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CubeSatTOF – A 1U High-Performance Time-Of-Flight Mass Spectrometer for Planetary Atmospheres

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Abstract

We developed a 1U time-of-flight mass spectrometer for a CubeSat spacecraft for quantitative analysis of the chemical composition measurements of thin planetary atmospheres and exospheres. Thanks to miniaturization, CubeSat-based missions started to synergize valuable scientifically measurements with technology demonstration capabilities. Our instrument will provide key data of the chemical and isotopic composition of neutral atoms and molecules. Such an instrument can be employed in the Earth's atmosphere, be a valuable addition to planetary spacecraft, and even would allow for swarm measurements.

1. Introduction

The trend of miniaturizing mass spectrometers to be compatible with the CubeSat format enables multiple novel applications in the upper atmosphere and exosphere of planetary objects. Present mass spectrometers are resource-intensive in terms of power-consumption, size, mass, and cost. Because of their lower need for resources, CubeSat mass spectrometers could be an addition to every planetary mission flying by a planetary body. Several of these CubeSats could be released to the planetary object during the mission, or even several at the time (a swarm exploration).

For example, a) Even though the Earth's atmosphere and exosphere are reasonably well known, further studies regarding atmospheric escape, the stability of the outer atmosphere, and its relation to the solar forcing are necessary. Moreover, compositional variations at the day-night terminator, night-side transport, exobase variations, and thermosphere temperatures are topics to be addressed.

b) Probably for any planetary mission performing a flyby of a planetary object, a CubeSat mass spectrometer being released toward the object on a collision course would provide valuable close-up investigations [5].

CubeSats could provide swarm measurements of chemical composition and therefore reveal variations over space and time. Whilst current CubeSat-type mass spectrometer or concepts of them suffer from limited sensitivity, isotopic accuracy, mass-resolution, or consumption of resources, we developed an instrument emphasizing a balance between these requirements.

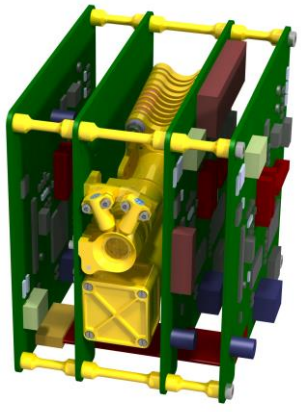

Figure 1: Computer model of the CubeSatTOF instrument.

2. Scientific goals

The instrument is designed to analyse upper planetary atmospheres and exospheres, where pressures are below $1 \cdot 10^{-6}$ mbar, from a bound or hyperbolic orbit. It quantitatively analyses the

chemical composition of the ambient gas with a high sampling frequency allowing for high spatial resolution along the spacecraft trajectory. Analysis additionally include the measurement of isotopic ratios of CHON elements and noble gases. Among other things, exospheric temperatures and atmospheric escape can be derived from these measurements.

3. Instrument

The CubeSatTOF instrument is a 1U time-of-flight mass spectrometer (Figure 1), which would be combined with a 1U unit for operations (communication, attitude control, power management, …), and perhaps an additional science module, to form a 3U spacecraft. The CubeSatTOF instrument benefits from heritage from the RTOF/Rosetta [2], [3] and NGMS/Luna-Resurs [4] instruments. It consists of an ion source with electron ionization, a drift tube, an ion mirror, and a microchannel plate detector for ion registration (Figure 2). Thanks to its design, which is similar to the P-BACE/MEAP instrument [1], the CubeSatTOF instrument is capable of accumulating mass spectra with a high cadence and therefore increasing its signal-to-noise ratio and reducing the down-link budget at the same time. The reliability of the instrument benefits from a simple design, which mitigates the influence of the extended use of COTs.

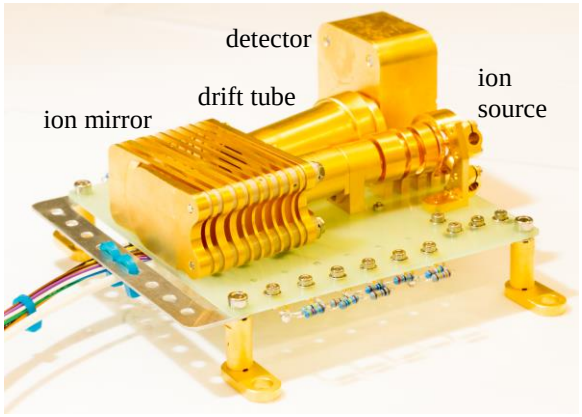

Figure 2: The flight hardware implementing the ion optics mounted on a breadboard. The detector is a prototype and therefore increased in size.

4. Summary and Conclusions

We presented a compact time-of-flight mass spectrometer for atmospheric composition measurements of neutrals. Thanks to its good performance, small dimensions and costs-effectiveness, this instrument is capable for scaled usage in CubeSat-swarm configurations and applicable for missions beyond Earth.

Acknowledgements

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