Martian Moon eXploration (MMX)

The new JAXA sample return mission to the Martian's moons

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Summary

1. What we know about Phobos and Deimos?
2. Martian Moon eXploration mission
3. MMX InfraRed Spectrometer
4. Phobos and Deimos in laboratory

Phobos and Deimos

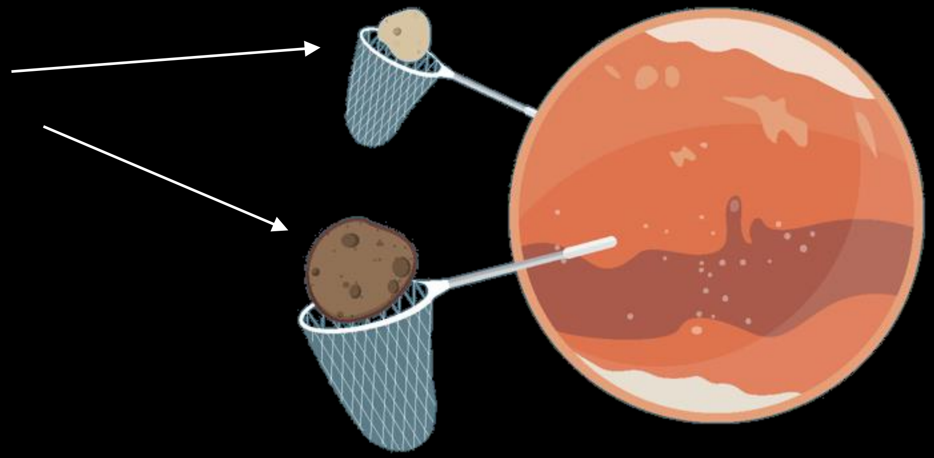
Asaph Hall discovered both the Red Planet's moons in 1877

Phobos is the larger moon (27x22x18 km) and it orbits Mars three times a day. It’s getting closer to the planet with a rate of 1.8 meters every 1000 years resulting in a crash into Mars in 50 million years or break up into a ring.

The smaller Deimos (15x12x11 km) orbits Mars every 30 hours. This moon is less cratered but covered by a thick regolith (probably around 100 m)

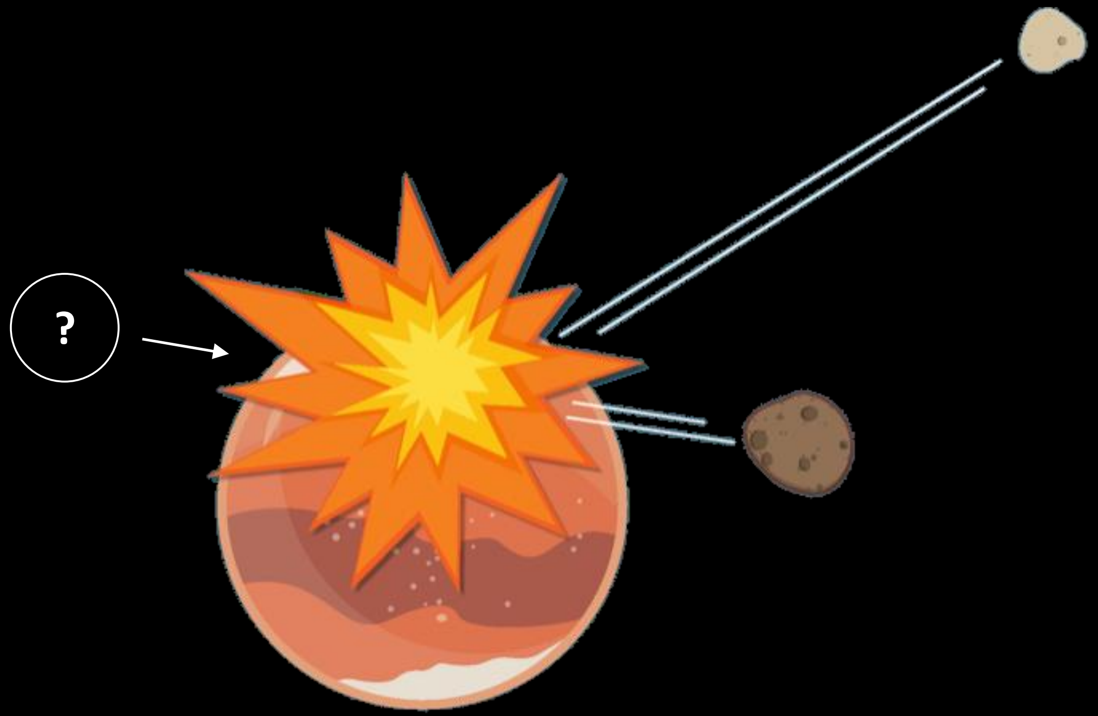
Origin of the moons

Two main hypothesis were proposed to explain the origin of the moon of Mars



ASTEROIDS CAPTURE

(Hartmann 1990; Higuchi, Ida 2017)



GIANT COLLISION

(Rosenblatt+ 2016; Hyodo+ 2018)

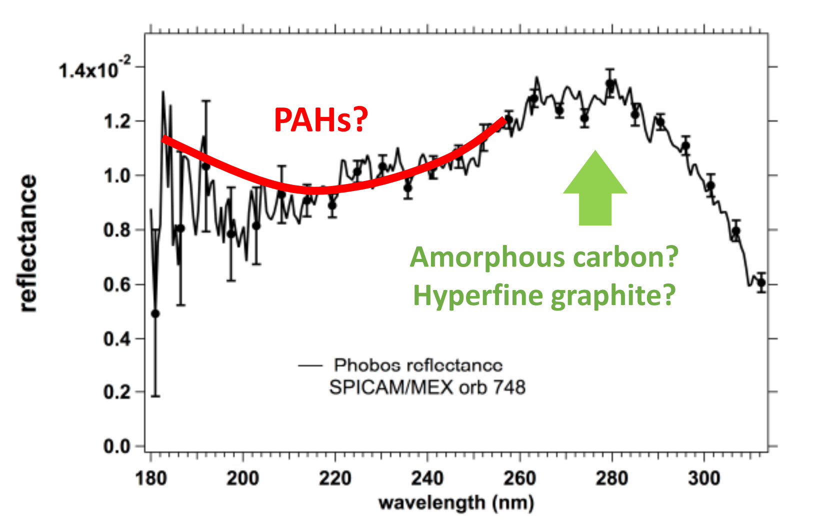
Moons composition

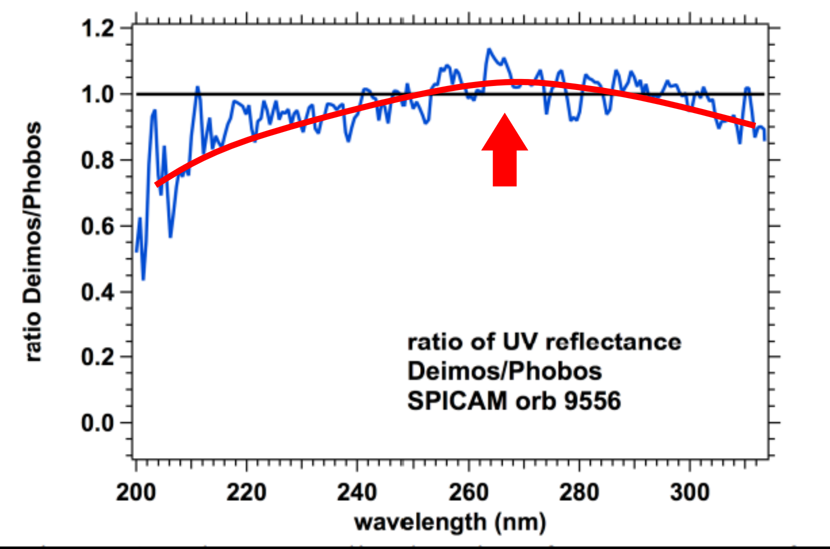
UltraViolet

Bertaux et al. (2011, 2016), using ESA Mars Express Spectroscopy for Investigation of Characteristics of the Atmosphere of Mars (SPICAM) data, suggested that the minimum in UV spectra at 220 nm could be due to an absorption band in solid, dehydrogenated coronene-like polycyclic aromatic hydrocarbons (PAHs).

Deimos spectrum may exhibit a weak peak around 260 nm, when ratioed against the spectrum of Phobos.

Peak at 280 nm likely indicates a significant concentration of sub-microscopic amorphous carbon on the surface of the satellites (Applin et al. 2018)





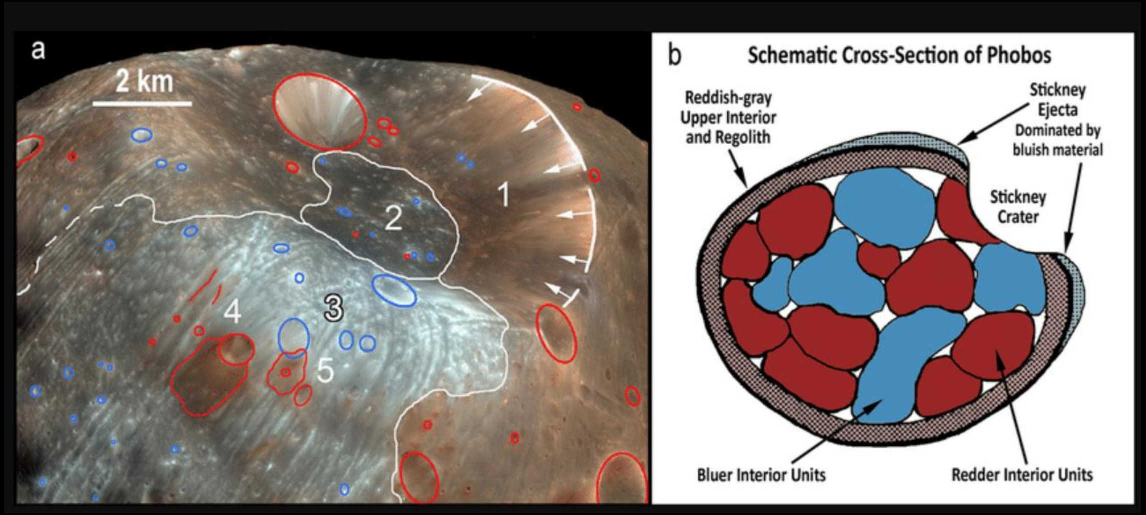
Bertaux et al. (2016)

Moons composition

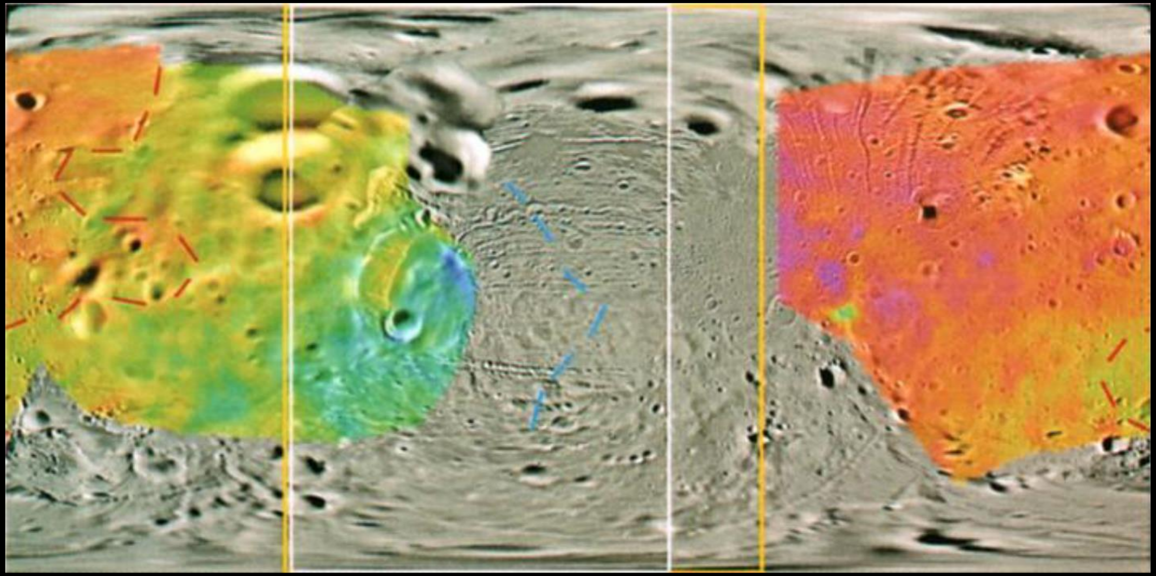
Visible - Near InfraRed

On Phobos, two distinct spectral units can be distinguish: the *red unit* with a visible/near-infrared colour ratio of 0.6–0.85 and the *blue unit* with a visible/near-infrared colour ratio of 0.85–1.2

The blue unit is associated with Stickney crater (the biggest on the moon) and its ejecta while the red unit dominate the rest of the moon.



Ramsley & Head 2021, Space Sci Rev 217, 86



Murchie, S. et al. 1999, J. Geophys. Res. Planets, 104, E4, 9069

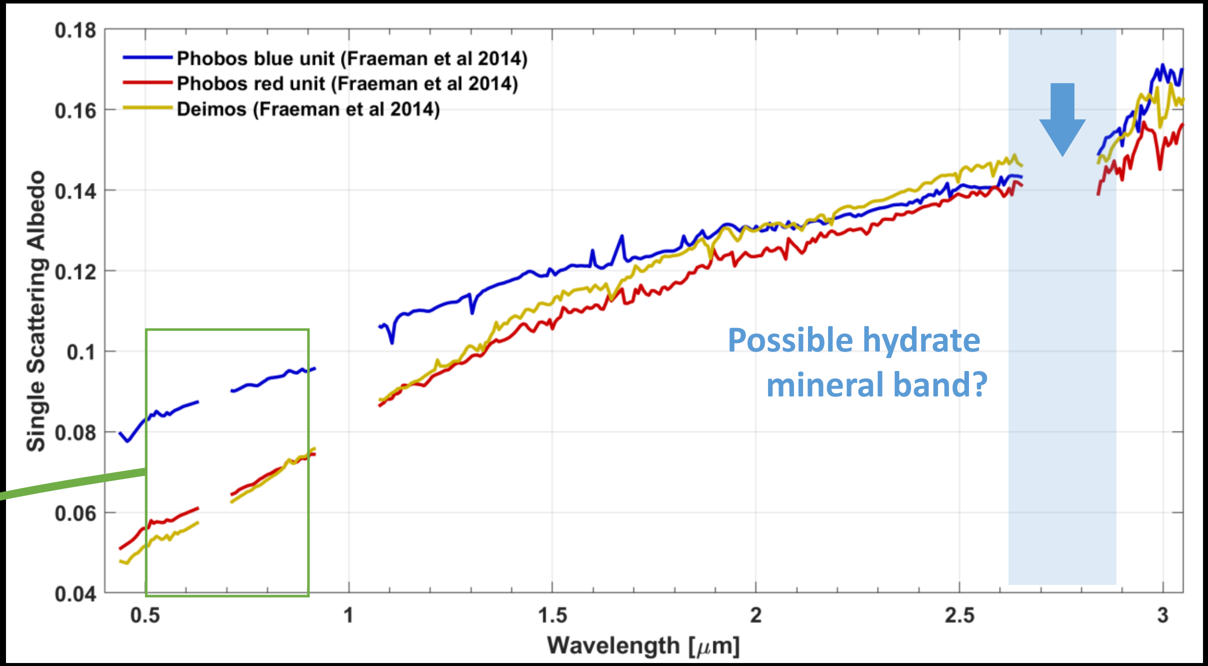
The most accepted conclusion is that the blue unit represent the pristine material of the subsurface of Phobos.

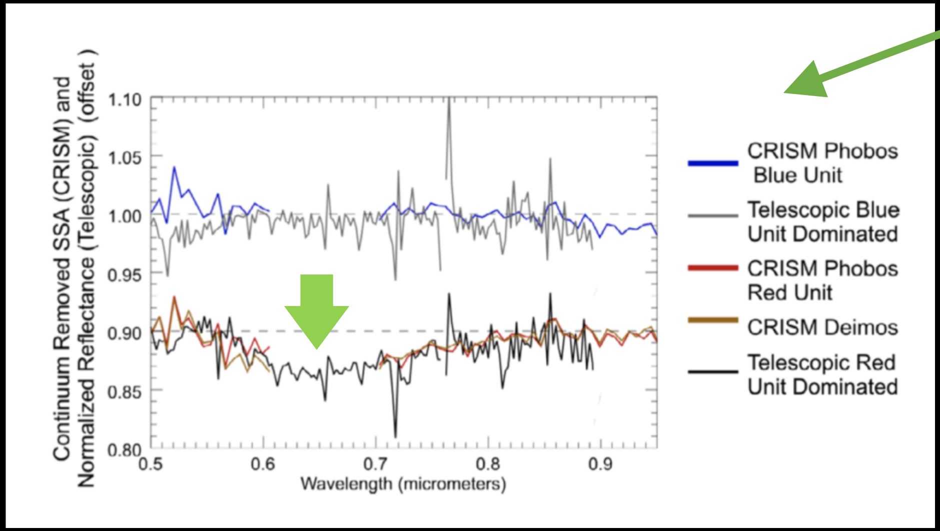
Deimos is generally close to Phobos red unit.

Moons composition

Near InfraRed

Several IR dedicated observation using ground-based telescopes were performed in the past, the most recent are: Rivkin et al 2002 and Takir et al 2021
Only Phobos-2 mission was observing Phobos as primary objective most of other data were collected from Mars orbiters in particular from MEx-OMEGA and MRO-CRIMS instrument.





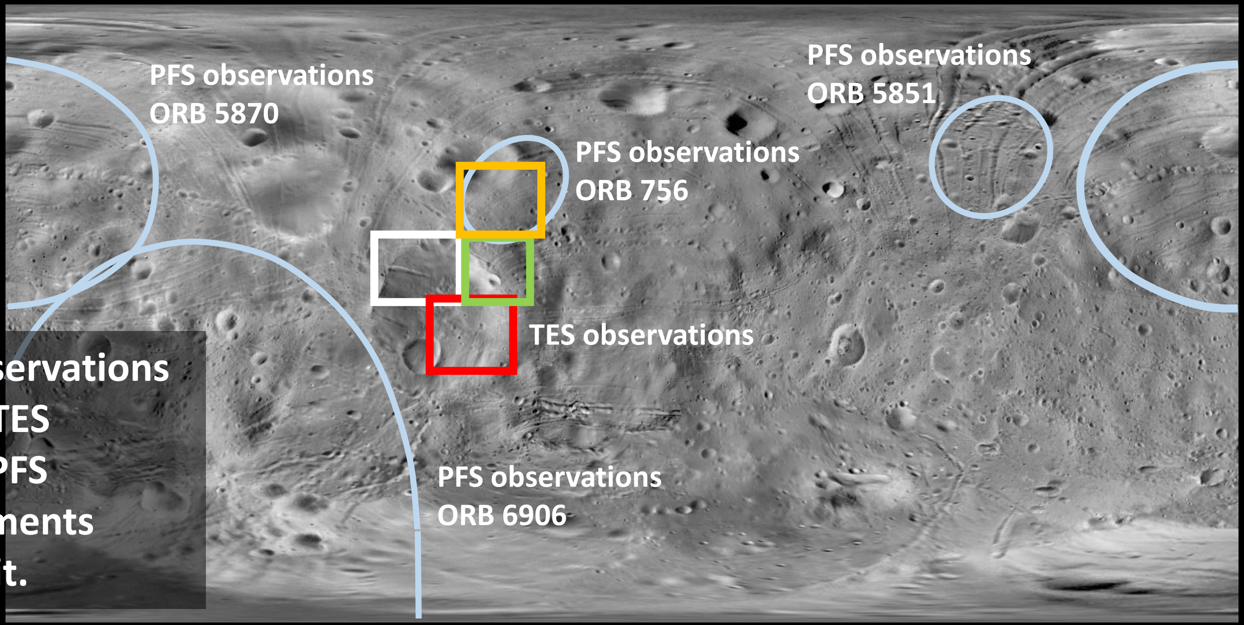
Phobos and Deimos spectra are mostly featureless with a difference in slope between Phobos blue and red units:

- a small 2.7 µm hydrated band can be present (less than 10%)
- a features at 0.65 µm was observed in data from CRISM and confirmed by ground-observation for Deimos and Phobos red unit. Possibly linked with highly desiccated Fe-phyllosilicates

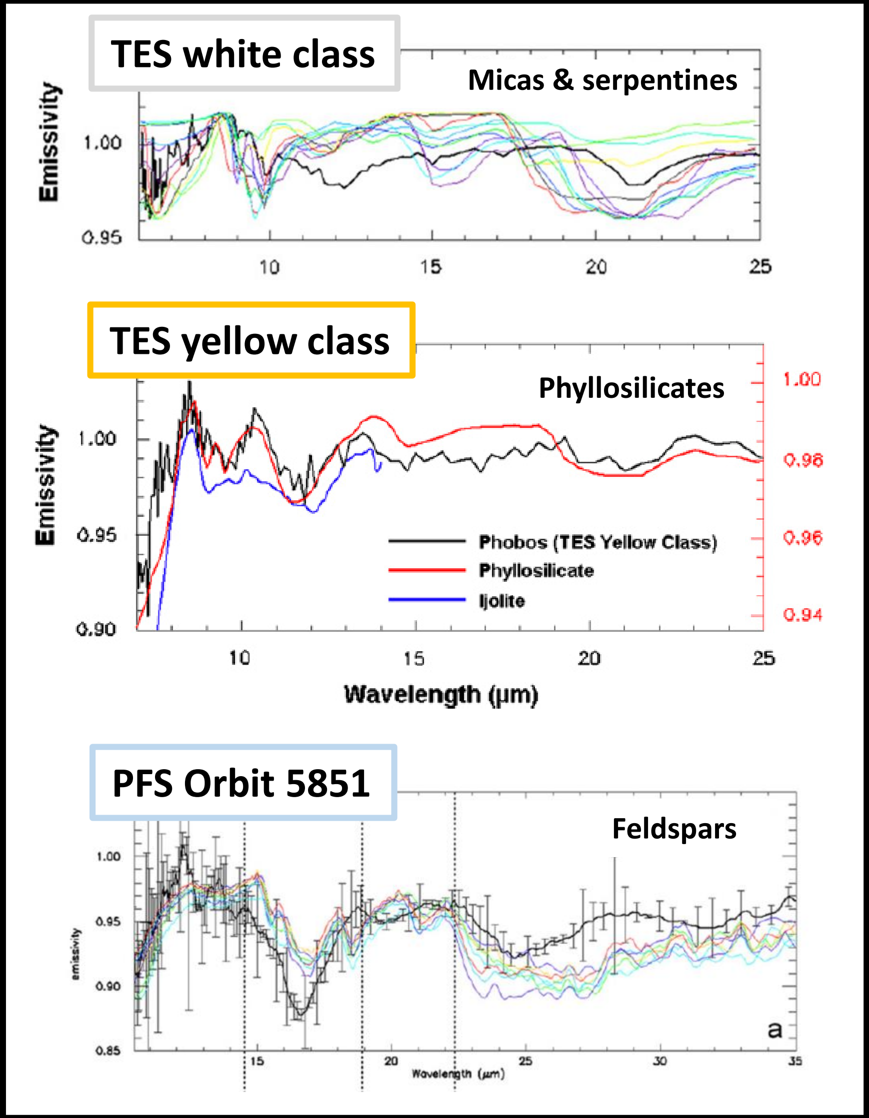
Moons composition

Thermal Infrared

Only two instruments observed Phobos, but not Deimos, in thermal infrared MGS-TES (Glotch et al 2018) and MEx-PFS (Giuranna et al 2011).
Despite noisy spectra and some debate on data quality, several difference in composition were observed with detected abundances of phyllosilicates (e.g. serpentine and mica) and tectosilicates (e.g. feldspar).



Location of observations performed by TES (squares) and PFS (circles) instruments from Mars orbit.



Giuranna et al 2011, PSS, 59, 13, 1308-1325

Phobos environment

Whatever the origin, Phobos and Deimos are equally intriguing object: ultra-primitive asteroids and Mars are (from two different points of view) relevant astrobiological targets.

However, we have to come to terms with the evolution of these two bodies and the environment that now presents itself. What temperatures are recorded on the surface? How much is the UV and ion irradiation?

Stickney crated, the most prominent feature is (9.7 km) seems to be related to blue and red units

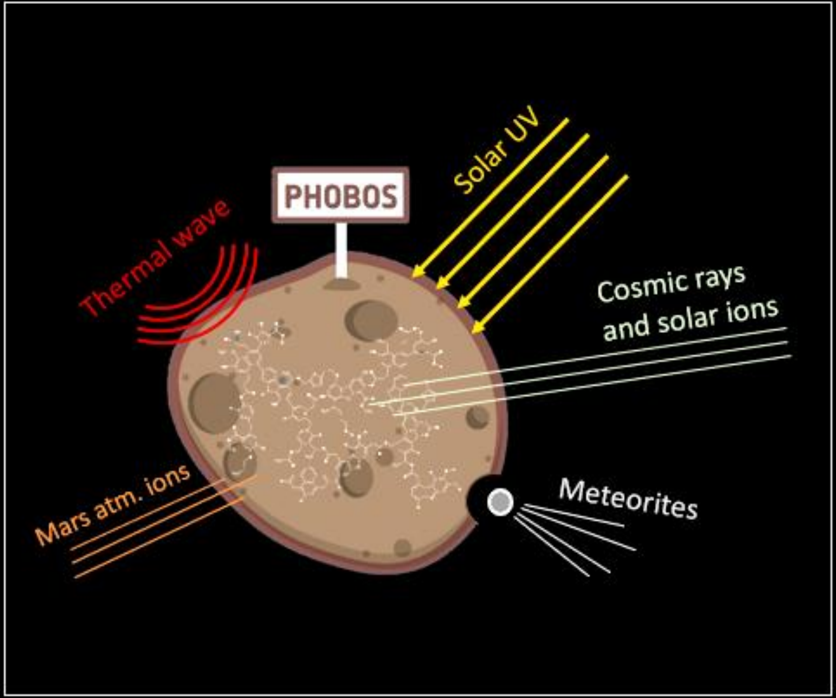
Some numbers for Phobos surface	
UV flux:	9000 - 12000 W/cm²
H^+ ion flux (650 eV):	5.7×10^7 eV/eV·cm²·s
O_2^+ ion flux (210 eV):	1.1×10^5 eV/eV·cm²·s
Temperature:	161 - 277 K

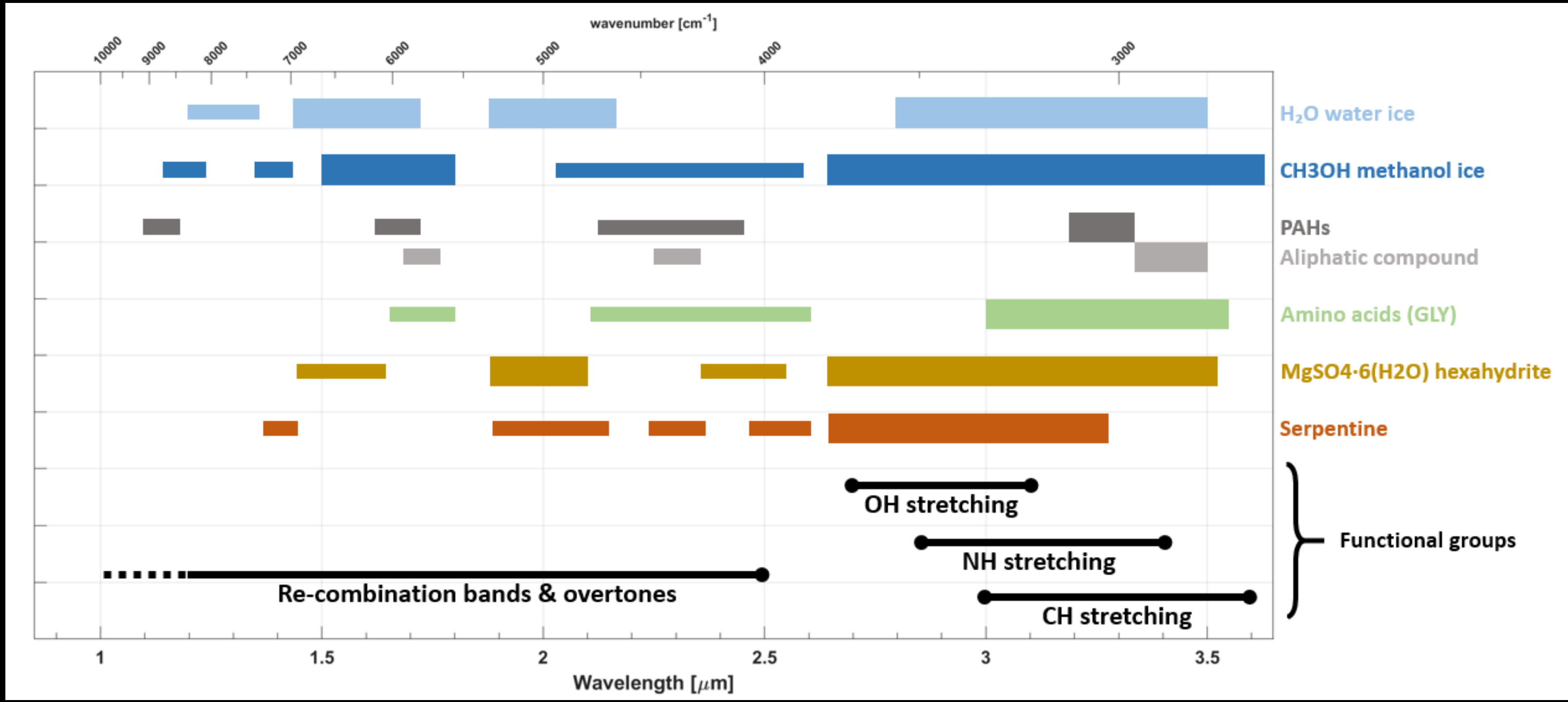
Phobos is characterize by a darker surface compare to Mars. Composition? Alteration?

Phobos environment

The survival of possible biomolecules on the surface (and subsurface) of Phobos is deeply linked to the moon's hard environment.

Laboratory analysis of processes that can alter the organic content in are essential to understanding what we can expect both in MIRS observations and in samples that will return to Earth.





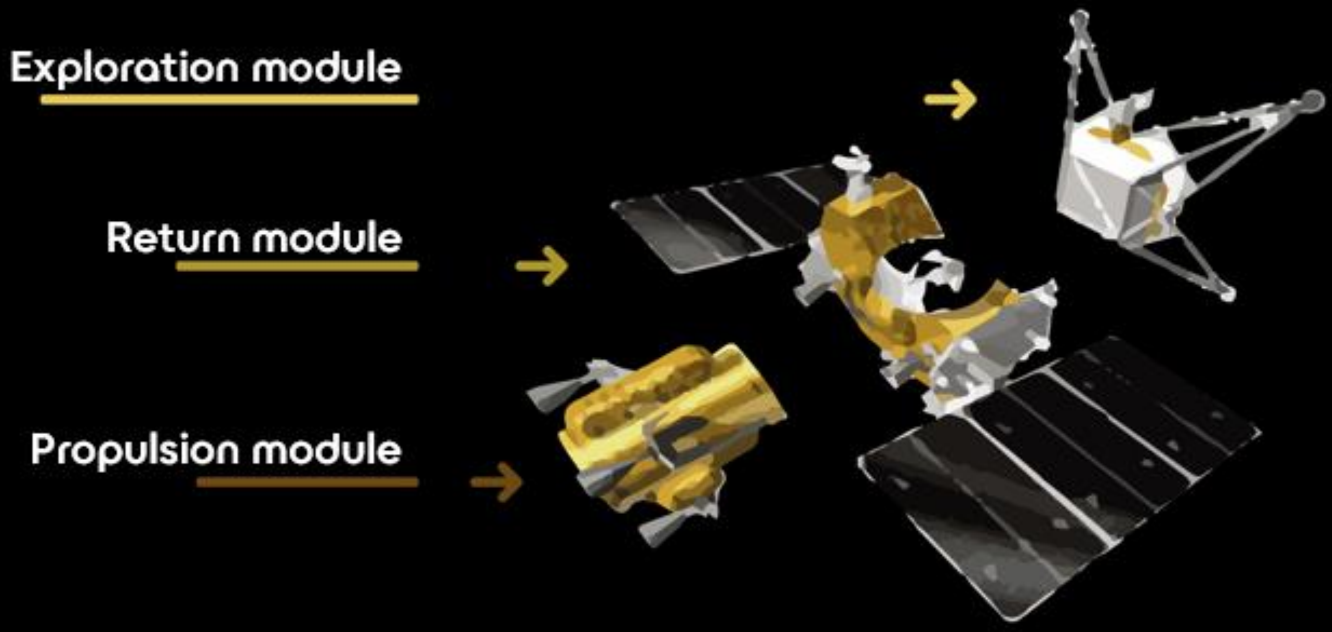
MMX mission overview

JAXA mission Martian Moons eXploration (MMX) is a mission to study Mars and its moons Phobos and Deimos.

In particular the mission aim to set the final constrains in the debate on the origin of the two moons (asteroid capture or giant impact).

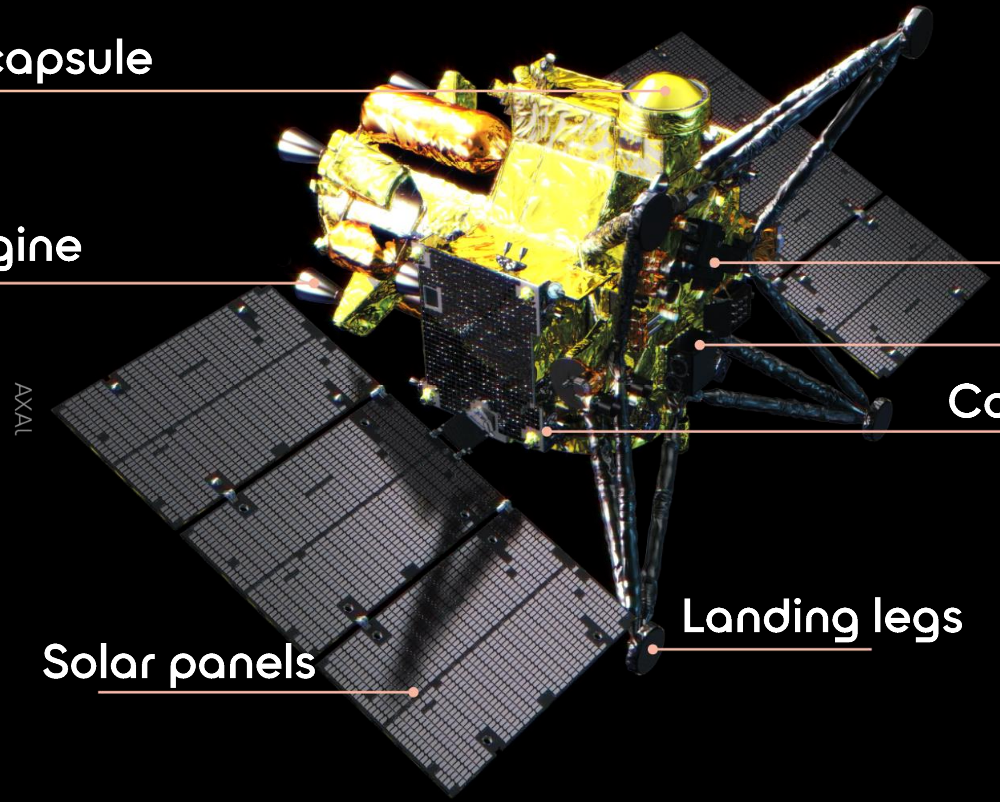
To achieve its objective the mission will return a sample (>10 g) from Phobos, the biggest moon, to Earth in 2029.

MMX is the third sample return mission from JAXA after Hayabusa1 and Hayabusa2 on asteroids Itokawa and Ryugu.



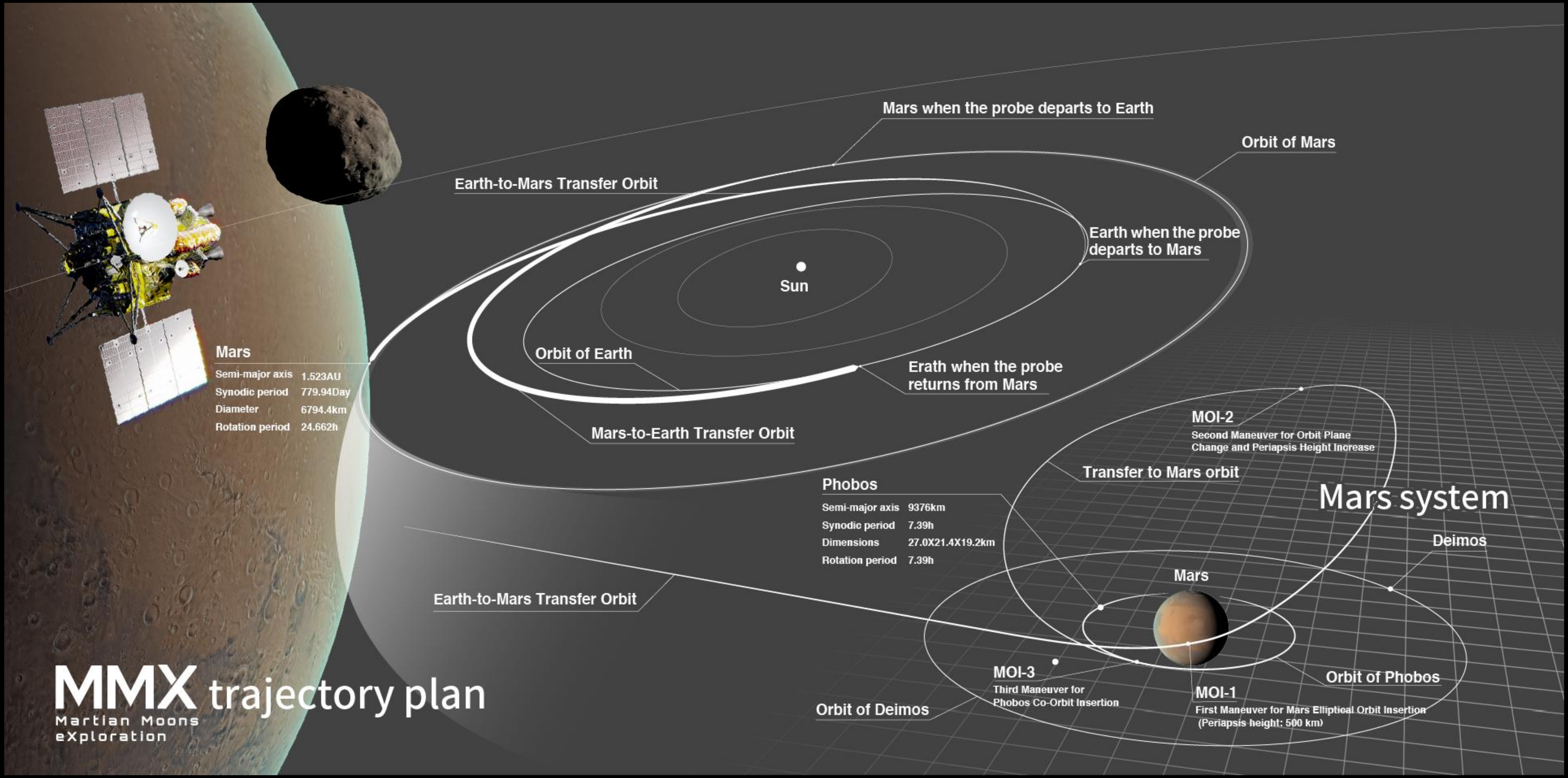
MMX payload

MMX host 7 scientific instruments and a rover that will be release on the surface with a Raman spectrometer, an infrared radiometer and several cameras



- **TENGOO** telescopic camera
- **OROCHI** filter camera
- **LIDAR** laser altimeter
- **MIRS** infrared spectrometer
- **MEGANE** γ-ray & neutron spectr.
- **CMDM** dust analyser
- **MSA** mass spectrometer
- **ROVER** surface exploration

MMX mission plan

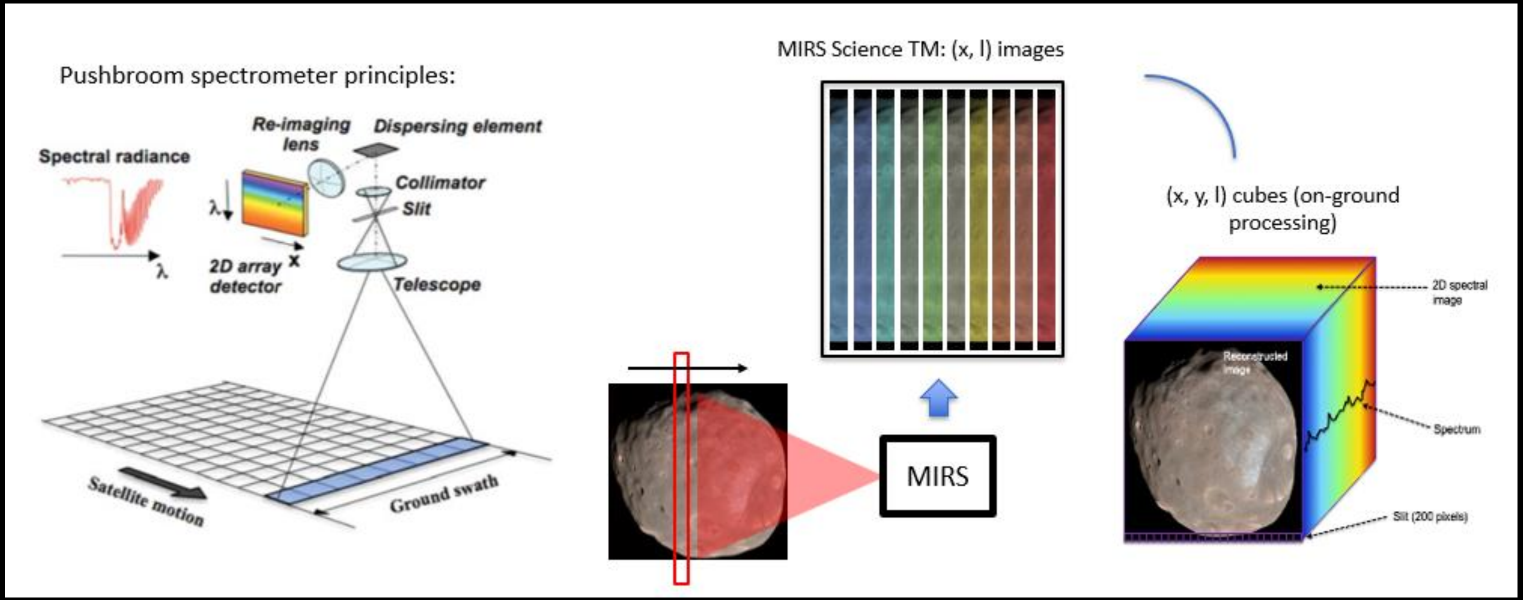


MIRS spectrometer

MMX InfraRed Spectrometer (MIRS) is an imaging spectrometer on board of study the infrared range of spectrum between 0.9 and 3.6 micron.

This wavelength range will allow us to investigate the surface distribution of constituent materials of the Martian moons in particular looking for water and organic material.

MIRS will also study Mars atmosphere in particular dust and water.



A single detector acquisition (2D matrix) provides the image of a stripe in one direction (spatial), and the spectrum of each point of the strip in the second direction (spectral). The second spatial dimension results from the orbital motion, or along-track scanner.

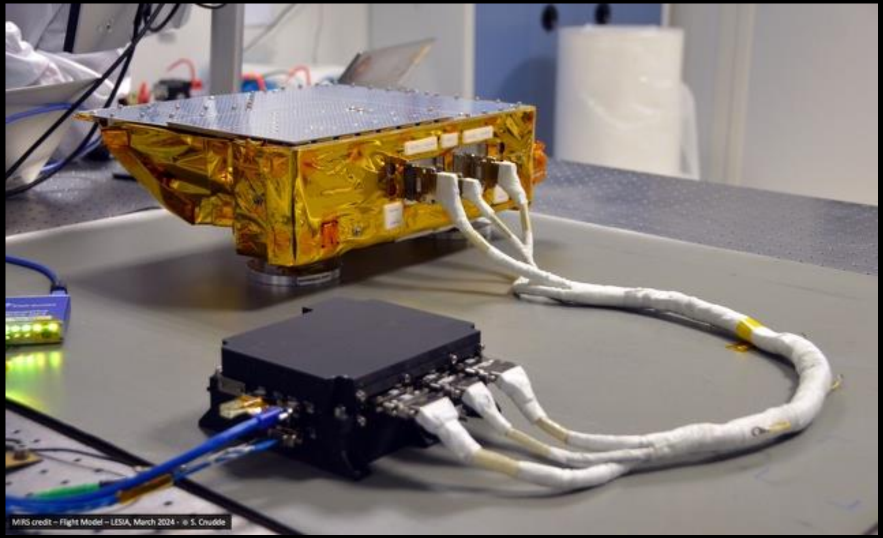
MIRS was developed by LESIA-Observatorie de Paris-PSL in collaboration with several institutions

LESIA l'Observatoire de Paris | PSL cnes LAB LATMOS Observatoire Midi-Pyrénées OMP irap JAXA

MIRS spectrometer

MIRS is composed by two different parts:

- **OBOX** – the opto-mechanic box that contain the optics, the detector and all the mechanism
- **EBOX** – the electronic box containing two electronic cards that are the interface between the instrument and the spacecraft



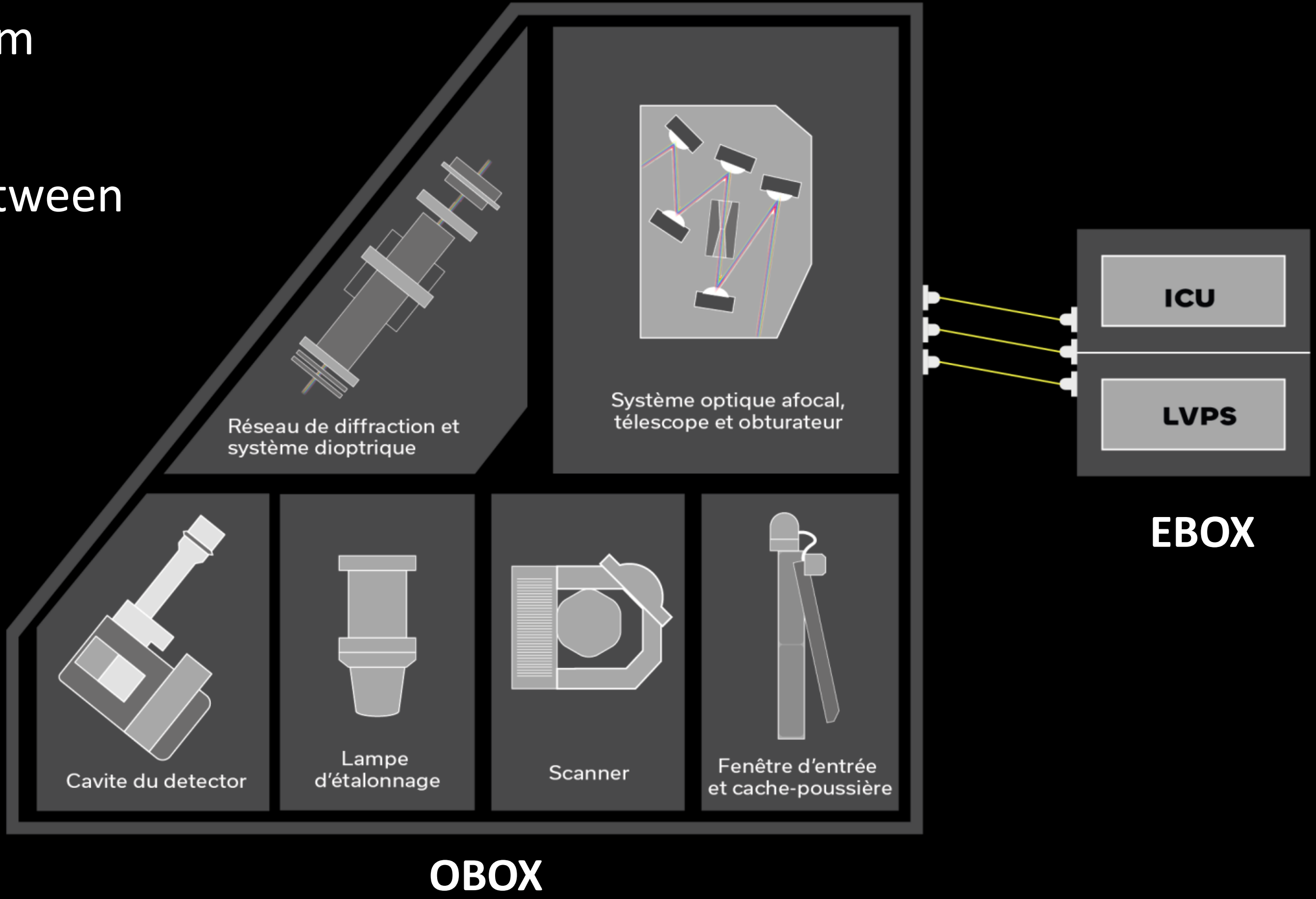


Photo and image credit: LESIA – Observatory of Paris

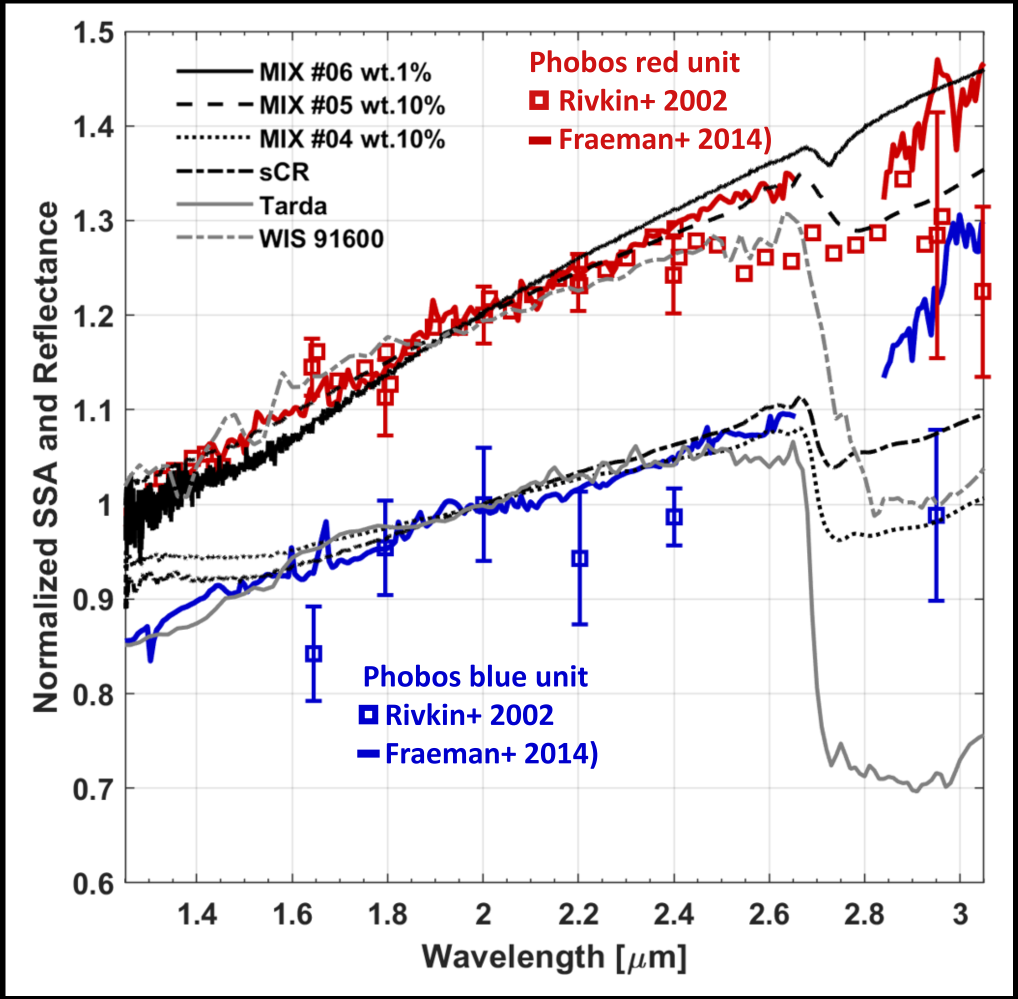
Finding analogs …

Several laboratory analog were proposed in the past years without a complete agreement with remote sensing data.

Some mix of basalt, phyllosilicate and amorphous carbon match quite well the red unit of Phobos (and therefore Deimos average spectrum), while CR meteorite simulant sample are more representative of Phobos blue unit.

This does not imply that Phobos blue unit is similar to a CR meteorite, but that the combination of minerals used for the simulant are close to a possible combination to reproduce the surface of the moon.

Some meteorite like Tarda and WIS 91600 match in terms of slope respectively the blue and red units of Phobos but both show a deeper hydrated bands.

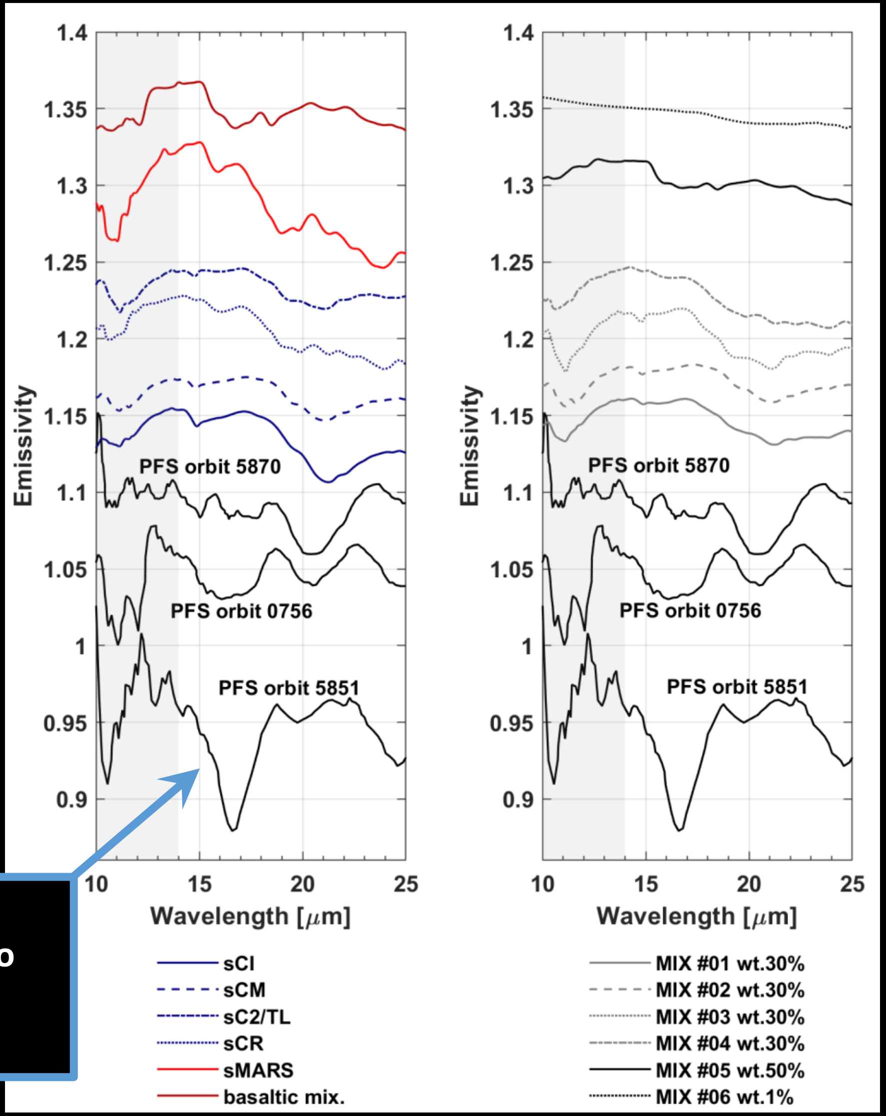


Poggiali, Matsuoka et al. (2022) MNRAS, 516 (1), 465–476

… using all the data available

The comparison can be extended in the MIR range using MGS-TES and MEx-PFS data

- To date no full match was found between analog samples and P&D spectra. Although, several pure simulant and mixture show a deep valley around 11 μm.
- Meteorite simulants although with smaller intensity, are the only sample presenting a small peak at 15 μm as well as observation from PSF
- Amorphous carbon mixture with basalt and phyllosilicate with the reduced spectral contrast are not well matching the PFS observations despite being among the best matches in the NIR range.



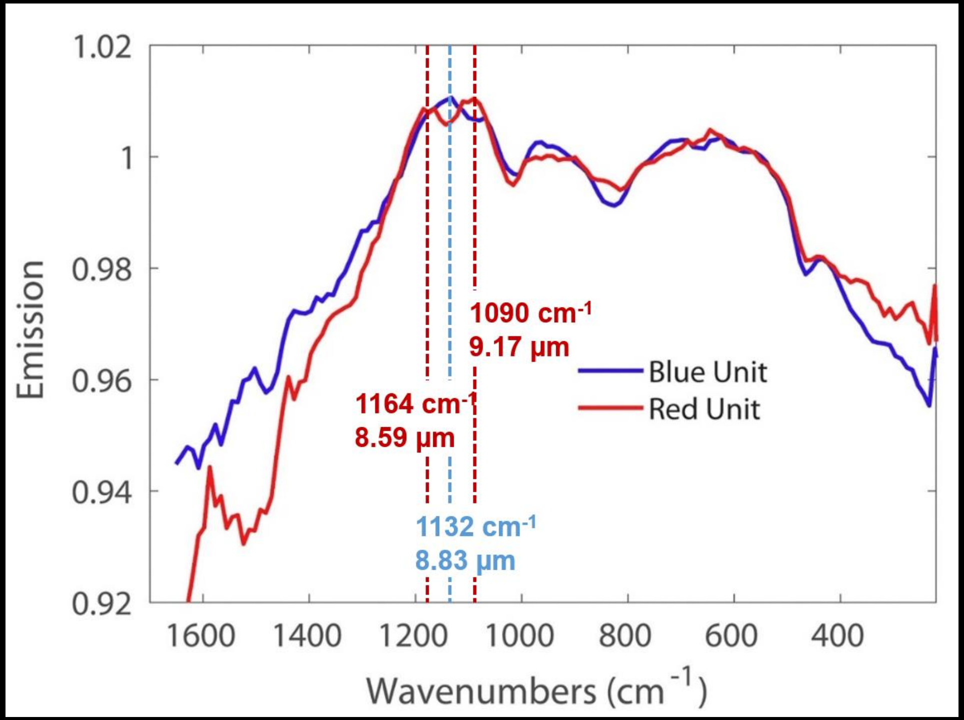
16.6 μm features could be related to presence of tectosilicates

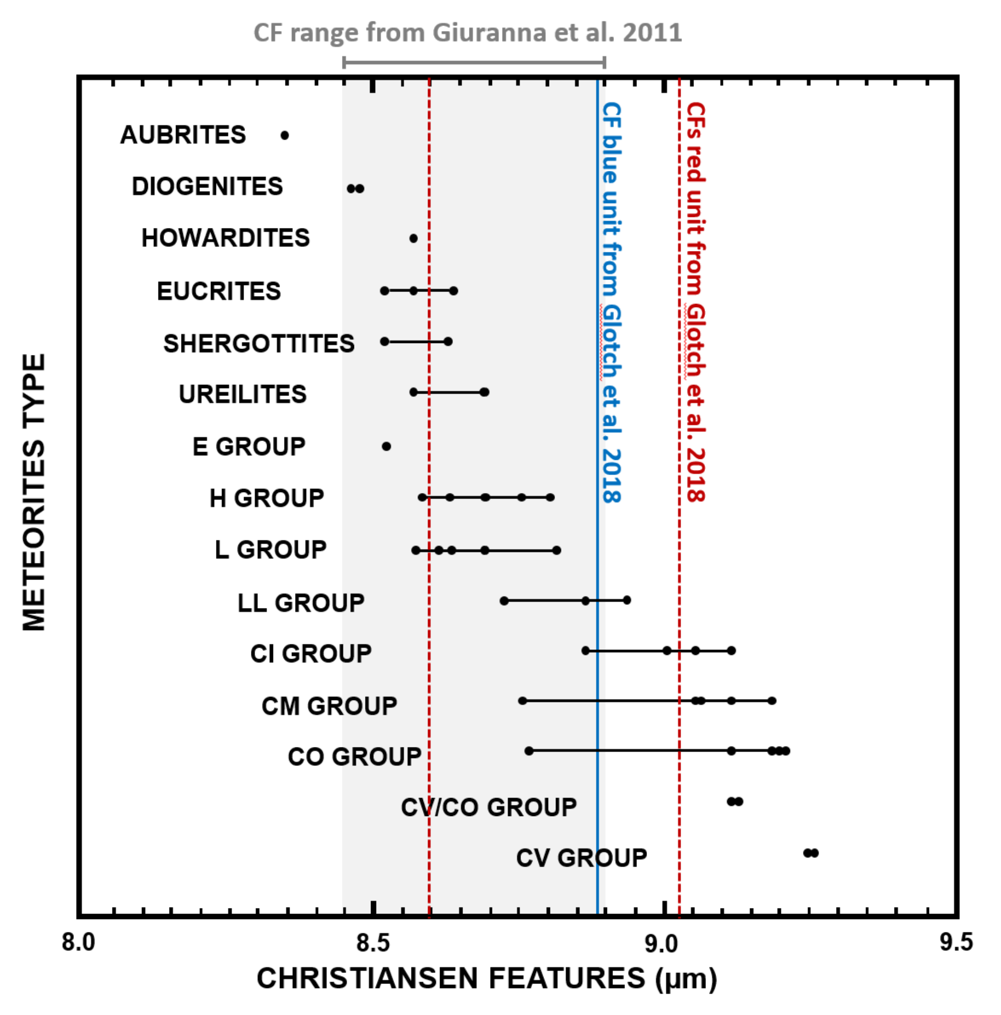
Poggiali, Matsuoka et al. (2022) MNRAS, 516 (1), 465–476

Going back to literature

Christiansen Features (CF)

Complex CF with doublet can occur when two different major components show their single. CF at such distant wavelengths that they do not average in a single peak (Salisbury+ 1991).





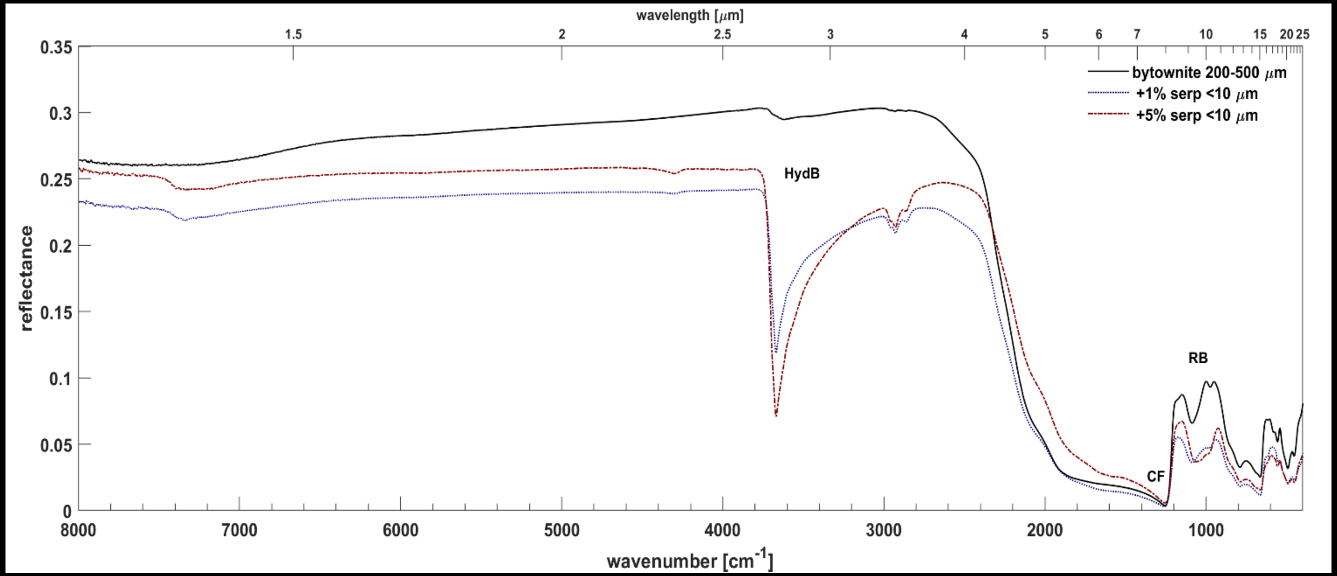
Poggiali, Matsuoka et al. (2022) MNRAS, 516 (1), 465–476

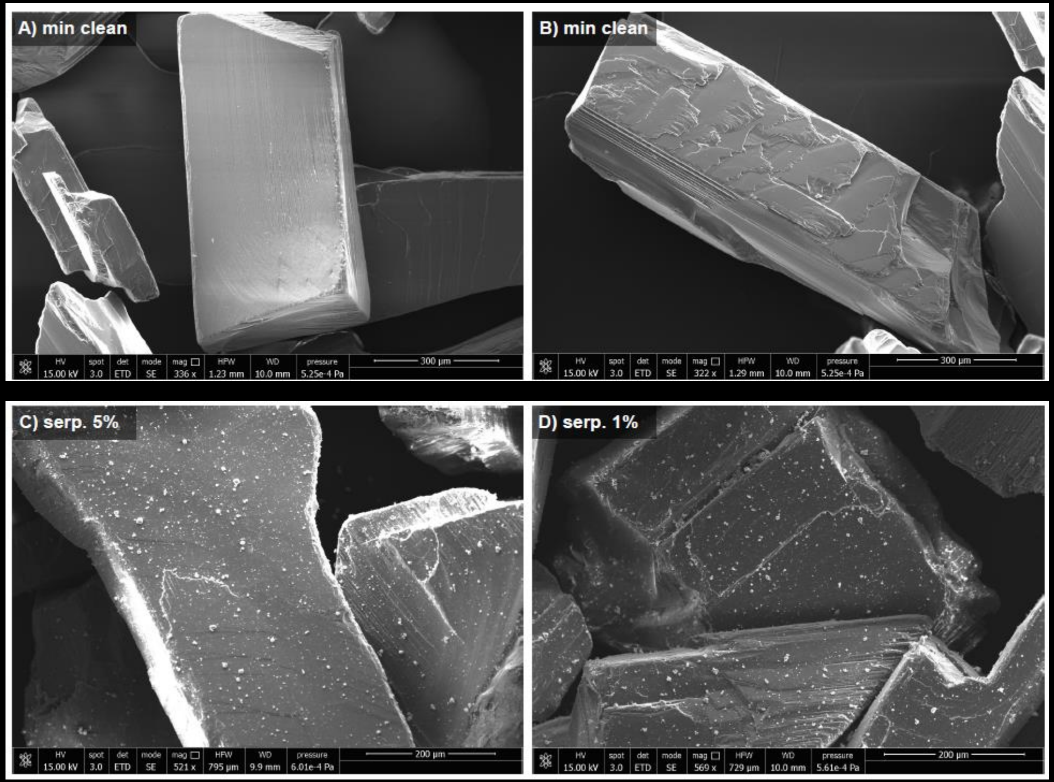
Thinking about new samples

How we can modify the spectrum selectively in one range?

Addition of 1 wt% or 5 wt% of hyperfine hydrate component is sufficient to change the spectrum of anhydrous mineral.

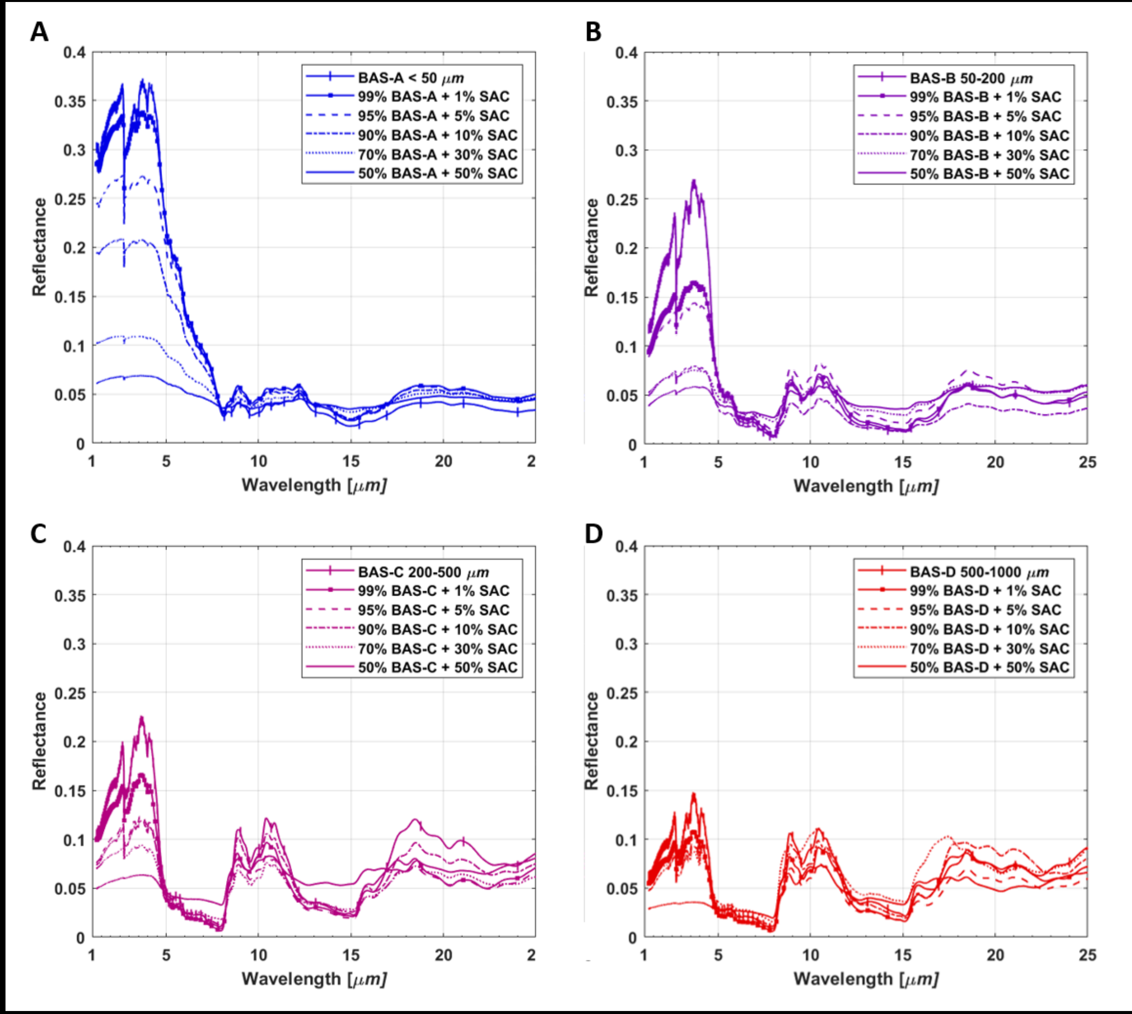
In almost all spectra, the major changes concern the appearing of a prominent hydrated band while MIR spectrum is mostly affected for reflectance level





Poggiali et al 2023, Icarus 394, 115449

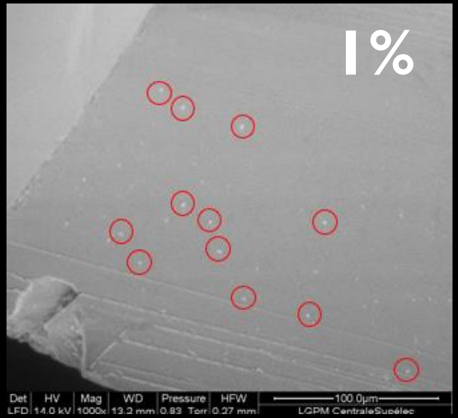
Thinking about new samples

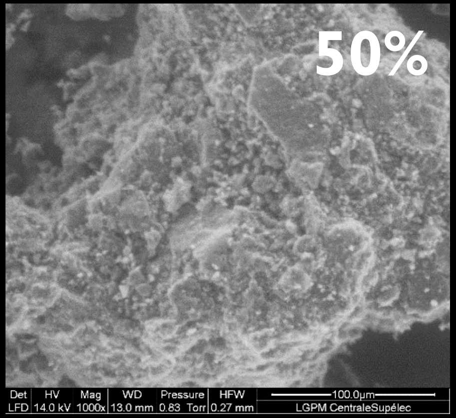


Poggiali et al 2024, A&A (in publication)

In the second study we mixed anhydrous mineral, bytownite and augite, with grain size < 50 µm, 50-200 µm, 200-500 µm, 500-1000 µm and amorphous carbon < 50 µm in different proportion from 1% to 50%.

We measured the spectrum from NIR to MIR to find the trend of modification and understand the outcome of complex mixtures





Conclusions

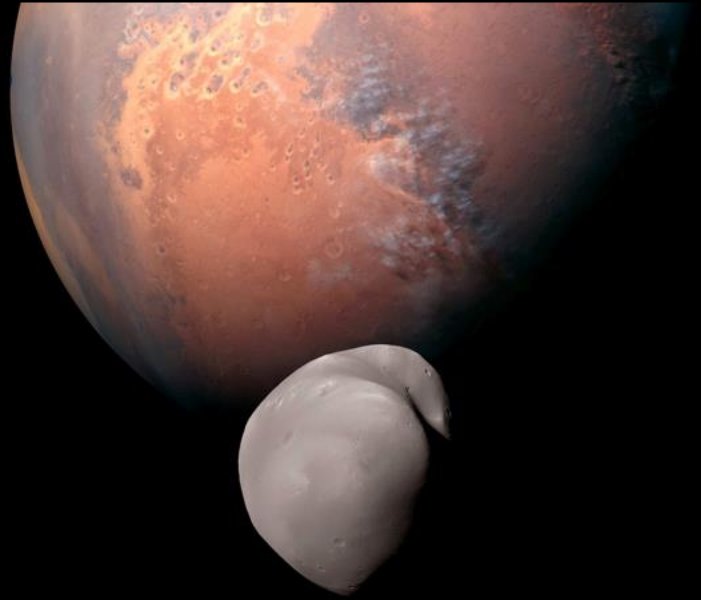
Nowadays our knowledge on Phobos and Deimos, the moon of Mars, is still incomplete in particular regarding the origin

MMX mission will be launched in 2026 to explore the Martian system focusing on the moons Phobos and Deimos

After orbital investigation and the landing of a rover the spacecraft will collect a sample to bring back to Earth on 2031

In preparation to the active phase of the mission a intensive laboratory work on analog sample is undergoing

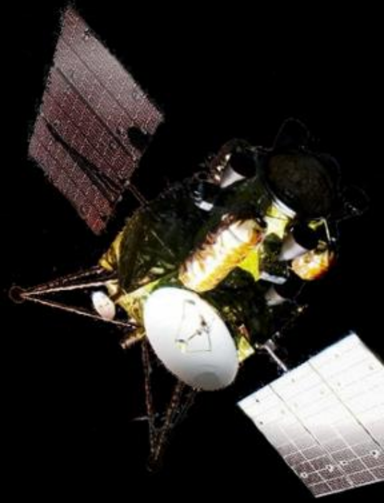
MMX
Martian Moons eXploration



MIRS
MMX InfraRed Spectrometer

Thank you for the attention!

Questions?



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