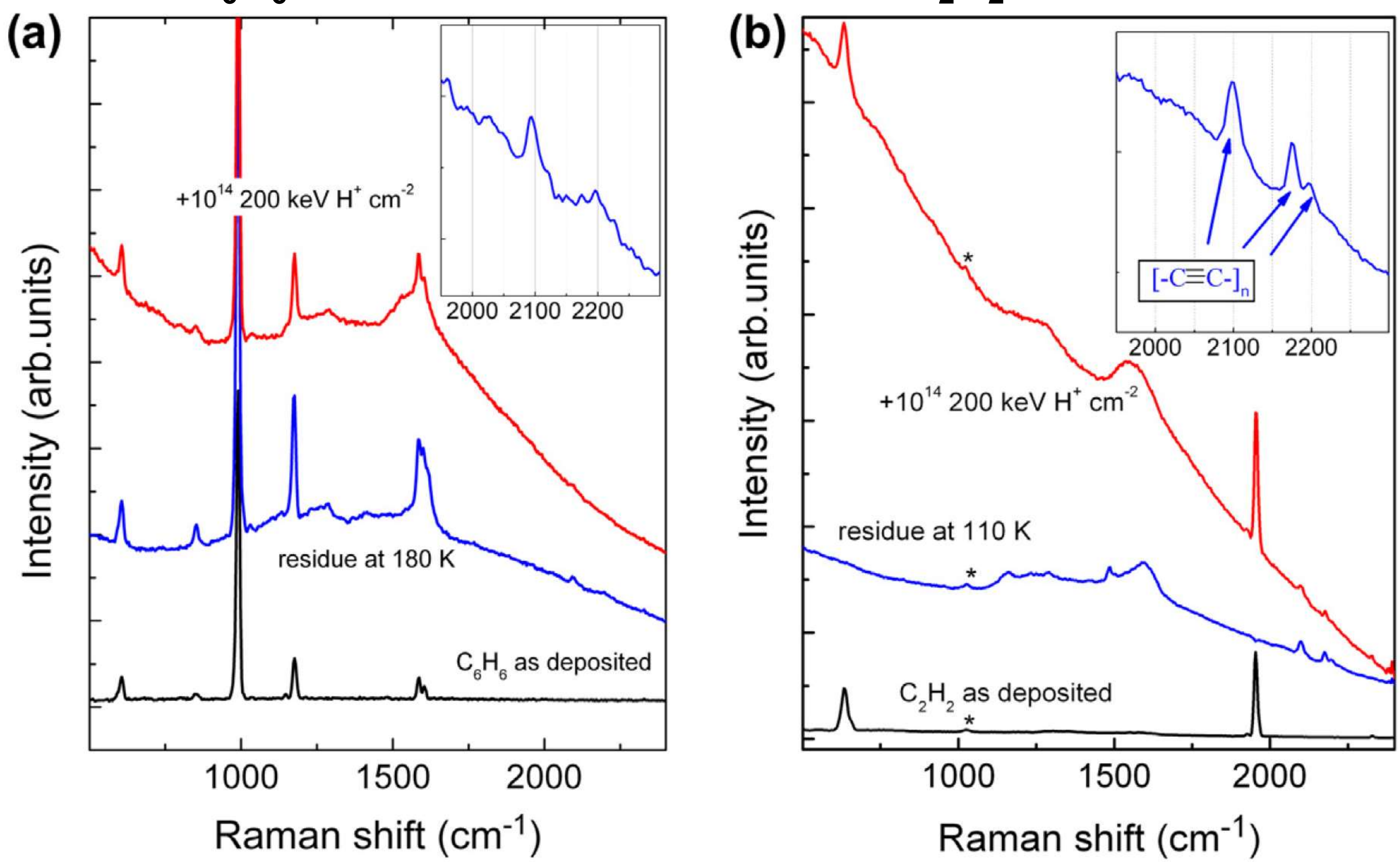
Interaction of ions with matter



J.F. Ziegler: SRIM (Stopping and Range of Ions in Matter); TRIM (TRansport of Ions in Matter)

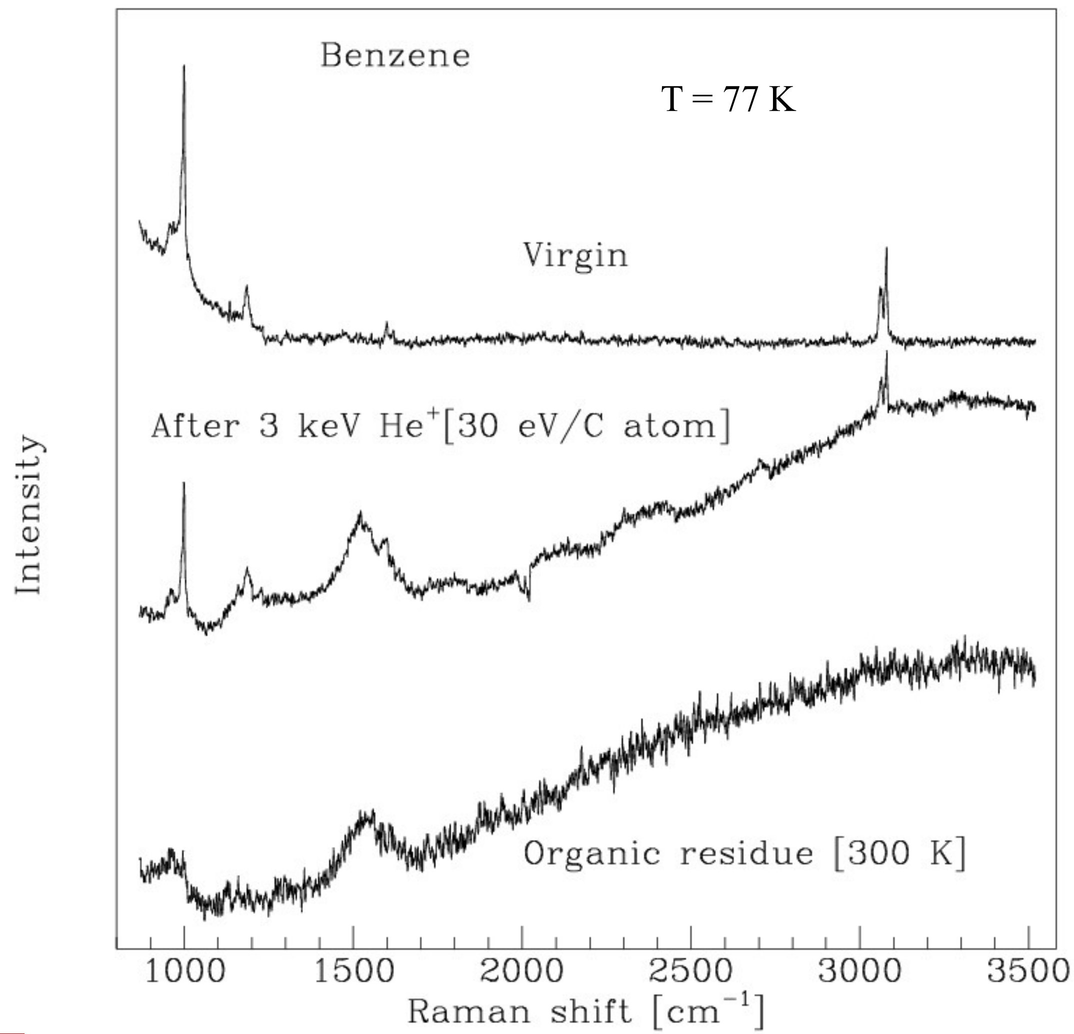
Formation of carbon chains

C_6H_6 + 200 keV H^+ **C_2H_2 + 200 keV H^+**

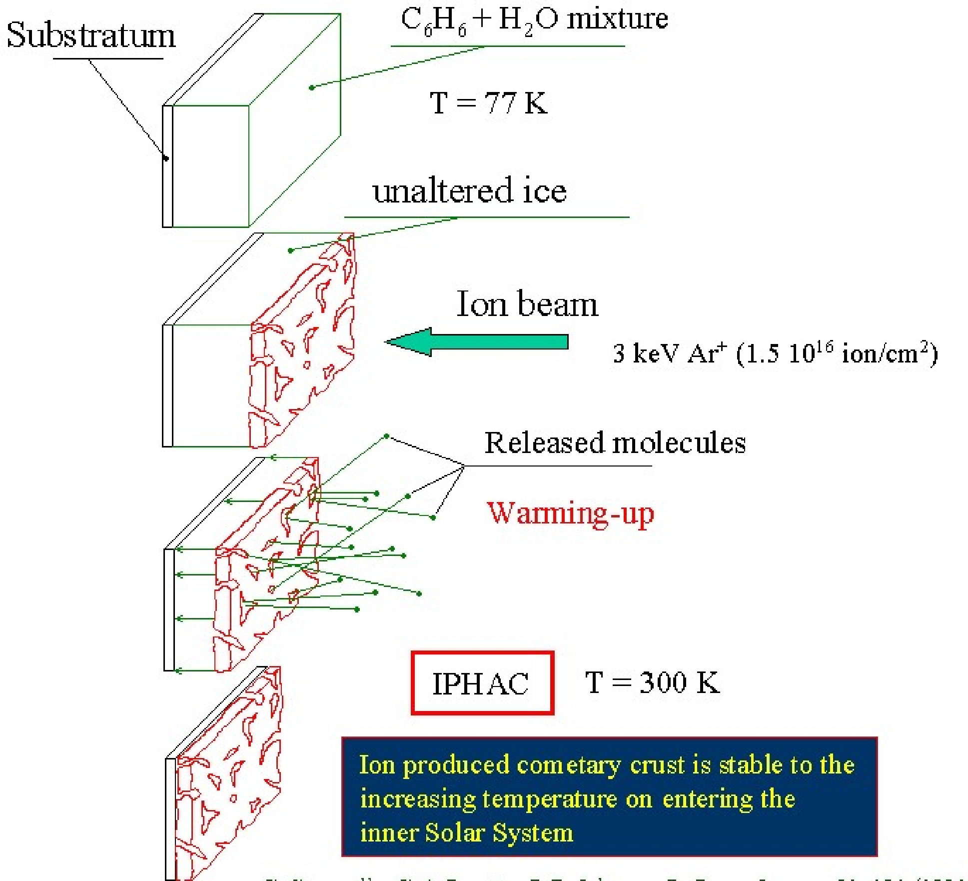


Puglisi et al. 2014, NIM B 326, 2

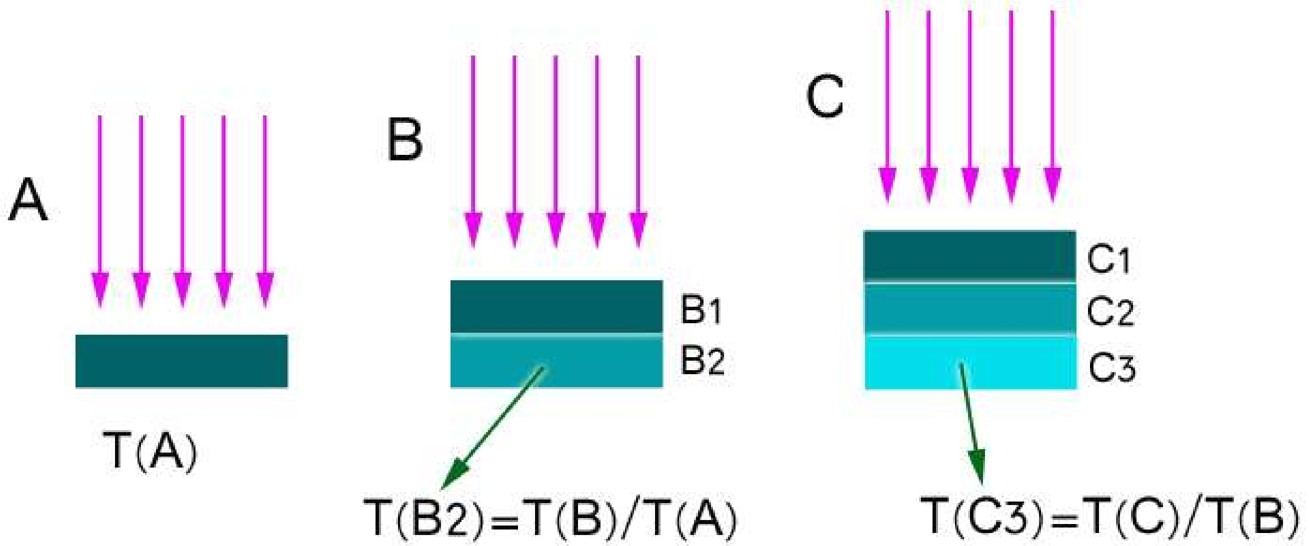
IPHAC (Ion Produced Hydrogenated Amorphous Carbon) formation is a general process, it has been observed for a large number of carbon containing targets both frozen (CH_4, C_4H_{10}, C_6H_6, etc. and their mixtures with H_2O, N_2) and refractory (polystyrene, polypropylene, graphite, diamond, PAHs, fullerenes, etc.)



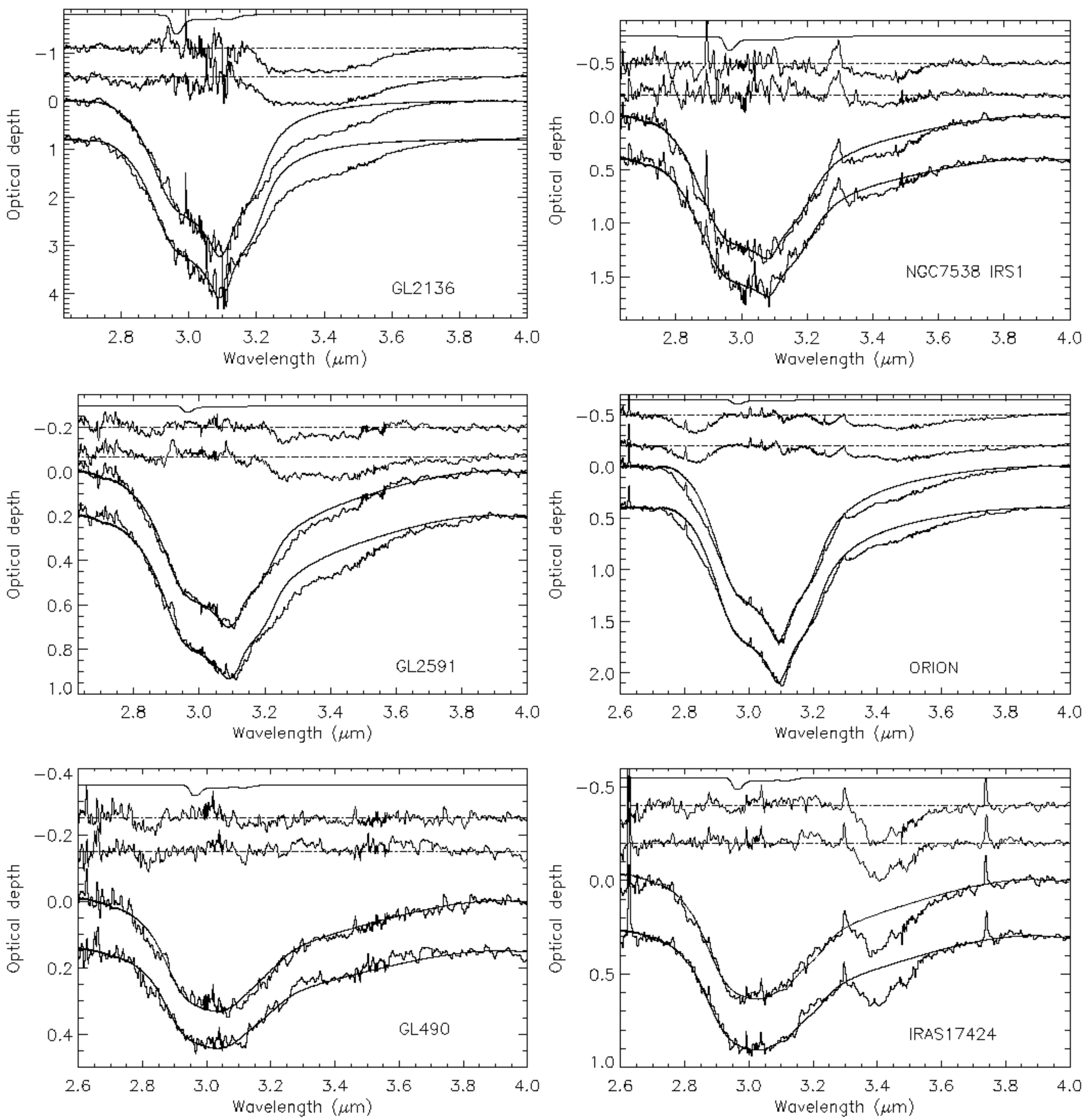
Strazzulla G., Baratta G.A., 1992, A&A, 266, 434



G. Strazzulla, G.A. Baratta, R.E. Johnson, B. Donn: Icarus 91, 101 (1991)


A
T(A)
B
B1
B2
T(B2)=T(B)/T(A)
C
C1
C2
C3
T(C3)=T(C)/T(B)

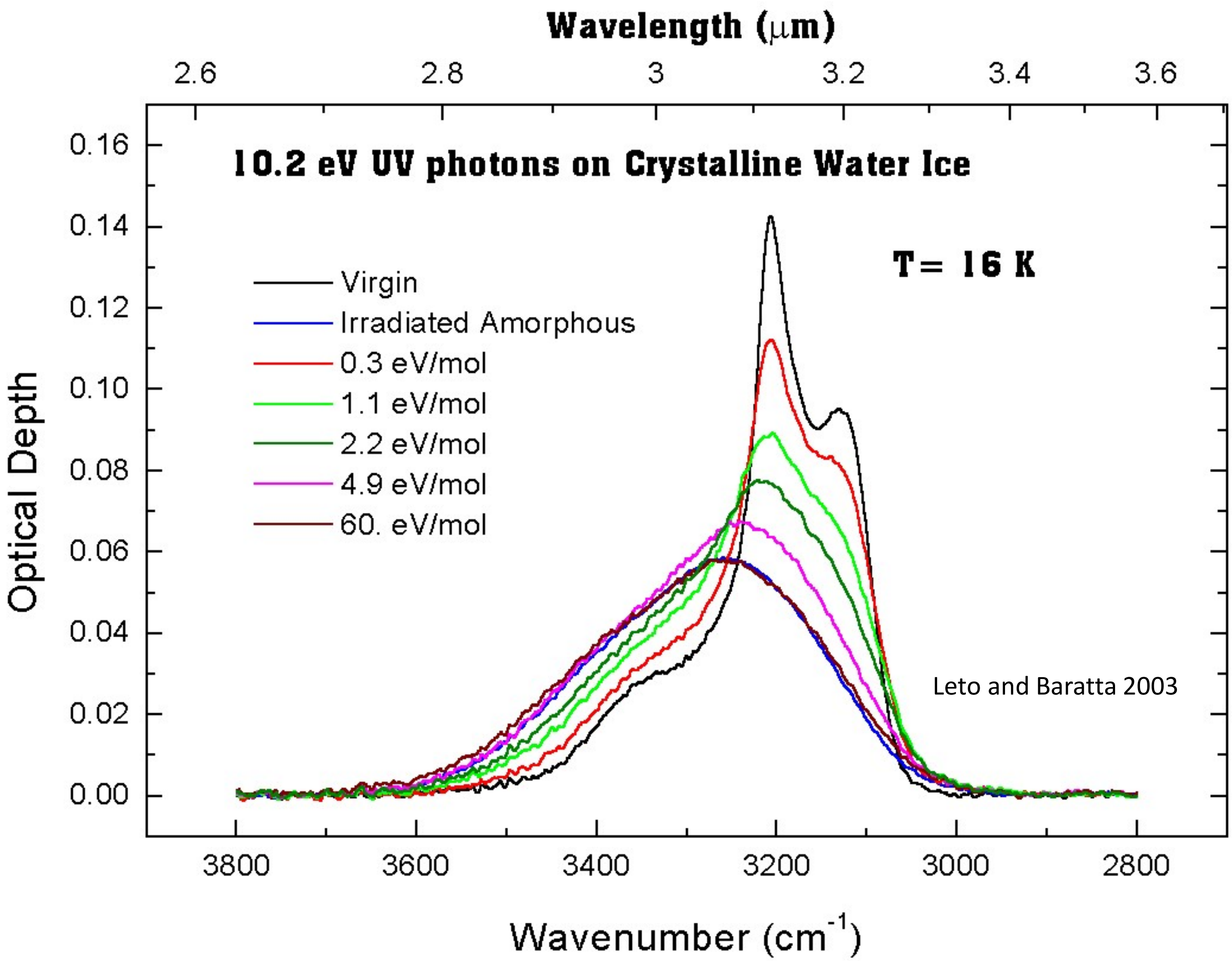
Water ice (H_2O)



Water ice shows various states of "crystallinity".

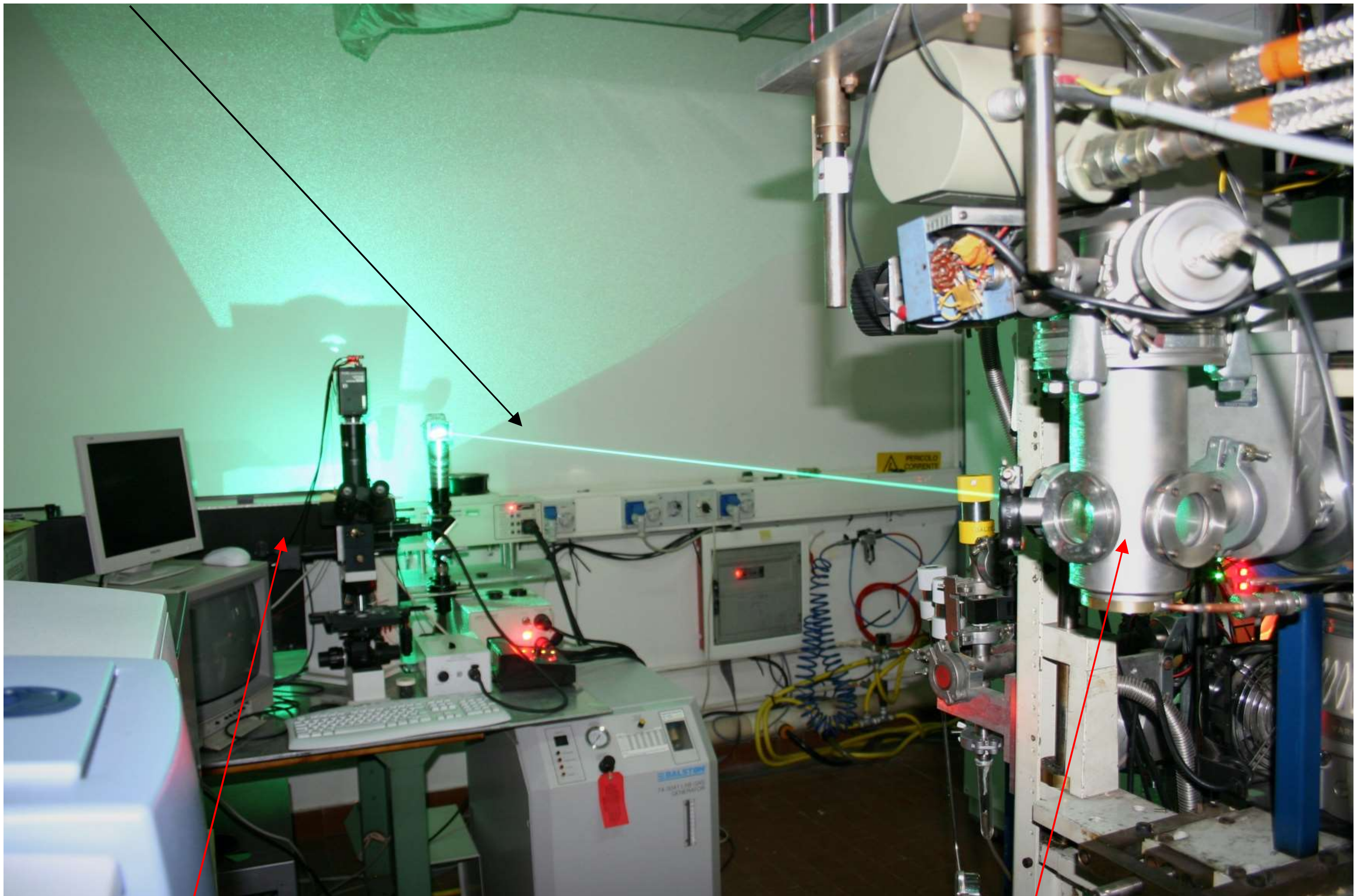
Dartois and d'Hendecourt, A&A 365, 144 (2001)

Effects of UV photolysis on c-H_2O



In situ Raman spectroscopy

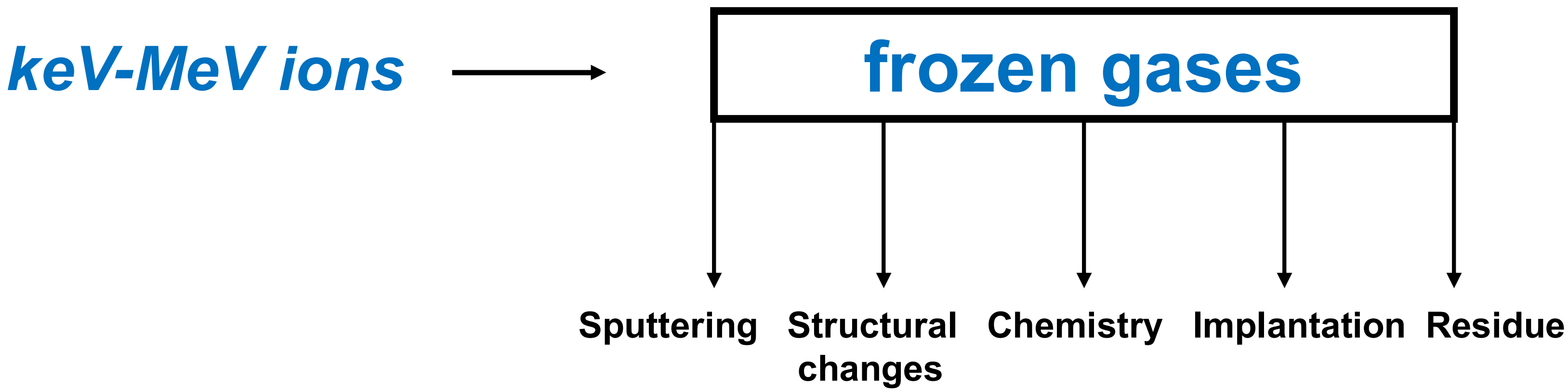
Laser Ar^{+} (514.5 nm)

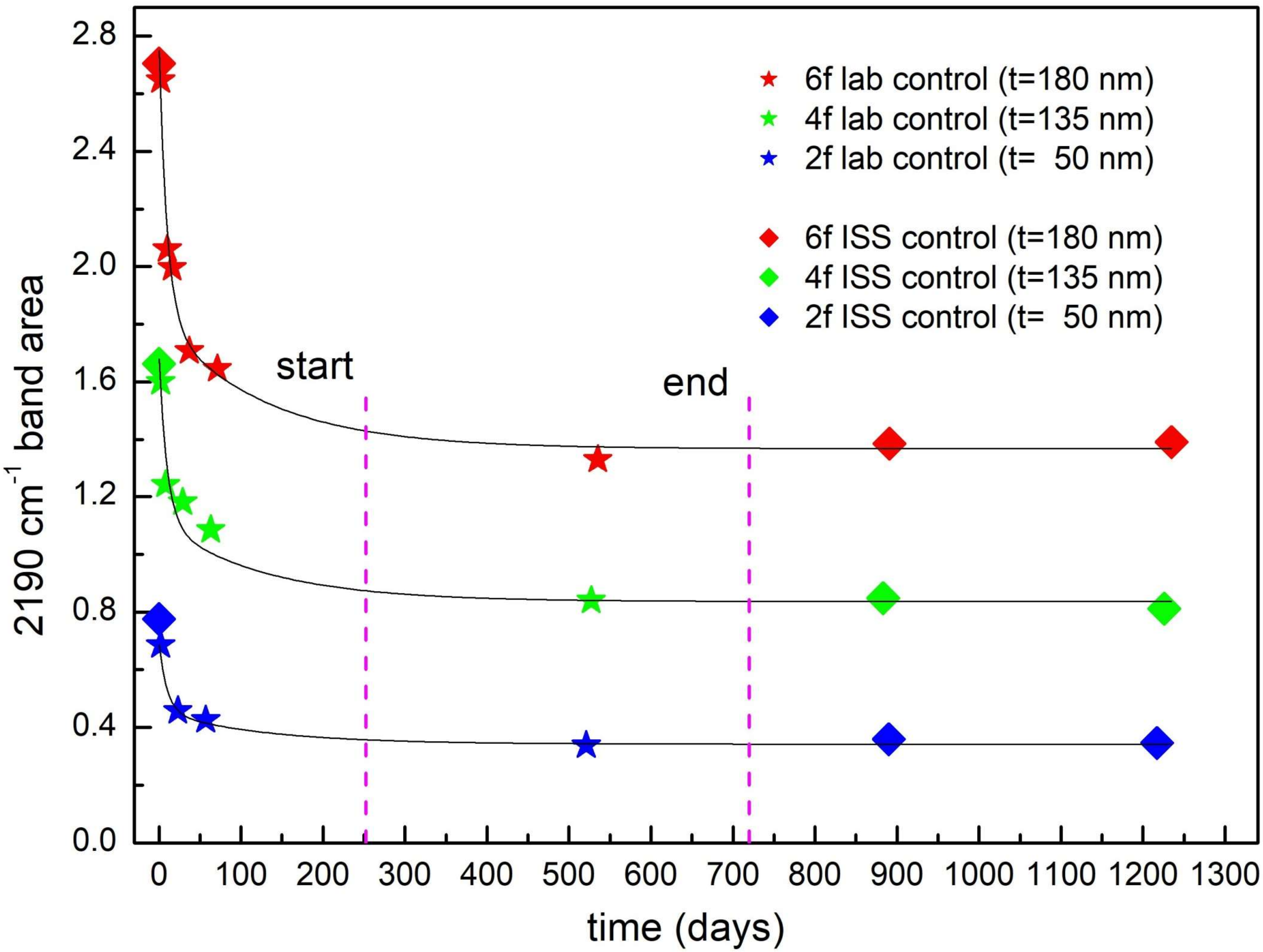


Raman spectrometer

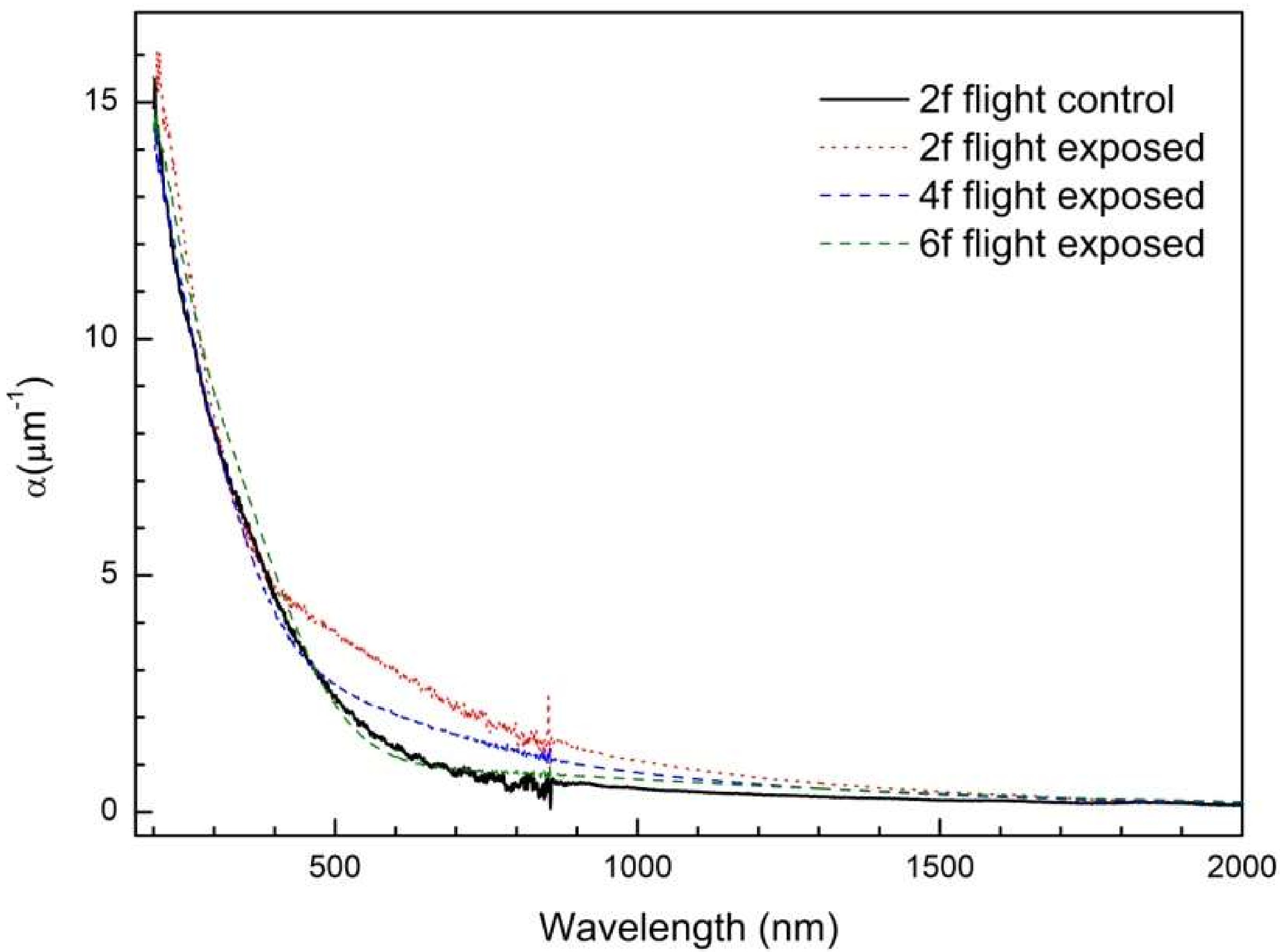
Vacuum chamber

Effects of energetic processing





Baratta, G. A.; Accolla, M.; Chaput, D.; Cottin, H.; Palumbo, M. E.; Strazzulla, *G., 2019, Astrobiology, 19, 1018-1036*



2f flight control
2f flight exposed
4f flight exposed
6f flight exposed
15
10
5
0
α(μm⁻¹)
500
1000
1500
2000
Wavelength (nm)

TABLE 1. ASSIGNMENT OF THE IR FEATURES OBSERVED IN THE ORGANIC RESIDUES

Wavenumber (cm^{-1})	*Implied functional group*	*Reference*
3500–3300	ali-NH_2, aro-NH_2 str.	(a)
3220	ali-NH_2, $-NH-$ str.	(a)
2980	$-CH_3$ str.	(a)
2940	$-CH_2-$ str.	(a)
2200	$-C\equiv N$, $-N\equiv C$,	(b, c)
	$-N=C=N-$	(c)
2150	OCN^-	(d)
1710	$C=O$ str.	(a)
1650–1630, 1560	arom. $C=C$, he-aro. $N=C$	
	ali-/aro-NH_2 bend	(a, c)
1450	$-CH_3$ bend	(a)
1415	$-CH_2-$ bend	(a)
1380	$C-CH_3$, $C-(CH_3)_2$	(a)
1339	$C-N$ arom. str.	(c)
1240	unidentified	

References: (a) = Quirico *et al.*, 2008; (b) = Mutsukura and Akita, 1999; (c) = Imanaka *et al.*, 2004; (d) = Palumbo *et al.*, 2004.

samp
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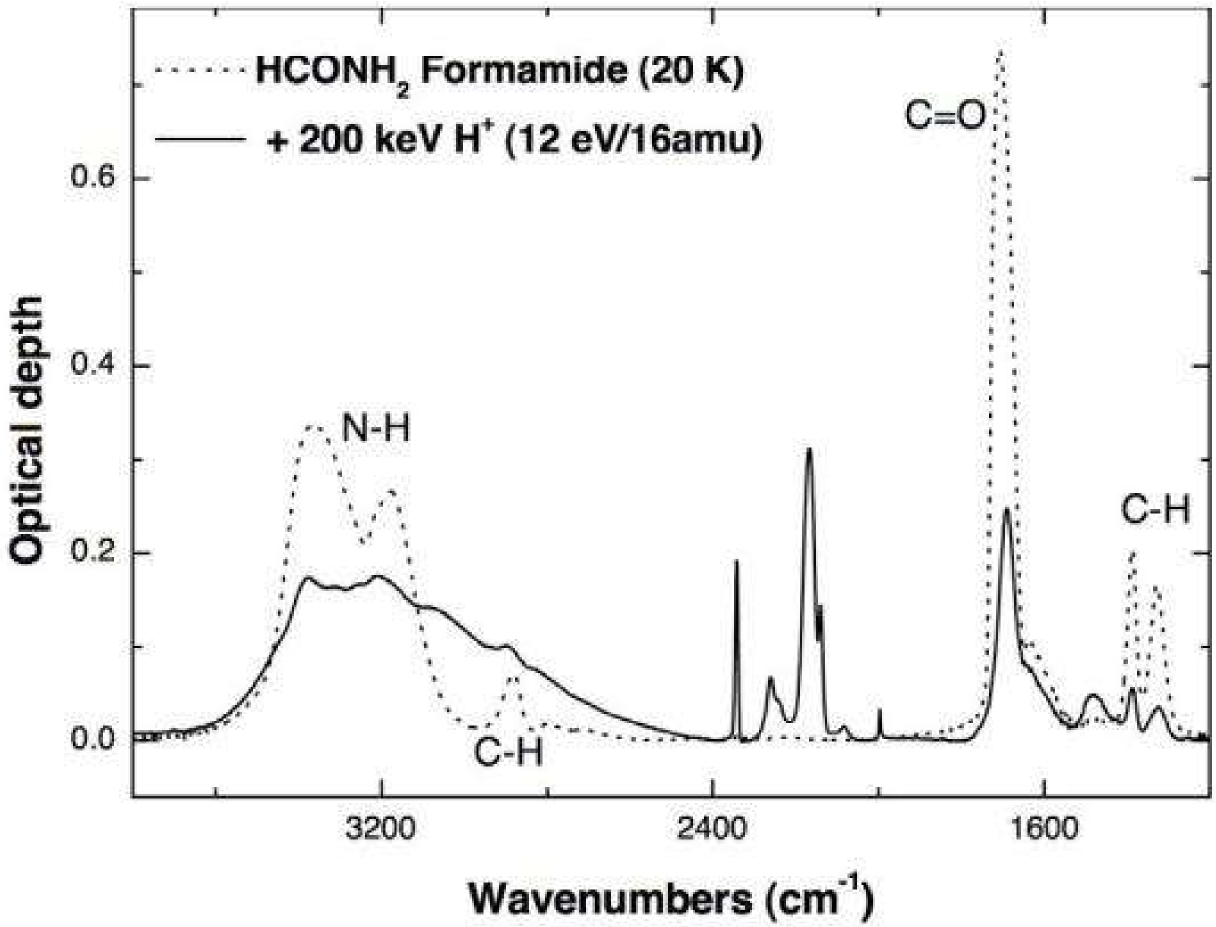
Baratta, G. A.; Accolla, M.; Chaput, D.; Cottin, H.; Palumbo, M. E.; Strazzulla, *G., 2019, Astrobiology, 19, 1018-1036*



Brucato J.R., Baratta G.A., Strazzulla G. 2006, A&A, 455, 395