A Compact Integrated Raman Spectrometer (CIRS)

Capability

Deployment

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Maturity in Science & Engineering

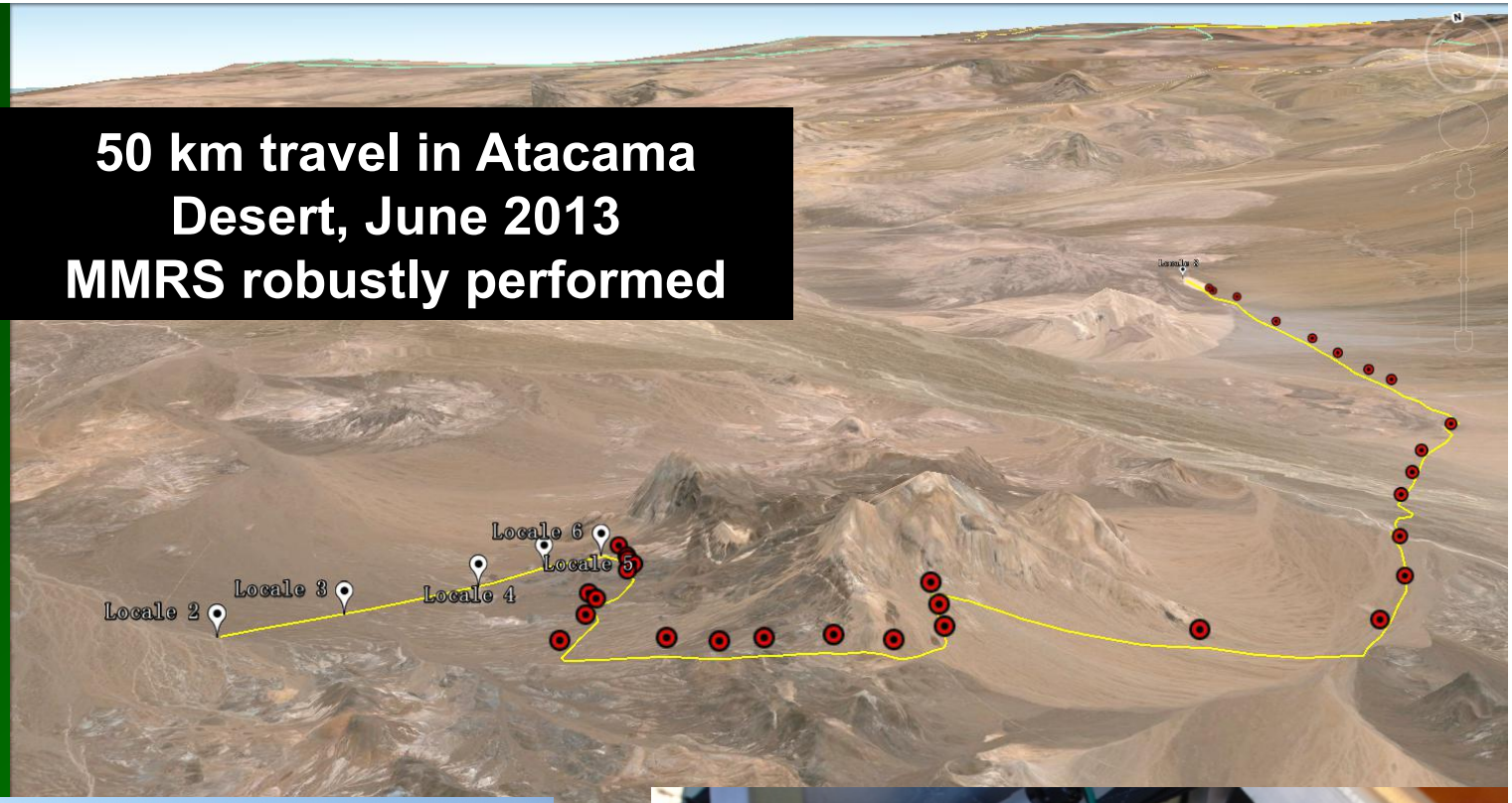
- Mars Microbeam Raman Spectrometer (MMRS) started in 1997 for Athena Payload;
- a *Category One* instrument by MSL payload reviews;
- Stand-alone tests in 2012 and autonomously operated by Zoë rover (50 km) in 2013 in Atacama Desert;
- CIRS (integrated optics, no optical fiber) fund by MatISSE in 2013;
- CIRS is proposed for Mars 2020, with extensive engineering developments in 2013 at JPL.

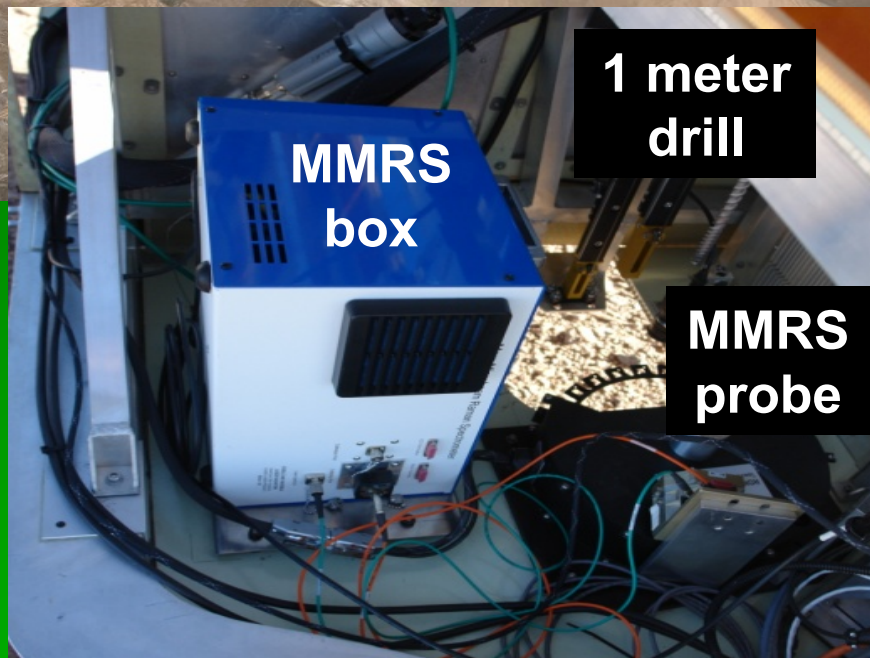
Washington
WASHINGTON·UNIVERSITY·IN·ST·LOUIS

NASA

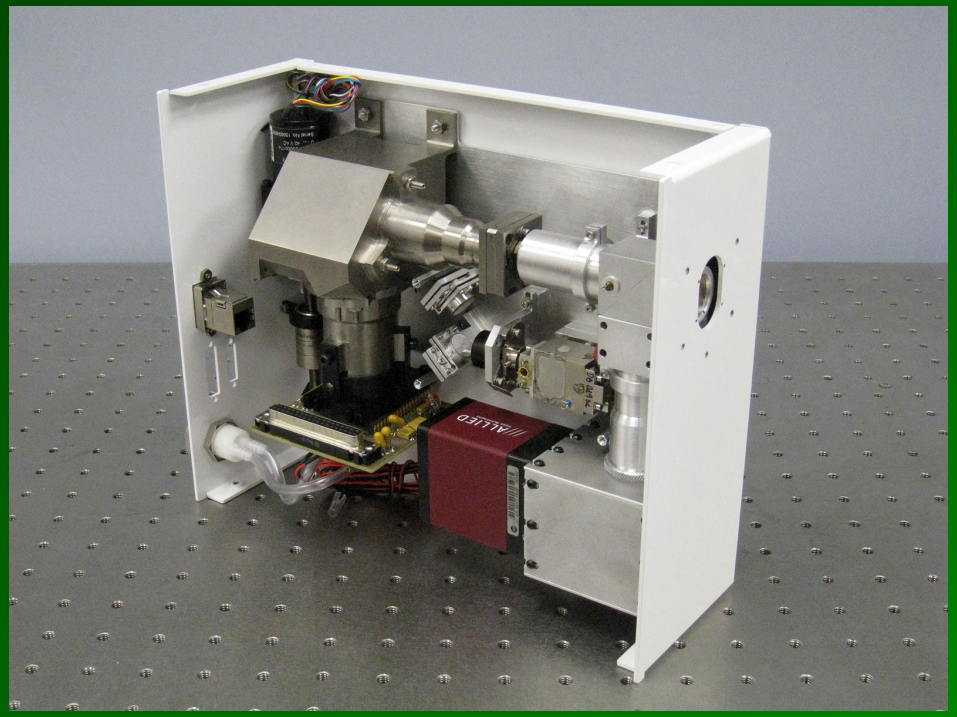
JPL

MMRS (Athena, PIDDP, MIDP, ASTEP)





CIRS prototype (MatISSE 2013-2016)



Laser units for testing

Table E.1.8-1: CIRS Key Technology Readiness Levels

Subsystem or Component	TRL	Justification
532 nm Laser	5	MatISSE to Date
Optical Configuration	5	MatISSE to Date
E2V 47-20 Focal Plane	9	13 different missions for 47 series
KAI 2020 / M50 Focal Plane	9/8	MSL, MAHLI, Mastcam, MARDI, OSIRIS-REx
Lightfield Image Processing	6	Pipeline similarity to commercial product

Laser Raman Spectroscopy for Planetary Explorations

Targets -- molecular species (ID & Quantify):

- Inorganic (minerals);
- Organic (biota, biomarkers);
- Gases (atmosphere);
- Fluids & frozen (dissolved species) ;

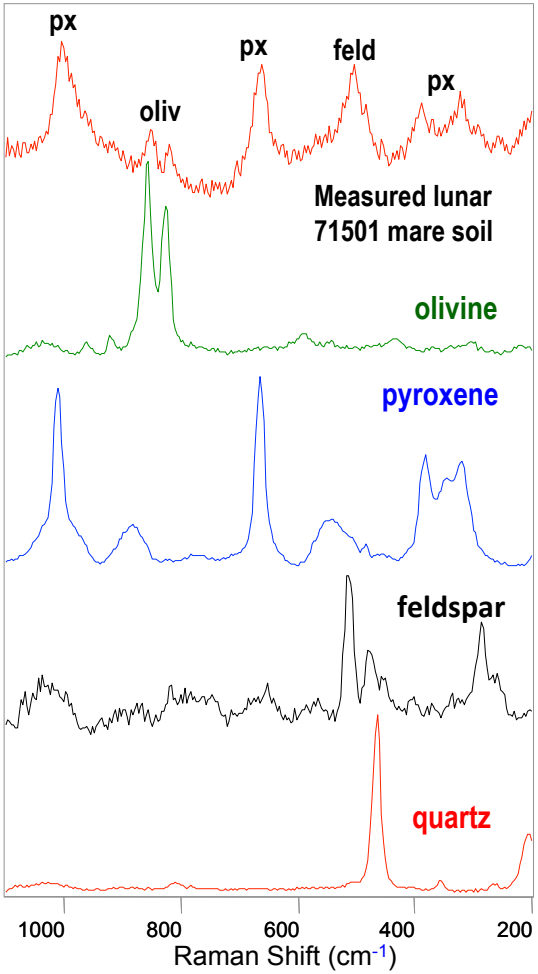
Inorganic and organic groups	covelency of major bond
carbon, sulfur, O_2, N_2, H_2	100%
perchlorates, nitrates, carbon-(H, N)	92-95%
sulfates, carbonates	80-81%
chromates, phosphates	75-65%
borates, vanadates	59-62%
silicates	51%
(Mg, Fe, Ca)-O	19-31%

Deployment – descending & landing missions:

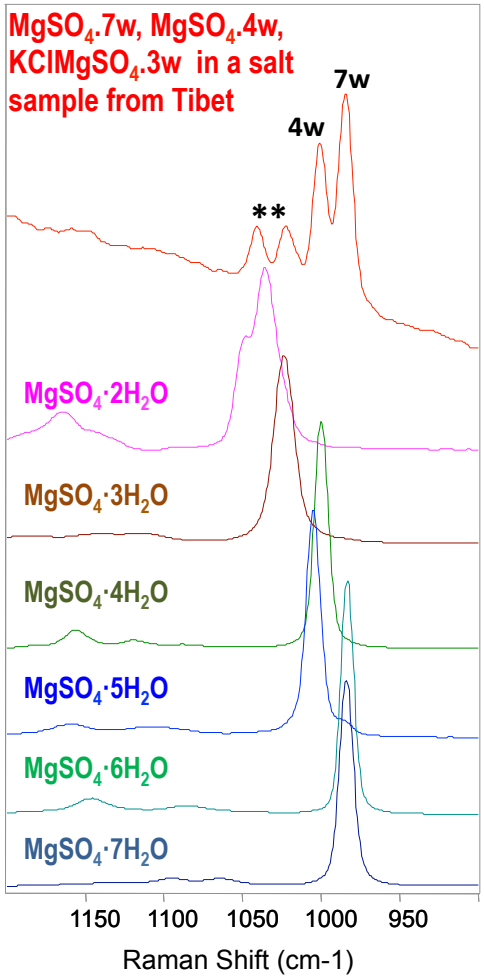
- Descending through layers of atmosphere;
- on Arm & mast of rover/lander;
- Immersive probe or whole system in ocean.

Solid phase (ID & quantify) – Moon, Mars, asteroids

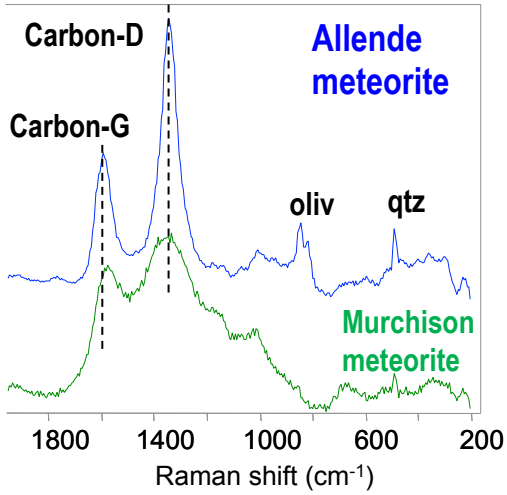
Igneous minerals

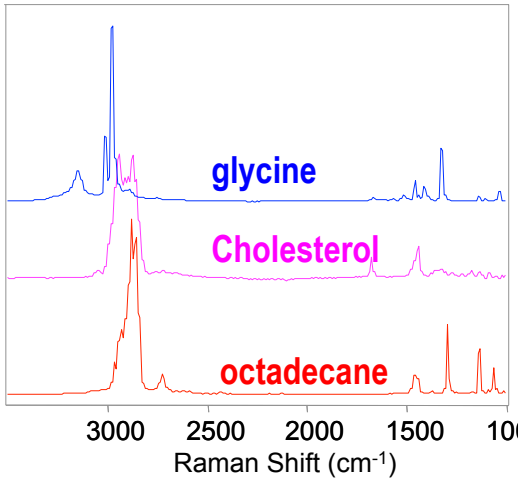


Hydrous salts



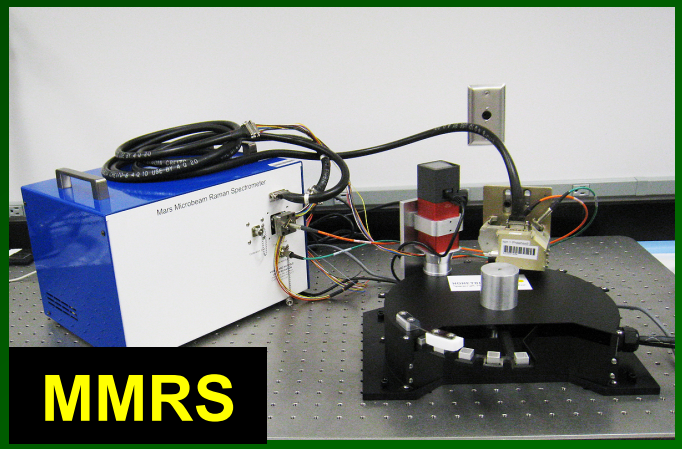
C & organics



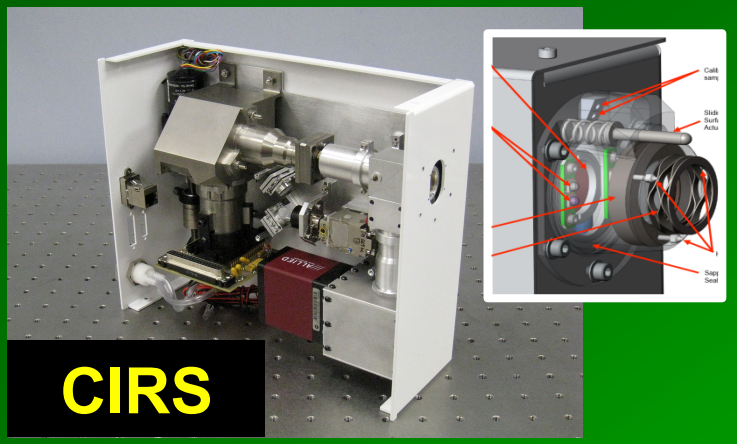


MMRS - CIRS deployed by arm

Spectrometer-optical fiber-probe



Integrated optics + context imager



Common features of MMRS vs. CIRS:

- Analyze the sample as is;
- ~ 27 mm working distance → detailed sensing;
- < 20 µm laser spot → rare & trace species;
- Line-scan → Geo-context & quantification;

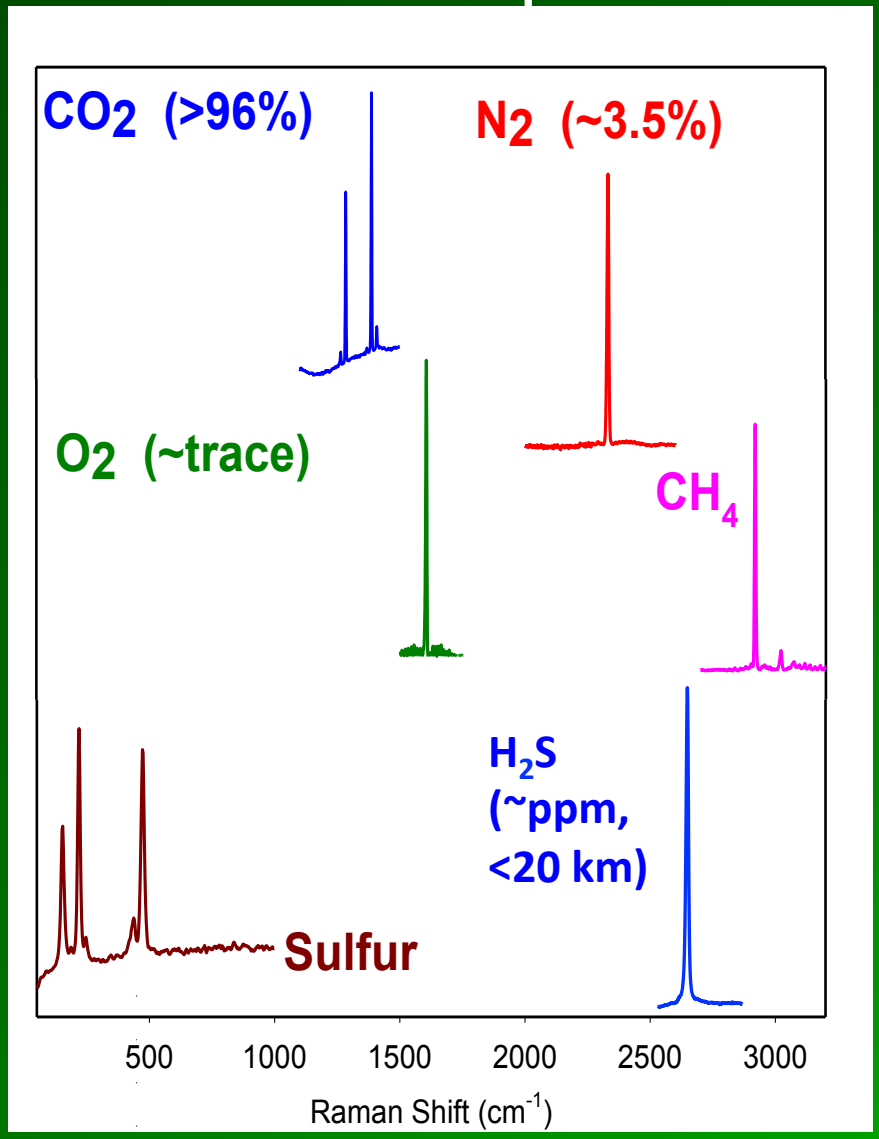
Different features of MMRS vs. CIRS:

- MMRS has a light-mass probe, w/an optical fiber cable to be handled – for simple rover;
- CIRS has a larger-mass optics, with context imager – for heavy duty rover;

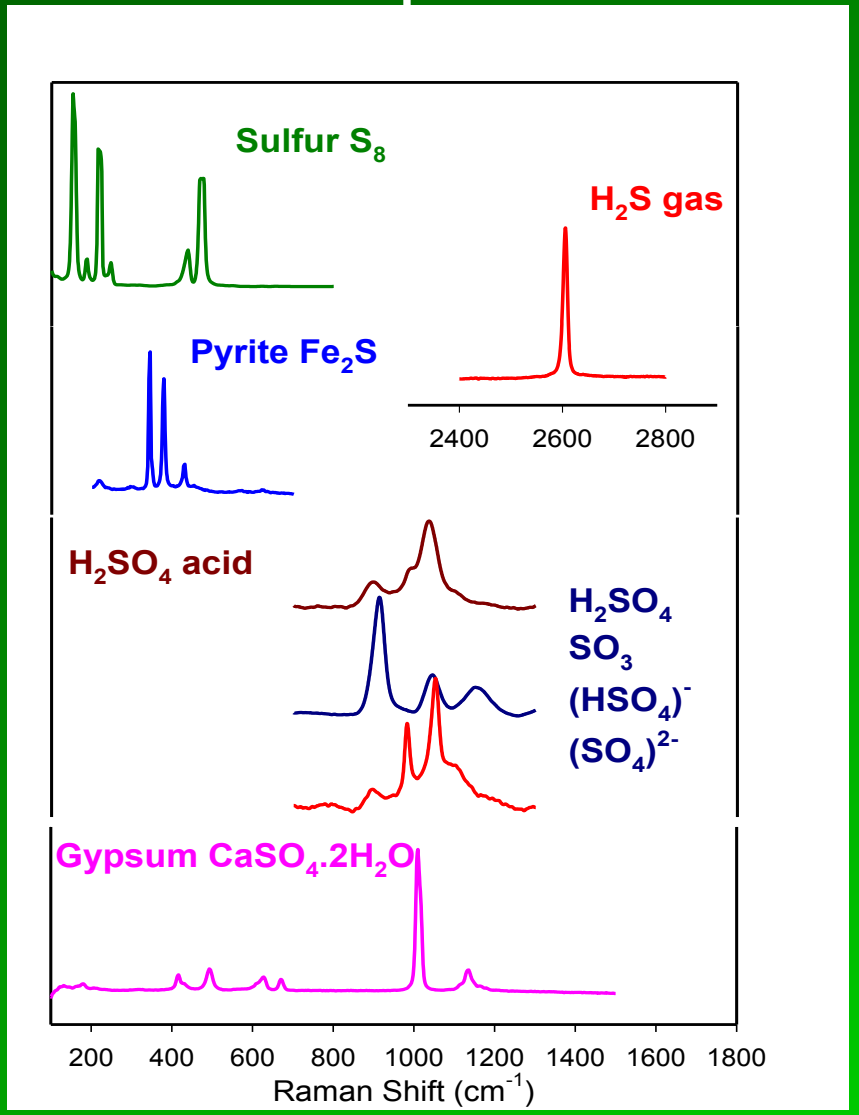
Deployment – to be placed directly on target.

Gas phase (ID & quantify) – Venus etc

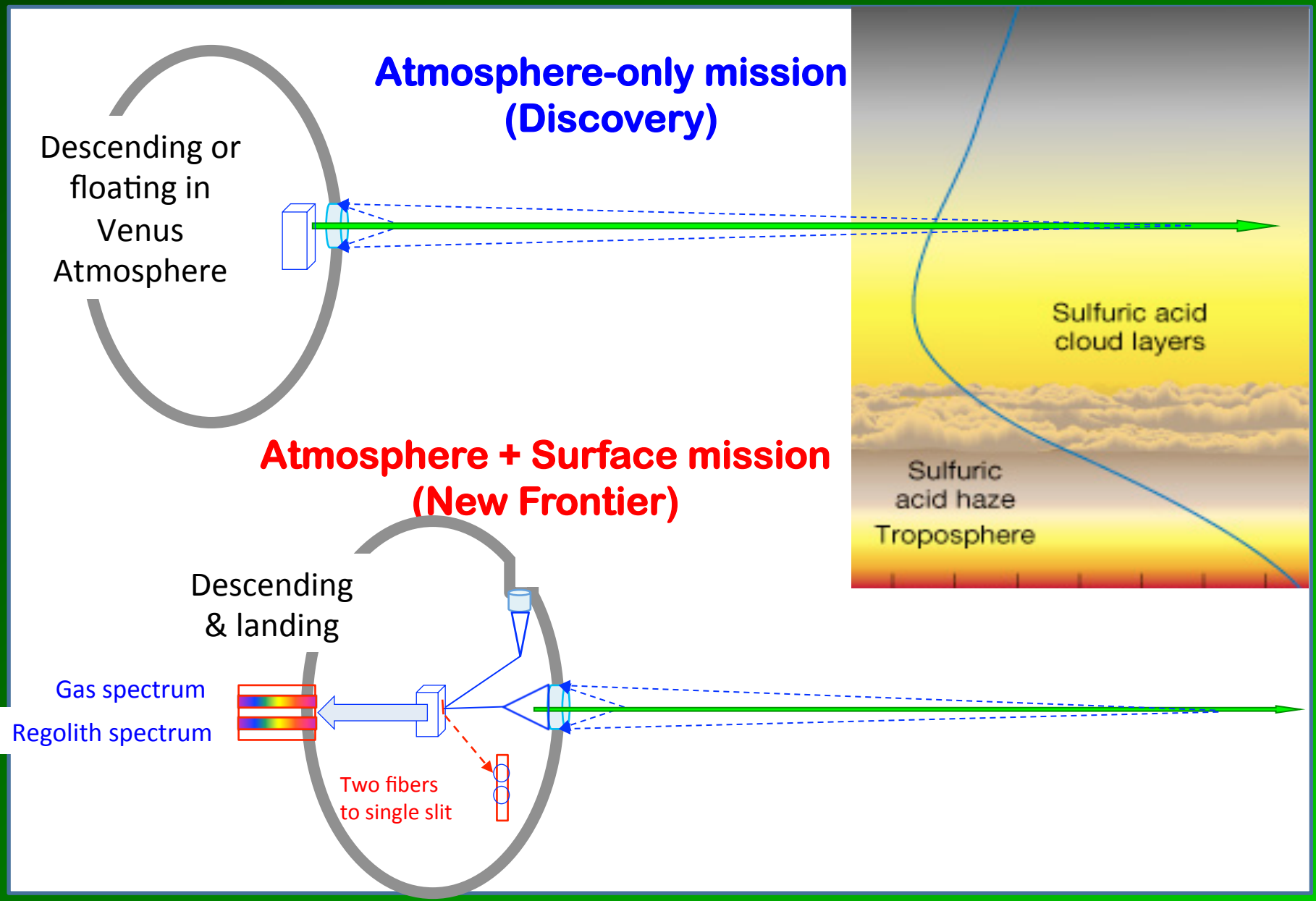
Gaseous components in Venus atmosphere



Possible compounds in Venus atmospheric aerosol



CIRS: flexible for Venus missions



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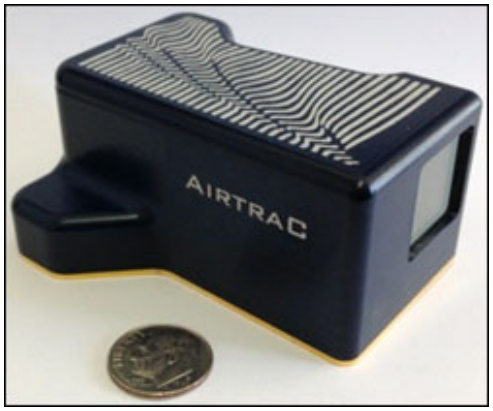
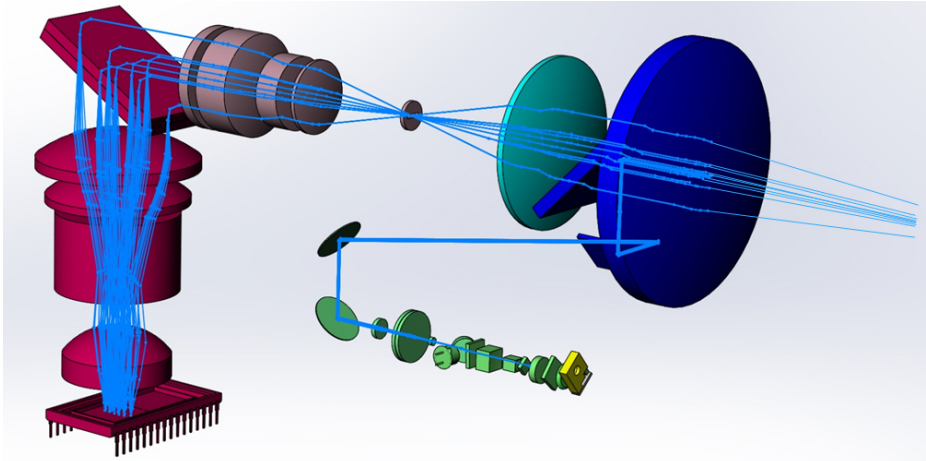
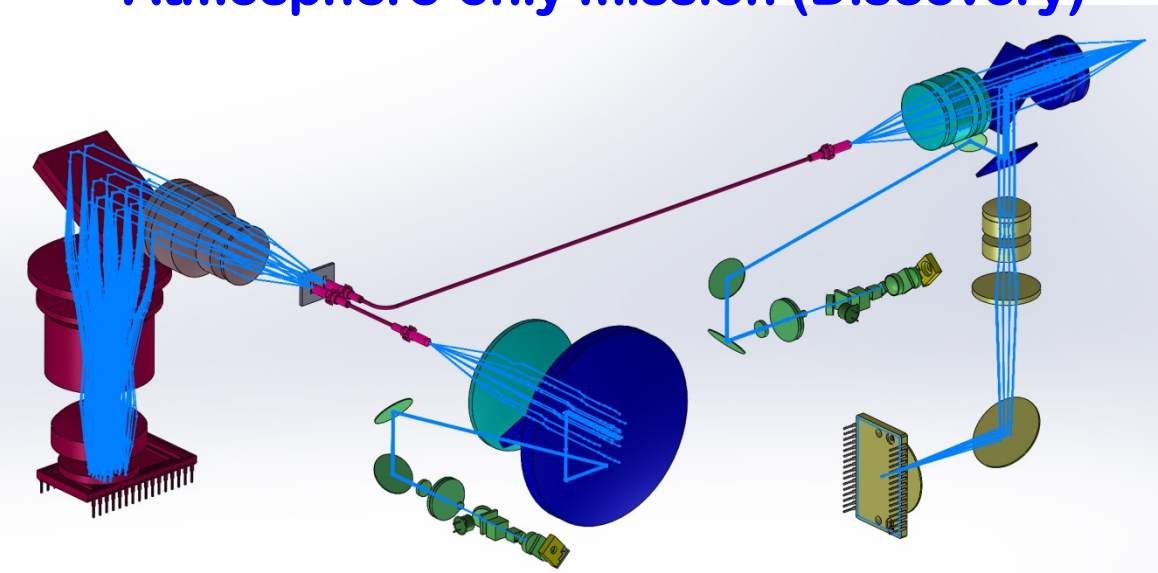


25mJ actively Q-switched 532nm laser (MIL spec)



Atmosphere-only mission (Discovery)

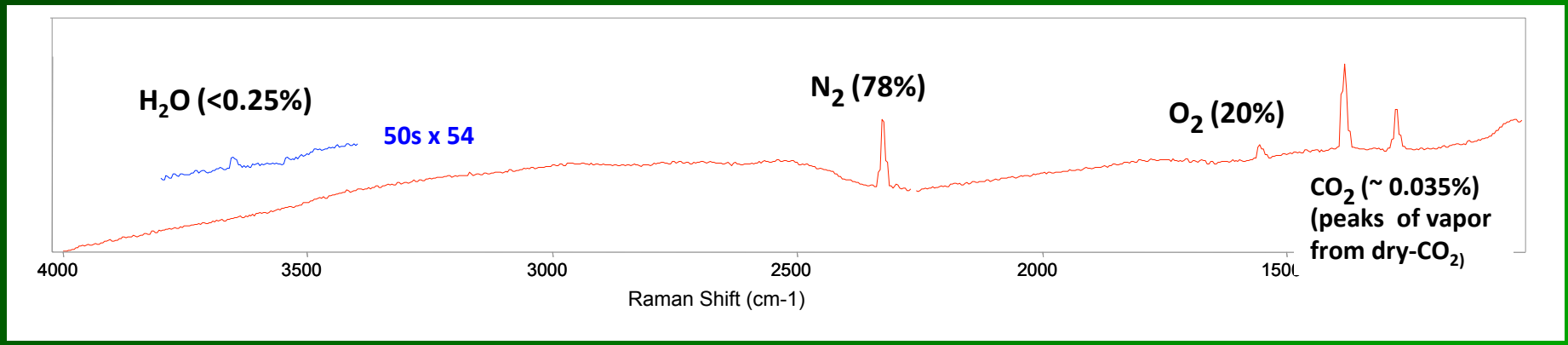
EMCCD provide gain and allow high speed shuttering (2 μs - ms)

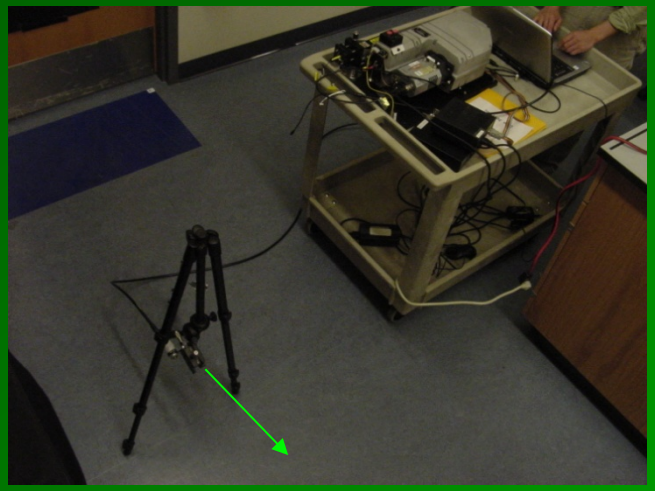


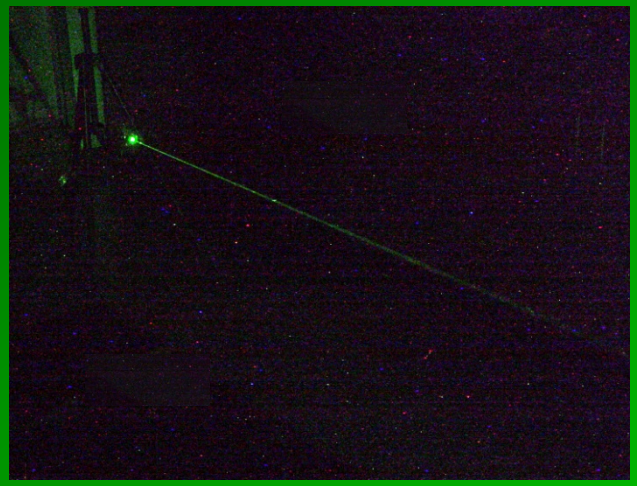
Atmosphere & Surface mission (New Frontiers)

A feasibility test in laboratory

P_{Earth} = 1 bar, cw laser of 12 mw, ½" optics, 5 m path: N_2, O_2 Raman peaks w/good SNR in 50 s





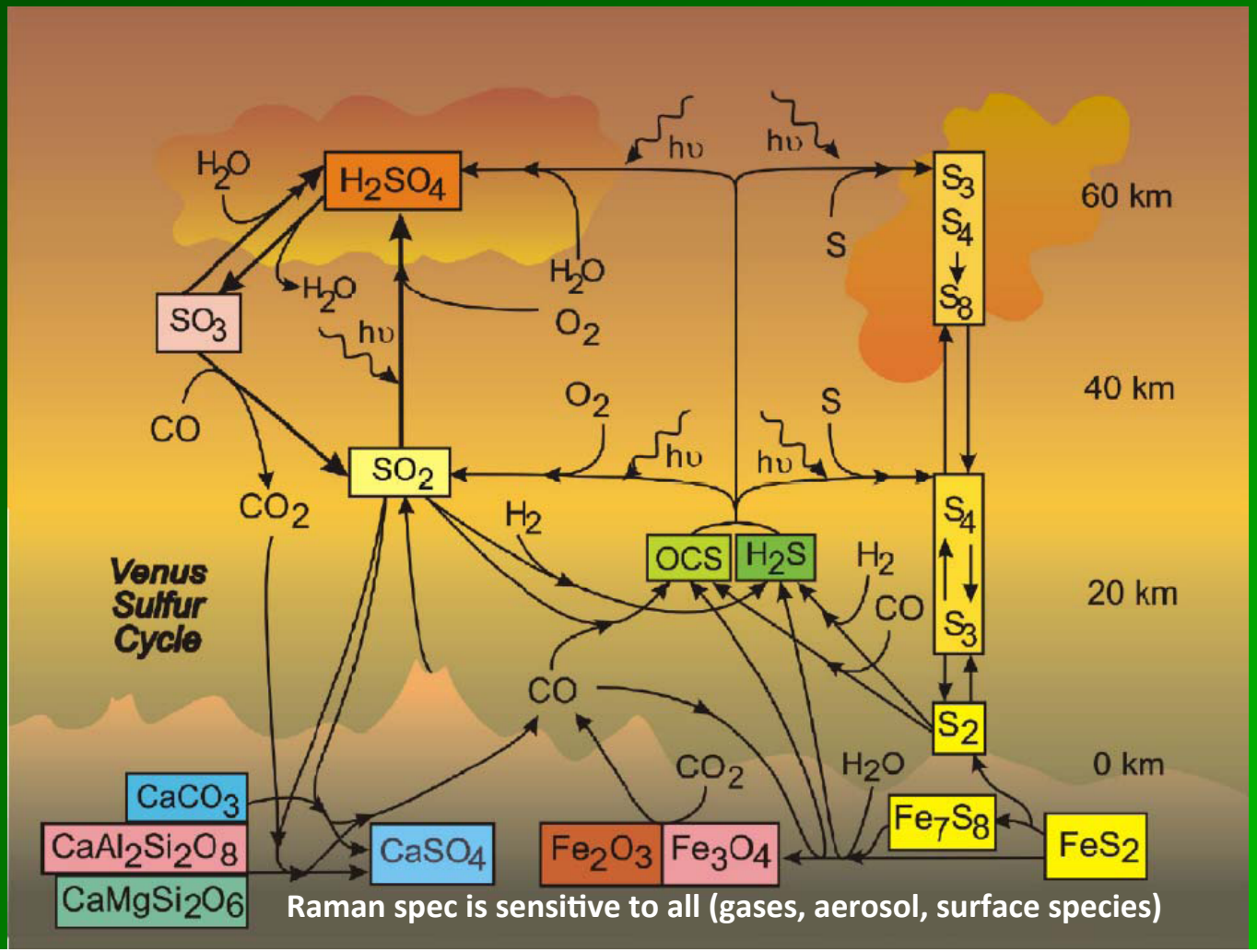


On Venus, ~ 92 bar, cw laser of 1w, 2" optics, 5-10 m path, Need $3x10^{-4}$ s to get gas peaks with similar SNR.

Time is a major limitation for Venus missions – we would use a meas-logic different from SAM, i.e.

Get a Raman spectrum in every second

(then detailed data digestion back Earth)

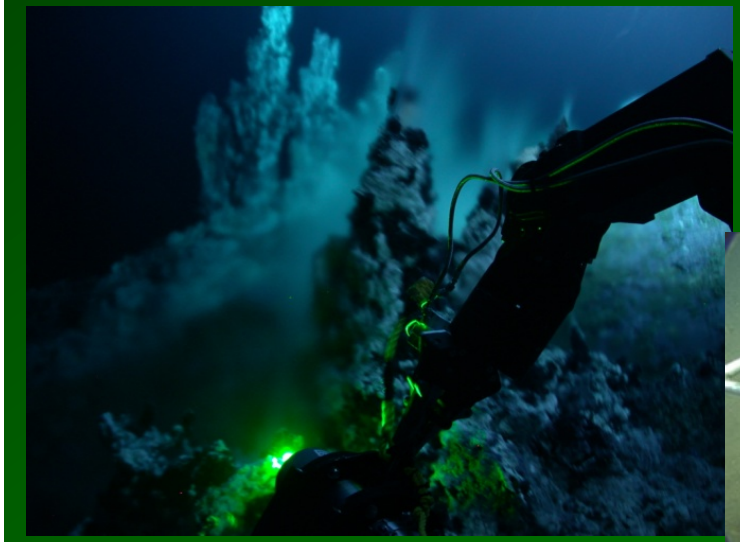


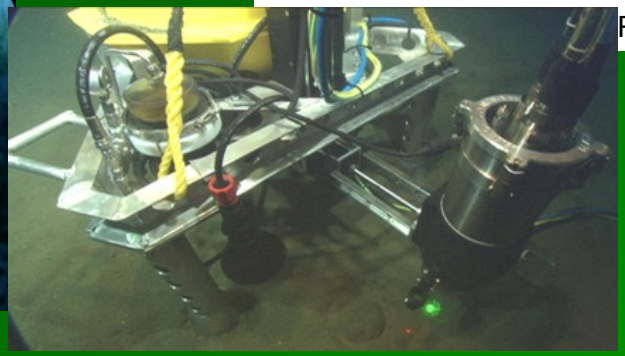
Data density

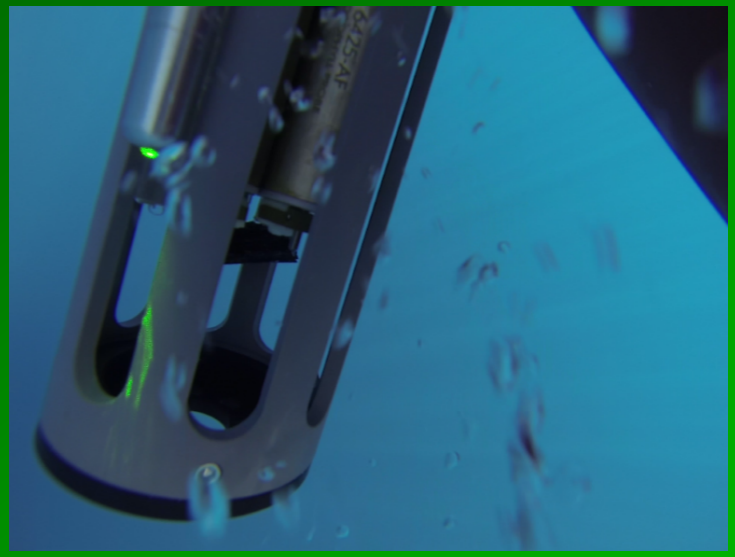
20 min
= 1200 spectra

Liquid · frozen · dissolved species

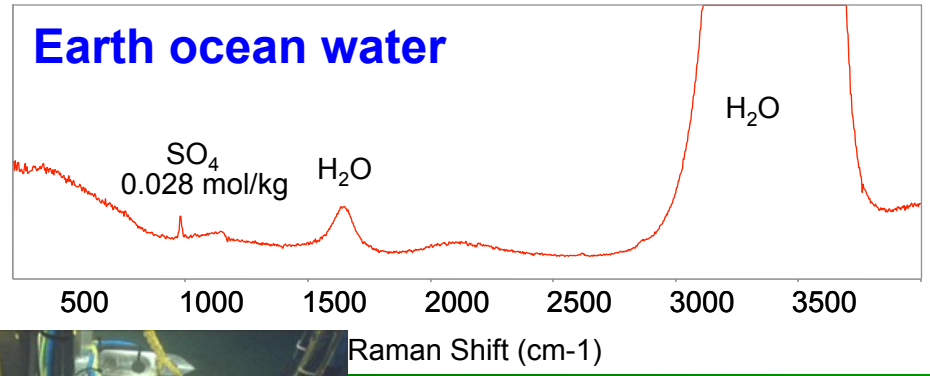
Raman system used in deep ocean

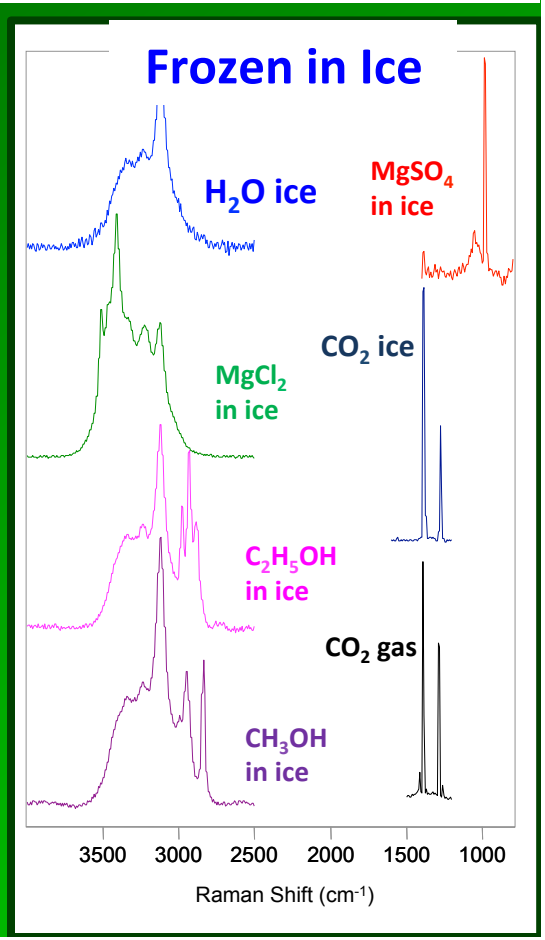




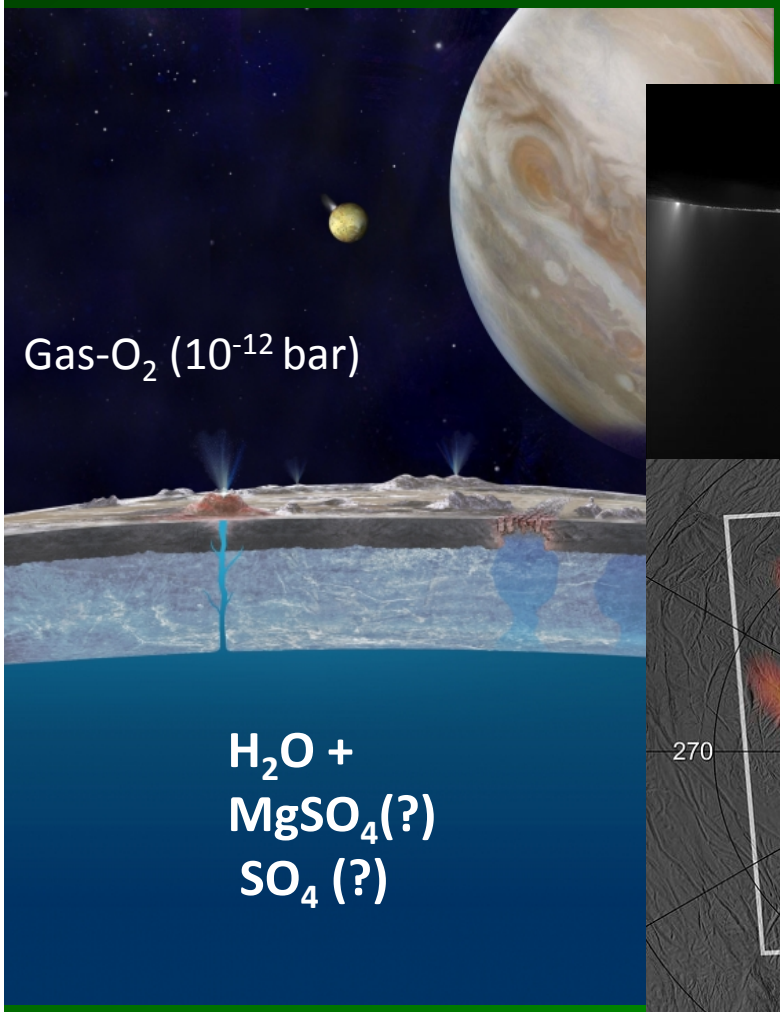


Raman probing lake water

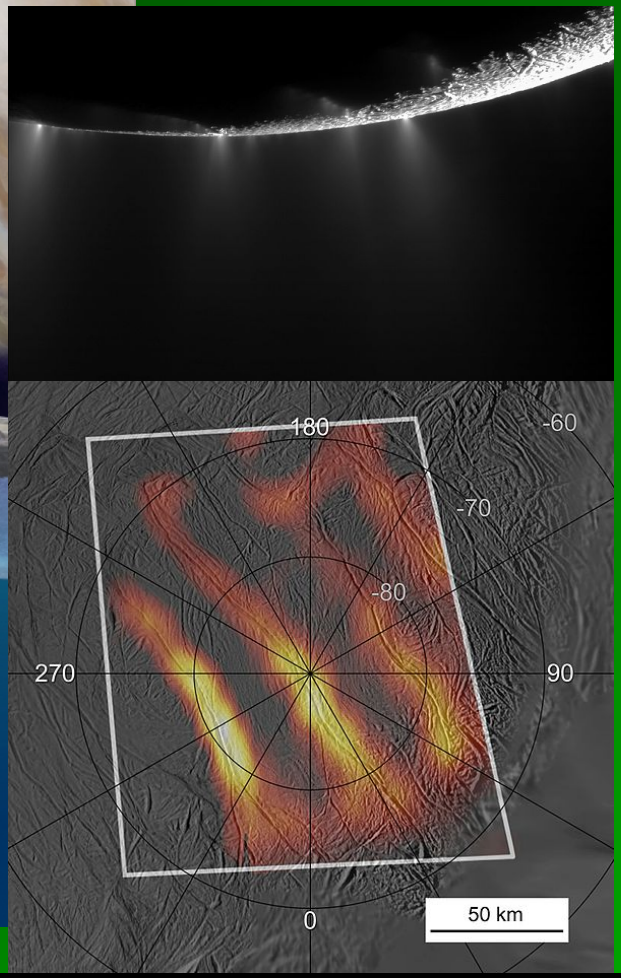




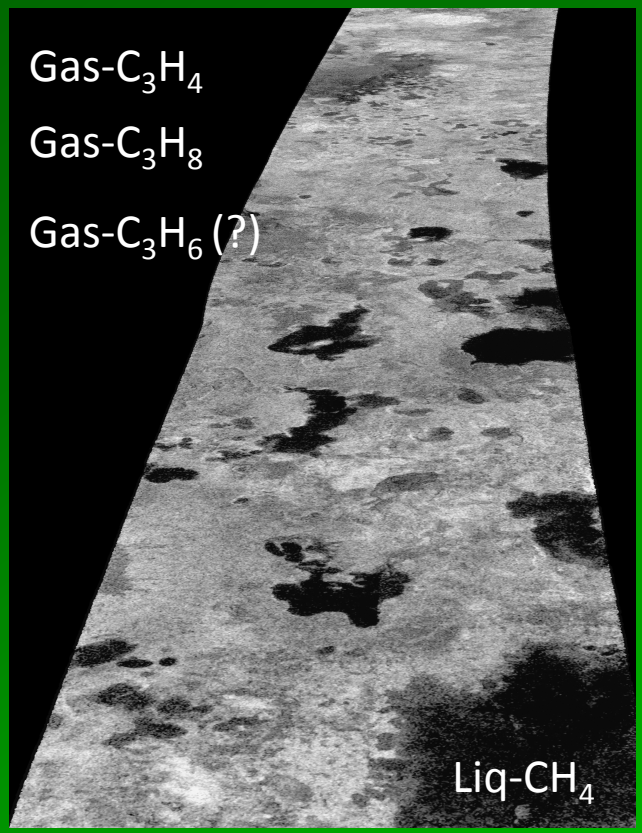
Exploration of icy world



Subsurface water ocean of Europa



Subsurface salty water ocean of Enceladus (organics in jet dust)



hydrocarbon lakes on Titan northern hemisphere (2013 Cassini-Huygens)

Acknowledgements – NASA PMD funds