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Detecting the elemental and molecular signatures of life

Laser-based mass spectrometry technologies

Whitepaper

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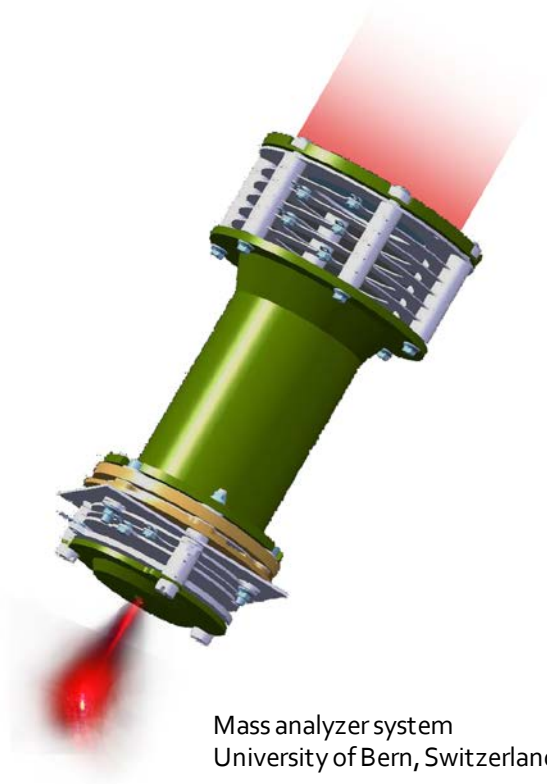
Laser-based Mass Spectrometry

- Collection of *in-situ* surface analysis techniques, based on:
  - Laser pulses are used for material removal
  - Mass analyzer for the chemical analysis of removed material



Mass analyzer system
University of Bern, Switzerland

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The main flavors of laser-based MS

- Laser **Desorption / Ionization** Mass Spectrometry (LDMS)
  - Low intensity laser pulses → release molecules from a surface
  - Molecular analysis on surfaces and from extracts
- Laser **Ablation / Ionization** Mass Spectrometry (LIMS)
  - High intensity laser pulses → complete atomization & ionization
  - Element & isotope analysis in rocks and other solid materials

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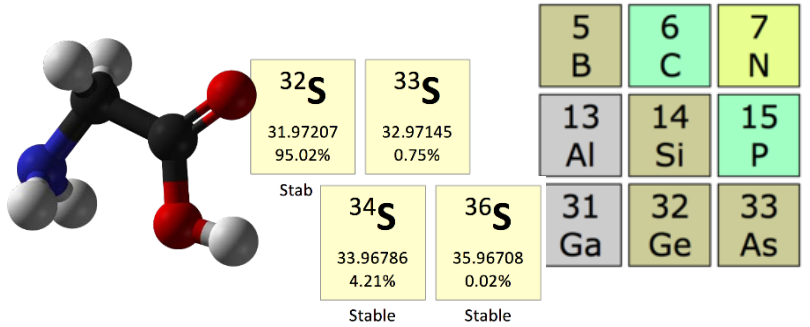
Benefits of Laser-based MS: Versatility

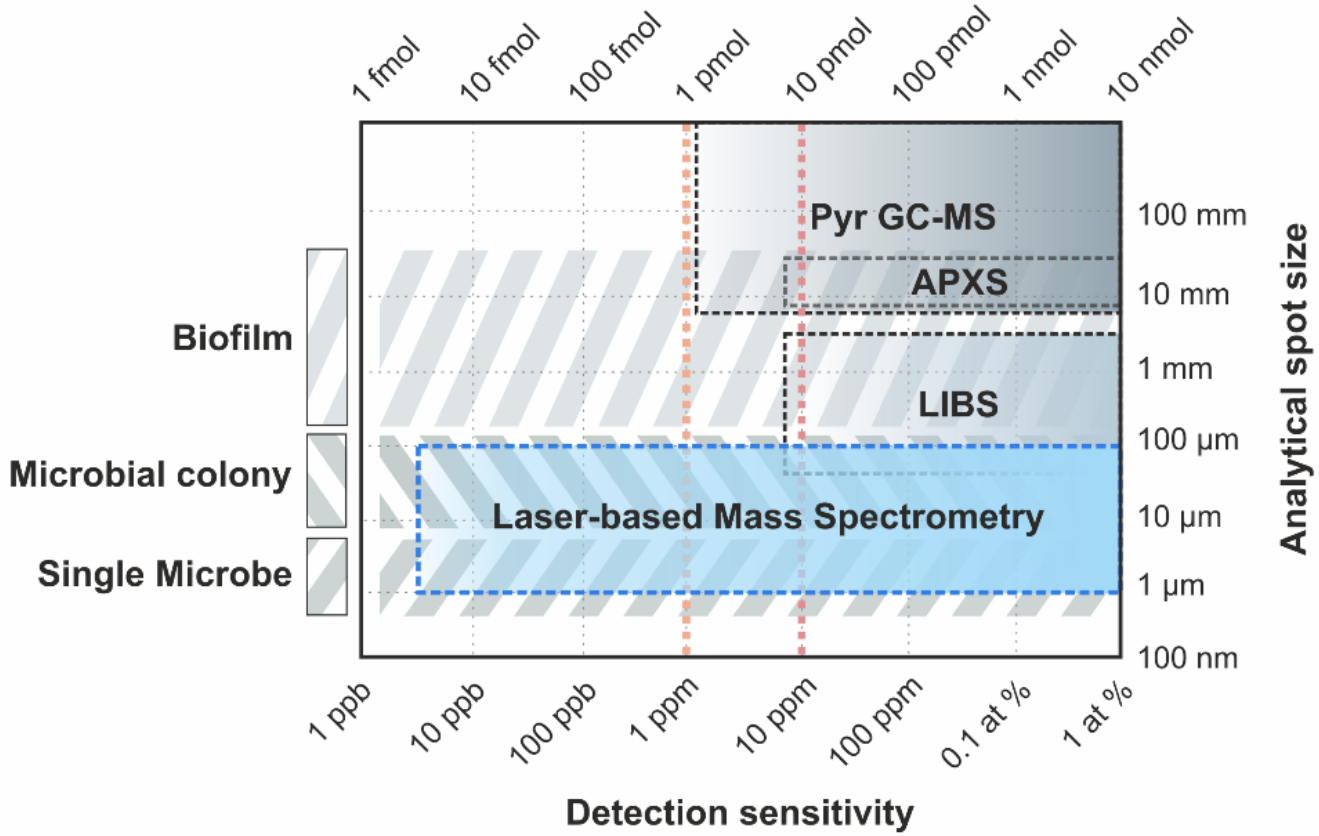
Can analyze diverse samples

And detect a variety of biosignatures



Instruments can be specialized, but are inherently capable of performing different types of analyses

Benefits of laser-based MS: Sensitivity on small scales



Ligterink et al. 2020

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Laser-based MS systems around the world

- Switzerland: ORIGIN, fs-LIMS
- Europe & USA: MOMA (ESA-Roscosmos Rosalind Franklin rover)
- France & USA: LAb-CosmOrbitrap, CORALS
- USA: L2MS
- Russia: LAZMA (Roscosmos Phobos-Grunt mission)

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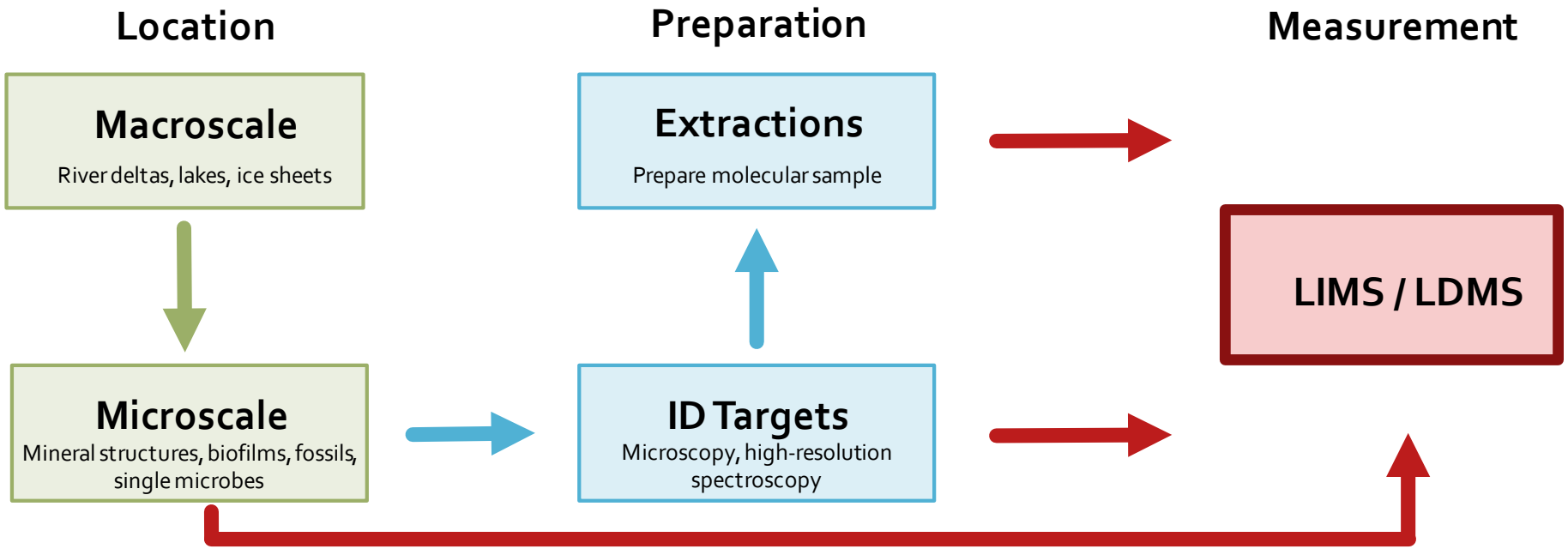
Laser-based MS on Mars: General strategy

- LIMS/LDMS provides spatially resolved chemical analysis of solids with micrometer resolution
- LIMS/LDMS can be used for pre-assessment or secure detection



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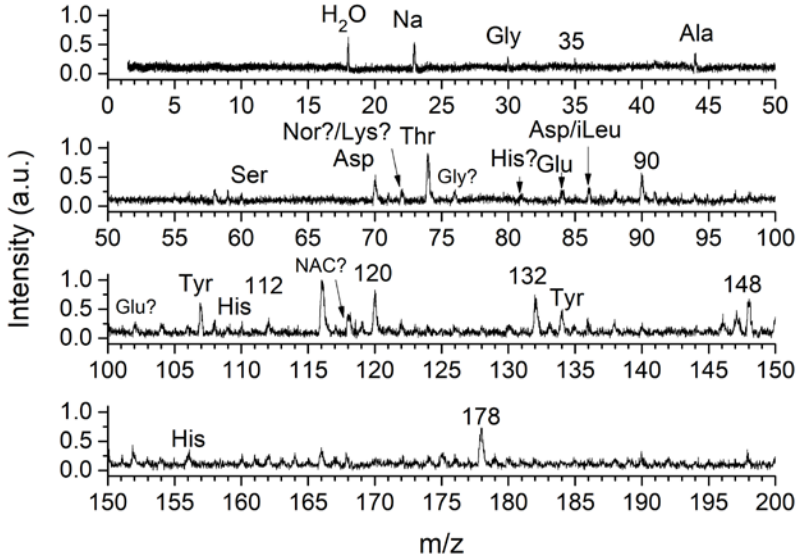
Laser-based MS on Mars: Ice caps

On Mars any kind of liquid extract can be used



Amino acid extract of Yeldoma Permafrost material measured with ORIGIN – Schwander et al. in prep

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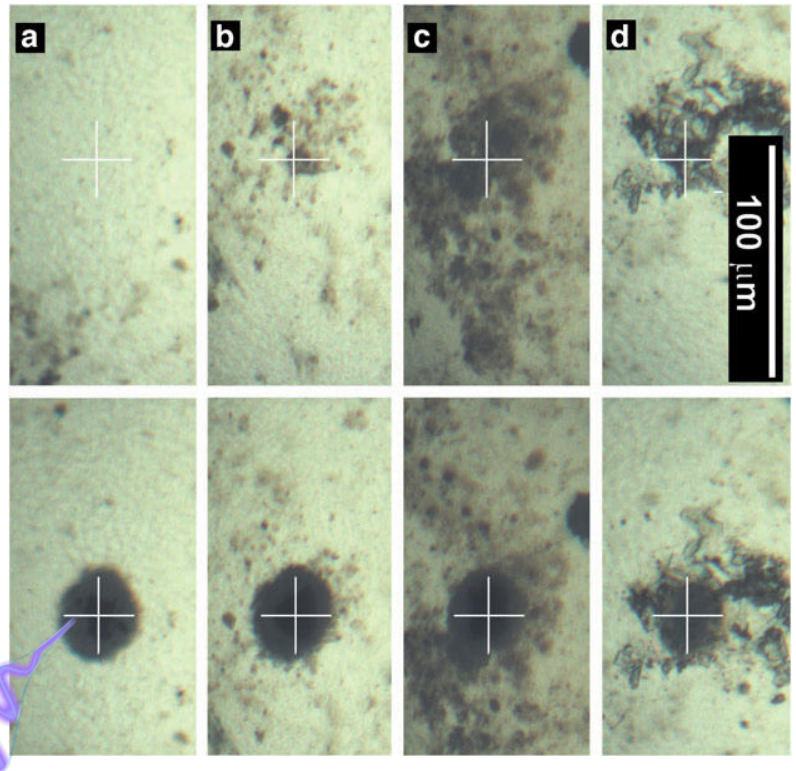
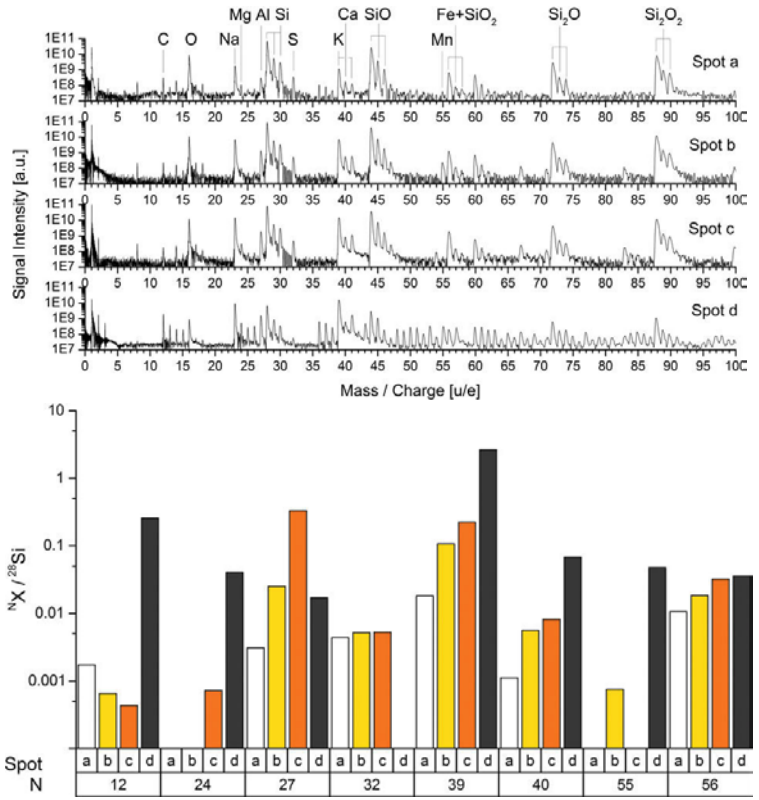
Laser-based MS on Mars: Fossilized life

On Mars need:

- Manipulator
- Cutter



1.8 Gyr gunflint chert – Mars analog – Wiesendanger et al. 2018



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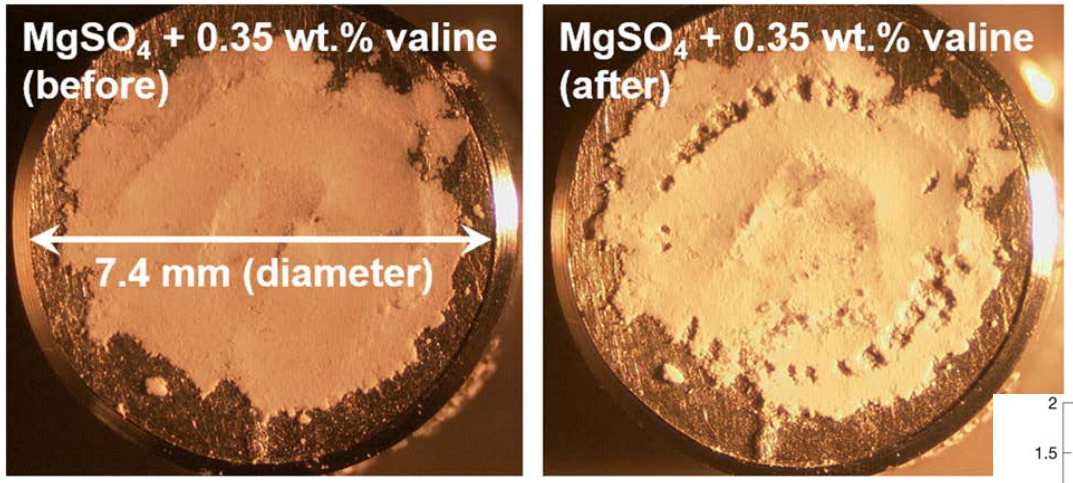
Laser-based MS on Mars: Soil

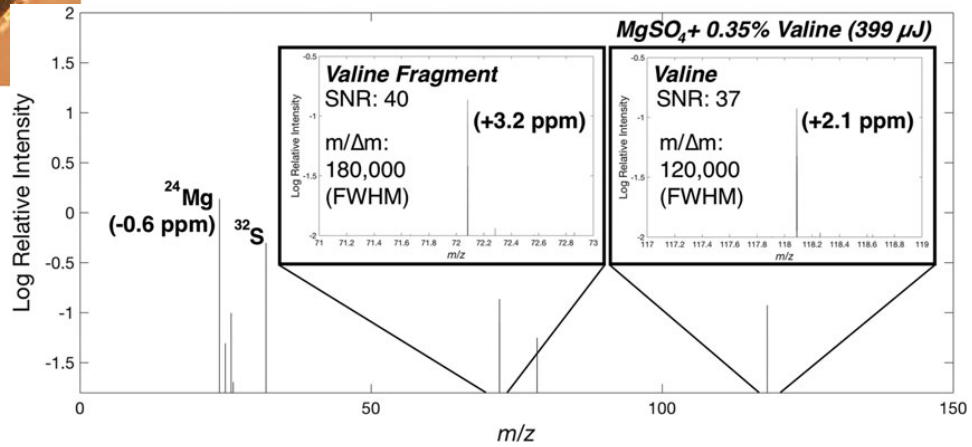


On Mars this can be:

- Drill sample
- Surface soil
- Grinded rock

On Mars need:

- Soil collection mechanism



$MgSO_4$ doped with Valine – Arevallo et al. 2018

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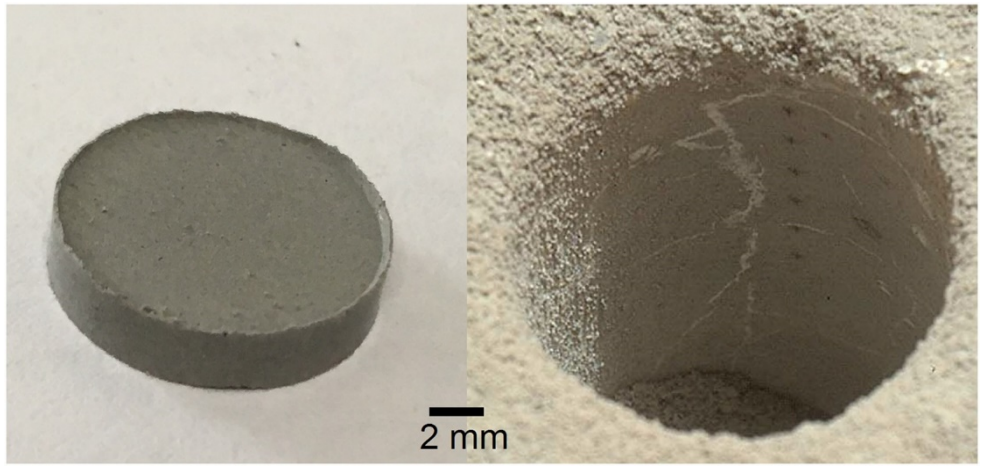
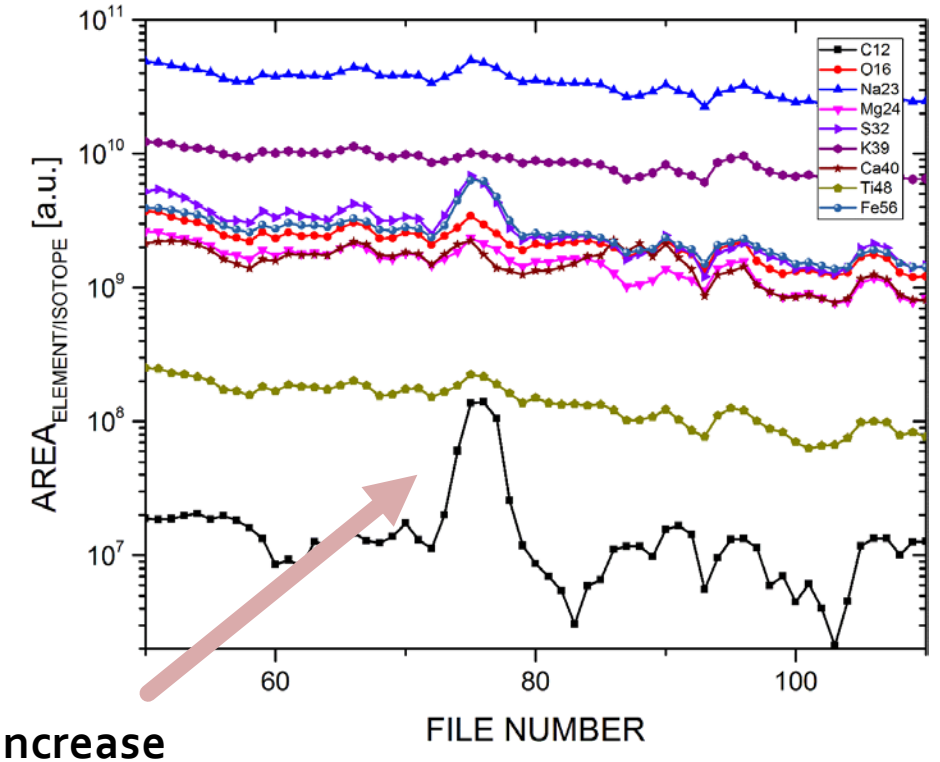
Laser-based MS on Mars: microbe signatures



Bacillus subtilis in Martian mudstone analog – fs-LIMS measurement – Stevens et al. 2019



Use depth profiling to find subsurface signatures of life

Carbon increase

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Thanks from the co-authors and signatories

Niels F.W. Ligterink,
Andreas Riedo,
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Cyril Szopa,
Jorge Vago,
Adrian Southard

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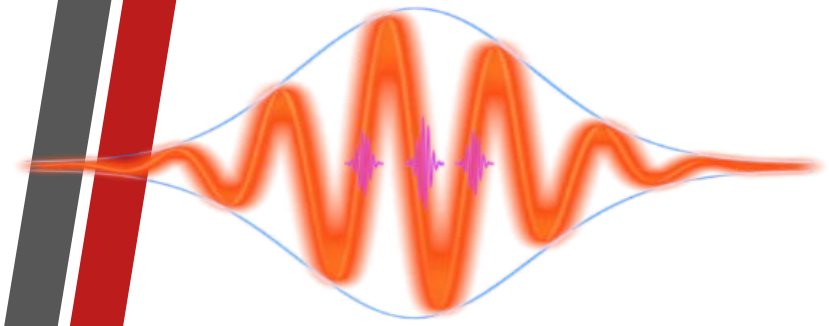
Backup slides

How it works: Laser-matter interaction



Molecules or atoms

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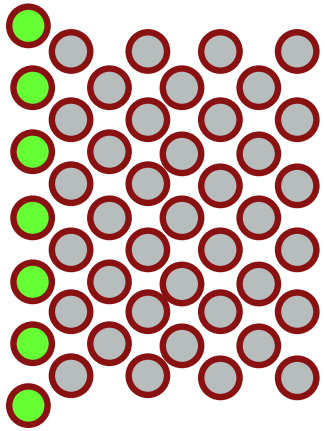
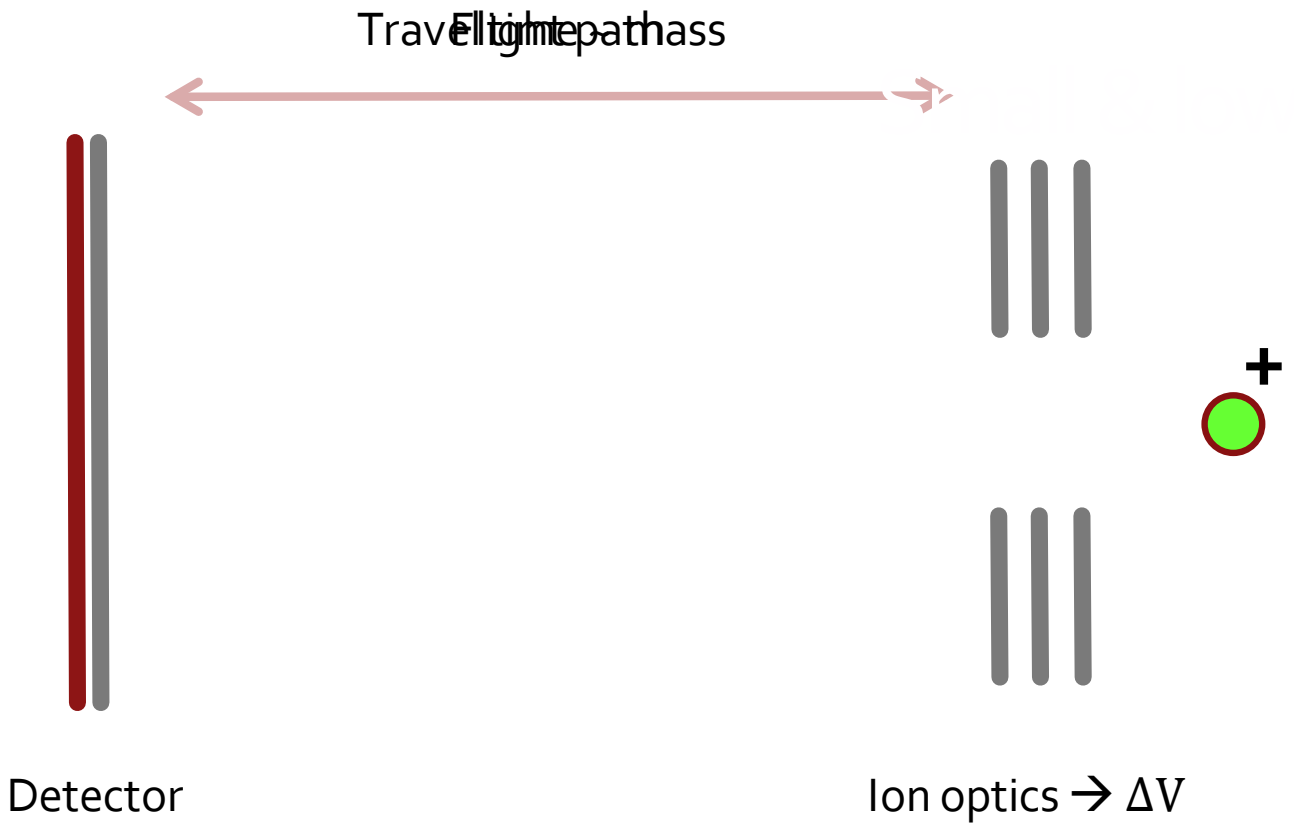


Surface

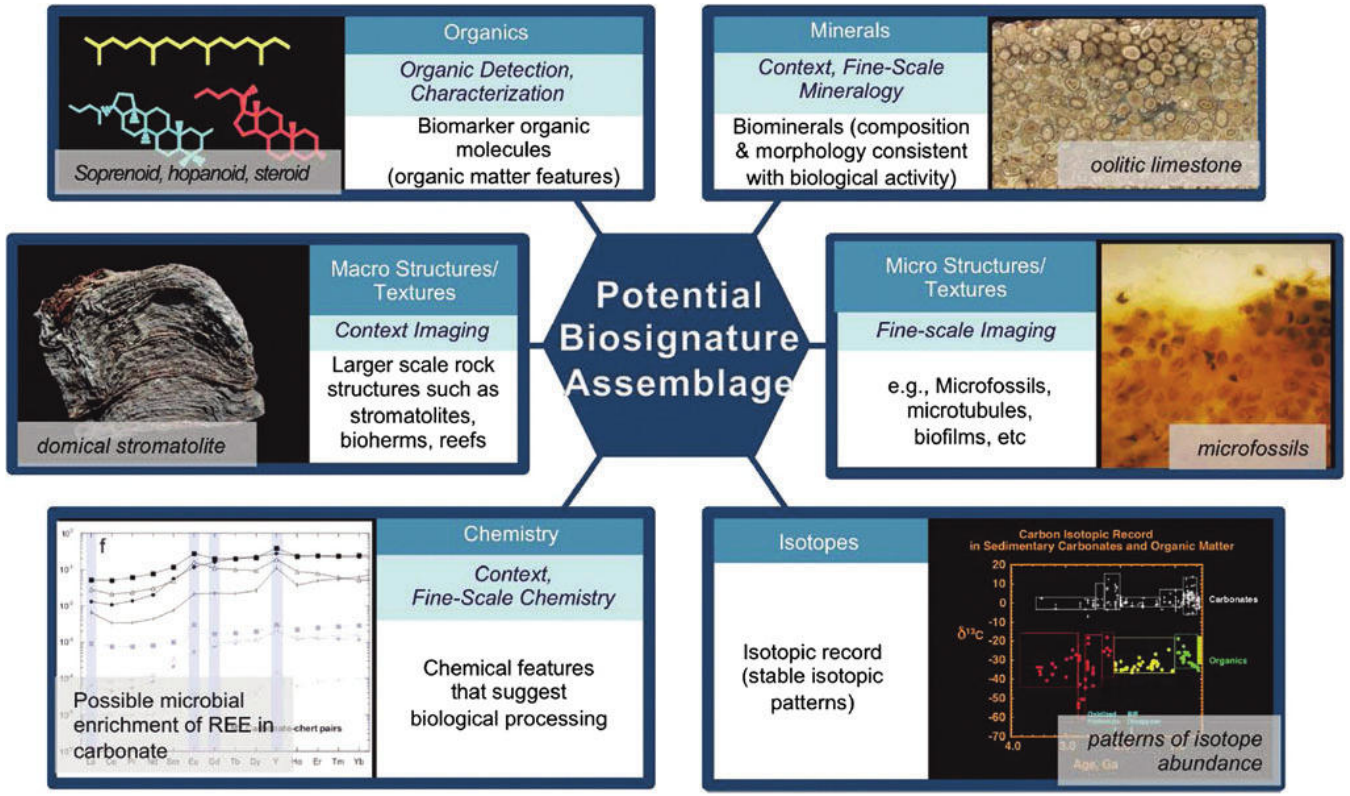
Low I_{pulse} = desorption intact molecules

High I_{pulse} = atomization solid material

How it works: Mass analysis



Biosignatures



Biosignatures
Hays et al. 2017

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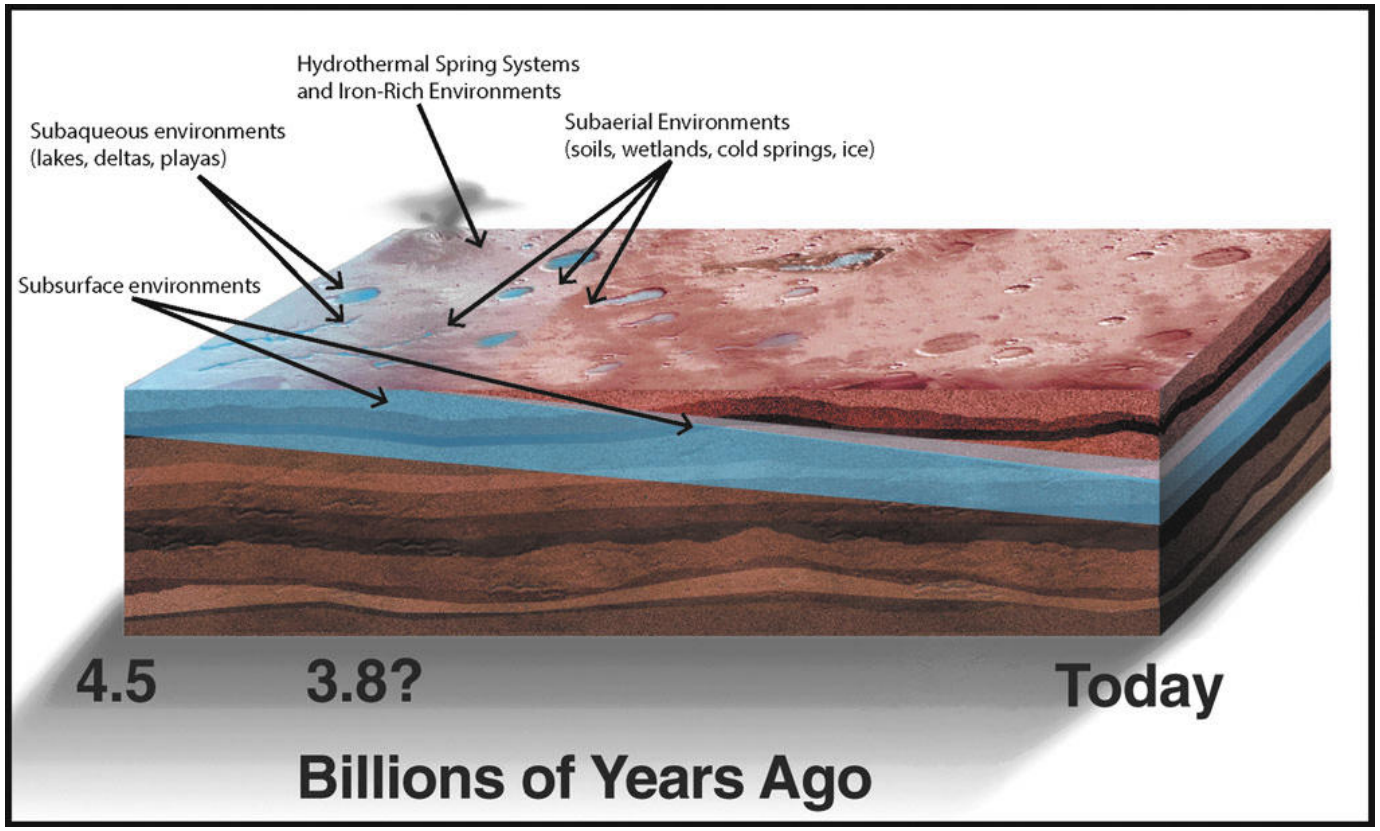
Mars environments



Ancient Martian environments
Hays et al. 2017