Instruments for in-situ measurements of the gas giants and their satellites

Conference or Workshop Item

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Instruments for *in-situ* measurements of the gas giants and their satellites

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In-situ measurements

Advantages:
• Scale from km to m, mm and μm
• Ground truth, physical properties
• Direct analysis of chemical composition
In-situ measurements

Disadvantages:
• Short time scale
• One location
• Landing – high risk
• Limited payload mass/power

Genesis landing
Planetary probes

**Kronos** *(cosmic vision 2007)*

Atmospheric Structure Instrument
- Density, pressure temperature

Doppler Wind Experiment

Nephelometer
- aerosol size, shape composition

Elemental Composition and isotopes
- D/H $^{13}$C/$^{12}$C $^{15}$N/$^{14}$N He, Ne, Ar Kr, Xe

Heritage Galileo + Rosetta Ptolemy
Titan - Huygens

Descent Imager and Spectral Radiometer
Doppler Wind Experiment
Huygens Atmospheric Structure Instrument
Surface Science Package
Gas Chromatograph and Mass Spectrometer
Aerosol Collector and Pyrolyser
Titan Atmospheric Chemistry

Cassini INMS and CAPS detected organics >10000 amu at 950km

- Sunlight
- Energetic particles

Molecular CH$_4$ and N$_2$

- Ionisation: C$_2$H$_5^+$, HCNH$^+$, CH$_5^+$, C$_4$H$_5^+$
- Dissociation: C$_2$H$_2$, C$_2$H$_4$, C$_2$H$_6$, HCN

Benzene (C$_6$H$_6$) and other organics (100 – 350 amu)

High mass organics >10000 amu

Tholins

Formation pathways?
Types of organics?
How complex are organics?
Are O containing organics formed?
Chirality?
Analysis Organics

GC - MS
GC – separates compounds, identification by MS

Derivatisation required for amino acids and chirality

Life Marker chip - ExoMars
Target specific molecules
High sensitivity
~1.5 kg
High Resolution Mass Spectrometry

Time of Flight
Rosetta, ROSINA and COSAC
Mass range 2-500  M/ΔM  500

MBToF
Mass range 2-10 000  M/ΔM  10 000

Orbitrap
M/ΔM 100 000
GC x GC MS

Combination of non-polar column followed by polar column

GCxGC analysis of tholin sample

MS requirements
M >600 amu,
F >10Hz
M/ΔM >600
Stable Isotopes (1‰)

\[ \delta^{13}C = \left\{ \frac{\left( ^{13}C/^{12}C \right)_{\text{sample}}}{\left( ^{13}C/^{12}C \right)_{\text{reference}}} - 1 \right\} \times 1000 \% \]

\(^{12}C\) bonds preferably made and broken

Carboxylic acids formed by solid phase reactions with carbonates
Isotopic Analysis

Mass Spectrometer Schematic: depicting a triple-collector system arranged to analyze CO₂.

Stable magnetic field
Simultaneous collection — separate ions in space
Faraday cup collectors
Flat topped peaks
Chemical processing
Reference material

Curiosity, SAM TLS
\(^{18}O/^{16}O, \quad ^{13}C/^{12}C\) precision ~1‰

Heritage
Pheonix, TEGA
Beagle2, GAP (6kg)
System diagram

- GCxGC, High resolution MS, targeted detection, astrobiology
- High precision Isotope MS
In-situ measurements at Europa / Enceladus

In-situ by orbiter
Subterranean ocean
No atmosphere
Hard surface

Enceladus
- Instrumented projectiles
- Survive high impact speed
- Penetrate surface ~ few metres
- An alternative to soft landers
- Low mass/lower cost => multi-site deployment

Penetrators

- Detachable De-orbit Stage
- Point of Separation
- Payload Instruments
- PDS (Penetrator Delivery System)

\[\text{UCL}\]
\[\text{Imperial College London}\]
\[\text{Surrey Space Centre}\]
\[\text{PSSRI}\]
\[\text{QinetiQ}\]
\[\text{University of Leicester}\]
Penetrator trials Pendine

MS Overview

Heritage Rosetta, Ptolemy
Mass range 10 – 150 amu
Unit mass resolution
Mass ~ 0.5kg
Power 2W
Summary

• Determination of noble gas concentration

• Measurement of noble gas isotopes

• Measurement of D/H, $^{13}\text{C}/^{12}\text{C}$, $^{15}\text{N}/^{14}\text{N}$, $^{18}\text{O}/^{16}\text{O}$ and $^{17}\text{O}/^{16}\text{O}$ isotopes

• Detailed organic chemical analysis M/DM > 10 000 and mass range >. 10000

• Possibility of measurements on surface of Europa and Enceladus