UNIVERSITÄT BERN

Chemical and Isotopic Composition Measurements on Atmospheric Probes for Giant Planets

Peter Wurz[1], Audrey Vorburger[1], Hunter Waite[2], and Olivier Mousis[3]

[1] Universität Bern, Physikalisches Institut, Space Science and Planetology, Bern, Switzerland

[2] Southwest Research Institute, Space Science and Engineering Division, San Antonio, Texas, USA

[3] Aix Marseille Université, CNRS, LAM, Marseille, France

peter.wurz@space.unibe.ch

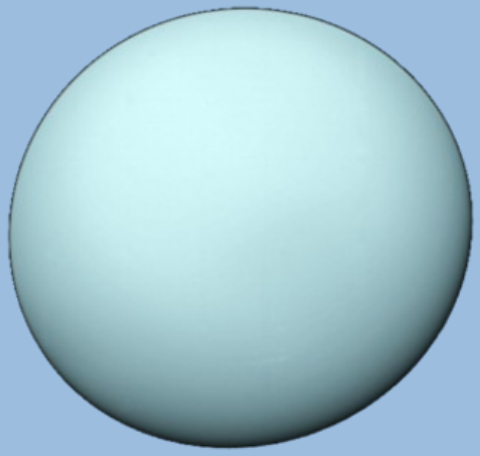
Uranus & Neptune

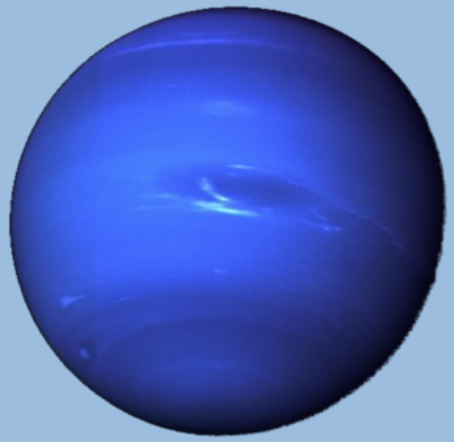
UNIVERSITÄT BERN

Most frequently observed type of exoplanet,
but **least understood class** of planets in our Solar System

No designated Uranus or Neptune mission yet
→ almost all information from remote sensing

Remote sensing has its limitations, though
→ **mass spectrometer for *in situ* measurements**





NASA / JPL

Solar System Formation and Evolution

UNIVERSITÄT BERN

Species of interest:

- major volatiles
  (CH_4, CO, NH_3, N_2)
- noble gases
  (He, Ne, Ar, Kr, Xe)
- isotopic ratios
  (D/H, $^{13}C/^{12}C$, $^{15}N/^{14}N$, $^{3}He/^{4}He$, $^{20}Ne/^{22}Ne$, $^{38}Ar/^{36}Ar$, $^{36}Ar/^{40}Ar$, as well as those of Kr and Xe)

See O.Mousis et al., '**Key Atmospheric Signatures for Identifying the Source Reservoirs of Volatiles in Uranus and Neptune**', Space Science Reviews (2020), accepted.

→ imposes **high performance requirements** on mass spectrometers

Mass Spectrometer Requirements

UNIVERSITÄT BERN

- Mass range
  1 – 300 u

- Sufficient mass resolution
  m / Δm ≈ 500

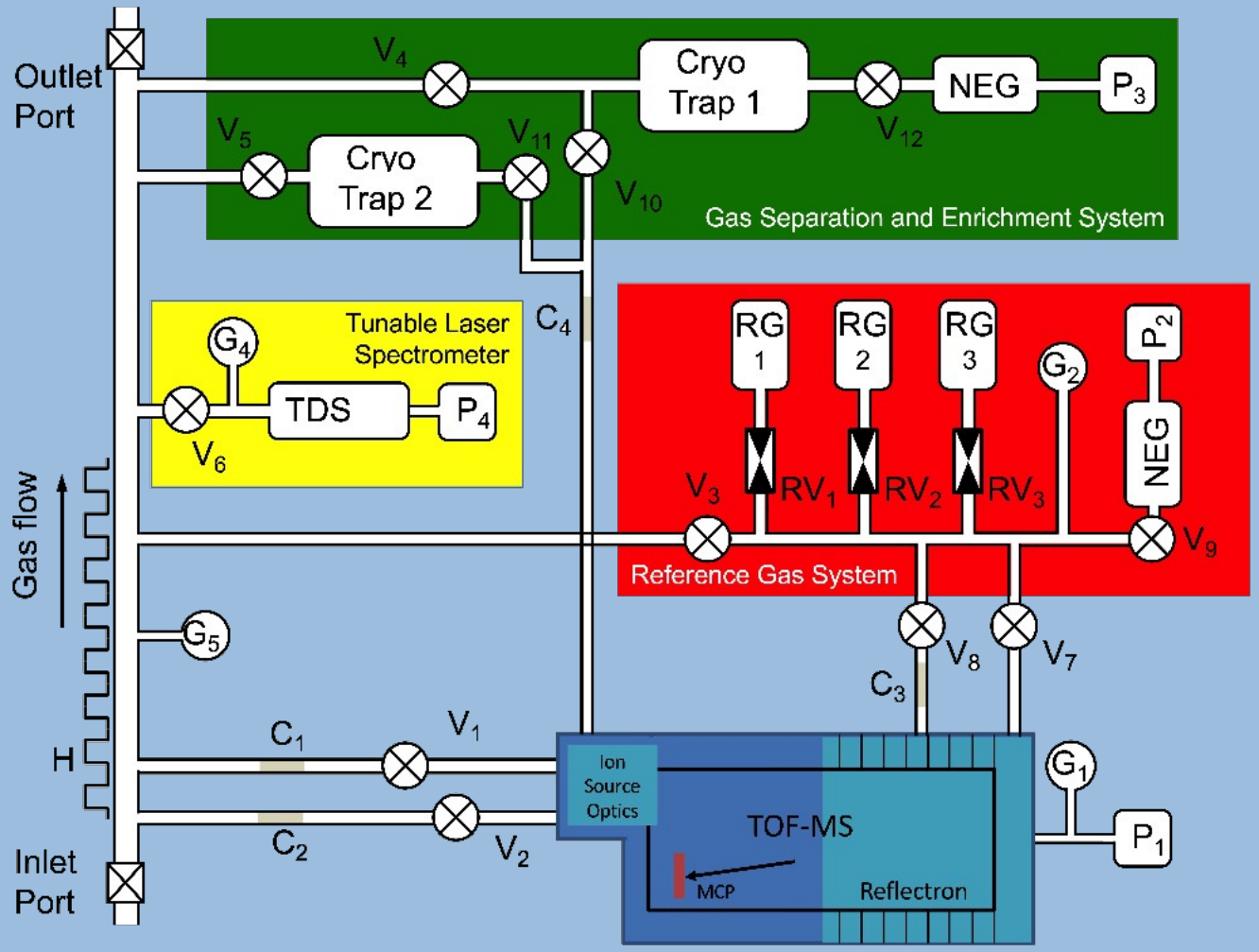
- Sufficient sensitivity
  10 decades dynamic range, plus isotopes
  Measurement time 10 – 90 minutes (descent time)

- Limit complexity
  Accommodation in the atmospheric probe

- Limit resources
  Power, volume, mass

Proposed Mass Spectrometer System

b
UNIVERSITÄT
BERN



Proposed Measurement Sequence

UNIVERSITÄT BERN

6 Phases:

– Phase 0: ‘empty space’ until entry in planetary atmosphere

– Phase 1–2: High-speed descent through the upper atmosphere

– Phase 3–5: Low-speed descent through the atmosphere proper

– Phase 6: Final descent until loss of contact

Phase	Altitude [km]	Time span, from–to [sec]	Pressure [mbar]	Integration time [sec]	Vertical resolution [km]	Number of mass spectra
0	1500	–414.18 – 0	$1.00{\cdot}10^{-7}$	30		14
1	450	0 – 172	$1.00{\cdot}10^{-4}$	15	76.05	11
2	15	172 – 183	$4.00{\cdot}10^{2}$	12	38.02	1
3	14	183 – 235	$4.20{\cdot}10^{2}$	11	0.21	5
4	10	235 – 581	$5.00{\cdot}10^{2}$	10	0.12	35
5	–13	581 – 2101	$1.60{\cdot}10^{3}$	15	0.23	101
6	–140	2101 – 3684	$2.40{\cdot}10^{4}$	20	1.09	29

Measurement Accuracies

UNIVERSITÄT BERN

Phase 1	Accuracy	Isotopes	Accuracy
H_2, low sensitivity	5.00%	HD/H_2	0.90%
He, low sensitivity	5.00%	^{3}He/^{4}He	1.70%
He/H_2	1.50%		
CH_4, low sensitivity	5.00%	^{12}C/^{13}C	1.90%
H_2S, low sensitivity	5.10%		
C_2H_2, low sensitivity	9.00%		
C_2H_6, low sensitivity	8.60%		
Ne, low sensitivity	5.70%		
Ar, low sensitivity	5.00%		
Kr, low sensitivity	12.10%		
Xe, low sensitivity	41.80%		

Phase 2	Accuracy	Isotopes	Accuracy
H_2, low sensitivity	5.00%		
HD/H_2	0.90%		
He, low sensitivity	5.00%	^{3}He/^{4}He	1.70%
He/H_2	1.50%		
CH_4, low sensitivity	5.00%	^{12}C/^{13}C	1.90%
NH_3, low sensitivity	5.00%	^{14}N/^{15}N	12.60%
H_2S, low sensitivity	5.10%		
C_2H_2, low sensitivity	9.00%		
C_2H_6, low sensitivity	8.60%		
Ne, low sensitivity	5.70%		
Ar, low sensitivity	5.00%		
Kr, low sensitivity	12.10%		
Xe, low sensitivity	41.80%		

Phase 3 / 4 / 5	Accuracy	Isotopes	Accuracy
CH_4, high sensitivity	5.00%	^{12}C/^{13}C	0.30%
NH_3, high sensitivity	5.00%	^{14}N/^{15}N	1.50%
H_2O at 2 bar, high sensitivity	6.50%		
H_2S, high sensitivity	5.00%		
CO, high sensitivity	163.80%		
CO_2, high sensitivity	457.70%		
PH_3 at ~1 bar, high sensitivity	5.10%		
AsH_3, high sensitivity	69.20%		
GeH_4, high sensitivity	445.00%		
C_2H_2, high sensitivity	5.10%		
C2H6, high sensitivity	5.10%		
Ne, high sensitivity	5.00%		
Ar, high sensitivity	5.00%		
Kr, high sensitivity	5.20%		
Xe, high sensitivity	6.10%		

Phase 6	Accuracy	Isotopes	Accuracy
CH_4, high sensitivity	5.00%	^{12}C/^{13}C	0.20%
NH_3, high sensitivity	5.00%	^{14}N/^{15}N	1.04%
H_2O at 10 bar, high sensitivity	5.00%	^{16}O/^{17}O	7.40%
		^{16}O/^{18}O	3.10%
H_2S, high sensitivity	5.00%		
CO, high sensitivity	110.50%		
CO_2, high sensitivity	308.60%		
PH_3, high sensitivity	5.00%		
AsH_3, high sensitivity	46.80%		
GeH_4, high sensitivity	300.00%		
C_2H_2, high sensitivity	5.00%		
C_2H_6, high sensitivity	5.00%		
Ne, high sensitivity	5.00%	^{20}Ne/^{21}Ne	5.40%
		^{21}Ne/^{21}Ne	5.40%
Ar, high sensitivity	5.00%		
Kr, high sensitivity	5.10%		
Xe, high sensitivity	5.50%		

Noble gases (3 times cryotrap)	Accuracy
Ar, enriched	
^{36}Ar/^{38}Ar	0.10%
Kr, enriched	
^{78}Kr/Kr$_{tot}$	1.06%
^{80}Kr/Kr$_{tot}$	1.13%
^{82}Kr/Kr$_{tot}$	0.46%
^{83}Kr/Kr$_{tot}$	0.28%
^{84}Kr/Kr$_{tot}$	0.23%
^{86}Kr/Kr$_{tot}$	0.21%
Xe, enriched	
^{124}Xe/Xe$_{tot}$	6.18%
^{126}Xe/Xe$_{tot}$	8.74%
^{128}Xe/Xe$_{tot}$	6.28%
^{129}Xe/Xe$_{tot}$	1.19%
^{130}Xe/Xe$_{tot}$	0.85%
^{131}Xe/Xe$_{tot}$	0.87%
^{132}Xe/Xe$_{tot}$	0.49%
^{134}Xe/Xe$_{tot}$	0.60%
^{136}Xe/Xe$_{tot}$	0.74%

For more information...

UNIVERSITÄT BERN

see A. Vorburger, P. Wurz, and H. Waite, "**Chemical and Isotopic Composition Measurements on Atmospheric Probes**," Space Science Review (2020), accepted.