Simulations of MMX/MIRS Phobos observations

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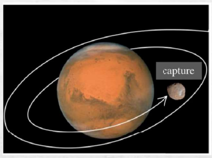
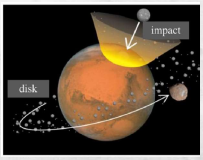
I. Context

Phobos origins ?



1. Asteroid capture

Small, irregular shape, low albedo, spectrum similar to D-type [1,2,3].



2. In situ formation

Inclination, eccentricity [4]

Objective

Prepare the observation and interpretation of the MIRS observations (near-infrared spectrometer (0.9 - 3.6 µm) onboard MMX [5]) of Phobos and Deimos

MMX mission will explore Phobos and Deimos and unravel the mystery of their origin by in situ observations and sampling of the surface.

II. Simulations

- 3 simulators (Fig. 1):

  1. **AURORA** [6]: observation mission scenario

  2. **OASIS** [7]: Phobos field of view, generation of geometric information + computation of bidirectional reflectance

  3. **MIRAGES** [8]: instrument response

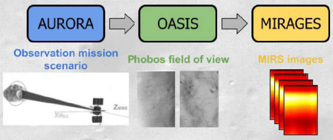


Fig. 1: Simulation chain for MIRS.

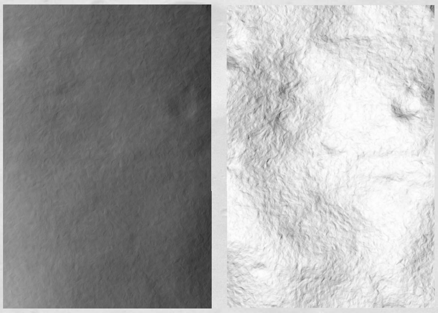
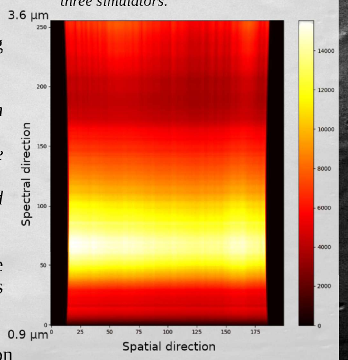


Fig. 2: Example of surface reflectance at 1 µm (left) and temperature at 3 µm (right) landscapes obtained with OASIS simulation.

Fig. 3: Example of a typical MIRS image for a QSO-H orbit, obtained after the three simulators.



- **OASIS** (Fig. 2) computes in the following order:

  (1) the illuminations angles from the mission scenario defined using ***AURORA***
  (2) the bidirectional reflectance with the Hapke model
  (3) the thermal component with a Standard Thermal Model

  The model does not account for multiple scattering and Mars reflected light on Phobos and Deimos.

- **MIRAGES** (Fig. 3) models light propagation through the mirrors, grating, and other optical elements

- Simulated images are finally processed by part of the MIRS pipeline to obtained corrected and calibrated images
  - Distortion correction
  - ADU to I/F conversion
  - Spectral registration

- A thermal correction is applied to remove the contribution of the thermal tail

III. Detectability

- Study of the detectability of components of interest for the Phobos' surface, i.e. hydrated minerals and organics.

- We defined patches of different size from a diameter of 3.5 km to 12.9 m at the surface of Phobos (Fig. 4).

- We used laboratory spectra of Phobos simulants [9] as input for the patches spectra.

- Patches are detectable for a size of approximately 40 m → in agreement with the expected spatial resolution in QSO-H orbit (31 – 66 m/px).

- An example of a MIRS observation sequence with a hydrated mineral patches can be seen in Fig. 5.

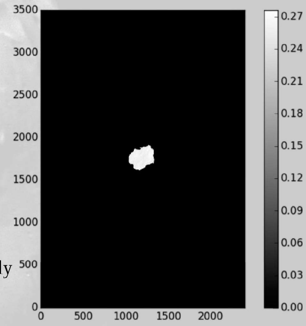


Fig. 4: Example of a patch defined at the surface of the simulated Phobos landscape.

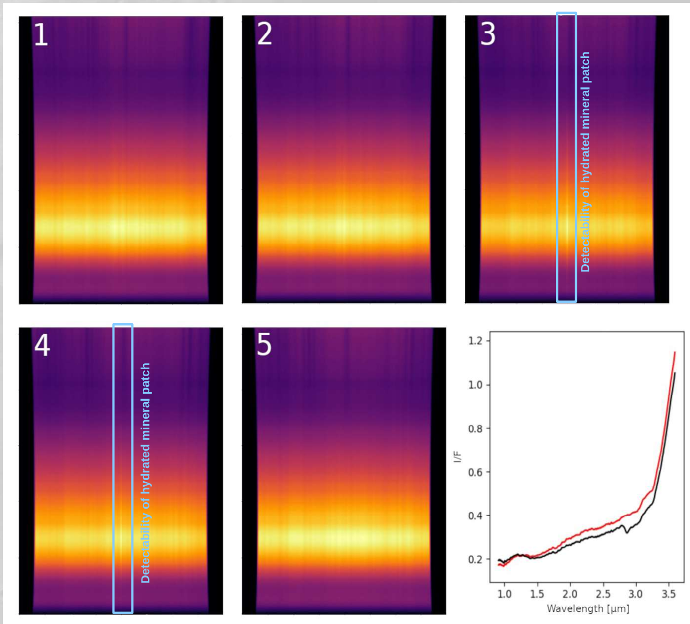


Fig. 5: Example of 5 images of a MIRS observation sequence on a landscape obtained by OASIS. The passage on the hydrated mineral patch can be visually seen as a bright line through the spectral direction in the center of the images 3 and 4. Bottom left corner: Example of two 1D spectra extracted for a MIRS image (panel 3), before thermal tail removal. The black solid line corresponds to the phyllosilicate patch MIRS rendered spectrum, and the red solid line correspond to the 'classic' Phobos surface MIRS spectrum. The 2.7 µm band due to OH in hydrated mineral is clearly visible in the black spectrum.

IV. Conclusions

- We demonstrate the possibility of simulated MIRS observations to prepare the future interpretation of the data.
- The expected MIRS spatial resolution is achieved in our simulations for a typical QSO-H orbit.

V. Further investigations

- Simulation of the Deimos flyby scheduled in September 2027
- Implementation of the Martian contribution

References

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[9] Wargnier *et al.*, 2024. Icarus.

Acknowledgments

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