CubeSatTOF:

Planetary Atmospheres Analyzed with a 1U High-Performance Time-Of-Flight Mass Spectrometer

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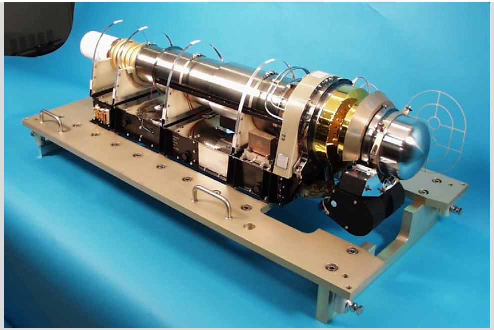
SSC20-WKIII-02

@RicoFausch

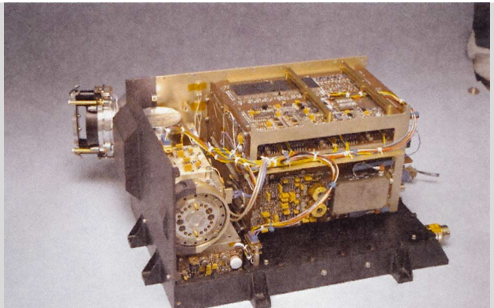
Introduction

Evolution of mass spectrometers as a payload



RTOF / ROSINA / ROSETTA

100 cm class



Waite et al., Space Sci. Rev., 2004

INMS / Cassini

30 cm class

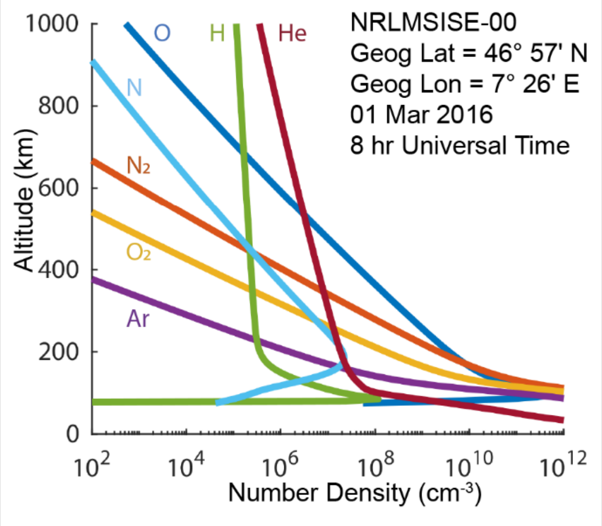
NIM / PEP / JUICE

Fausch et al., IEEE Aerospace Conf., 2018

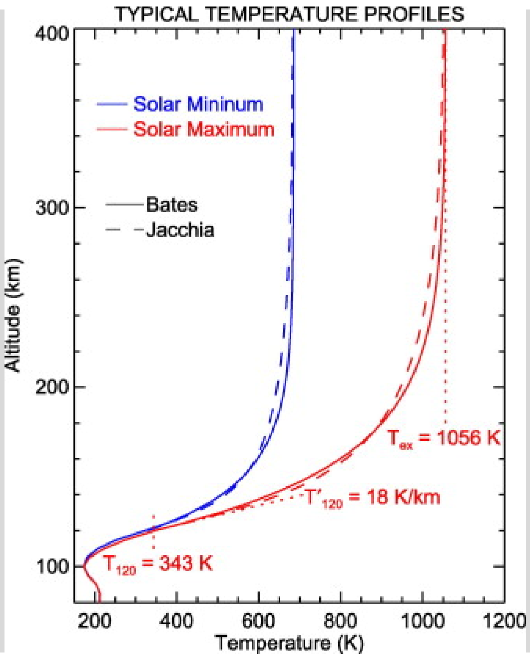
NGMS / Luna 27

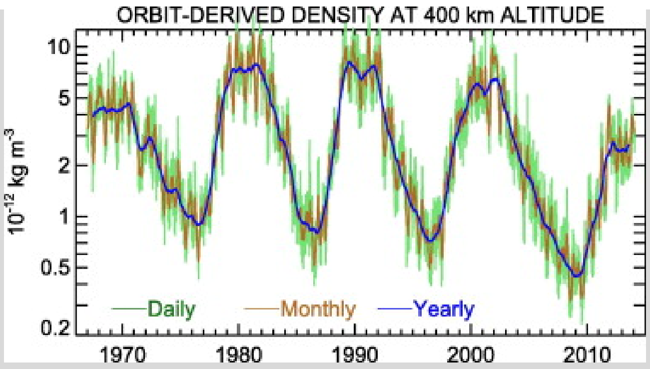
Science Case

Terrestrial exosphere I



Fausch et al., SSC20, 2020; after Picone et al., J. Geophys. Res., 2002.





Emmert, Adv. Space Res., 2015.

Science Case

Terrestrial exosphere II

Primary scientific goals

Chemical composition
Exospheric temperatures
Atmospheric escape
Temporal variations

Secondary scientific goals

Variations at the day-night terminator
Night-side transport
Establish TRL 8 for planetary entry probes

Fausch et al, SSC20, 2020.

	Major species	Minor species	Traces of elements
Neutrals	H, N, O, N_2, CO, NO, O_2	D, ^{15}N, ^{17}O, ^{18}O	Noble gases, …
Ions	H^+, He^+, N^+, O^+, N_2^+	D^+, $^{15}N^+$, $^{17}O^+$, $^{18}O^+$	NO^+, OH^+, …

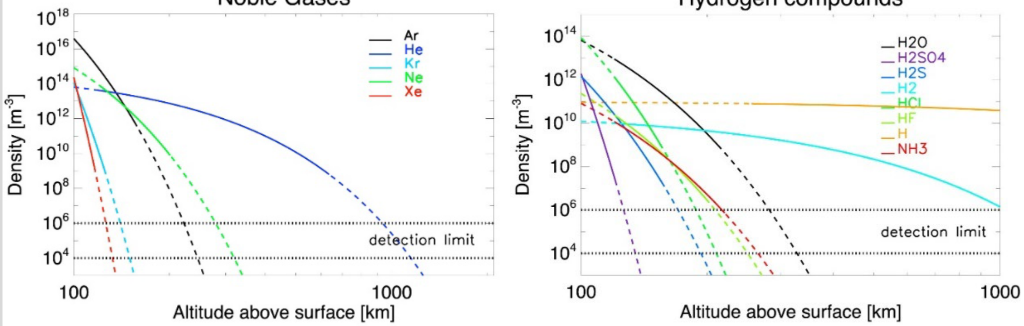
Science Case

Planetary exospheres

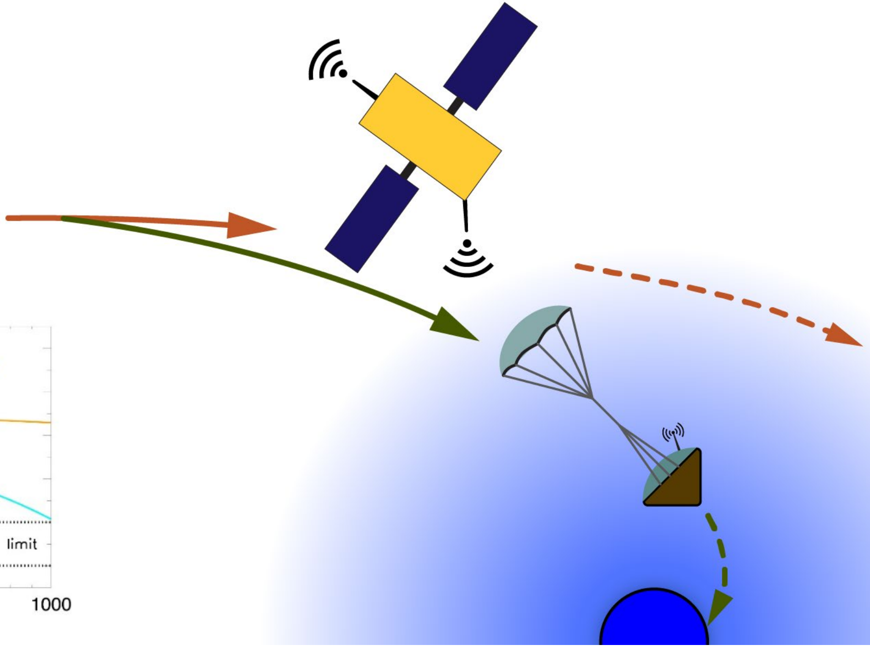
Lammer et al., Astrobiology, 2002.

Table 13.1. A summary of average exobase altitudes h_{ex} and temperatures T_{ex} , escape velocities v_∞ and escape energies E for O, N and CO_2 for the most important terrestrial planets

	h_{ex} [km]	T_{ex} [K]	v_∞ [km/s]	E_O [eV]	E_{CO2} [eV]	E_N [eV]
Venus	≈ 200	≈ 600	10.40	8.96	24.64	7.84
Earth	≈ 300	≈ 1000	11.20	10.40	28.60	9.10
Mars	≈ 200	≈ 220	5.02	2.08	5.72	1.82

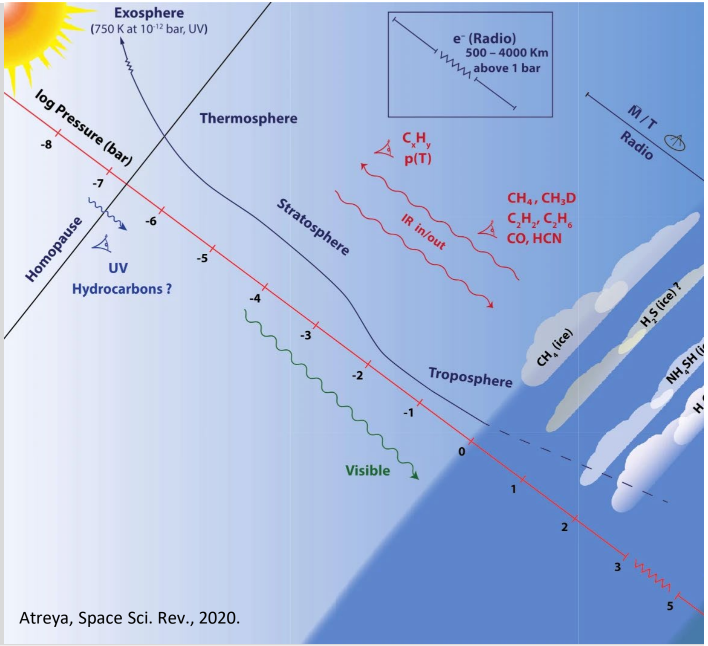


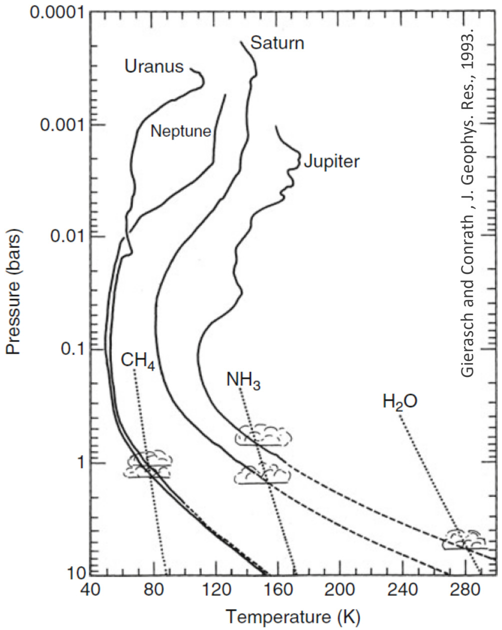
Gruchola et al., Planet Space Sci, 2019.

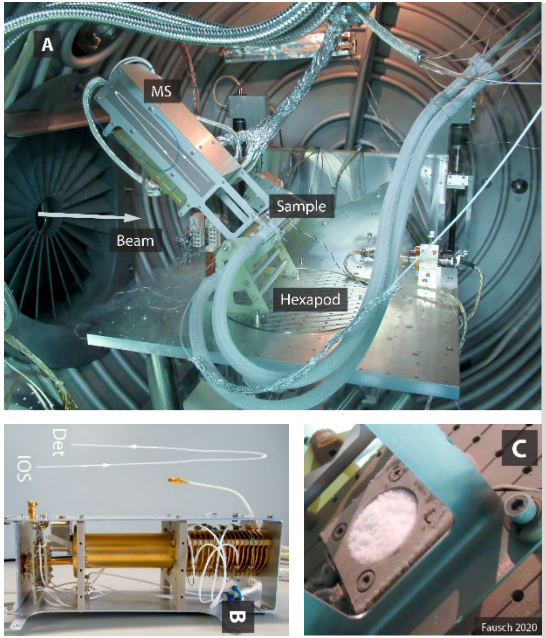


Science Case

Deep atmosphere composition / laboratory use

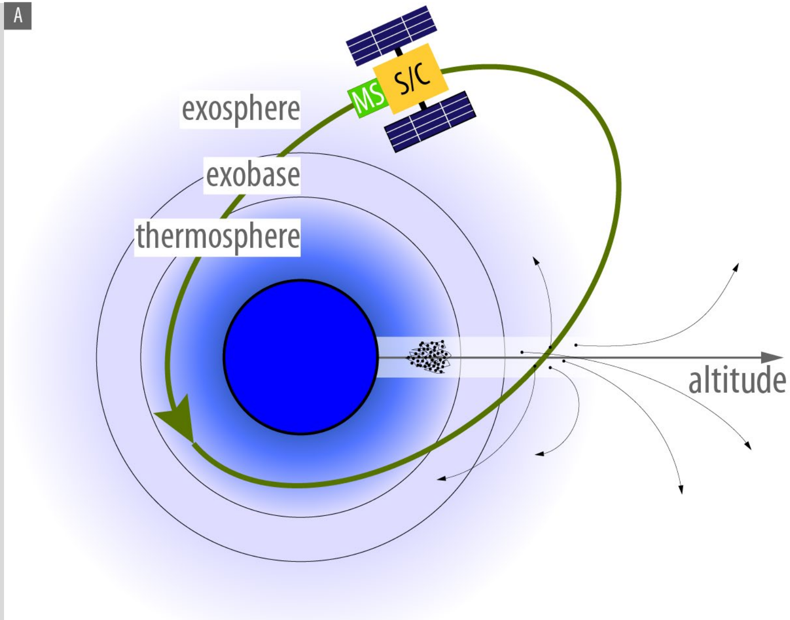




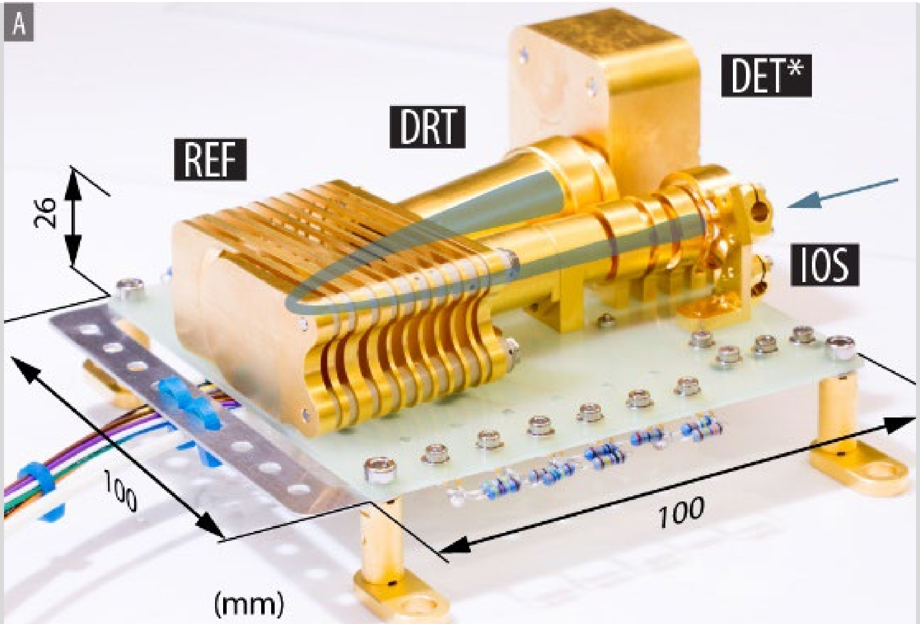


The CubeSatTOF instrument

Concept of operation



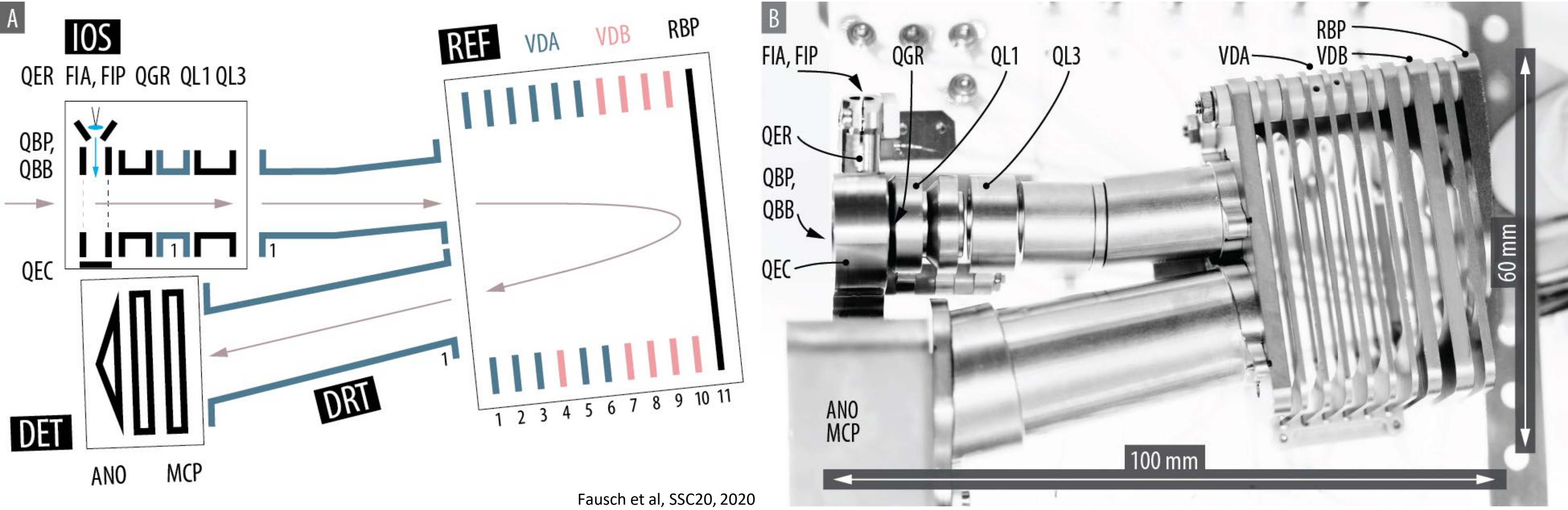
Fausch et al, SSC20, 2020.



Fausch et al, SSC20, 2020.

The CubeSatTOF instrument

Ion optical system



Fausch et al, SSC20, 2020

The CubeSatTOF instrument

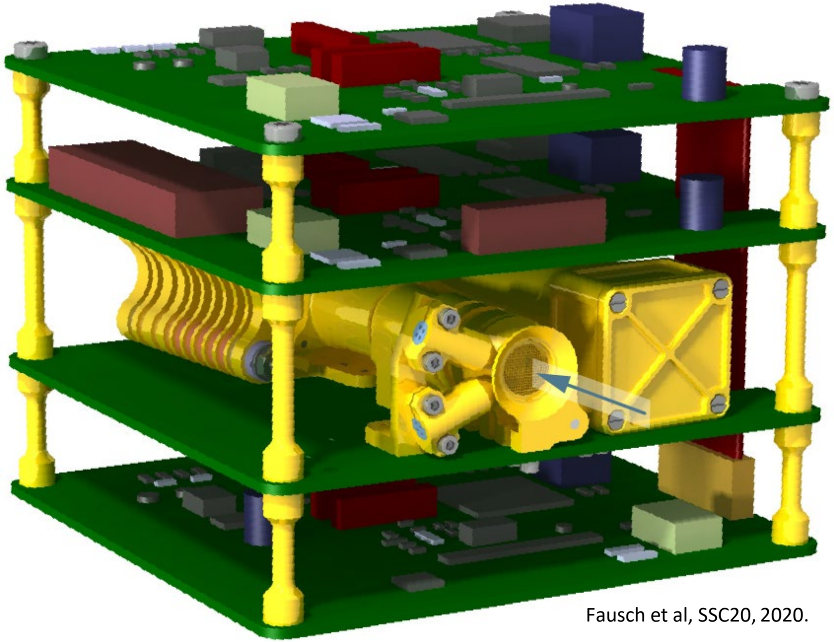
TOFWERK

b UNIVERSITÄT BERN

Modularity

- Detector (sensitivity vs. size)
- Read-out electronics (radiation tolerance vs…
    - Hi-Rel parts / COTS (cost)
    - Shielding (mass)
- Ion source (lifetime vs. power consumption)
- According software architecture

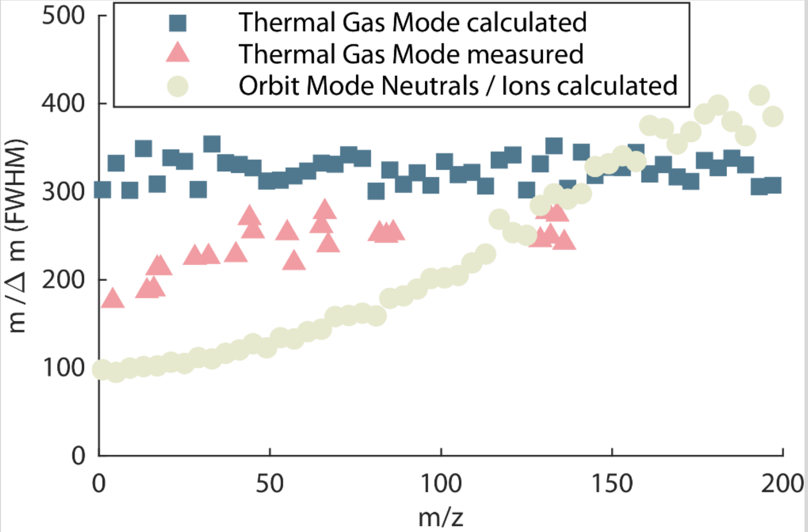
focus of the first instrument for LEO



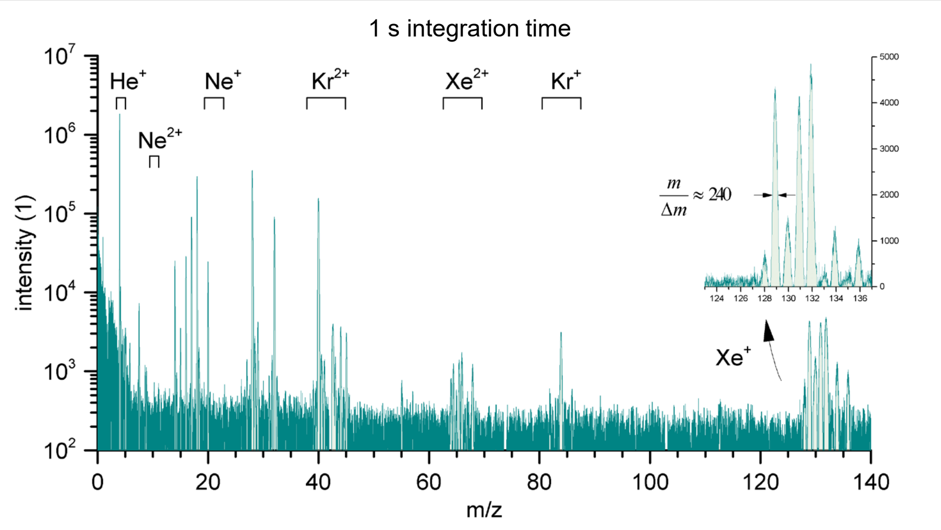
Fausch et al, SSC20, 2020.

The CubeSatTOF instrument

Ion optical performance



Fausch et al, SSC20, 2020.



Fausch et al, SSC20, 2020.

Discussion

The CubeSatTOF instrument

- Initial energy tolerant ion source
- Applicable to likely upcoming missions
- Ion optical performance is sufficient for three mission types
- Analysis of

  … species in a mass range of about *m/z* 1 – 300 (Thermal Gas Mode)

  … neutrals and ions

  … noble gases including Kr and Xe

  … isotopes of CHON elements, D/H, noble gases, etc.

  … traces of species not yet discovered

Conclusion

The CubeSatTOF instrument

- 1 U mass spectrometer
- High performance
- $m/\Delta m$ 240 at ^{129}Xe
- Isotope analysis
- Modularity