Ultra High resolution mass spectrometer,
ORBITRAP for ILMA

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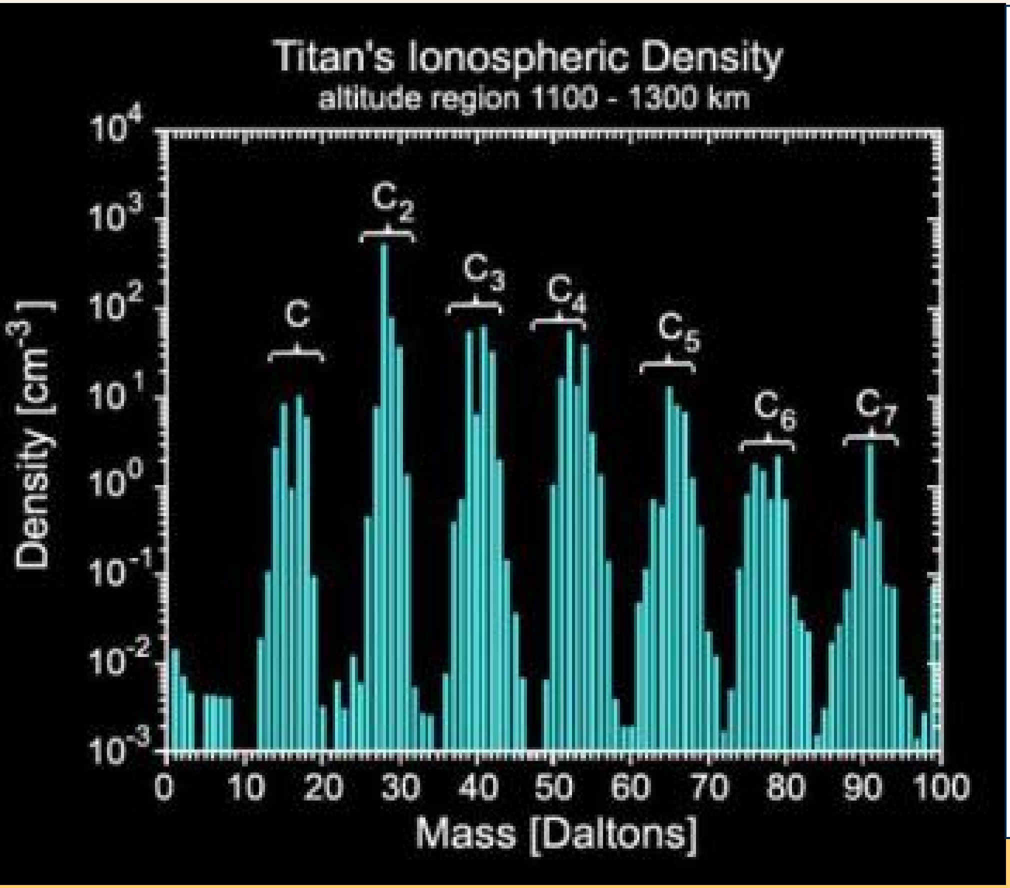
Nathalie Carrasco	**LATMOS**		
Jean Jacques Berthellier	**LATMOS**		
Cyril Szopa	**LATMOS**		

LPG

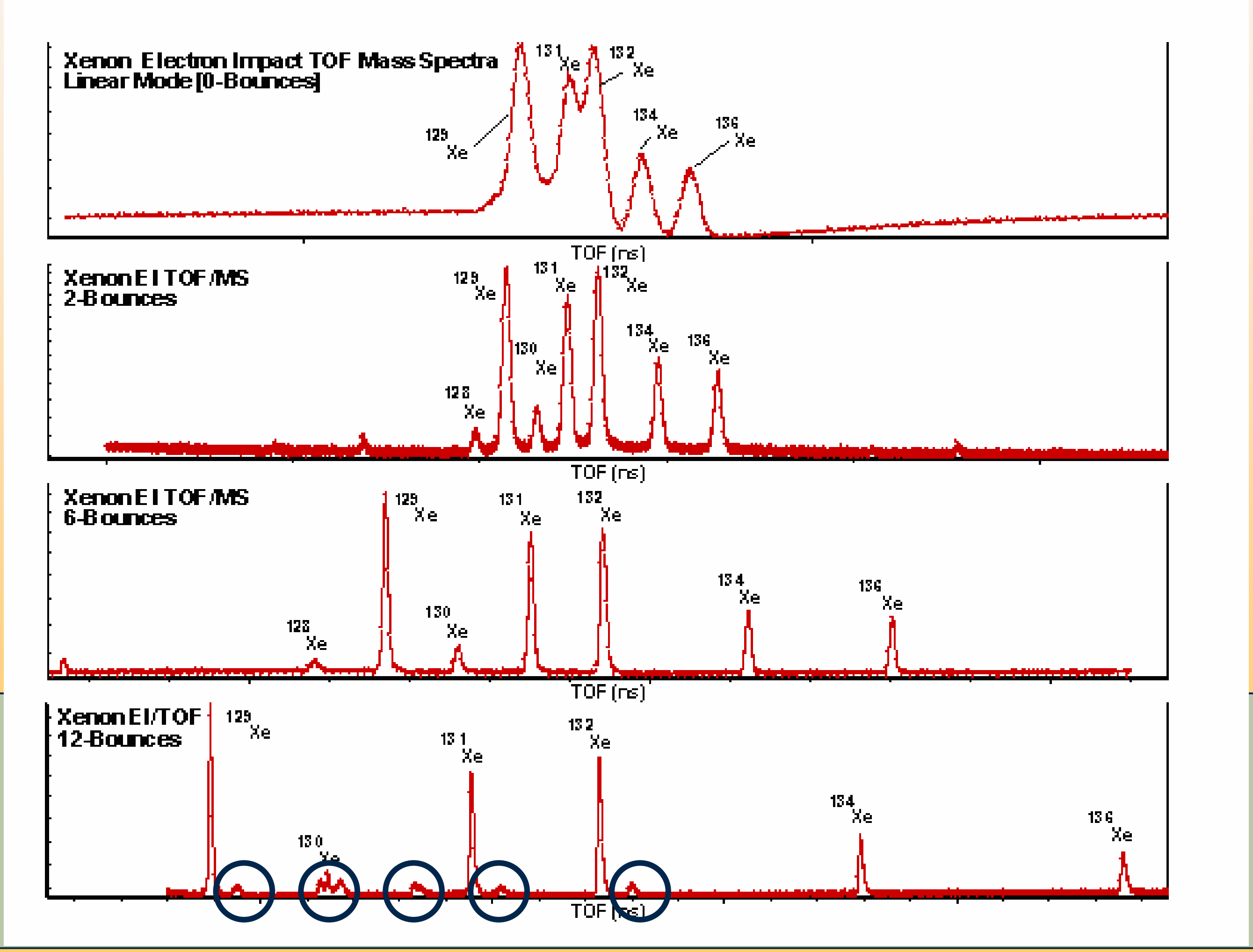
Cassini (INMS)
ionic densities in Titan ionosphere



C_7NH^+	99.0109	resolution
$C_8H_3^+$	99.0235	7857
$C_4N_3H_9^+$	99.0797	1761
$C_5N_2H_{11}^+$	99.0923	7857
$C_6NH_{13}^+$	99.1049	7853
$C_7H_{15}^+$	99.1174	7920

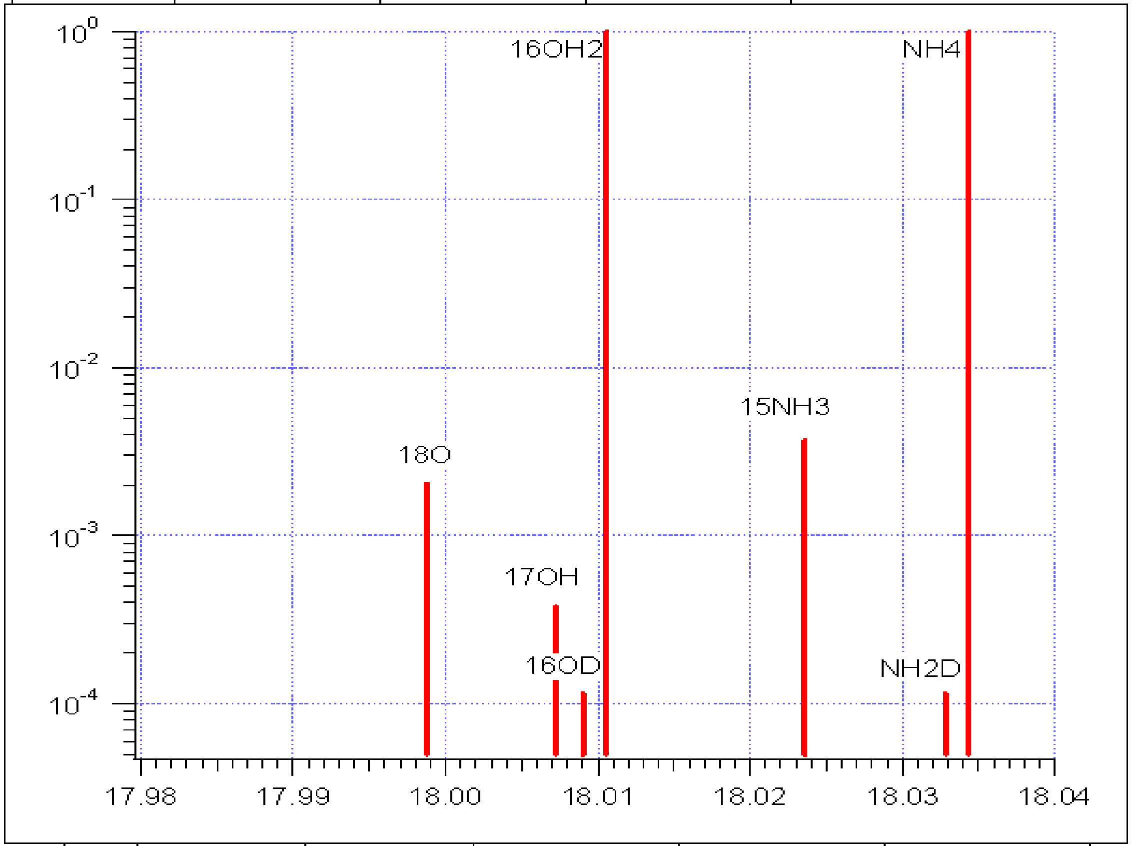
Measurement of Xe isotopes?? (B. Marty)

LPG



need for H/D inside primitive molecules?? (T. Owen)

Point	atome	masse	int
0	H	1.00783	0.999885
1	D	2.0141	0.000115
2	o16	15.995	0.99757
3	O17	16.9991	0.00038
4	O18	17.9992	0.00205
5	N14	14.0031	0.99632
6	N15	15.0001	0.00368



Point	ions18	masse18	intensite18	dif18	resol18
0	18O	17.9988	0.00205	0	inf
1	17OH	18.0072	0.00037995633	0.00844002	2133
2	16OD	18.009	0.00011472055	0.00177574	10137
3	16OH2	18.0106	0.99734062	0.00155067	11608
4	15NH3	18.0236	0.0036787309	0.0130177	1383
5	NH2D	18.0328	0.00011455046	0.00924301	1947
6	NH4	18.0344	0.99586189	0.00154877	11622
7					

Rosetta's
Rosina
DFMS
3 000
16 kg

Mass
Filter

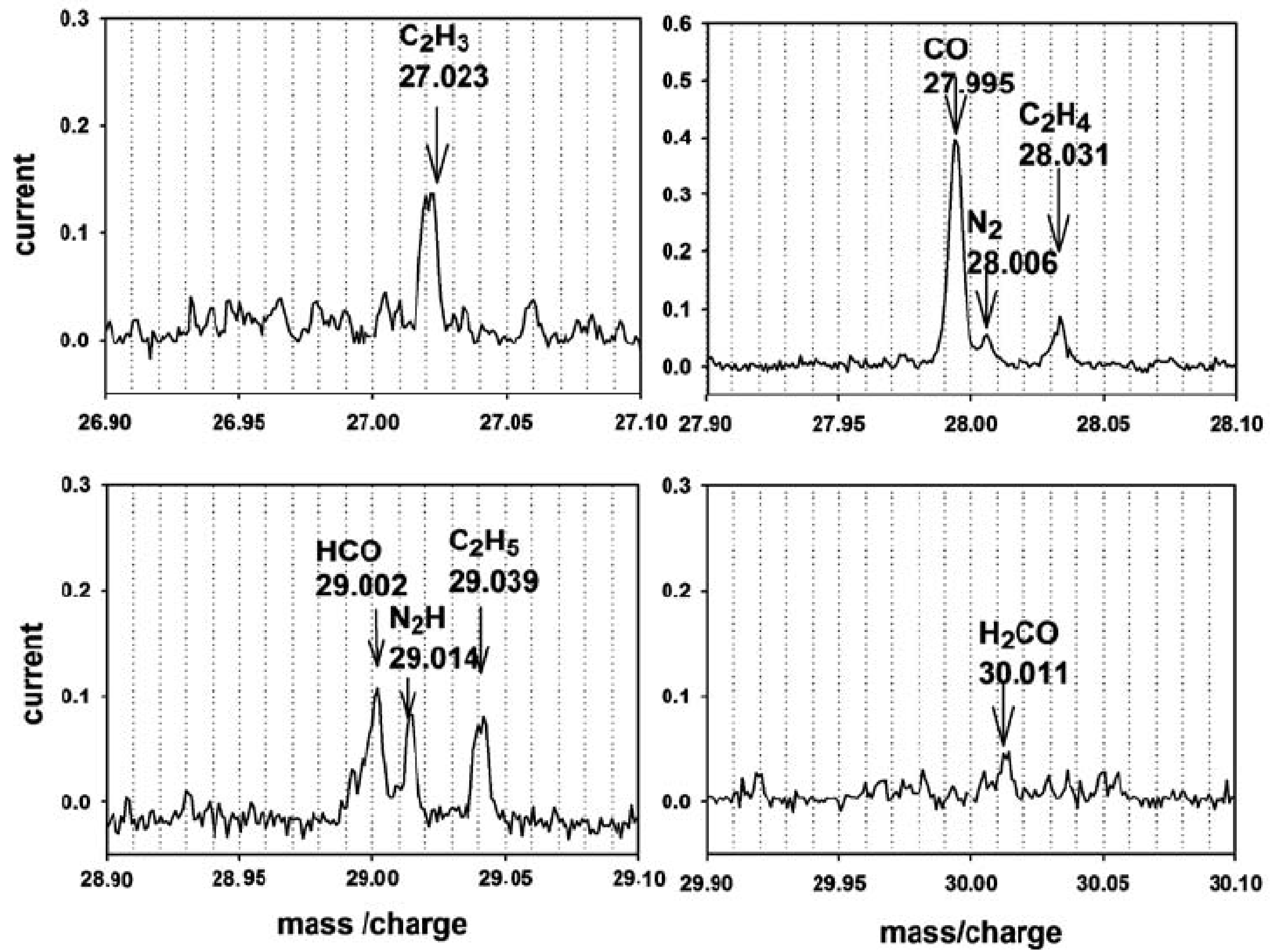
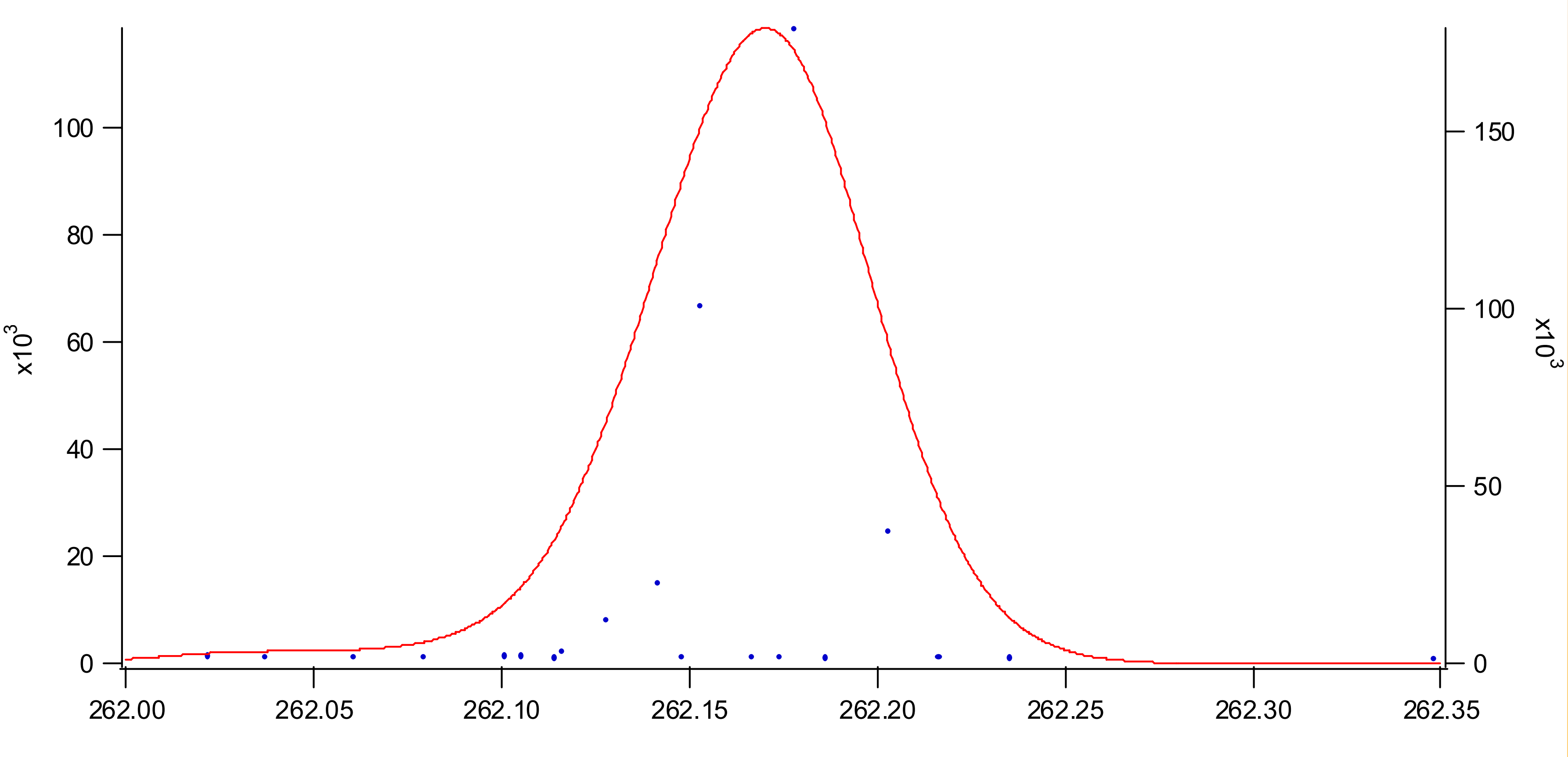


Figure 12. Part of a high resolution background mass spectrum from space at a total pressure of 4×10^{-11} mbar. Integration time was 20 s per mass. The triplets at mass/charge 28 and 29 amu/e can be separated easily.

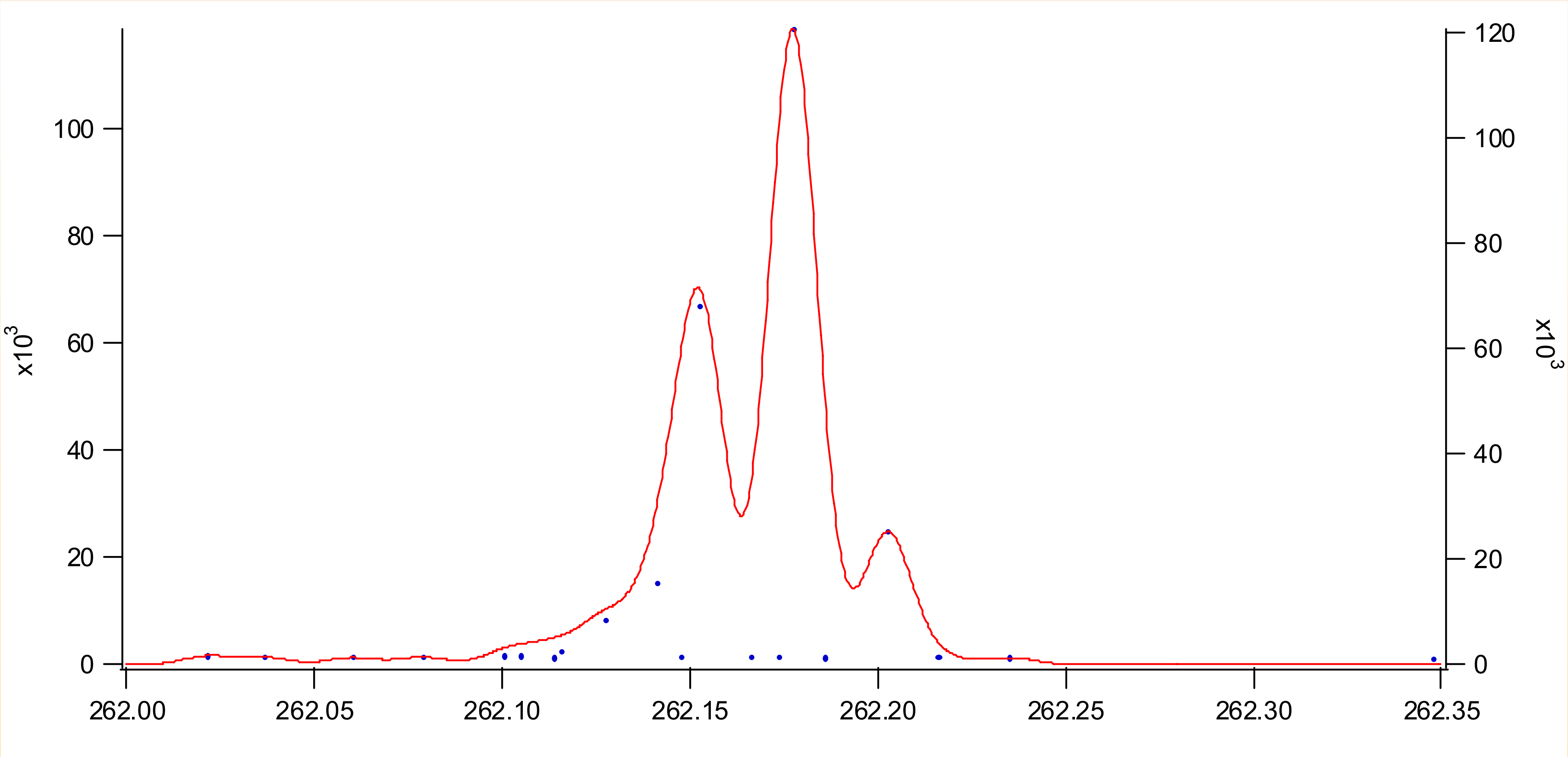
What if we study Titan with DFMS ?

LPG



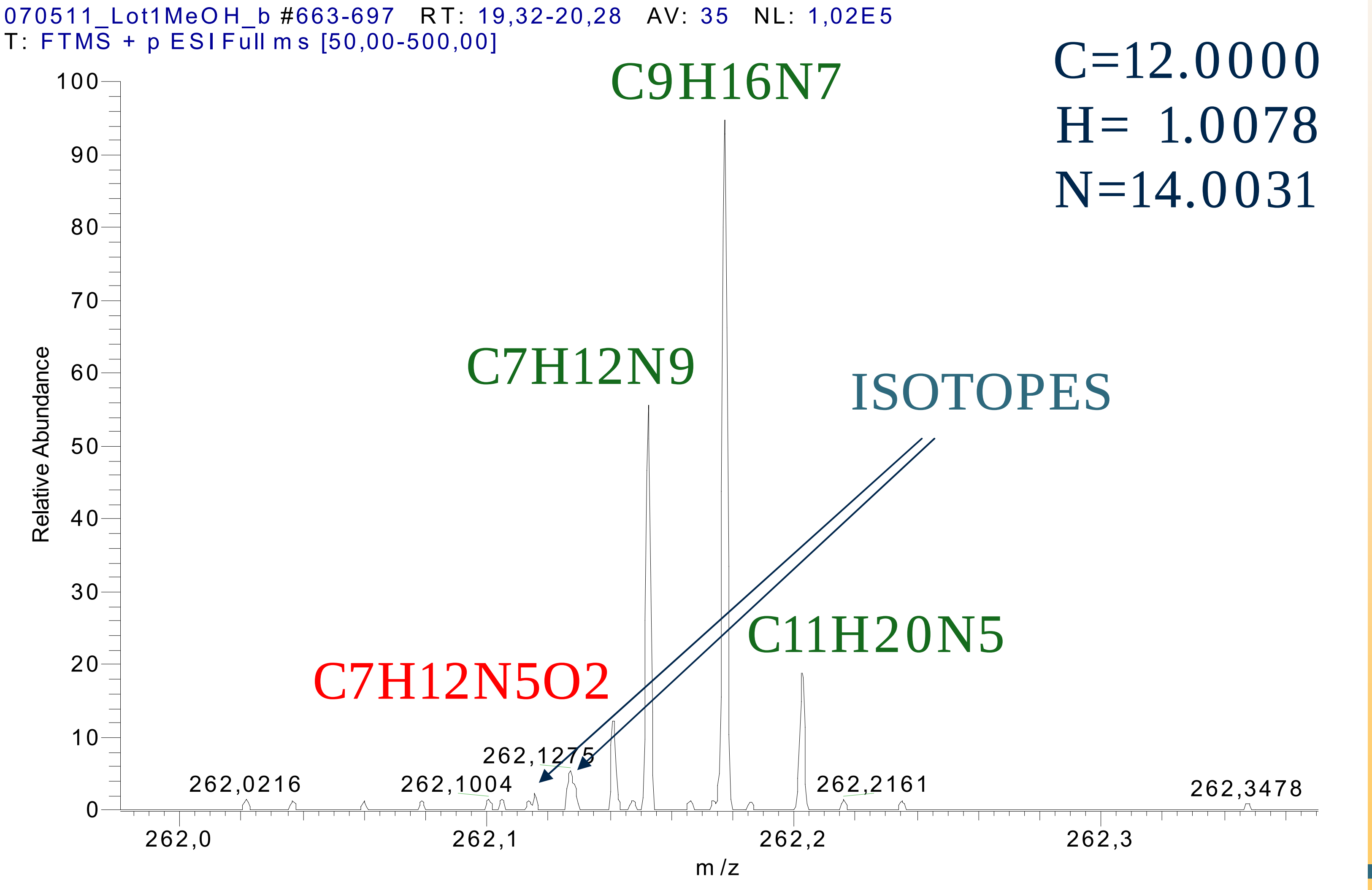
LPG

10 000 resolution...

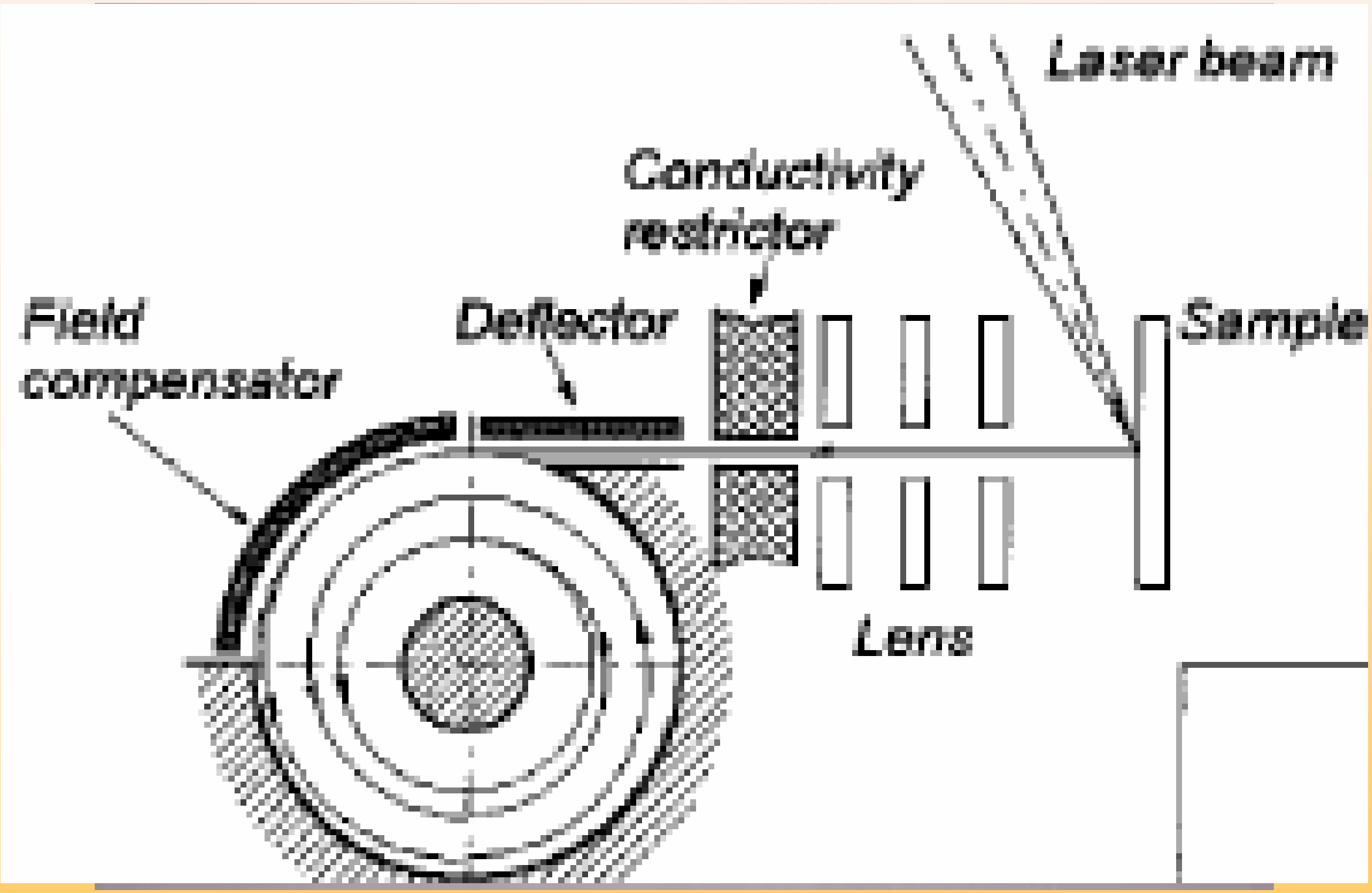


LPG

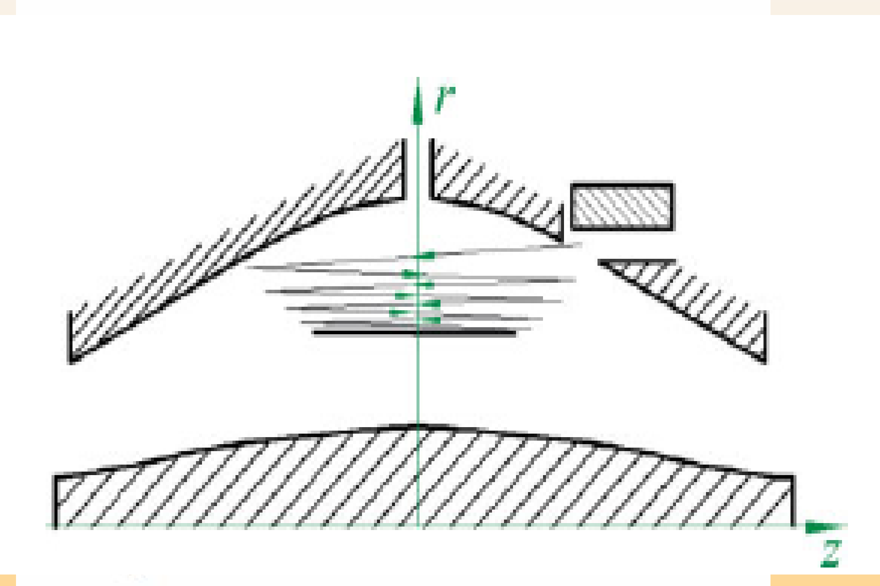
Orbitrap : 100 000



Orbitrap, big box... but very small analyser inside



Orbitrap, new concept for mass spectrometry



Detection by image current + FT

Simultaneous measurement of all ions

- Electrodes shapes

$$z_{1,2}(r) = \sqrt{\frac{r^2}{2} - \frac{(R_{1,2})^2}{2} + (R_m)^2 \ln\left[\frac{R_{1,2}}{r}\right]}$$

- Ion frequencies along Z

$$\omega_z = \sqrt{\frac{q}{m}k}$$

- Ultimate Resolution : 100 000 at mass 400

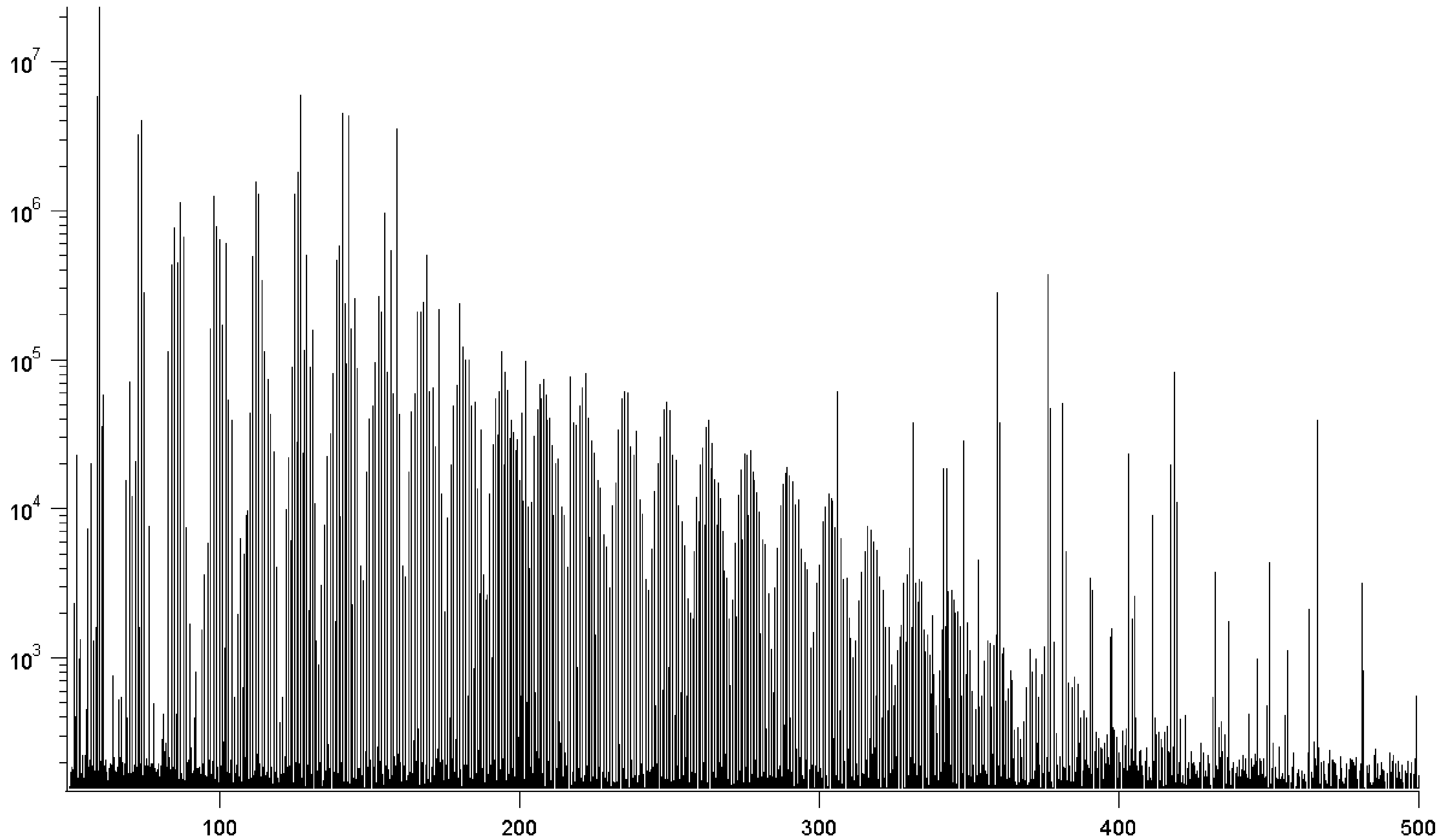
Orbitrap, potential

- Ultra high resolution 100 000 at mass 400, adjustable during mission, as it depends only on the integration time
- Very small volume, lightweight : l=4 , ϕ= 4 cm
- Good detection Dynamic 50 000
- Positive or negaitve Ions as only one potential to invert
- All ions are analysed simultaneously
- No detector, no saturation, ...
- no RF, no moving part
- Ideal for solids or aerosols
- Source by laser or pulsed ions ➔ ILMA

LPG

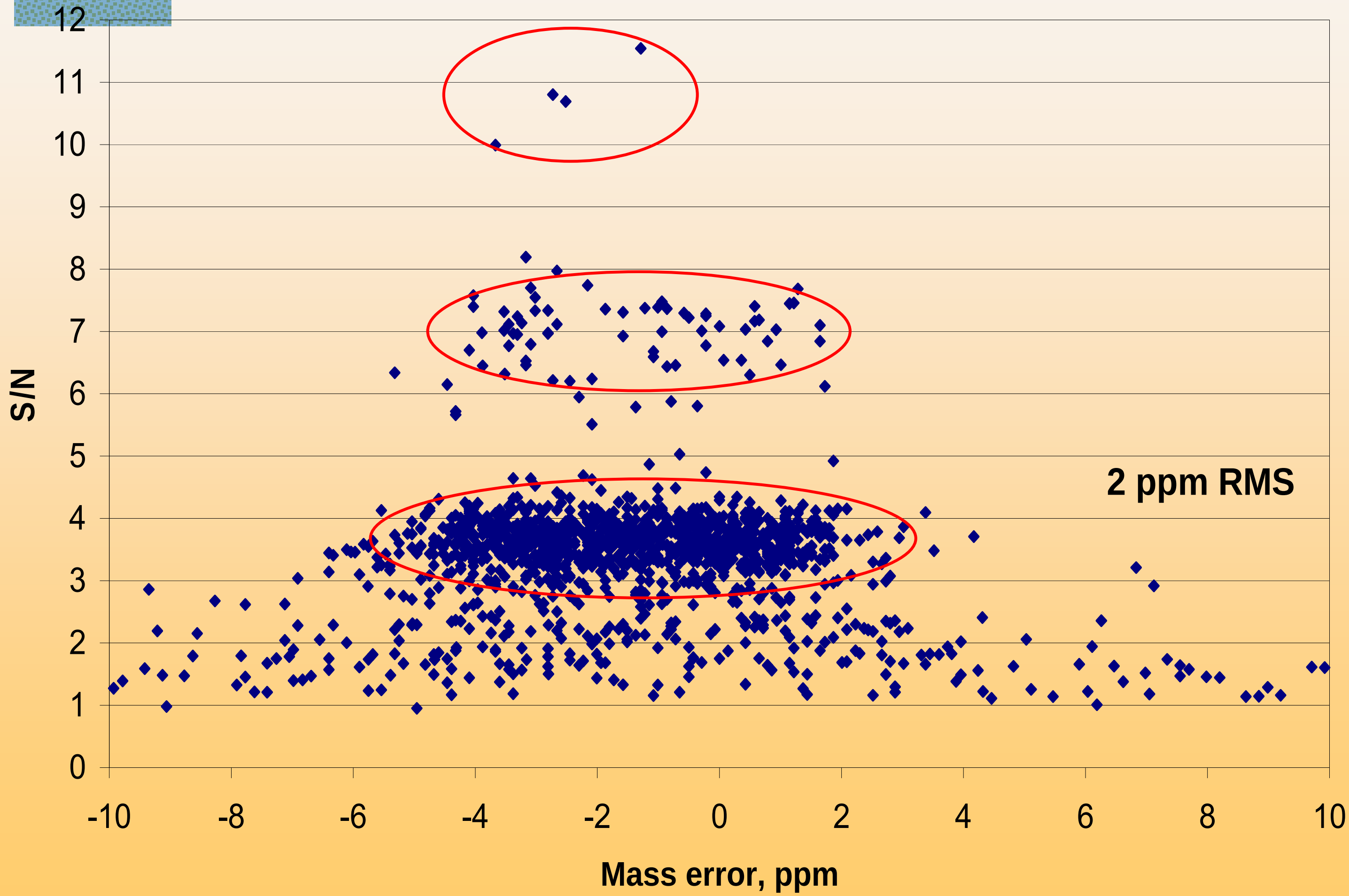
Tremendous effect of signal averaging

(1 spectrum vs average of 400)



LPG

Sensitivity: 6 charges



3 ions

2 ions

1 ion

Many of these ions decay (R<35,000)

For 1 ion with +20 charges, S/N=3.7 on average (0.76 sec acquisition). It means that Noise-band≈5.5 charges. This fits with noise characteristics of image current preamplifier.

ILMA
Ion Laser Mass Spectrometer

ILMA, a high resolution mass spectrometer for in situ analysis of mineral and organic composition of NEOs

Hervé Cottin and the ILMA team

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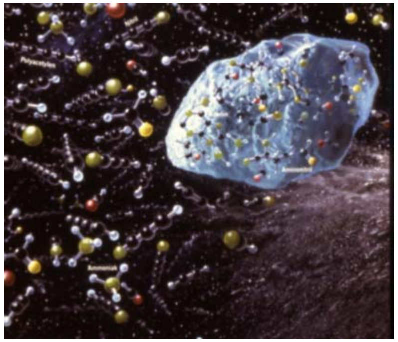
AUSTRIAN RESEARCH CENTERS CSNSM lisa LPC2E MPS BERGISCHE UNIVERSITÄT WUPPERTAL LATMOS Laboratoire de Planétologie Grenoble

Cosmic Vision & Marco Polo Science objectives
-Origin of the Solar System
-Origin of life



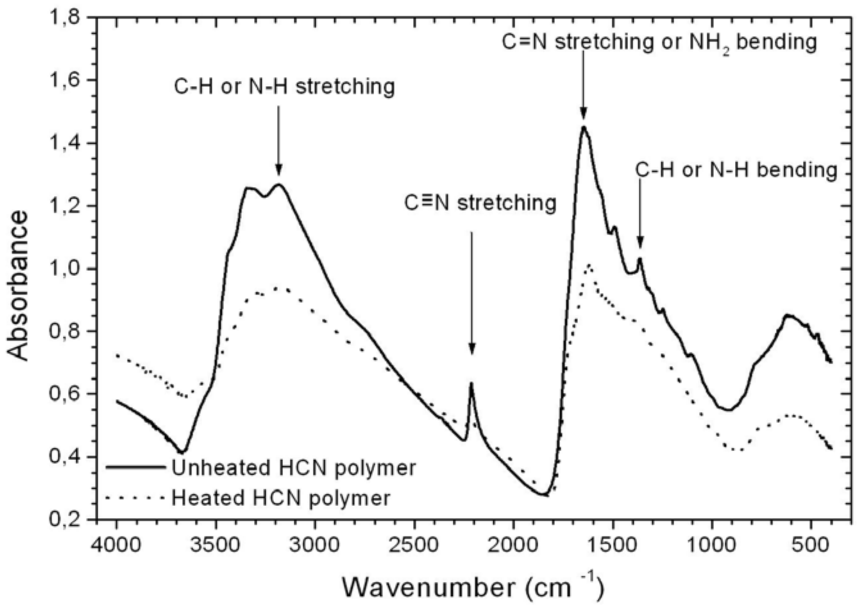
Astrobiology relevance of the mission if organic compounds are measured

- Need an actual identification of the molecular structure
- Possible with high resolution mass spectrometry

In situ measurements of organics are mandatory

Pristine organic material can be highly sensitive to T (as low as 320 K)

Contamination must be evaluated



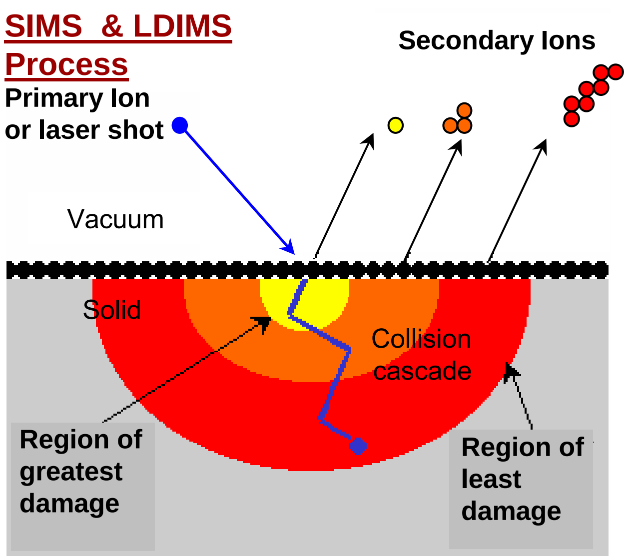
ILMA
Ion Laser Mass Spectrometer

What is ILMA ?

A new generation high resolution mass spectrometer, proposed to be part of the MSC or the lander payload.

ILMA is an **ion trap Fourier Transform mass spectrometer** using **SIMS** (Secondary Ion Mass Spectrometry) and **LDIMS** (Laser Desorption Ion Mass Spectrometry

ILMA is built on an **ORBITRAP** analyser
Resolution > 100 000 !



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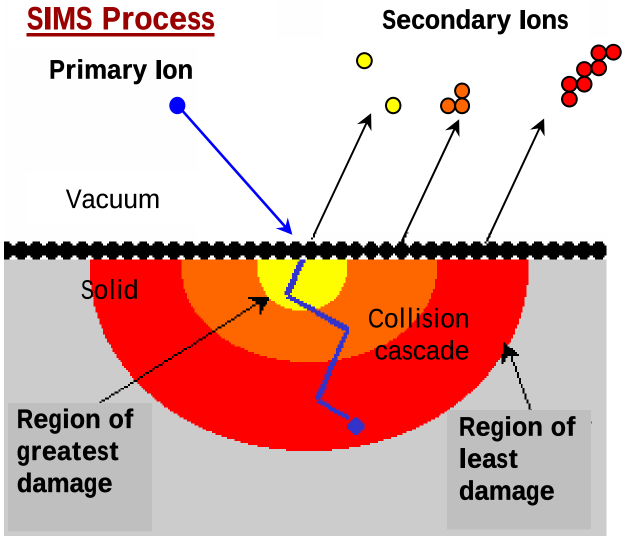
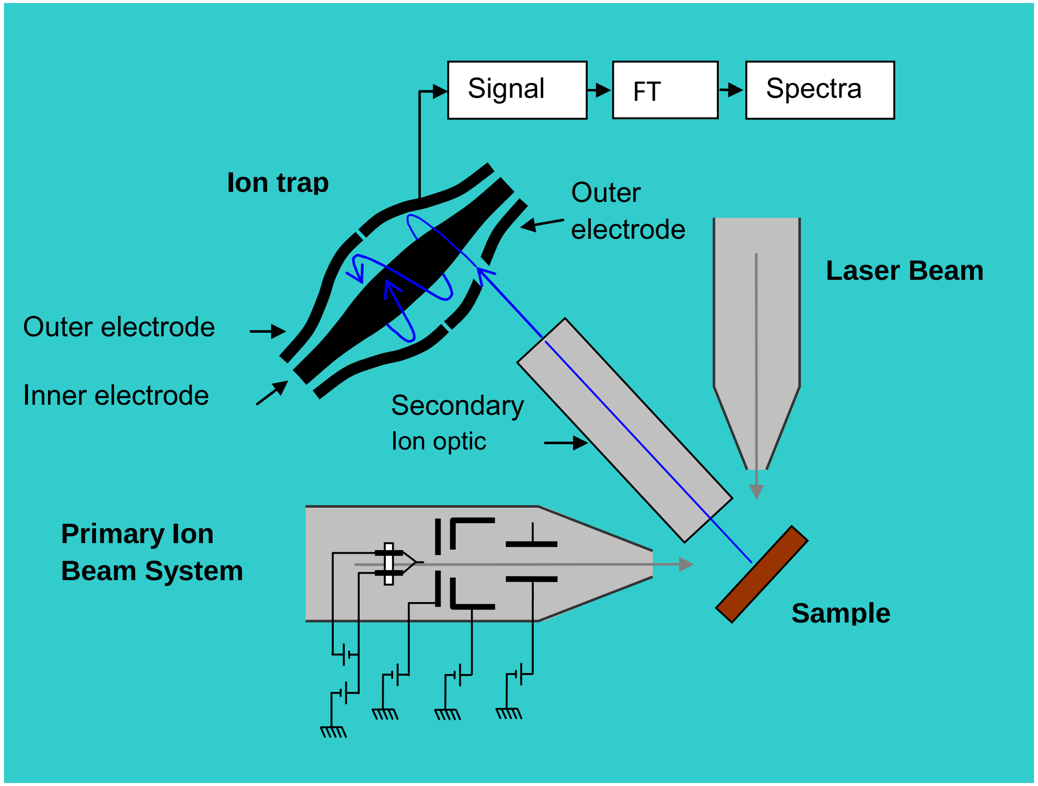


TECHNICAL REQUIREMENTS

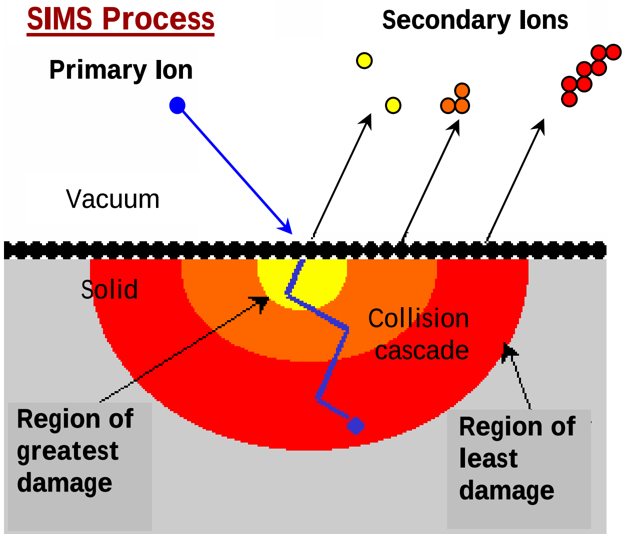
Mass:	**~ 3 kg Laser + Ion gun**
	~ 2 kg Laser only
Volume:	15x15x5 cm^3
Electronic unit :	15x10x3 cm^3
Mean power:	**~ 9 W**
Mass range:	1-30 / 25-750 amu
Mass resolution:	**100,000** at 50% height at 400 amu
Analyzed area:	a few μm^2 to 1 mm^2

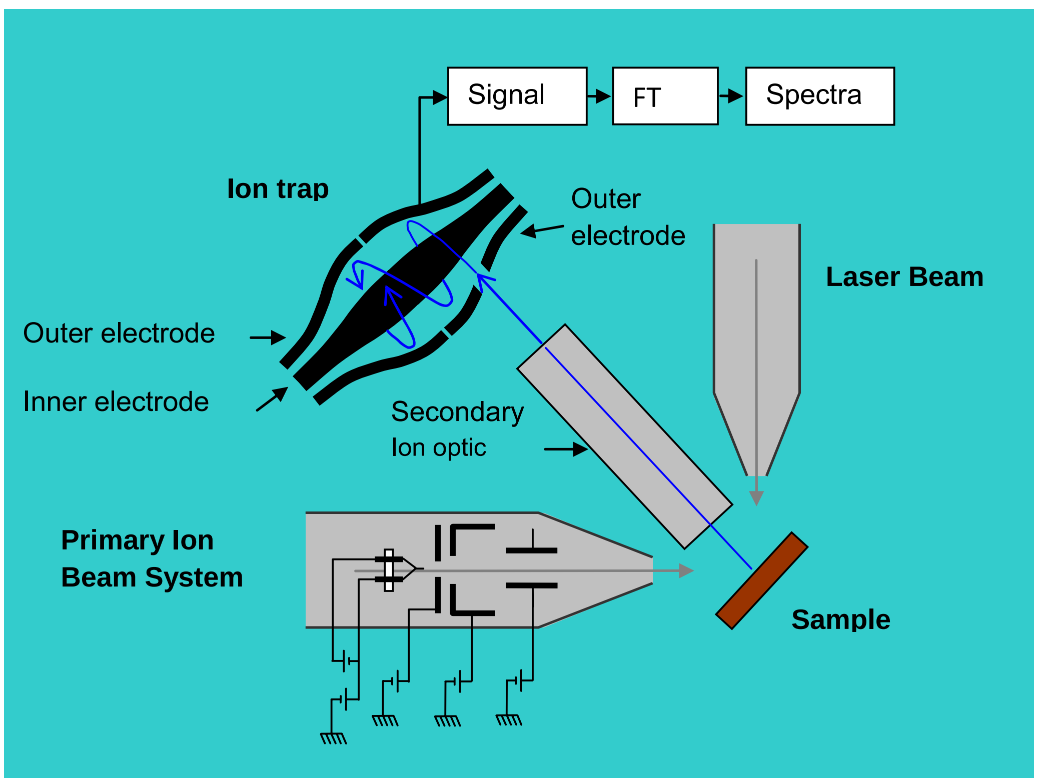


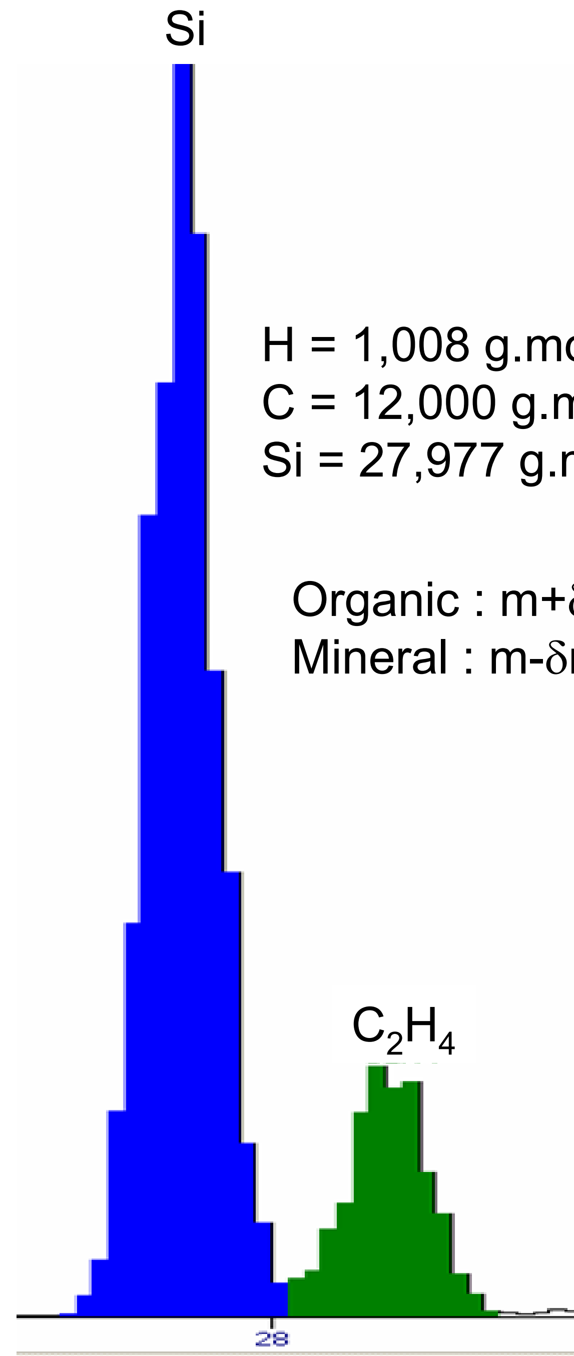
Thanks to the high resolution

Analysis of Minerals & Organics

With amount << 1g !







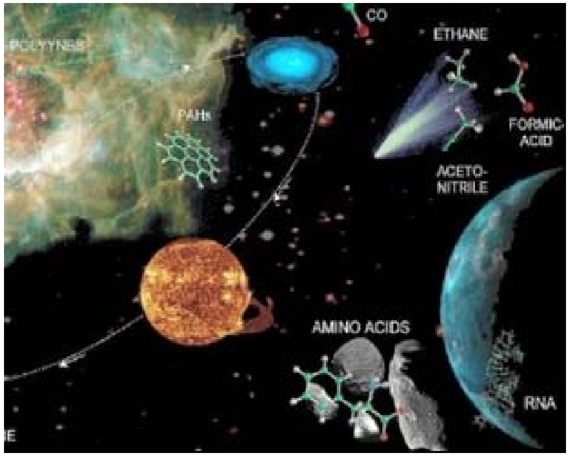
H = 1,008 $g.mol^{-1}$
C = 12,000 $g.mol^{-1}$
Si = 27,977 $g.mol^{-1}$

Organic : $m+\delta m$
Mineral : $m-\delta m$

ILMA and the origin of the Solar System

ILMA will characterize *in-situ* the elemental, isotopic and molecular composition of the targeted NEO.

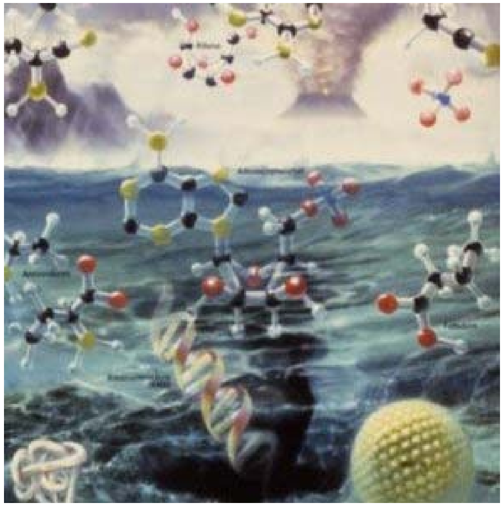
- Measurement of various isotopic ratios ($^{12}C/^{13}C$, $^{14}N/^{15}N$, $^{16}O/^{17-18}O$, $^{28}Si/^{29-30}Si$)
- Information on the formation processes, alteration (hydrothermalism), interstellar component...
- Datation is possible : $^{207}Pb/^{206}Pb$



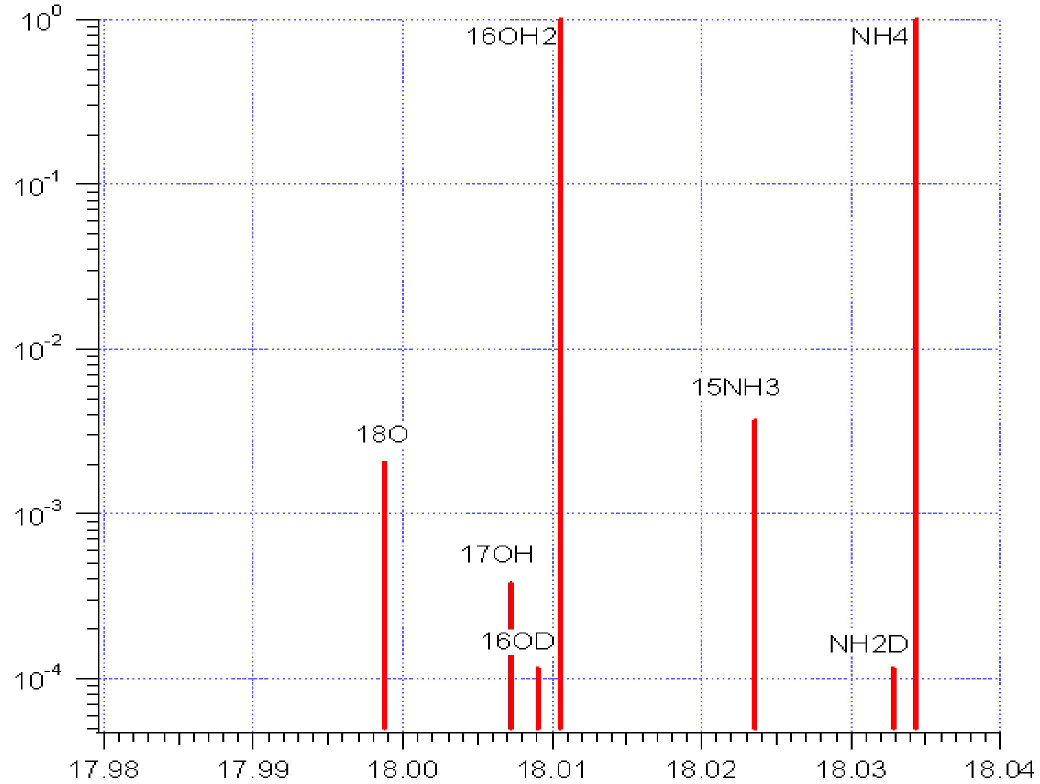
ILMA and the origin of Life

ILMA will analyze volatile and organic compounds in the NEO.

- The measurement of D/H ratios will give better **constraints on the origin of water on Earth.**
- D/H and C/H ratios will help link the **organic** component of the NEO to the different families of organic material present in meteorites.
- Analysis of organic molecules will asses **the relevance of NEOs for the origin of life**.



Resolution ↗ = Science ↗



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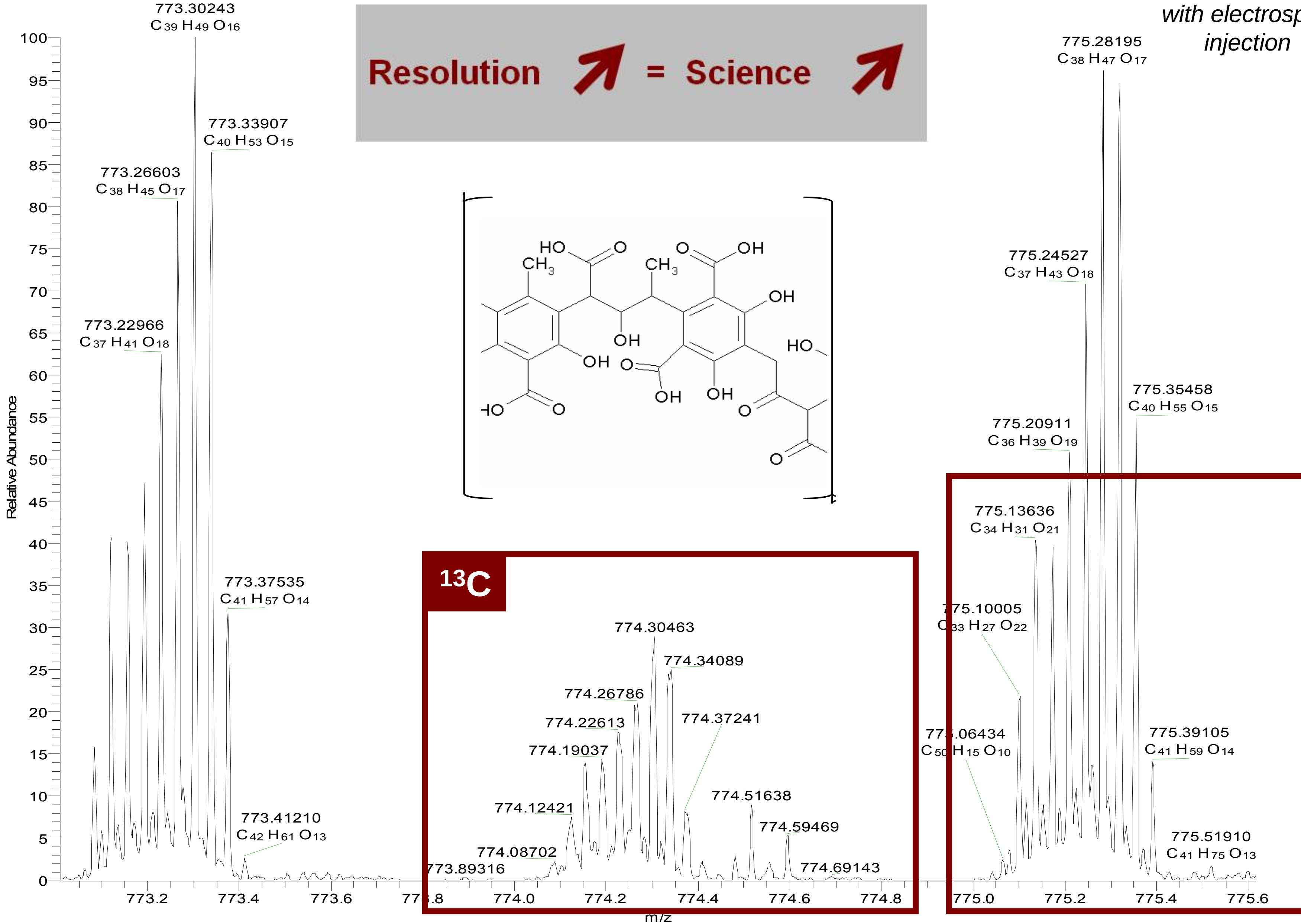
5	NH2D	18.0328	0.00011455046	0.00924301	1947
6	NH4	18.0344	0.99586189	0.00154877	11622
7					

Example : analysis at mass 18

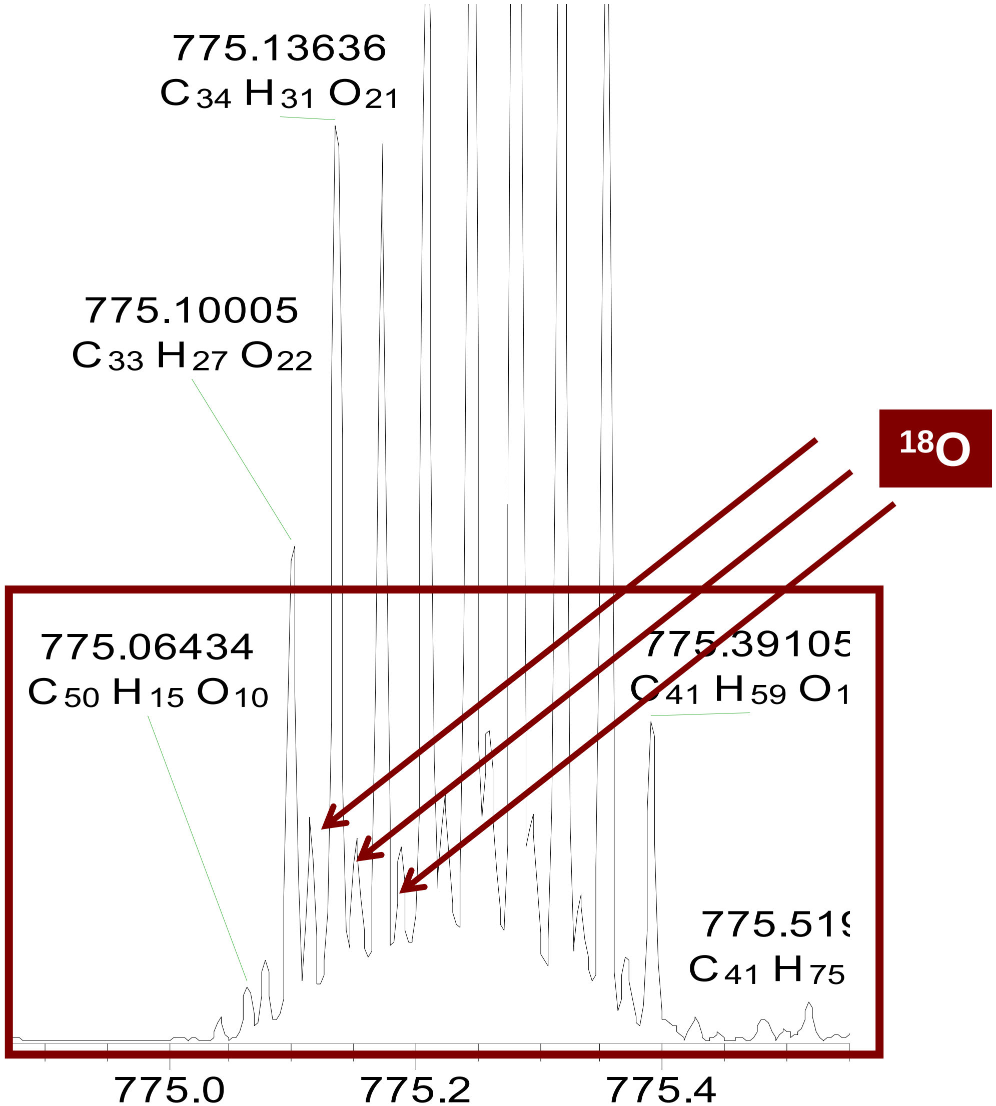
Resolution ↗ = Science ↗

Lab. measurement with electrospray injection



Example : acid fulvic (humus component, high molecular weight organic)

Lab. measurement with electrospray injection



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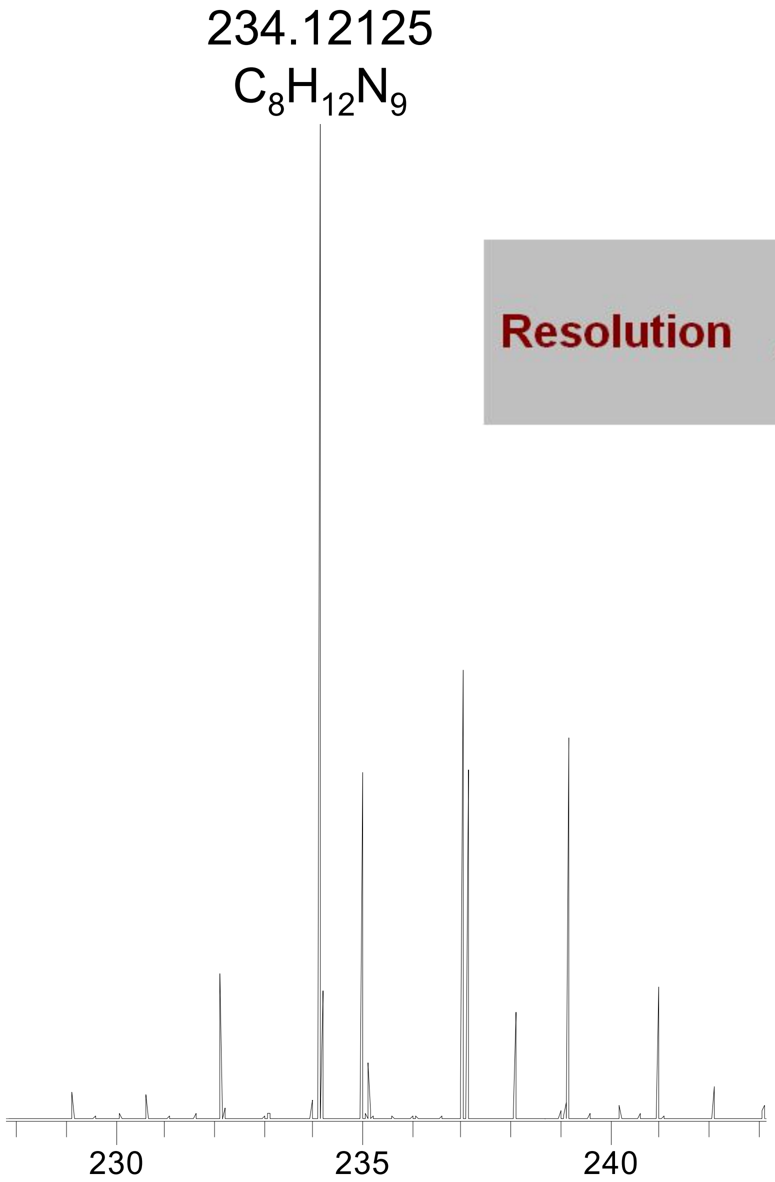
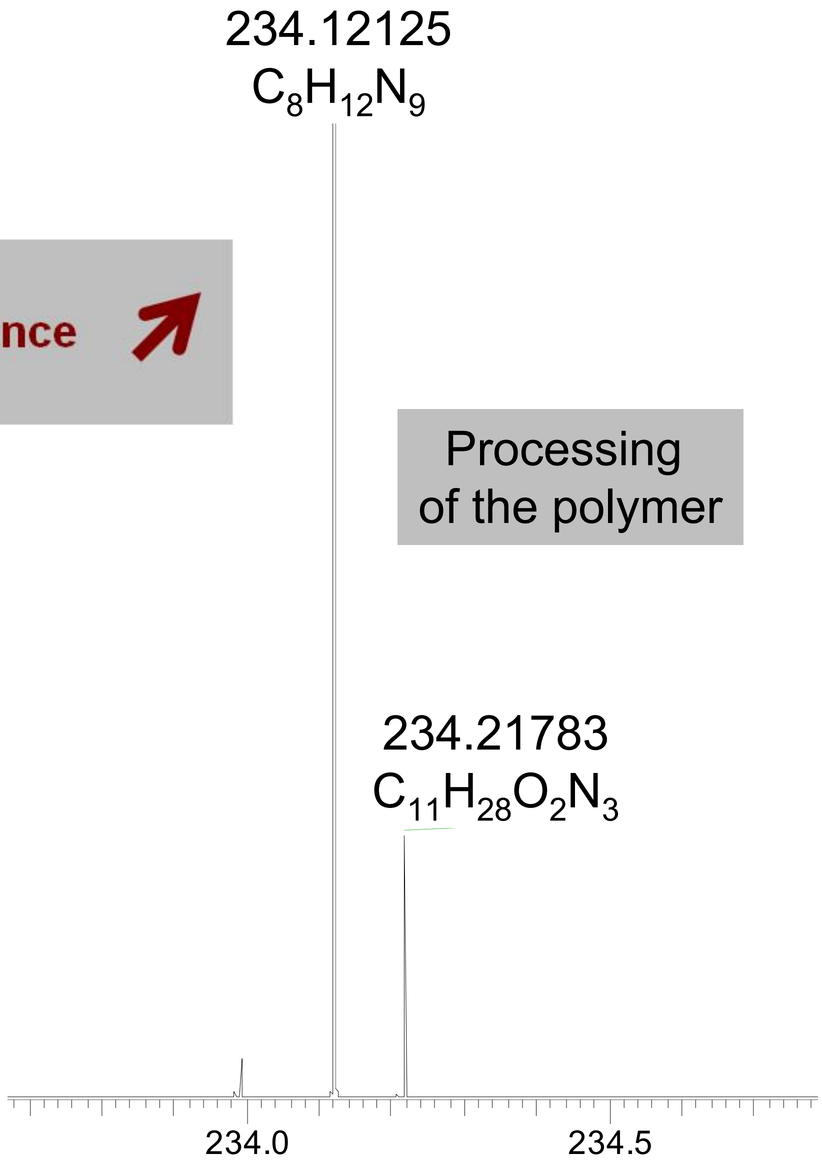


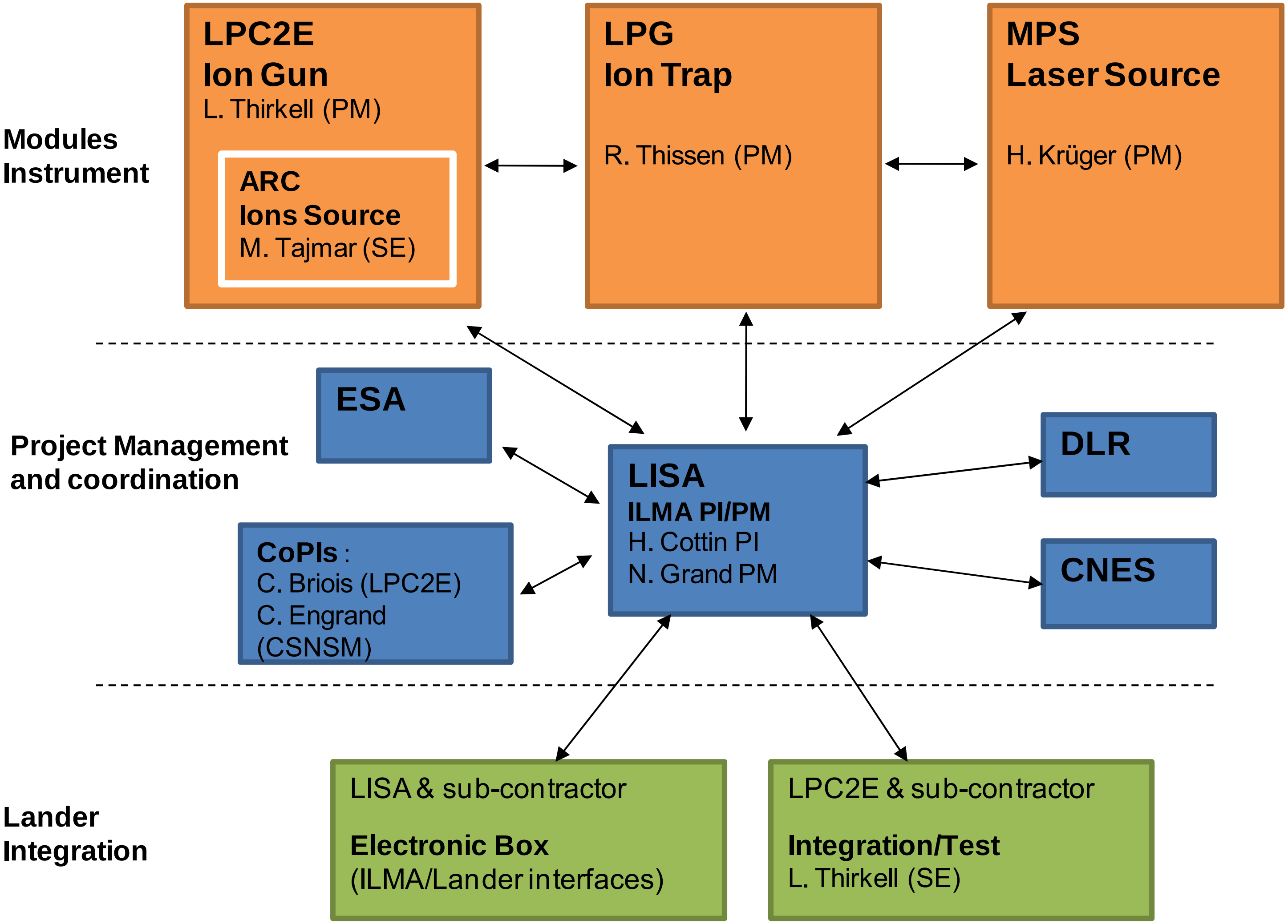
Resolution ↗ = Science ↗



Processing of the polymer

Example : HCN polymer at mass 234

Lab. measurement with electrospray injection



Co-Investigators -
M. Aliman (Zeiss GmbH.), **D. Bockelée-Morvan** (Obs. Paris), **J.R. Brucato** (Florence Obs.), **N. Carasco** (LATMOS), **M. Chaussidon** (CRPG), **S. Derenne** (Paris), **S. Erard** (Obs. Paris), **M. Fulchignoni** (Obs. Paris), **A. Glasmachers** (U. Wuppertal), **M. Hilchenbach** (MPS Katlenburg-Lindau), **R. Kallenbach** (MPS Katlenburg-Lindau), **A. Makarov** (Thermofisher), **P. Michel** (Obs. Côte d'Azur), **Tomoki Nakamura** (Kyushu University), **E. Quirico** (LPG), **S. Russell** (NHM London)**, G. Strazzulla** (Catania Obs.), **C. Szopa** (LATMOS), **W. Steiger** (ARC).

CONCLUSIONS

Collaboration with the inventor of the concept (A. Makarov) and the ThermoFisher company distributing the commercial version (NDA agreement between ThermoFisher company and the participating teams).

Laboratory prototype coupling laser & orbitrap foreseen by Oct. 2009

CNES is supporting ILMA

A team with a strong experience of mass spectrometry (some of the CoIs involved in the COSIMA mass spectrometer onboard ROSETTA)

ILMA is a unique opportunity to characterize the context of the sampling. Either on the mother spacecraft or on a lander. For 2 kg.

⇒Mineral and organic molecular composition

⇒Isotopic ratios (D/H, C, O, N, Si…)

⇒Dating

Earth as seen from NEA TOUTATIS, 29/9/2004, 1.5 million km from Earth