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Laboratory activity at INAF-IAPS on planetary surfaces analogues

Annibale de Gasparis Workshop – Napoli – INAF-OAC – 7-8/11/2019

Outline

- Exploration of rocky bodies
- Planetary analogues
- Laboratory setup @INAF-IAPS
- Spectroscopy of planetary analogues
- Conclusions

Rocky / icy bodies exploration

The surface composition of Solar System bodies is revealed by:

- **Earth-based telescopic observations** (UV, VIS, NIR, IR) (Keck, VLT, IRTF, TNG…)
- **Interplanetary missions** (Dawn, Rosetta, Cassini, and upcoming: ExoMars-2020, JUICE)

- Technique: **spectroscopy** (UV, VIS, NIR, mid-IR, X, n, …)

Rocky / icy bodies exploration

Mars:

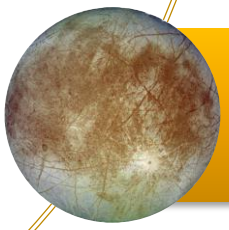
- Volcanic crust (basaltic material)
- Phyllosilicates / hydrous minerals
- Carbonates / sulfates / hydroxides

Ceres:

- Phyllosilicates / NH_4-phyllosilicates
- Carbonates / dark components
- Organic matter

Vesta:

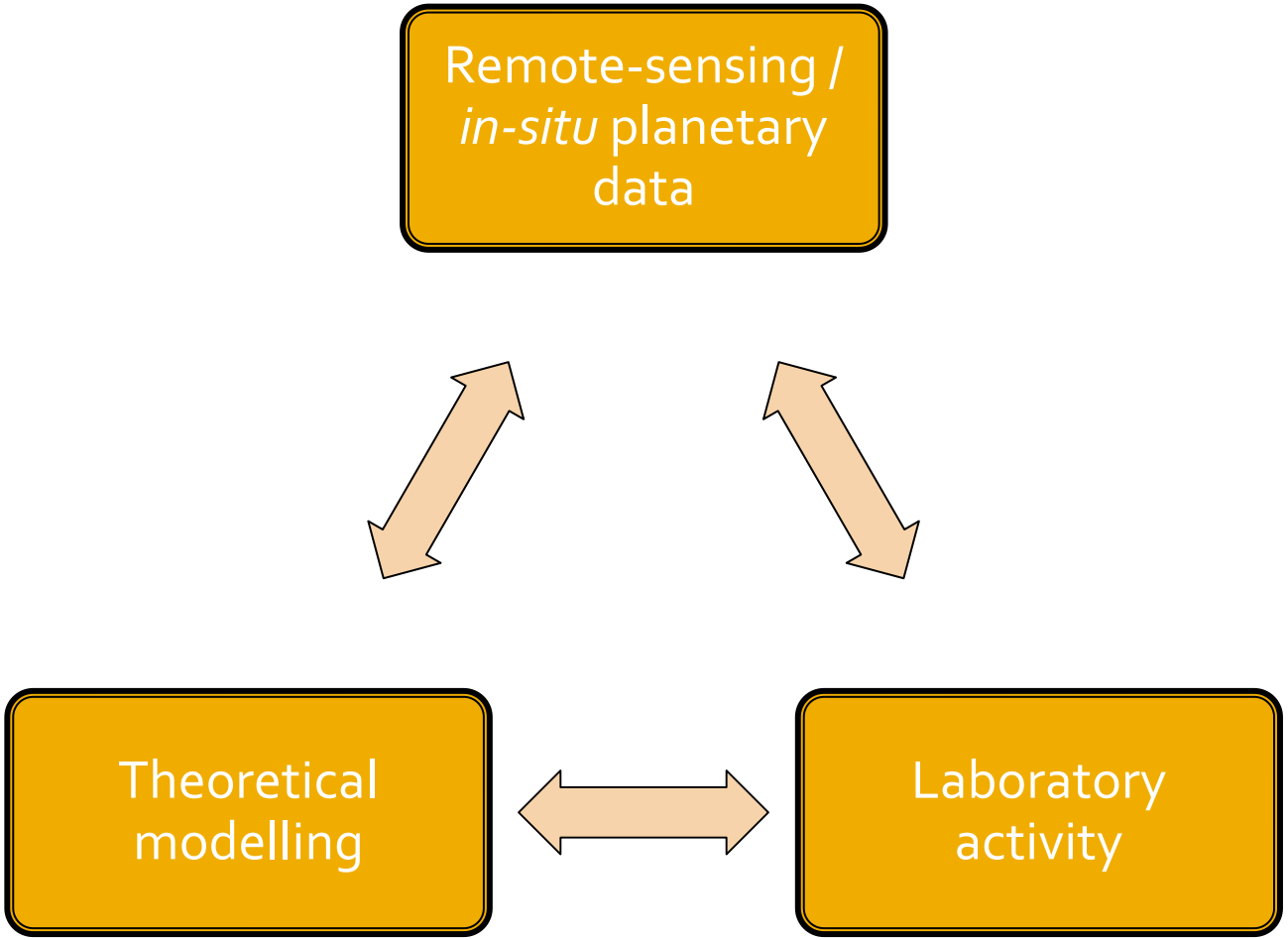
- Poly-mict regolith (Howardites)
- Basaltic upper crust (Eucrites)
- Pyroxenitic lower crust (Diogenites)



Europa:

- H_2O-icy leading hemisphere
- Heavily hydrated "non-icy" materials
- Hydrated sulfuric acid

Rocky / icy bodies exploration



Rocky / icy bodies exploration

Spectroscopy by <u>Remote Sensing</u>:

> **New data** from planets, moons, minor bodies, etc..

> Data need **interpretation**

Spectroscopy in the <u>Laboratory</u>:

> **Known samples**

> **Controlled conditions** (P, T, etc…) + simulations

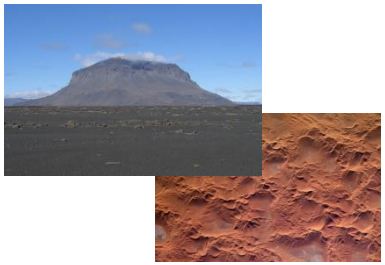
> Experiments are **repeatable**

> To **reproduce spectra** in lab

Planetary analogues

Planetary **Analogues**

- **Surface**
  - **Composition**: Minerals, rocks
  - Morphology / structures / **environments**
  - **Physical properties**: regolith, permafrost
- **Atmosphere**
  - **Gases** / Mixtures



Planetary analogues: surfaces

Planetary **Analogues**

Surface

Composition: Minerals, rocks

Workflow

Choice

Sampling in the **field** | Buy

Preparation

Slab: reducing, cutting | **Powder**: grinding, sieving

Measure

Spectroscopy, microscopy, …

Data analysis

Spectral fitting, linear mixing/unmixing, …

Planetary analogues: surfaces

Planetary **Analogues**

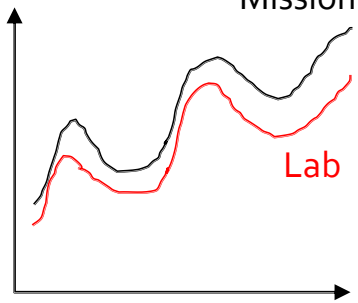
Surface

Composition: Minerals, rocks

Workflow

Want to reproduce observed spectra in the lab

Lab spectrum from samples



Remote-sensing spectrum from planet

Laboratory setup @INAF-IAPS

Spectroscopy activity for planetary surfaces analogues (C-Lab):

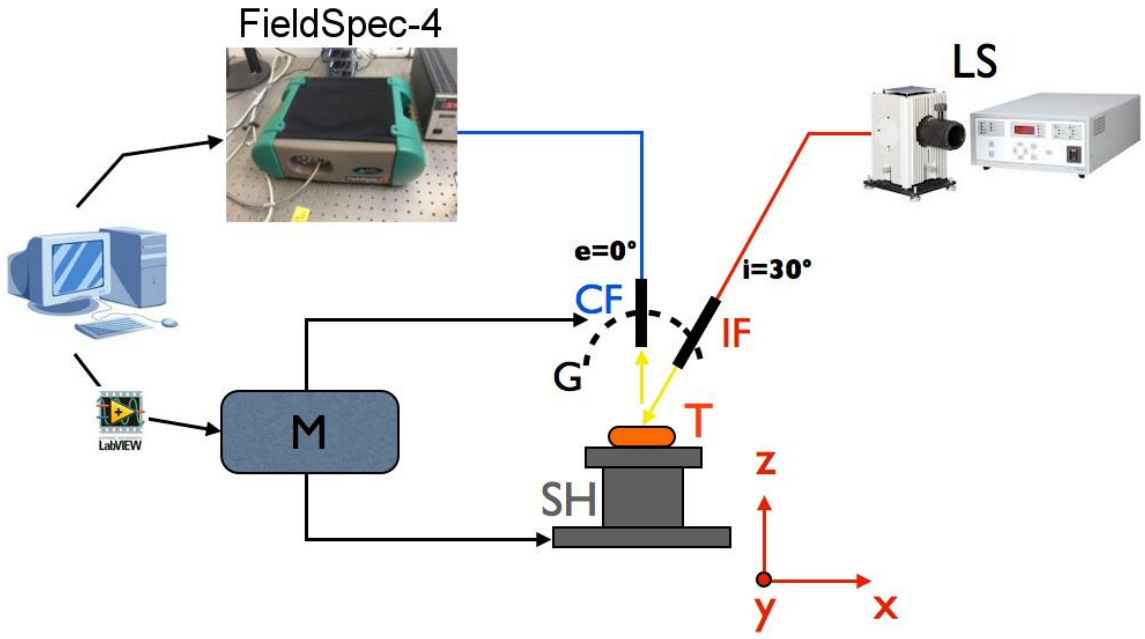
- **ASD FieldSpec 4** + QTH 100 W lamp
- **Ma_MISS**/ExoMars-2020 BreadBoard setup
- **SPIM** (Spectral Imager) facility
- Environmental **Simulation Chamber**
- **Raman** spectrometer (NEW!)

Laboratory setup @INAF-IAPS

Spectroscopy activity for planetary surfaces analogues (C-Lab):

- **ASD FieldSpec 4**

- Spectral range: VNIR (0.35-2.5 μm)
- Resolution: 5 mm
- Light Source: QTH lamp (100W)
- Detector: FieldSpec

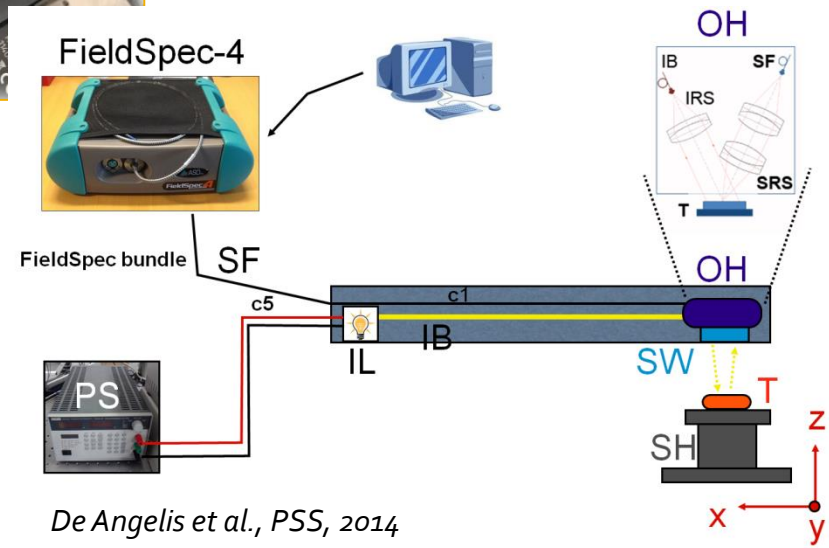


Laboratory setup @INAF-IAPS

Spectroscopy activity for planetary surfaces analogues (C-Lab):

- **Ma_MISS/ExoMars-2020 BreadBoard**

- Spectral range: VNIR (0.5-2.3 μm)
- Resolution: 0.12 mm
- Light Source: Ma_MISS lamp (5W)
- Detector: FieldSpec



De Angelis et al., PSS, 2014

Laboratory setup @INAF-IAPS

Spectroscopy activity for planetary surfaces analogues (C-Lab):

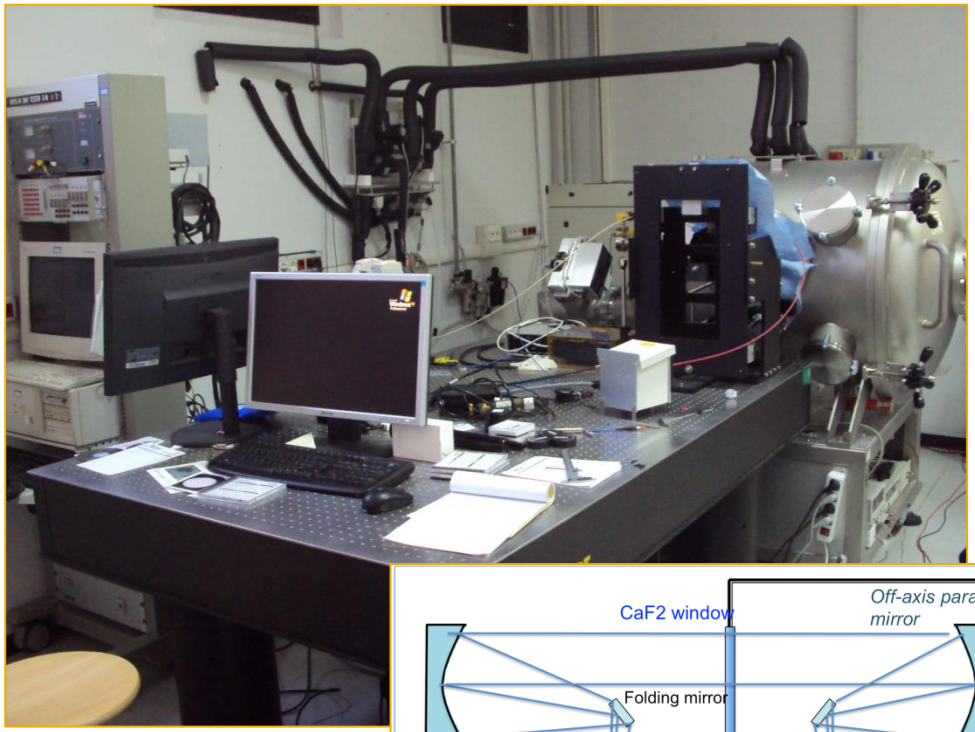
- **SPIM facility**

- Spectral range: VNIR (0.4-5 μm)

- Resolution: 0.038 mm

- Hyperspectral Imager

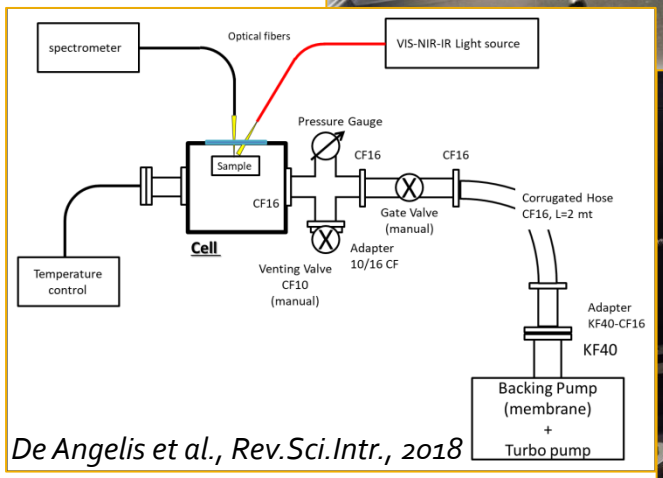
- Detector: CCD (λ<1μm) + HgCdTe (λ>1μm)



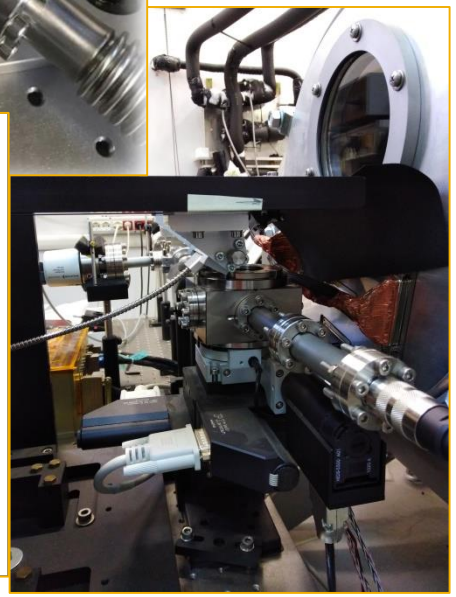
Laboratory setup @INAF-IAPS

Spectroscopy activity for planetary surfaces analogues (C-Lab):

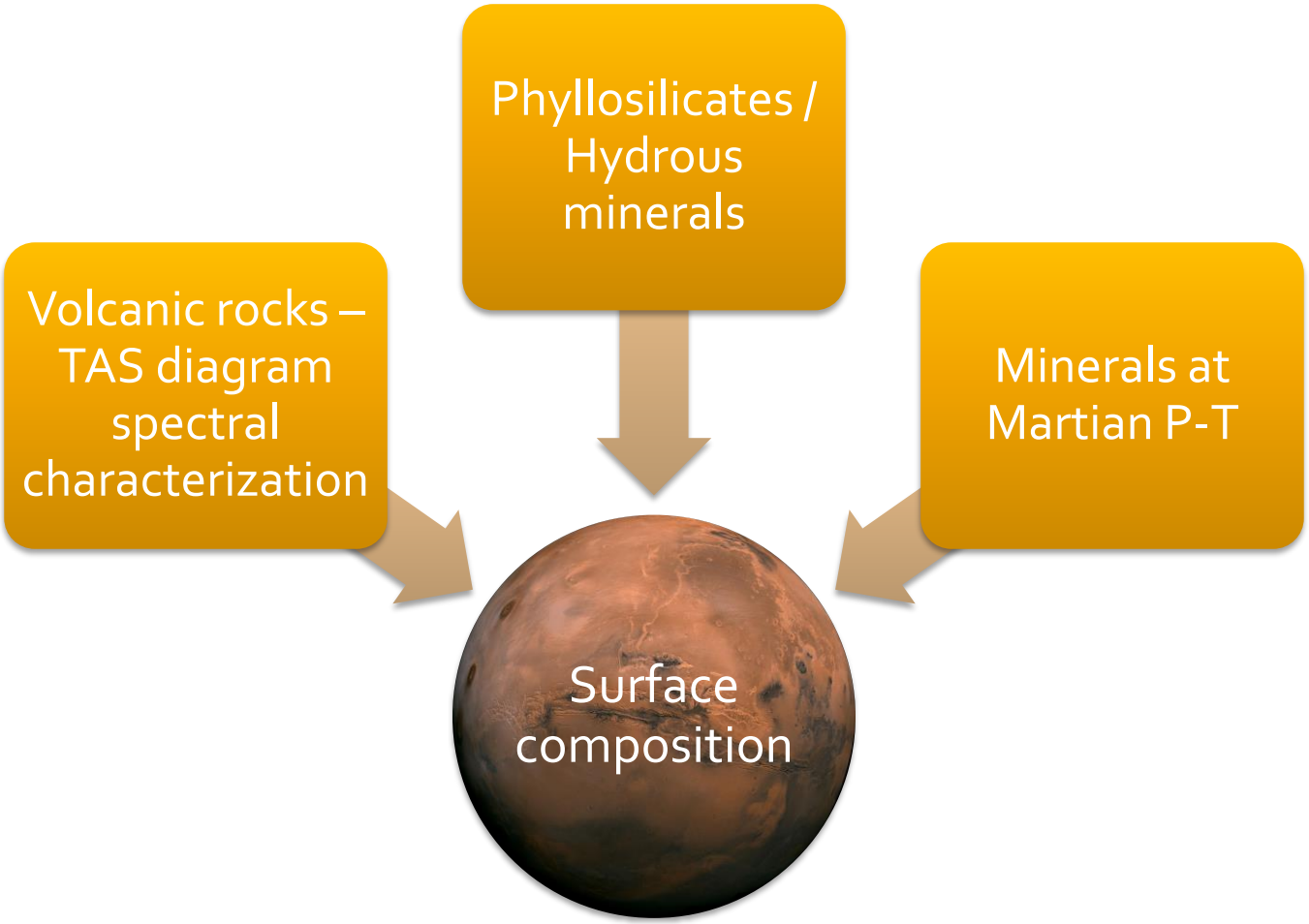
- **Environmental Simulation Chamber**
- Temperature: T_{max}=673K
- Pressure:
  vacuum >10^{-7} mbar
- Setup:
  FieldSpec / SPIM



De Angelis et al., Rev.Sci.Intr., 2018

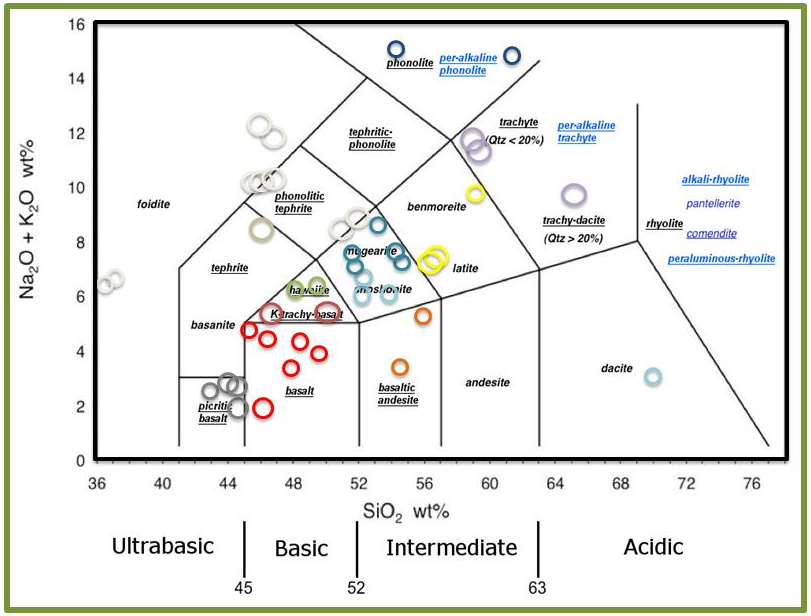


Planetary analogues (i): Mars



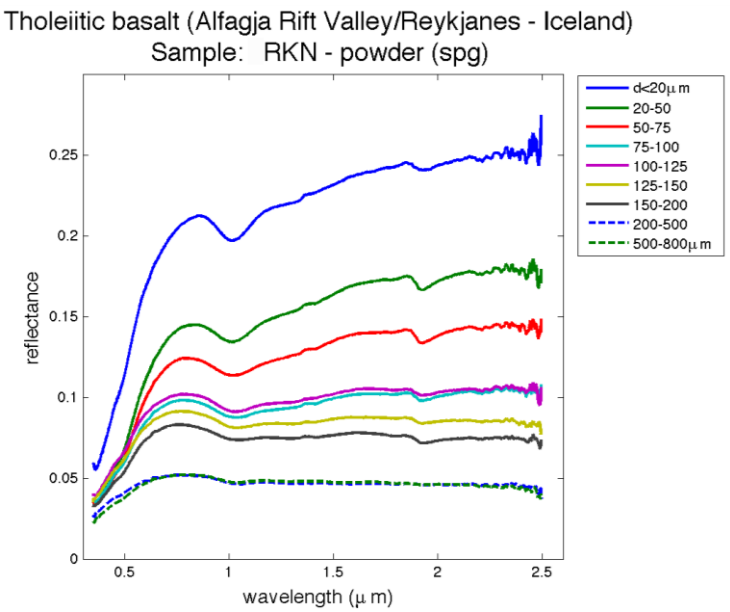
Planetary analogues (i): Mars

- Volcanic rocks chemical classification: **TAS-diagram**



Spectral classification of volcanic rocks based on TAS

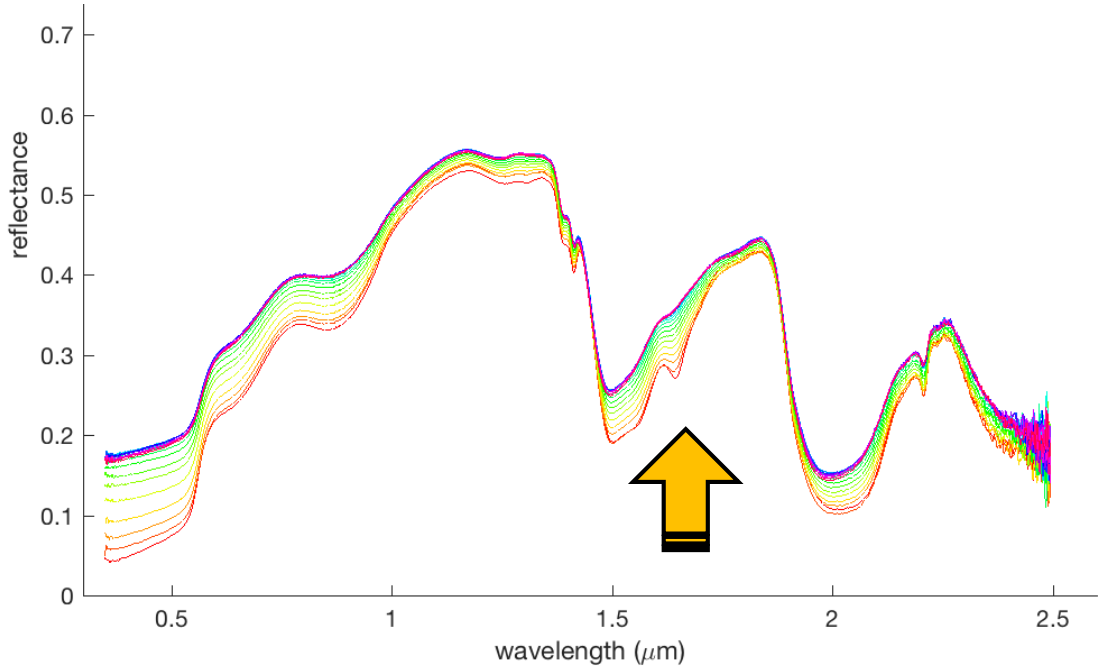
Basic-ultramafic lavas (basalt)



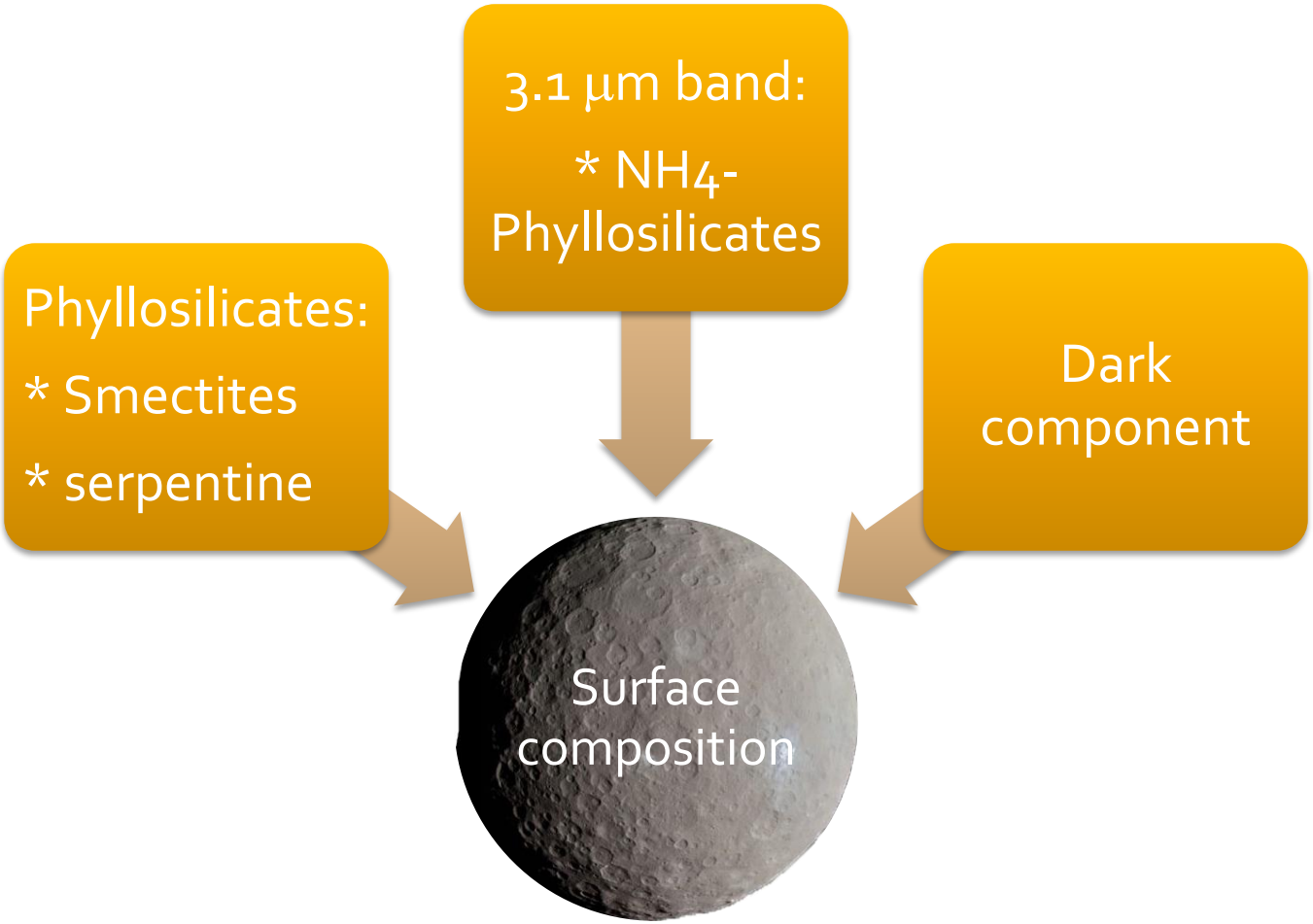
Planetary analogues (i): Mars

- Mars analogues vs **hydration/humidity**
- Sample: alterate volcanic rock
- Liq.N2-T
- Room-T

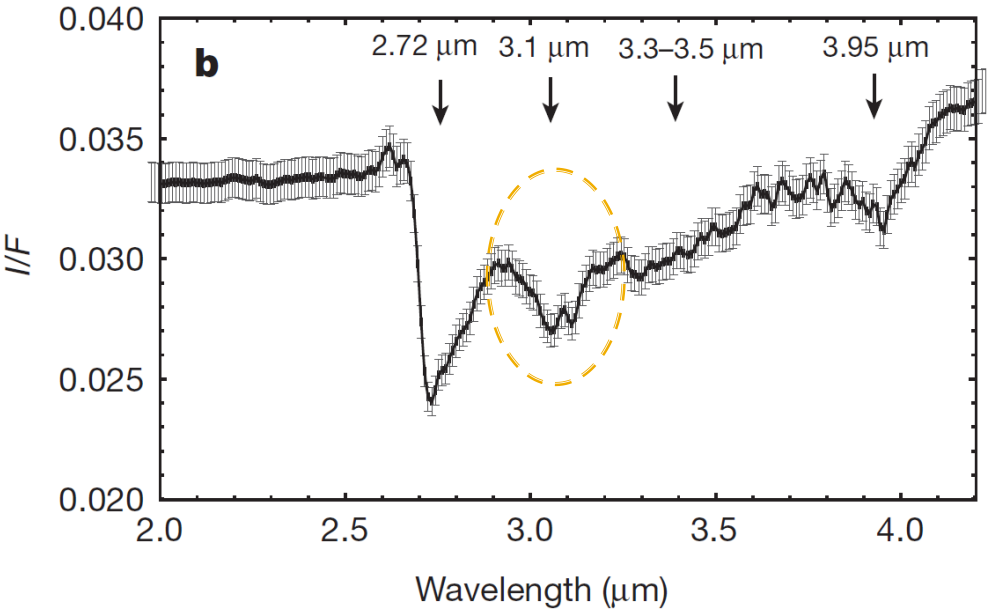
CBF6 (Fioranello mine) - FieldSpec



Planetary analogues (ii): Ceres



Planetary analogues (ii): Ceres



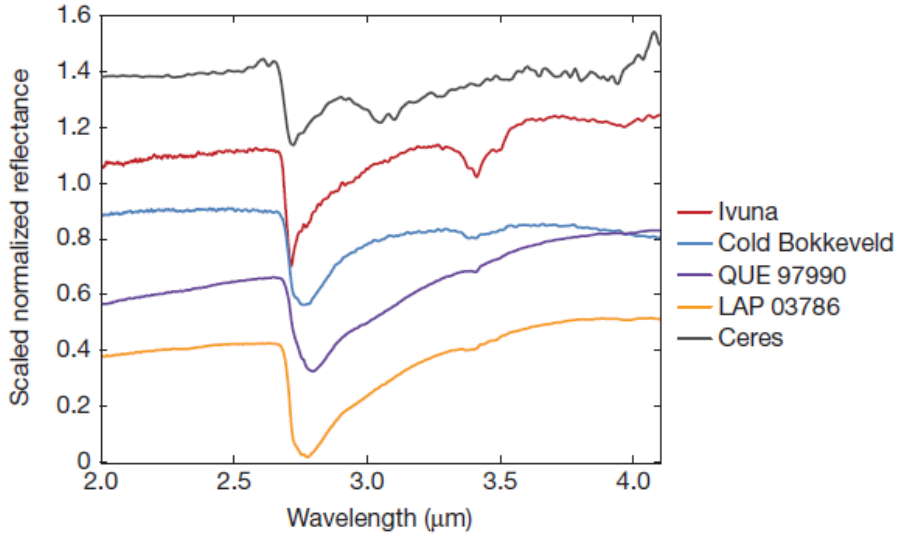
[De Sanctis et al., 2015, Nature]

3.1-μm band attributed to:

- **NH_4-phyllosilicate** (King et al., 1992; De Sanctis et al., 2015)

Other interpretations:

- **Brucite** (Milliken&Rivkin, 2009)
- **H_2O-ice/frost** (Lebofsky, 1981)



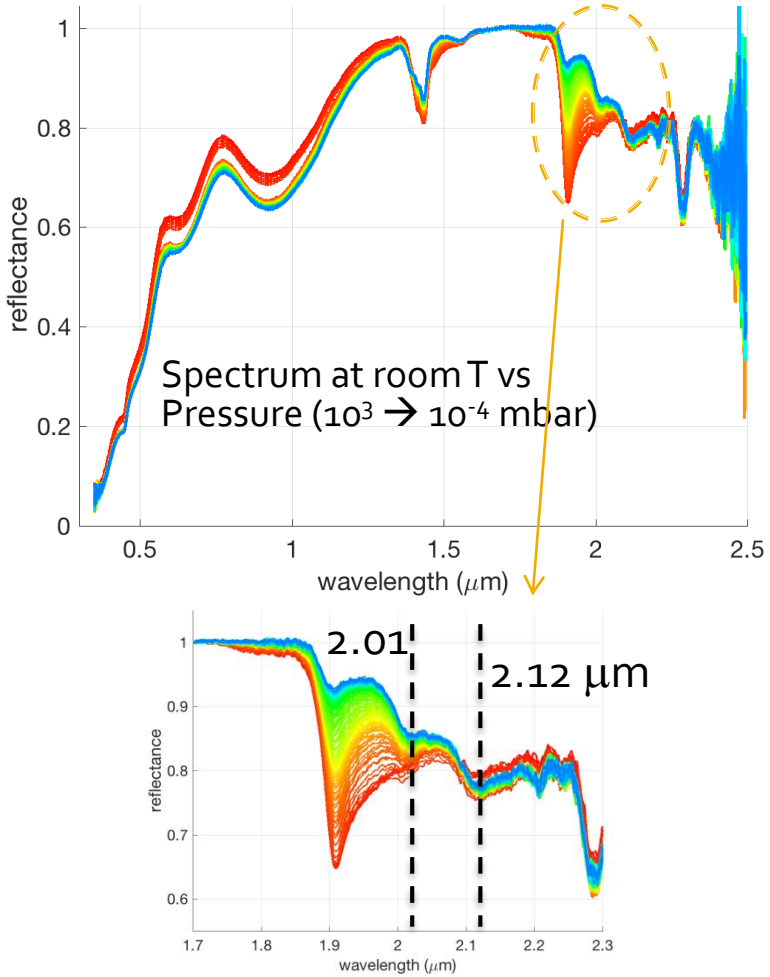
- **Brucite** (Milliken&Rivkin, 2009)

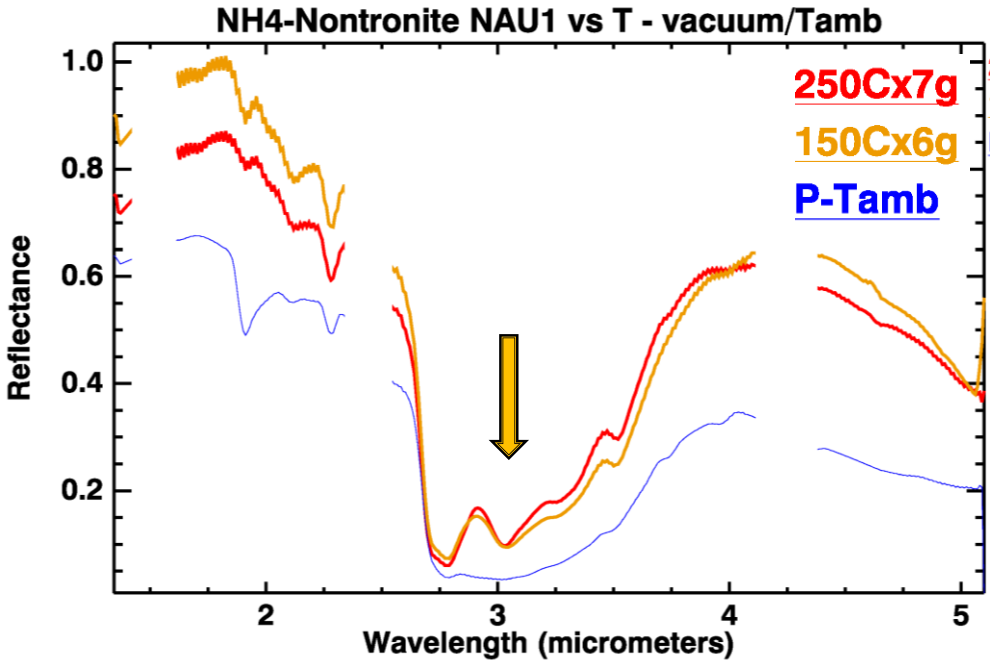
  ➔ ruled out below detection limit by lab experiments with mixtures (De Angelis et al., 2016)
- **H_2O-ice/frost** (Lebofsky, 1981)

  ➔ maybe can give a contribution

Planetary analogues (ii): Ceres

- Ammonium-bearing phyllosilicates: **vs P-T**

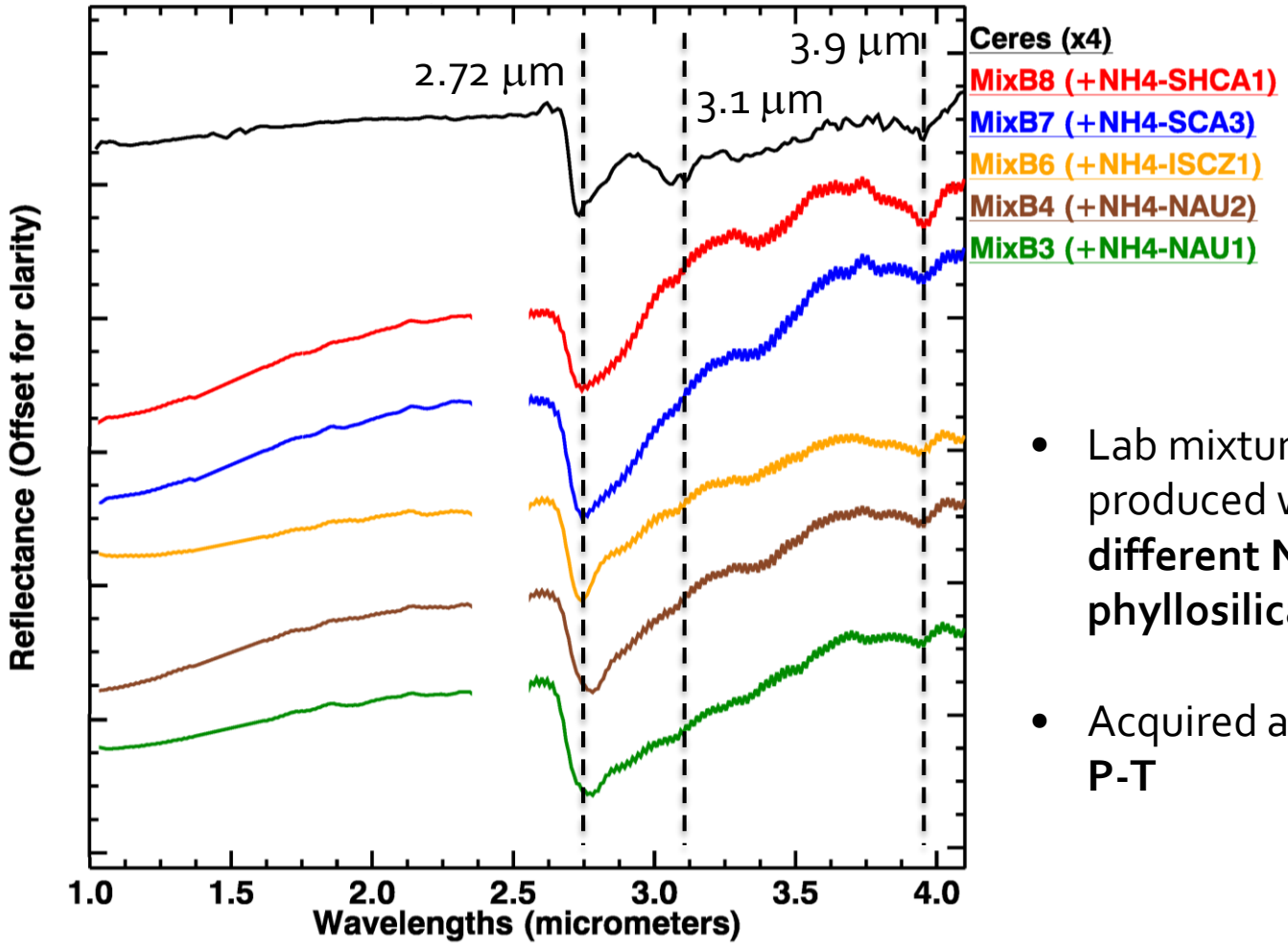




- @room P-T: the 3.1-μm NH_4 band is hidden by H_2O
- After heating for 6 days @150°C [acq. in vacuum]
- After heating for 7 days @250°C [acq. in vacuum]

Planetary analogues (ii): Ceres

- Ammonium-bearing phyllosilicates: **mixtures**

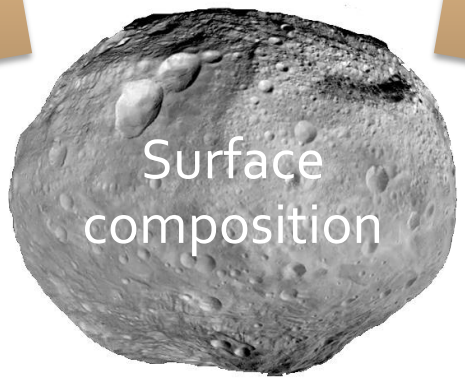


- Lab mixtures produced with **different NH_4-phyllosilicates**
- Acquired at **room P-T**

Planetary analogues (iii): Vesta

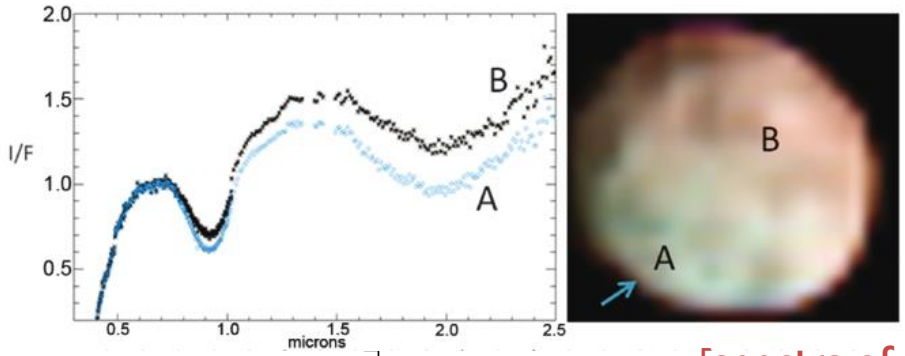
HED meteorites

Terrestrial basalts/ultra mafic rocks

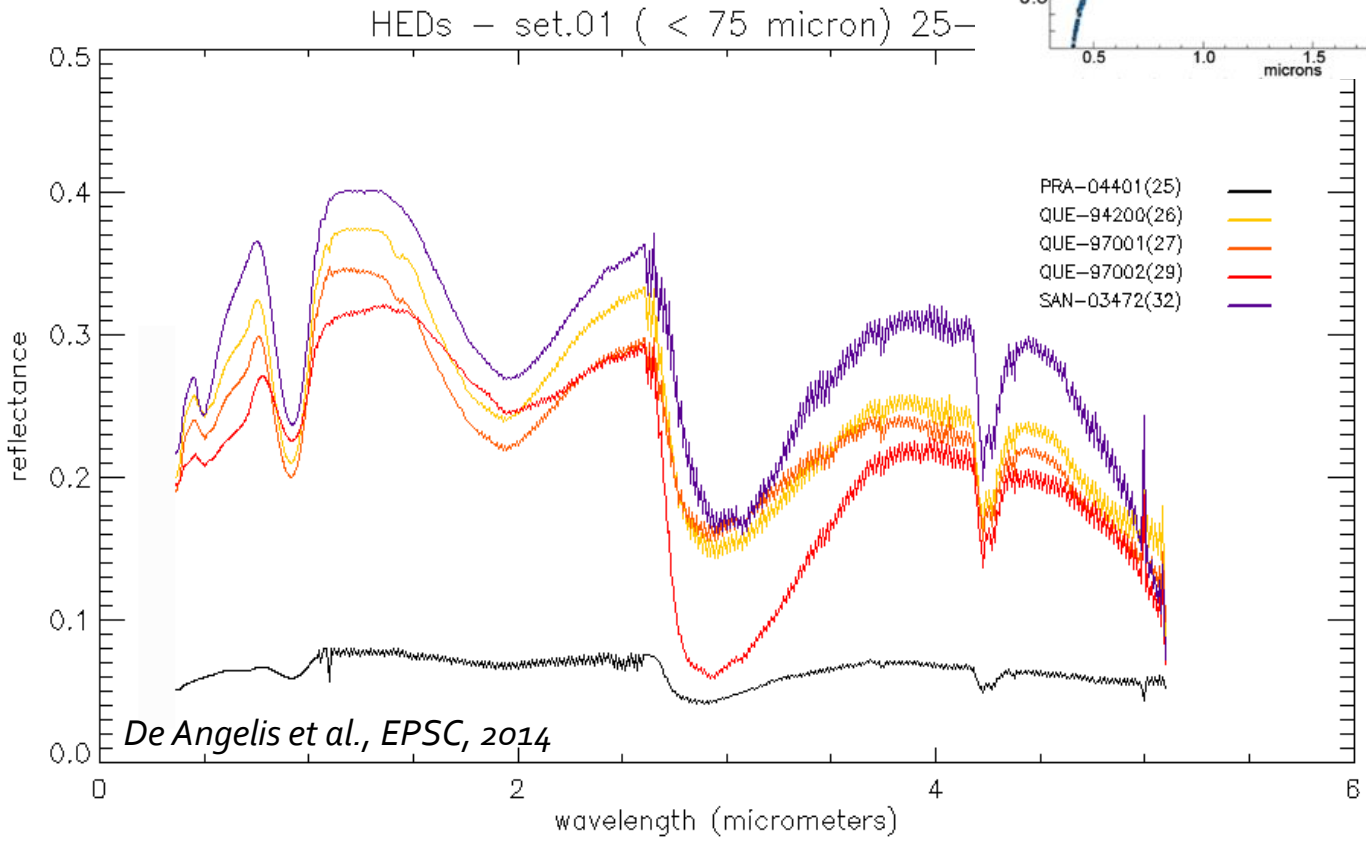


Planetary analogues (iii): Vesta

- HED meteorites:
  Howardites



[**spectra of Vesta by Dawn/VIR**; *De Sanctis et al., 2012, Science*]

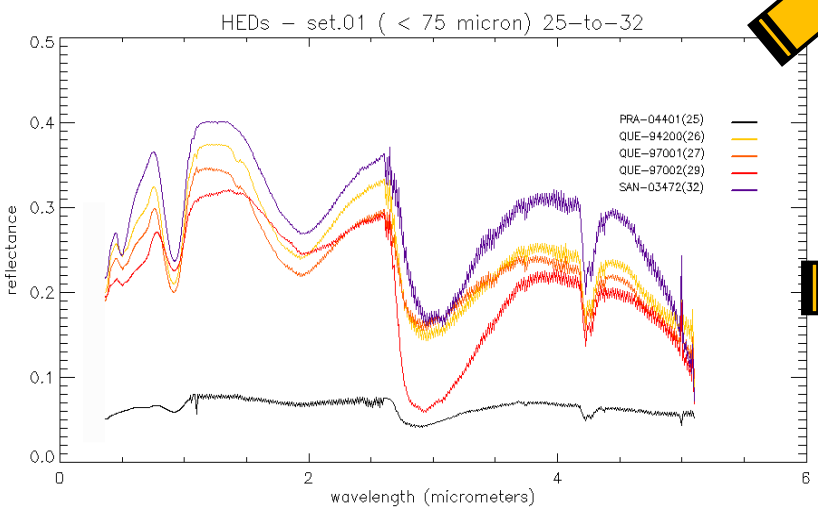


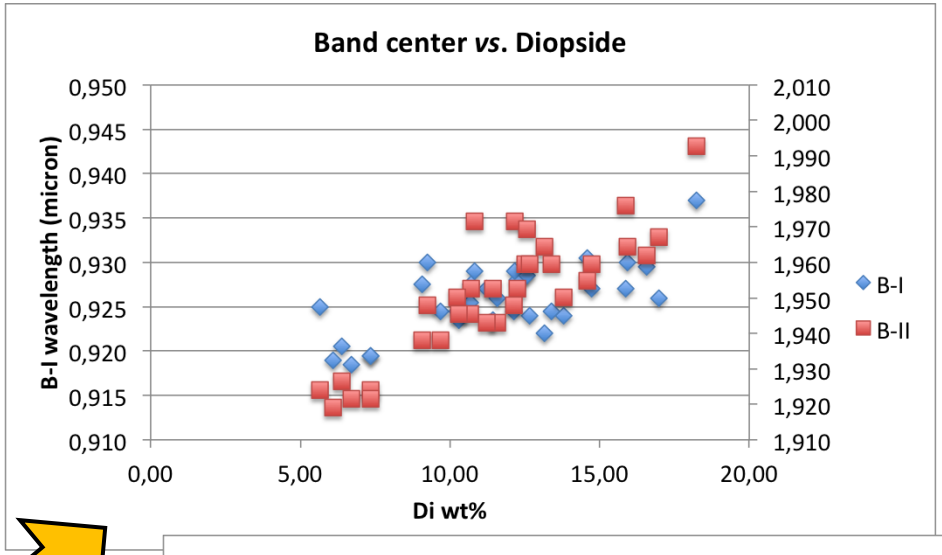
Lab VNIR analyses of Howardites meteorites:
The regolith of Vesta

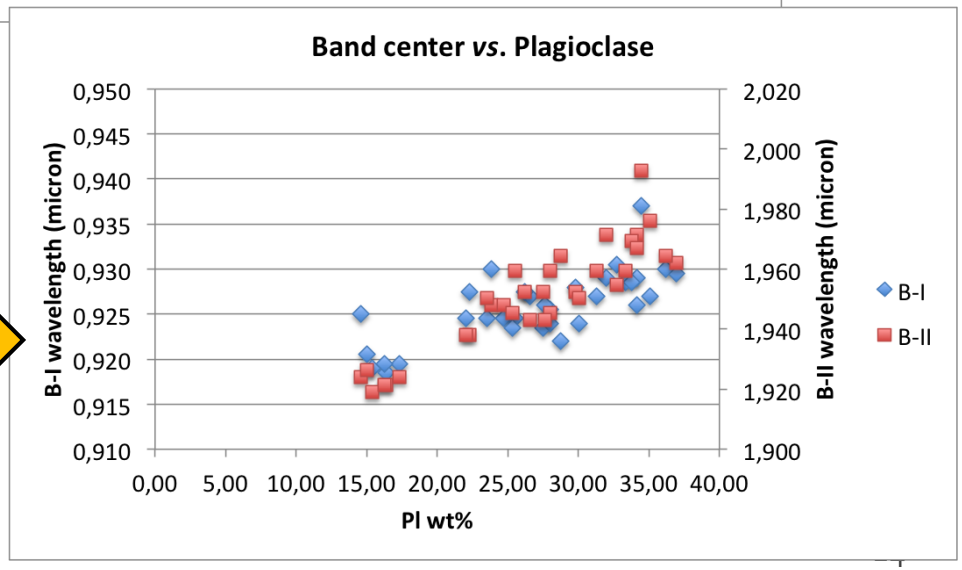
Planetary analogues (iii): Vesta

- HED meteorites:
  Howardites

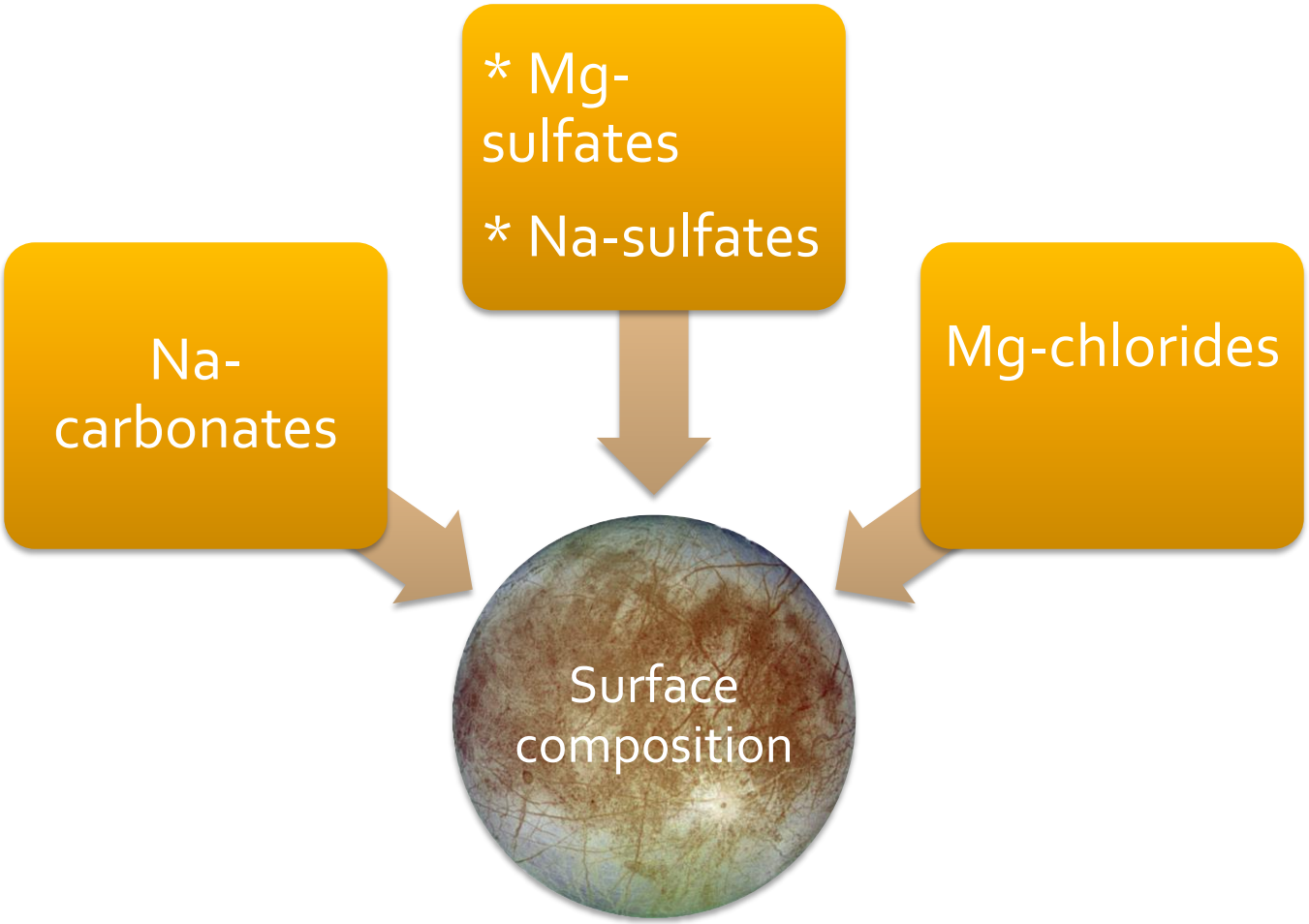
Lab VNIR analyses of Howardites meteorites:
The regolith of Vesta







Planetary analogues (iv): Europa

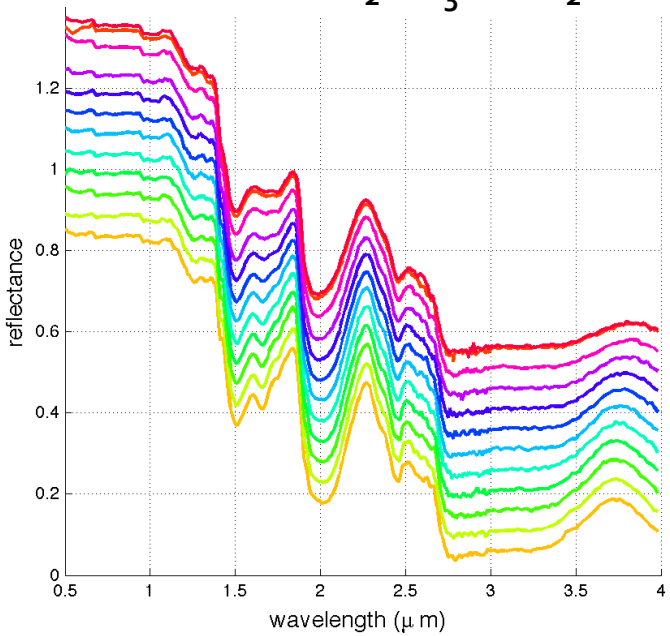


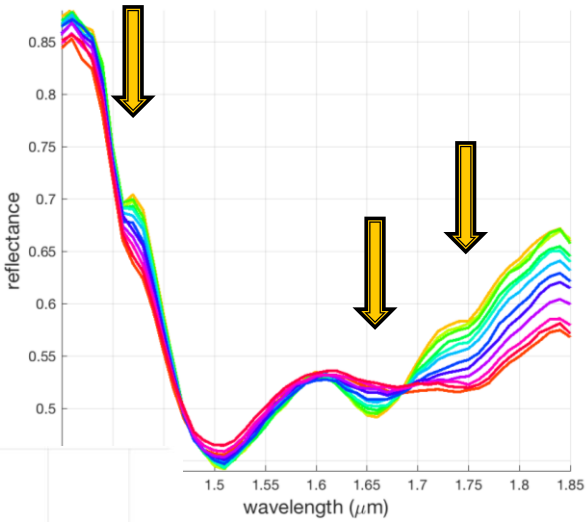
Planetary analogues (iv): Europa

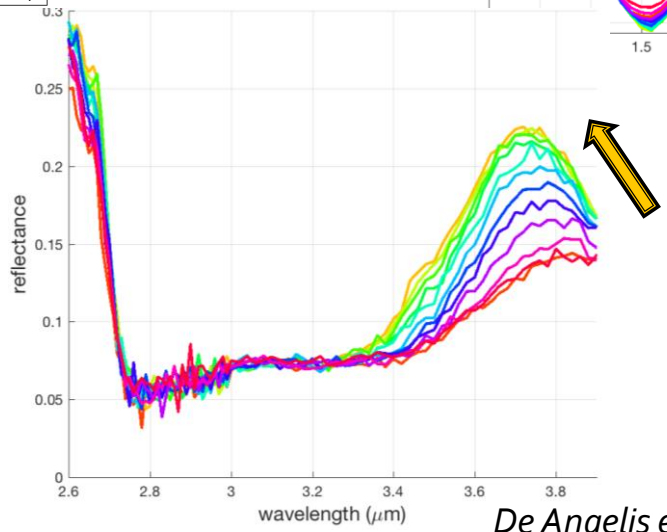
- **Heavily hydrated salts** @IPAG-Lab Grenoble

Na-carbonates:

Natron: $Na_2CO_3 \cdot 10H_2O$







- Grain size 36-50 μm
- T=93-279K
- Range: 0.8-4 μm

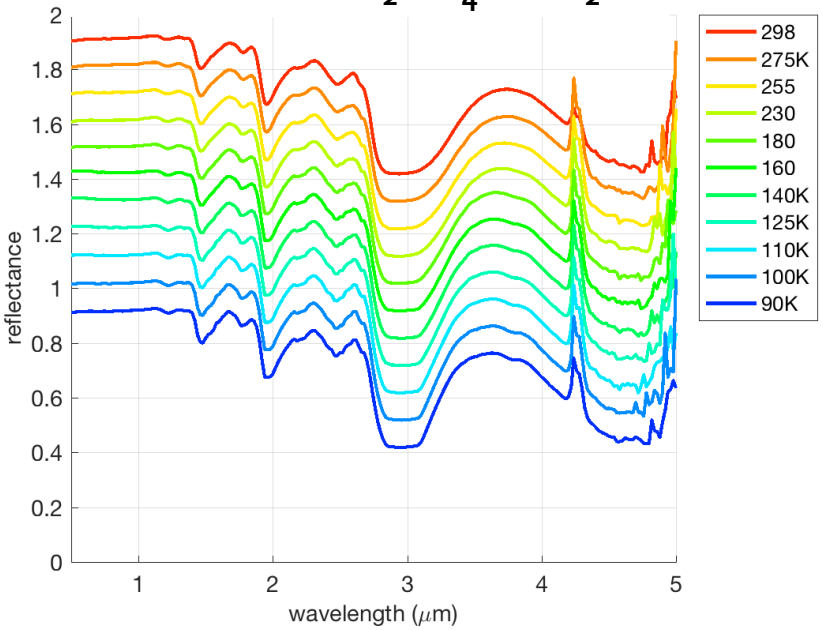
De Angelis et al., Icarus, 2018

Planetary analogues (iv): Europa

- **Heavily hydrated salts** @IPAG

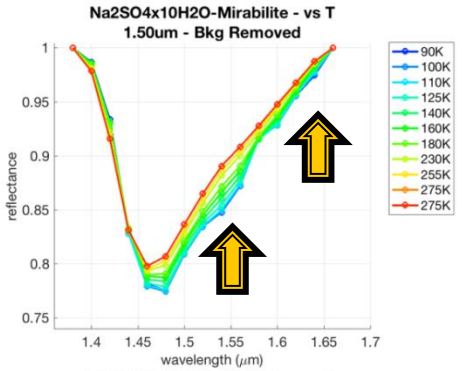
Na-sulfates:

Mirabilite: $Na_2SO_4 \cdot 10H_2O$

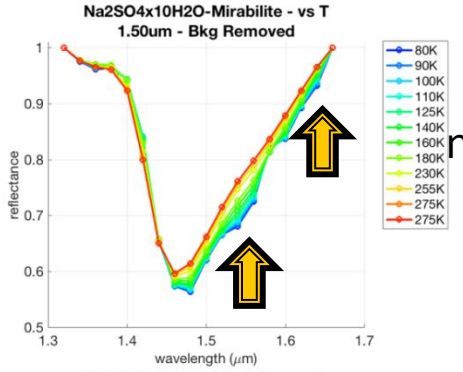


- Grain size 36-50 μm
- T=90-298K
- Range: 0.5-4.8 μm

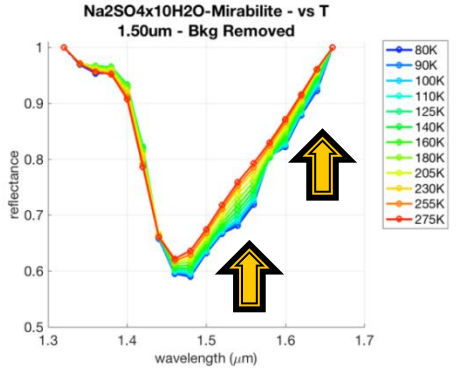
1.5-μm band



fine



medium



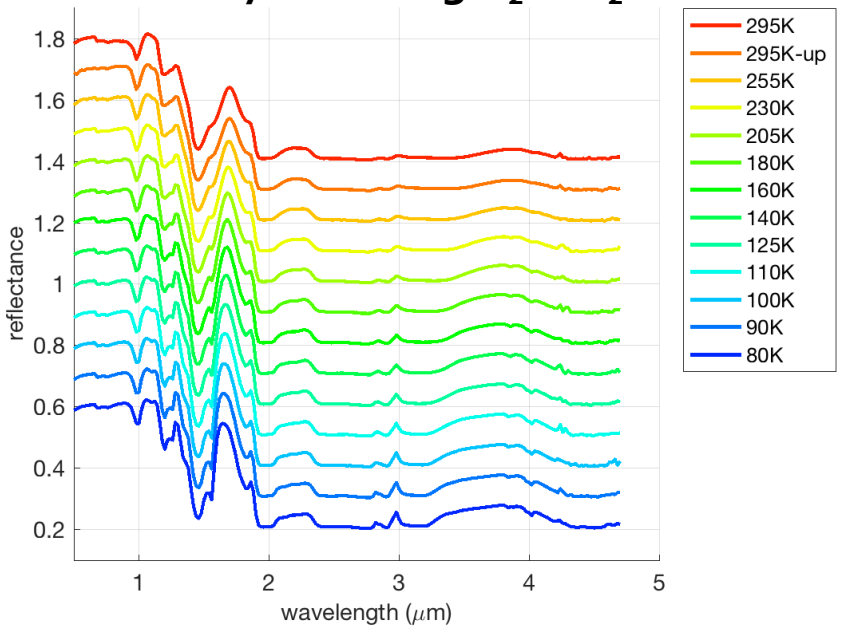
coarse

Planetary analogues (iv): Europa

- **Heavily hydrated salts** @IPAG

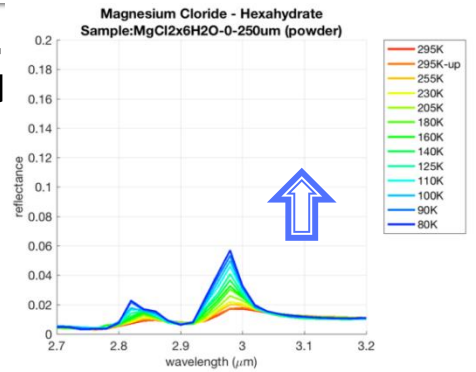
Mg-chlorides:

Hexa-hydrate: $MgCl_2 \cdot 6H_2O$



- Grain size 0-250 μm
- T=80-295K
- Range: 0.5-4.8 μm

3.0-μm peak



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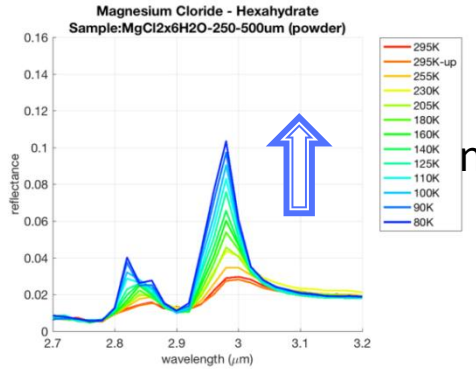

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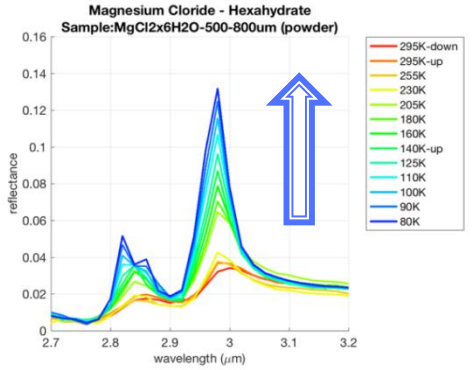

coarse

Conclusions

- **Lab Studies** on planetary analogues: crucial for **remote-sensing data interpretation**
- VIS/IR **Spectra of rocks influenced** by:
  - Mineralogy / Grain size / Crystalline structure
  - Temperature / Pressure / Hydration
- Spectra to be measured in **simulated conditions**, that are comparable with planetary environments