Instruments for In Situ Analysis of Subsurface Samples on Mars

Examples and Prospects

W. Brinckerhoff
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Some of the Mars Surface Science Payloads (So Far)

- **VL1, VL2** – Cameras, Met Pkg, XRFS, GCMS, Bio Pkg (GEx,LR,PR); Scoop (20 cm)
- **MPF** – ASI/MET, IMP, APXS; no sampling
- **MER**x2 – PanCam, MI, MiniTES, Mossbauer, APXS, RAT; no sampling
- **PHX** – SSI, RAC, MECA, TEGA(MS), MET; Scoop with RASP
- **MSL** – MARDI, MastCam, REMS, RAD, DAN, MAHLI, APXS, ChemCam, CheMin, SAM; Multi-functional SA/SPaH, sampling drill

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- **ExoMars Rover** – PanCam, CLUPI, WISDOM, Adron, Ma_MISS, MicrOMEGA, RLS, MOMA; 2 m drill and SPDS
- **ExoMars Surface Platform** – Many Met, Dust, and Rad sensors; Cameras, FAST (IR), Seismometer, M-DLS, MGAP
- **M2020** – Mastcam-Z & other cameras, SuperCam, SHERLOC & WATSON, PIXL, MOXIE, MEDA, RIMFAX; coring drill system, MHS?

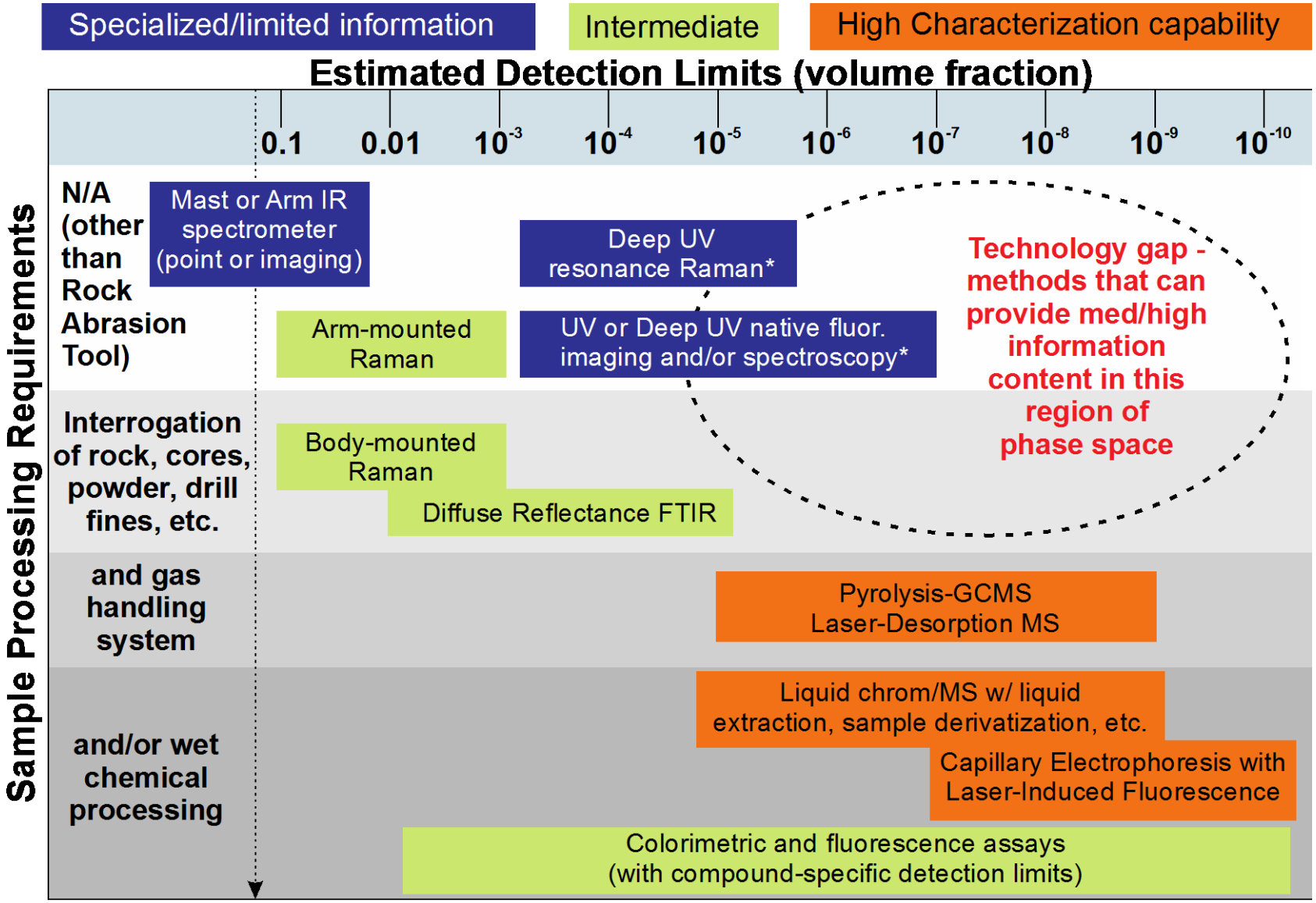
Over 60 instruments deployed to analyze surface samples & envt!

Measurement Objectives

- Focusing on science objectives. Prospecting and evaluating water and other resources may use similar techniques but not my expertise!
- Example science objectives
  - Life detection (past or present): search for biosignatures; composition and morphology
  - Habitability (past or present): identify chemicals, minerals, geology that support conditions for life
  - Planetary evolution: geology/materials recording past/ancient processes & climate; imaging, chemistry, mineralogy, isotopes/age dating, etc.

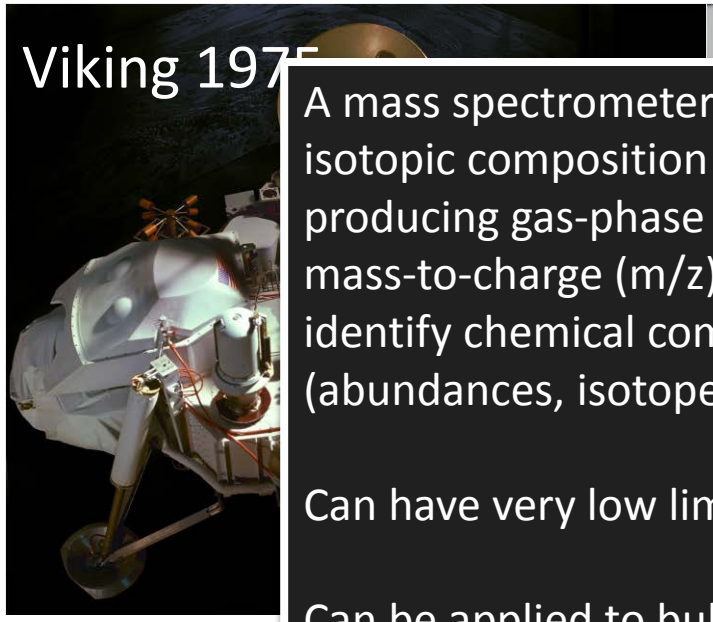
Example Measurement Approaches

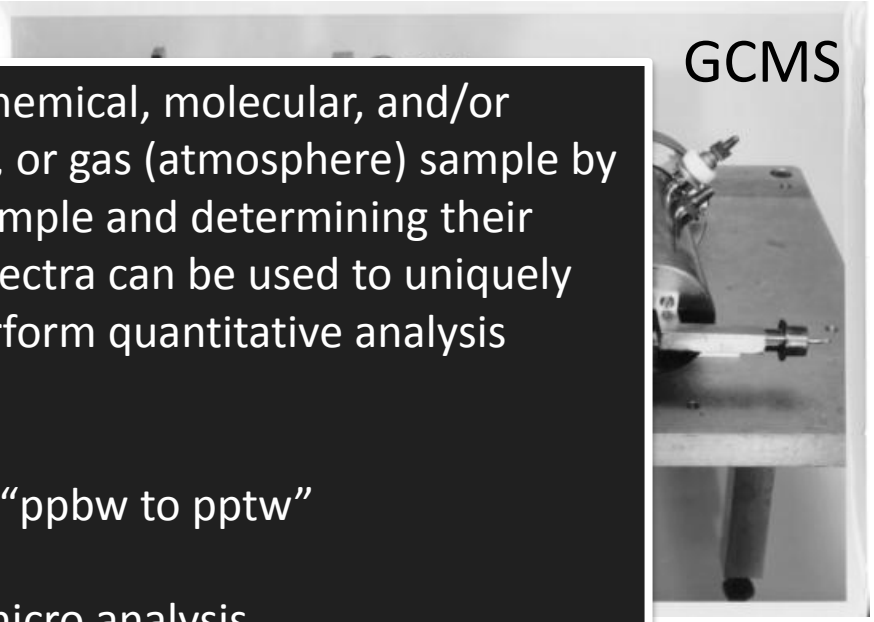
(stolen from M2020 SDT report)



One Key Approach: Mass Spectrometry

(or, talk about what you know)





A mass spectrometer measures the chemical, molecular, and/or isotopic composition of a solid, liquid, or gas (atmosphere) sample by producing gas-phase ions from the sample and determining their mass-to-charge (m/z) values. Mass spectra can be used to uniquely identify chemical compounds and perform quantitative analysis (abundances, isotope ratios, etc.).

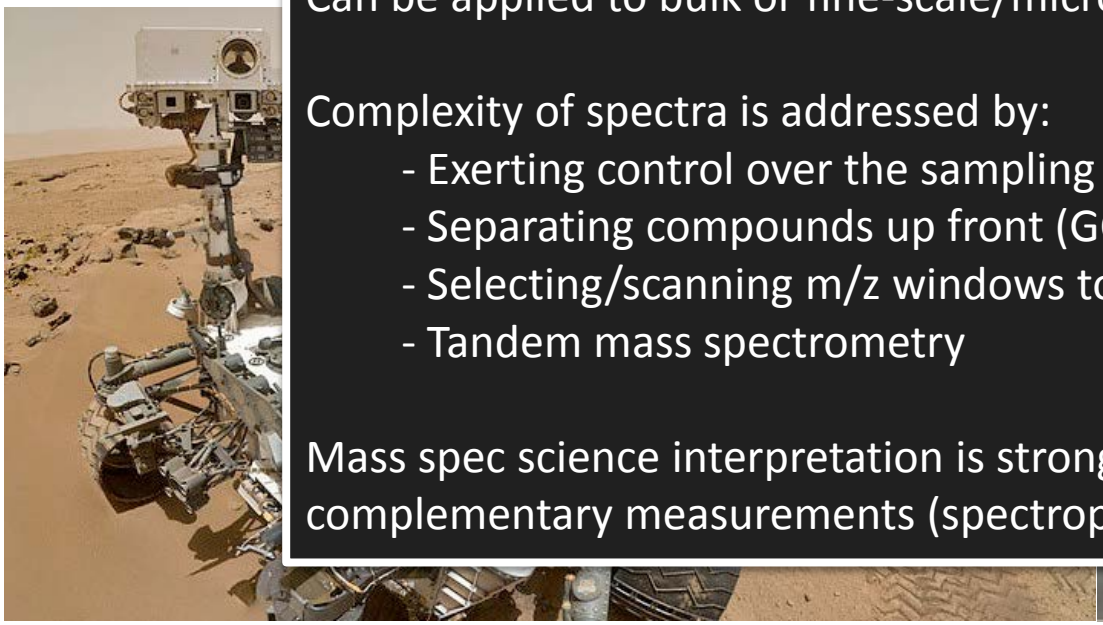
Can have very low limits of detection “ppbw to pptw”

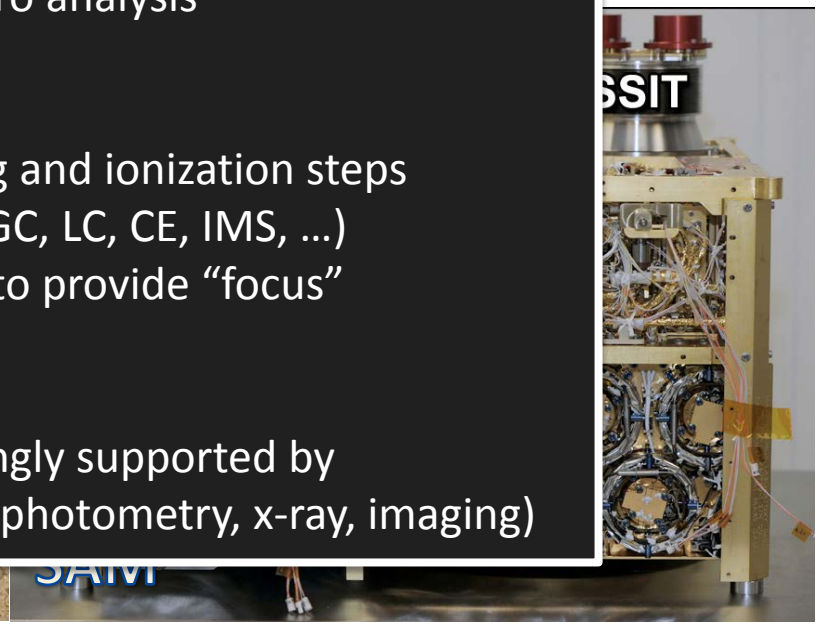
Can be applied to bulk or fine-scale/micro analysis

Complexity of spectra is addressed by:

- Exerting control over the sampling and ionization steps
- Separating compounds up front (GC, LC, CE, IMS, …)
- Selecting/scanning m/z windows to provide “focus”
- Tandem mass spectrometry

Mass spec science interpretation is strongly supported by complementary measurements (spectrophotometry, x-ray, imaging)





The First Z-Axis Mission: ExoMars Rover

ESA-Roscosmos mission

Launch: July, 2020

Mass: 310 kg

Power: solar arrays

Duration: 218 sols

Sampling: 2 m drill

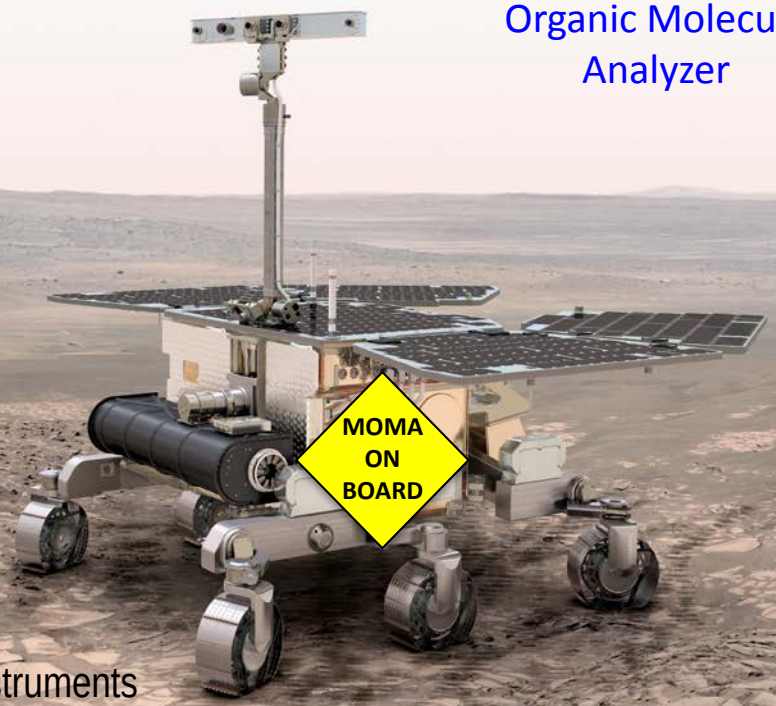
Payload: 9 instruments

Remote and Contact instruments

Analytical Laboratory instruments

MOMA, MicrOmega, Raman

MOMA = Mars Organic Molecule Analyzer



ExoMars Rover Science Objective: Seek the Signs of Life!

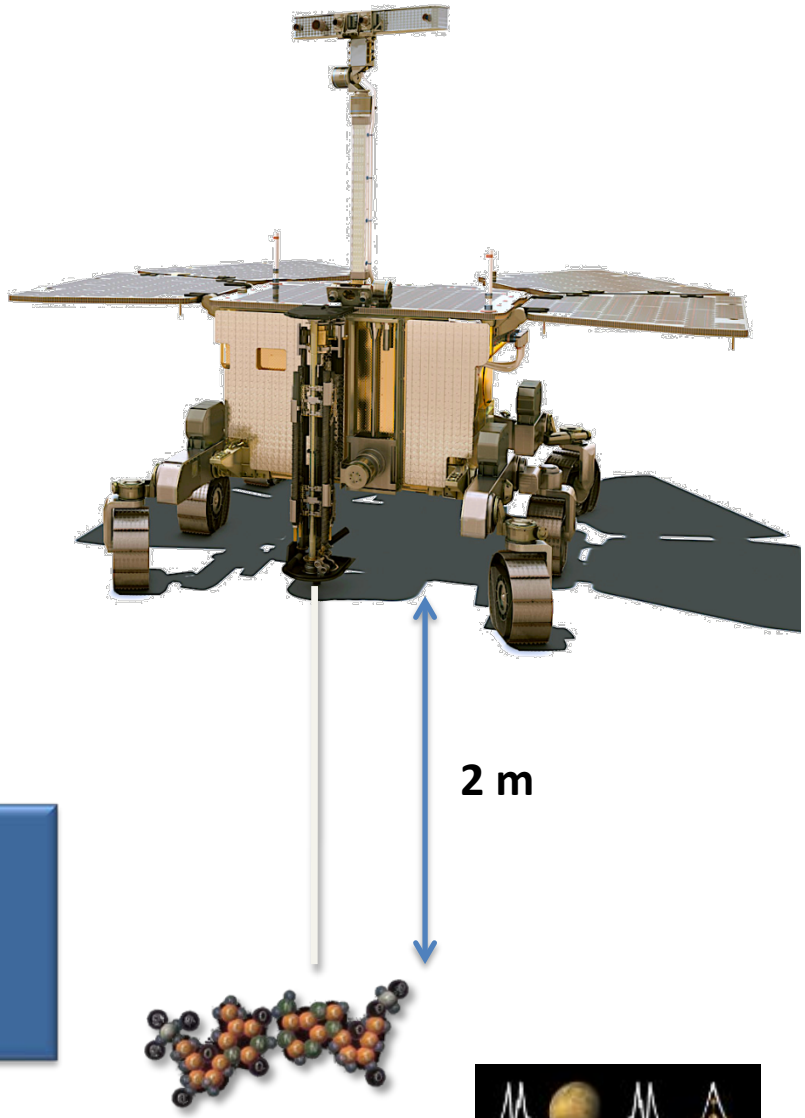
ExoMars with MOMA Enables Critical Mars Science!

Search for signs of past or present life?

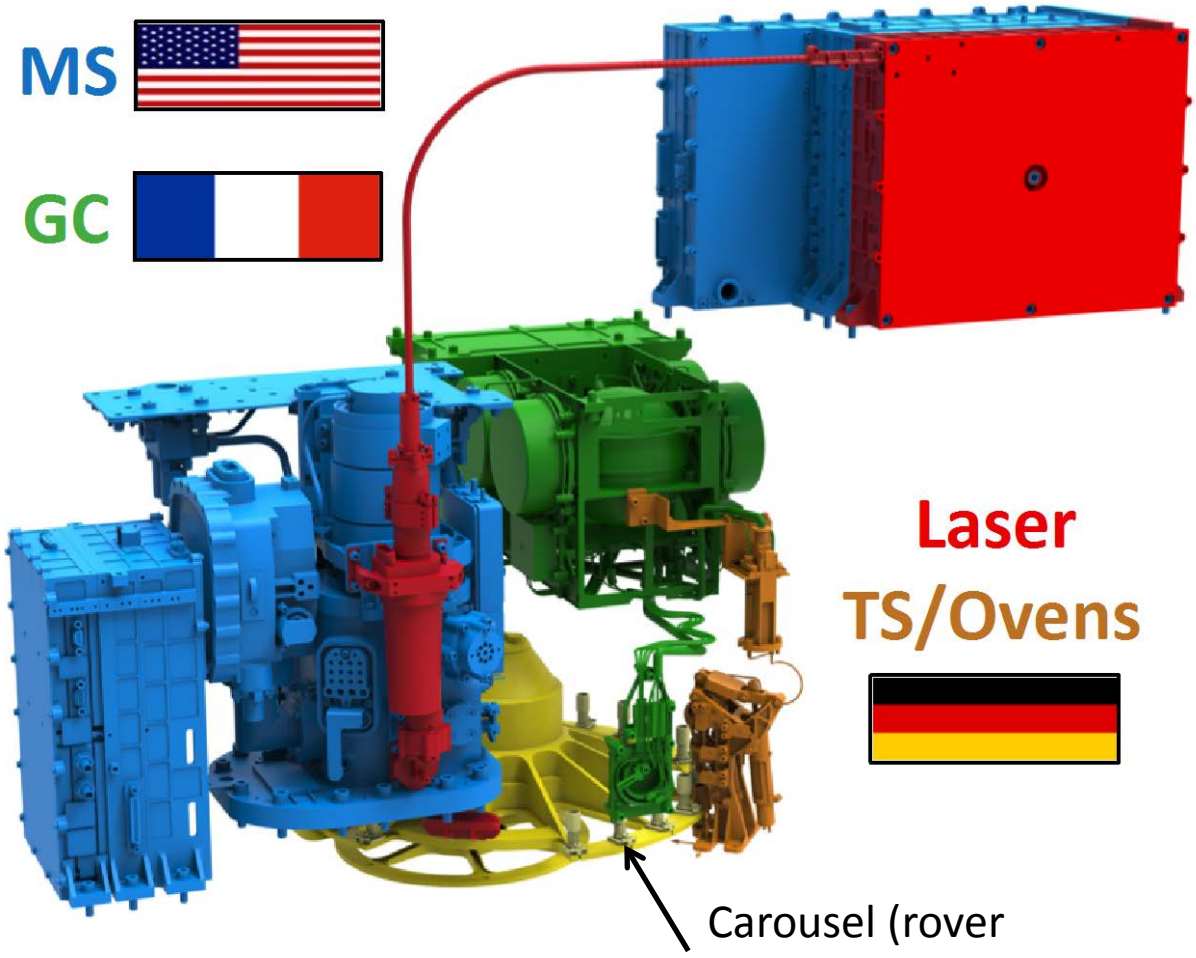
- Complex organics with *nonrandom, repeating structures* (e.g., biopolymers)
- Organics do not exist in isolation: potential mixture of abiotic/meteoritic and biogenic
- *Chirality* (handedness) as a biomarker

The surface of Mars is bathed in ultraviolet and cosmic radiation, potentially leading over time to the degradation of complex organics in the uppermost surface layers.

MOMA provides both *pyrolysis/gas chromatography and laser desorption MS* analysis of samples from as deep as 2 meters, potentially revealing a gradient of organics!



MOMA is a dual-source (gas chromatograph and laser) mass spectrometer investigation providing organic molecular analysis



Mass: about 12 kg

PI: Fred Goesmann, MPS
DPI: Francois Raulin, U. Paris

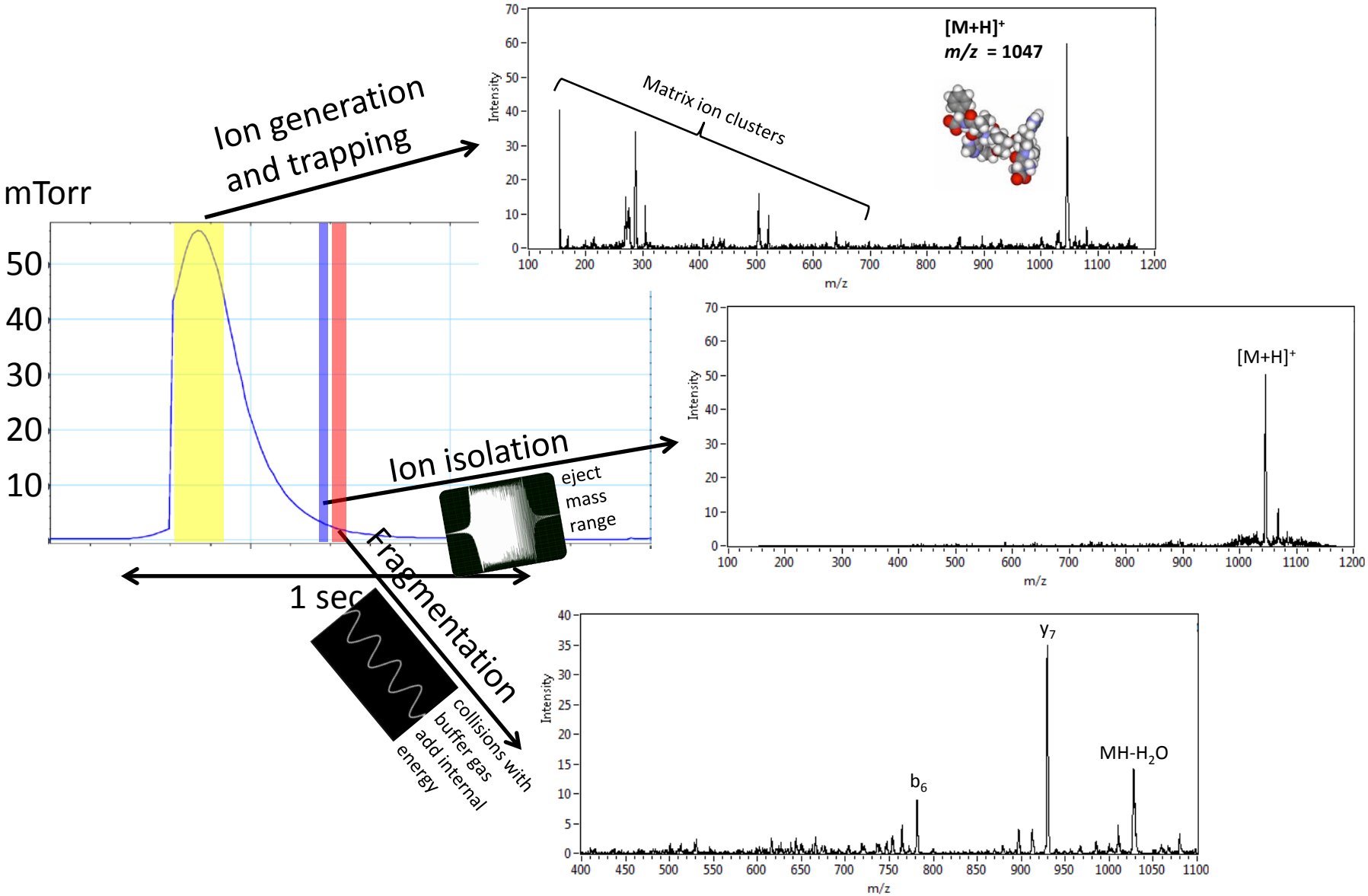
GCMS
Pyrolysis Ovens ~ 30
Chemical Derivatization:
- MTBSTFA - general
- DMF-DMA – chiral aa
- TMAH – lipids

Electron Ionization

LDMS
Laser: 266 nm, 1.5 ns pulses
Mars ambient laser desorption
Prompt laser ionization

Ion Trap
m/z range 50 – 1000 Da
Resolution < 0.5 Da
MS and MS/MS modes

MOMA MS/MS Operation



Instruments for Future Subsurface Missions

- A balanced, multi-faceted payload science payload still makes sense for missions with strong focus on subsurface access
  - Potential to discover a "protected" zone quite different from the surface environment; A range of chemical states, products possible
  - No orbital imaging/spectroscopy to provide direct "general map" of geological and mineralogical diversity in advance
    - Sounding could provide critical material and layer/boundary data
- Some important payload capabilities (biased view)
  - Assuming a fixed lander, deep drill mission (10s of meters) …
  - Surface and atmospheric composition **baseline** before drilling
  - Ability to capture and analyze **volatiles** released in drilling
  - Ability to examine **bore hole wall** during drilling (water, organics)
  - Ability to conduct **broad chemical and stable isotopic analysis** (bulk and fine-scale) of solid (maybe icy) samples at selected depth intervals
  - Depending on site, a multi-technique **life/biosignature** detection investigation of depth samples; also needed to rule out fwd contam.