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Laboratory activity at INAF-IAPS on planetary surfaces analogues
Outline

- Exploration of rocky bodies
- Planetary analogues
- Laboratory setup @INAF-IAPS
- Spectroscopy of planetary analogues
- Conclusions
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
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$_2$O-icy leading hemisphere
- Heavily hydrated “non-icy” materials
- Hydrated sulfuric acid
Rocky / icy bodies exploration

Remote-sensing / *in-situ* planetary data

Theoretical modelling

Laboratory activity
Rocky / icy bodies exploration

Spectroscopy by Remote Sensing:

> New data from planets, moons, minor bodies, etc..
> Data need interpretation

Spectroscopy in the Laboratory:

> Known samples
> Controlled conditions (P, T, etc...) + simulations
> Experiments are repeatable
> To reproduce spectra in lab
Planetary analogues

Surface

Composition:
Minerals, rocks

Morphology / structures / environments

Physical properties:
regolith, permafrost

Atmosphere

Gases / Mixtures

Planetary Analogues
Planetary analogues: surfaces

**Surface**
- Composition: Minerals, rocks

**Planetary Analogues**
- Physical properties: regoliths, permafrost
- Atmosphere: Gases/Mixtures
- Data analysis: Spectral fitting, linear mixing/unmixing,
  Spectroscopy, microscopy, ...

**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

Composition: Minerals, rocks

Surface

Planetary Analogues

Workflow

Want to reproduce observed spectra in the lab

Remote-sensing spectrum from planet

Lab spectrum from samples

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

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

*De Angelis et al., Rev.Sci.Intr., 2018*
Planetary analogues (i): Mars

Surface composition

Phyllosilicates / Hydrous minerals

Volcanic rocks – TAS diagram spectral characterization

Minerals at Martian P-T
Planetary analogues (i): Mars

- Volcanic rocks
  chemical classification: TAS-diagram

Basic-ultramafic lavas (basalt)

Spectral classification of volcanic rocks based on TAS
Planetary analogues (i): Mars

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

CBF6 (Fioranello mine) - FieldSpec
Surface composition

Phyllosilicates:
* Smectites
* serpentine

3.1 μm band:
* NH₄-
Phyllosilicates

Dark component

Planetary analogues (ii): Ceres
Planetary analogues (ii): Ceres

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$_2$O-ice/frost** (Lebofsky, 1981)

- **Brucite** (Milliken&Rivkin, 2009)
  ➔ ruled out below detection limit by lab experiments with mixtures (De Angelis et al., 2016)
- **H$_2$O-ice/frost** (Lebofsky, 1981)
  ➔ maybe can give a contribution
Planetary analogues (ii): Ceres

- Ammonium-bearing phyllosilicates: vs P-T

- Spectrum at room T vs Pressure ($10^3 \rightarrow 10^{-4}$ mbar)

- @room P-T: the 3.1-μm NH$_4$ band is hidden by H$_2$O
- 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

Surface composition

HED meteorites

Terrestrial basalts/ultra mafic rocks
Planetary analogues (iii): Vesta

- **HED meteorites:** Howardites

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De Angelis et al., EPSC, 2014

Lab VNIR analyses of Howardites meteorites: The regolith of Vesta

HEDs – set.01 ( < 75 micron) 25–
Planetary analogues (iii): Vesta

- HED meteorites: Howardites

Lab VNIR analyses of Howardites meteorites:
The regolith of Vesta
Planetary analogues (iv): Europa

- Na-carbonates
- * Mg-sulfates
- * Na-sulfates
- Mg-chlorides

Surface composition
Heavily hydrated salts @IPAG-Lab Grenoble

Na-carbonates:
Natron: $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$

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

De Angelis et al., Icarus, 2018
Heavily hydrated salts @IPAG

Na-sulfates:
Mirabilite: $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$

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

1.5-μm band
Planetary analogues (iv): Europa

- **Heavily hydrated salts @IPAG**

  Mg-chlorides: Hexa-hydrate: MgCl$_2$·6H$_2$O

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

  3.0-µm peak

  fine

  medium

  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