ILMA: Ion Laser Mass Analyser
In Situ Analysis of Airless Bodies in the Solar System
The Hunt for Organic Matter


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**ILMA**

**Ion Laser Mass Analyser**

What is ILMA?

A new generation high resolution mass spectrometer, proposed to be part of a surface payload for airless bodies.

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

ILMA is built on an **ORBITRAP** analyser

Resolution > 100 000 !
From a commercial (ORBITRAP) to a space instrument
// development for JUICE (dust telescope) and Marco Polo type mission
Volume Properties
15x15x6 cm (+ electronic unit : 15x15x7 cm)

Mass Properties and Budget:
3 to 5 kg

Power and Energy Budgets:
*Maximum* power consumption is 24 W.

Data budget:
1Mo for one sample analysis.

No Pump

Thanks to the high resolution

Analysis of Minerals & Organics
H = 1,008 g.mol\(^{-1}\)
C = 12,000 g.mol\(^{-1}\)
Si = 27,977 g.mol\(^{-1}\)

LDIMS Process

Laser shot
Vacuum
Solid
Region of greatest damage
Collision cascade
Region of least damage
Desorbed Ions

Organic : m+\(\delta m\)
Mineral : m-\(\delta m\)

Ion trap
Laser Beam
Ion optic
Sample
Outer electrode
Inner electrode
Signal
FT
Spectra

C\(_2\)H\(_4\)

H \(\rightarrow\) FT \(\rightarrow\) Spectra

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The benefits of high resolution

Ions in orbitrap

\[ \omega = \sqrt{\frac{k}{m/z}} \]

a: \[ \frac{M}{\Delta M} \sim 3000 \]

b: \[ \frac{M}{\Delta M} \sim 10000 \]

c: \[ \frac{M}{\Delta M} > 60000 \]
up to \( m/z = 400 \) amu
Example: acid fulvic (humus component, high molecular weight organic)
The benefits of high resolution

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

Lab. measurement with electrospray injection
The benefits of high resolution

at $m/\Delta m_{50\%} > 1000$, there is a separation of peaks of different nominal mass (e.g., 325 Da versus 326 Da);
at $m/\Delta m_{50\%} > 10,000$, the resolution of small (<2500 Da) peptides of the same nominal mass differ by one amino acid (except for isomeric leucine and isoleucine); and
at $m/\Delta m_{50\%} > 100,000$, there is a separation of peaks for nominally isobaric species (i.e., molecules of the same nominal mass differing in elemental composition, e.g., $\text{N}_2$ versus CO, both $\sim$28 Da).

HRMS and the origin of the Solar System
HRMS can characterize in-situ the elemental, isotopic and molecular composition of an Asteroid, Comet or Moon.
- Measurement of various isotopic ratios (\(^{12}\text{C}/^{13}\text{C}, ^{14}\text{N}/^{15}\text{N}, ^{16}\text{O}/^{17,18}\text{O}, ^{28}\text{Si}/^{29,30}\text{Si})
- Information on the formation processes, alteration (hydrothermalism), interstellar component if any...

HRMS and the origin of Life
HRSM can analyze volatile and organic compounds at the surface of an airless body.
- The measurement of D/H ratios on asteroids and comets 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 Asteroids and Comets to the different families of organic material present in meteorites.
- Analysis of organic molecules will assess the relevance of NEOs for the origin of life.
- Analysis of organic molecules at the surface of a Jovian (or Kronian) moon will assess the astrobiological potential of the body.
From lab to space

- Laboratory Brassboard
- High Resolution
- Ion optic in microgravity
- Mass
In the last few months: Dramatic increase of resolution Fe @ 56 amu

From lab to space

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- High Resolution
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- Mass

06/2010: \( M/ \Delta M = 8300 \)

12/2011: \( M/ \Delta M = 46 \, 000 \)

01/2012: \( M/ \Delta M = 140 \, 000 \)

03/2012: \( M/ \Delta M = 190 \, 000 \)
From lab to space

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- High Resolution
- Ion optic in microgravity
- Mass

Analysis of organics

Mass Spectrum

- Adenine
- Adenine + H⁺
How to get the ions from the surface to the analyzer?

- Laboratory Brassboard
- High Resolution
- Ion optic in microgravity
- Mass
From lab to space

- Laboratory Brassboard
- High Resolution
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- Mass

**Diagram:**
- Laser Head
- Orbitrap vertical displacement mechanism
- Telescopic Ions Guide
- Electronic

**Diagram:**
- QCW diode laser
- Optical fiber
- Pump optics
- Dichroic mirror
- Saturable absorber Cr:YAG
- Laser rod Nd:YAG
- SHG - Second Harmonic Generation
- FHG - Fourth Harmonic Generation

**Notation:**
- QCW - Quasi Continues Wave
- Nd:YAG - neodymium-doped yttrium aluminium garnet
- Cr:YAG - chromium-doped yttrium aluminium garnet
- SHG - Second Harmonic Generation
- FHG - Fourth Harmonic Generation
From lab to space

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MS (Orbitrap, Pre-Amplifier, Box, Mecanisms) : 500 gr
Ion Guide (without electronic) : 200 gr
Laser (without electronic) : 500 gr
Main Electronics (including box) : 750 gr
High voltage electronics : 500 – 1500 gr (*)
Misc (harness, etc.) : 300 gr

Total : 2750 - 3750 gr
Total with 20% margins : 3300 - 4500 gr
• The ion guide study has to be finalized, currently in R&T with CNES support (TRL 5 planned for 2014)

• The Laser is already TRL5
CONCLUSIONS

High Resolution Mass Spectroscopy (HRSM) and ORBITRAP

- 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 , f= 4 cm
- Good detection Dynamic 50 000
- Positive or negative 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