EXPLORATION OF CRYOGENIC ENVIRONMENTS VIA ULTRAHIGH MASS RESOLUTION WITH THE AROMA INVESTIGATION. R. Arevalo Jr.[1], R. Danell[2], A. Southard[3], E. Hernandez[1], L. Hovmand[4], F. Tan[1], A. Grubisic[5], C. Gundersen[6], P. Mahaffy[1], M. Trainer[1], W. Brinckerhoff[1], S. Getty[1], H. Cottin[7], C. Briois[8], F. Colin[8], L. Thirkell[8], C. Szopa[9], V. Vuitton[10], M. Reinhardt-Szyba[11], and A. Makarov[11]
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Introduction: Recent missions to comets (e.g., Rosetta [1]), asteroids (e.g., Dawn [2]) and satellites of the outer planets (e.g., Galileo [3] and Cassini-Huygens [4]) have indicated that these solar system bodies may serve as prospective refuges for prebiotic organic matter and/or sites of organic synthesis due to the availability of carbon-rich starting materials, water ice and/or active sources of energy (e.g., hydrothermal activity, electrical discharges and impacts). In particular, the surfaces and subsurfaces of ocean worlds, such as Europa and Enceladus, have been identified as potentially habitable environments due to the myriad of active planetary processes that have shaped these landscapes (e.g., from cryovolcanism to tidal heating mechanisms; [5-7]). Understanding the history and dynamics of these environments will be key to: i) deciphering how organic materials are processed in the interstellar medium; ii) if/how prebiotic organics may have been delivered to planetary bodies; and, iii) how to categorize bodies as potentially habitable worlds.

Heritage quadrupole mass spectrometers are highly sensitive and quantitative instruments, but they detect chemical compounds with only limited mass resolution (generally $m/\Delta m \leq 500$, FWHM), leading to tenuous peak assignments and providing minimal structural information. In comparison, the PICASSO-funded Advanced Resolution Organic Molecule Analyzer (AROMA) enables molecular disambiguation through multiple analytical means, including:

- Higher mass resolving powers ($m/\Delta m$ up to 10^5) and accurate measurements of exact masses
- Ion isolation/excitation/enrichment (e.g., SWIFT)
- Tandem mass spectrometry (i.e., MS^n)

Moreover, AROMA delivers quantitative measurements of organic and inorganic chemical compounds via pyrolysis/gas chromatography mass spectrometry (pyr/GCMS) and laser desorption mass spectrometry (LDMS) modes of operation, which target volatile and non-volatile species, respectively.

The AROMA investigation leverages the progressive development of linear ion trap technologies at NASA GSFC, beginning with the Mars Organic Molecule Analyzer (MOMA) on the ExoMars rover [8], and continuing through the MatISSE (PI: Brinckerhoff), PSTAR (PI: Glass) and COLDTech (PI: Brinckerhoff) instrument maturation programs. A strategic partnership between GSFC (USA), Thermo (DE) and a consortium of French laboratories is integrating a heritage-derived linear ion trap with the CosmOrbitrap analyzer (**Fig. 1**) developed and demonstrated previously at LPC2E in Orléans (FR; [9]).

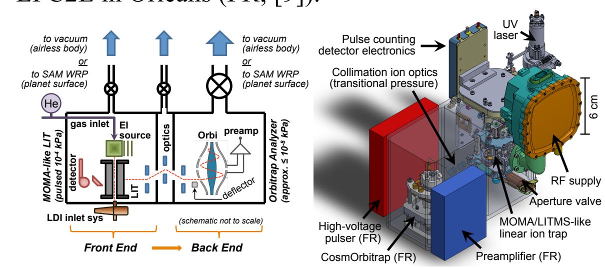

Fig. 1. *The AROMA instrument schematic design (left) and potential implementation for low-pressure cryogenic environments (right), estimated at <10 kg and requiring <40 W average power.*

Development of AROMA: Through the ROSES PICASSO Program, an experimental testbed (Phase I) has been assembled in order to quantify the achievable performance of an Orbitrap™ analyzer as a function of: i) challenging environmental conditions, such as elevated pressures; ii) compromised electronics, such as limited slew rates and high-voltage stability; and, iii) constrained resources, including power, energy and data volume. The results of these trade studies will inform the requirements of adaptable AROMA spaceflight implementations customized per environment.

In Phase II of the development program, a synergistic instrument design that unites the AROMA linear ion trap and the CosmOrbitrap analyzer will be built and tested. The primary analytical challenges that will be addressed in this effort are: i) ejection of tight ion packets (< µs widths) from a fully functional linear ion trap at high pressure (potentially pulsed); ii) ion collimation via an array of ion optics at intermediate pressure; and, iii) analysis of injected ions at sufficiently high mass resolution ($m/\Delta m$ up to 10^5 at m/z 100 Da).

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