MIRS - MMX OBSERVATIONS OF THE MARTIAN SYSTEM. M.A. Barucci [1], J.-M. Reess [1], P. Bernardi [1], S. Fornasier [1], A. Doressoundiram [1], M. Le Du [2], V. Tyrou [2], E. Sawyer [2], T. Iwata [3], H. Nakagawa [4], T. Nakamura [4] and MIRS team, [1]LESIA-Observatoire de Paris, Université PSL, CNRS, Sorbonne Université, Université de Paris, 92195 Meudon Principal Cedex, France, antonella.barucci@obspm.fr; [2]CNES, 18 Av. Edouard Belin, 31400 Toulouse, France ; [3]ISAS, JAXA, 3-1-1 Yoshinodai, Chuo-ku, Sagamihara, Kanagawa, 252-5210, Japan ; [4]Tohoku University, 6-3 Aramaki-aza-Aoba, Aoba-ku, Sendai, Miyagi, 980-8578, Japan.

Introduction: MIRS (MMX InfraRed Spectrometer) is an imaging spectrometer [1] on board of the Martian Moon eXploration (MMX) mission [2]. MMX is a JAXA mission to be launched in summer 2024 to Martian system to carry out extensive survey of the Martian moons, and to bring back samples (>10 g) from Phobos to Earth in 2029. The spacecraft will arrive into Mars system in 2025, injected into Phobos co-orbit and then in orbit around Mars like a Martian Moon in the so-called quasi-satellite orbits (QSOs). The QSOs will be settled at different altitudes in the equatorial plane of Phobos to obtain global mapping at different spatial resolutions and characterize the selected landing sites. Multiple flybys of Deimos will be performed. Diverse materials are known to exist across the surface of Mars moons [3], and it is essential to have a complete characterization of global composition to identify and evaluate the properties and geologic context of different materials. Observations of the Martian atmosphere will also be performed taking the advantage of quasi-equatorial spacecraft orbits.

MMX objectives: One of the major goals of the mission [2] is to decipher the origins of the Martian moons and constrain processes for planetary formation and material transport in the region connecting the inner and outer Solar System. The second is to clarify the driving mechanism of the transition of the Mars-moon system and add new knowledge to the evolution history of Mars. The advantage of the location of the Martian moons will allow to elucidate processes producing habitable terrestrial planets.

MIRS objectives: To achieve the objectives of the mission, MIRS has been selected and defined to contribute to answer to the following objectives:

- *Reveal whether Phobos originated as a captured asteroid or resulted from a giant impact*

- *Place new constraints on Deimos' origin*

- *Constrain the mechanisms of material circulation in the Martian atmosphere affecting the transitions in the Martian climate*

MIRS will achieve several of the mission requirements in particular: i) to spectroscopically characterize the global surface material distribution of Phobos at spatial resolutions better than 20 m to support the sampling selection; ii) to investigate composition of Deimos with a spatial resolution of about 100 m; and iii) to constrain transport processes of dust and water near the Martian surface, with observations of the mid- to low-latitude distributions of dust storms, ice clouds, and water vapor in the Martian atmosphere at different temporal resolutions.

MIRS instrument: MIRS is an imaging spectrometer that uses the push-broom acquisition principle. It is built at LESIA-Paris Observatory in collaboration with four other French laboratories and CNES with close collaboration with JAXA and MELCO. To accomplish the MIRS objectives, MIRS characteristics are:

- *Spectral range : 0.9 – 3.6 µm*
- *Spectral resolution (sampled) < 20 (+10%) nm*
- *Spectral sampling : 10 (+10%) nm*
- *IFOV : 0.35 mrad*
- *FOV : ≥ ±1.65°*
- *SNR: ≥ 100 in the region 2.7 - 3.2 µm in less than 2 sec integration.*

Observations of Phobos and Deimos: Observations of Phobos and Deimos with MIRS will allow to detect and characterize all present absorption features and their variations on the Phobos and Deimos surfaces. After the insertion to QSO, for Phobos, MIRS will acquire spectra from Hight, Medium and Low altitude [4] at SNR ratio > 100 (at least in the region 2.7-3.2 µm) to determine surface composition at different spatial resolution. During the QSO-M global survey (for +/-45° latitudes) a spatial resolution of about 20 m will be performed. The spacecraft will also observe polar regions of Phobos (above/low 30° latitudes) from a three-dimensional quasi-satellite orbit moving out of the equatorial plane of Phobos (QSO-M3D) [4]. The spectral radiometric absolute accuracy is expected to be of 10%, and the relative accuracy of 1%. The high SNR and unprecedented spatial resolution achieved by MIRS will permit to fully characterize the composition and mineralogy of both the red and blue units on Phobos and investigate the local compositional heterogeneity associated with the different geomorphological features across Phobos surface.

MIRS is expected to spectroscopically detect and characterize the presence of water (ice) (absorption bands at 1.5, 2.0 and 3.0-3.2 μm), hydrous silicate minerals (features at 2.7-2.8 μm, and minor overtones at 1.4 and 1.8 μm), or anhydrous silicates (bands in the 0.9-1.0 and 2.0 μm regions) and to measure organic matter (at 3.3-3.5 μm). The high SNR will also allow a detailed characterization of the absorption bands detected, permitting by the precise investigation of the band center, depth and area to well constrain the mineralogy, species abundances and composition of Phobos. These unprecedented data will allow scientists to cast light on the origin of Mars moons. MIRS will be able to measure the spectral radiance of the surface within the instrument footprint. At wavelengths longer than about 2.5 μm the thermal tail due to Phobos thermal radiation become more important than the reflected sun-light. The thermal tail depends of the temperature and consequently MIRS data can be used to derive the surface temperature. The thermal tail is also function of the infrared emissivity. It is important to model the thermal tail in the analysis of MIRS data, especially in the region around 2.7 – 3.2 μm where the reflectance spectra will be investigated for the presence of the phyllosilicate and water bands. The thermal tail can be used to assess the surface temperature and its spatial and temporal variations. The surface thermal inertia of Phobos will be derived at the instrument spatial resolution from thermal models.

To constrain the surface composition of Deimos, MIRS is expected to spectroscopically map major regions at a spatial resolution better than 100 m and detect the same major absorption bands as observed in Phobos. The data will also favor the search for heterogeneity that could be linked to topography or linked to the Martian phase aspect. Even if Deimos is not the target for the sampling, we will be able to take advantage of this mission to improve the compositional knowledge of the surface of this satellite. Priority of the observations is given to the surface areas less characterized by the previous space missions.

MIRS observations will also provide new insights into space weathering processes thanks to resolved spectral observations of small fresh craters and their ejecta. MIRS data associated with the OROCHI (Optical Radiometer composed of Chromatic Imagers) and TENGOO (Telescopic Narrow Angle Camera) instruments will give new insights on the surface characterization of these two moons.

Mars atmosphere: MIRS will be able to observe and constraint dust and water transport processes in the Martian atmosphere, by monitoring the distributions of dust content and storms, water ice clouds and water vapor. The 2.0 μm band will allow to monitor CO_2 (and thus pressure). The 2.6 μm band will permit to monitor water vapor with a daily basis monitoring [5] and spectral features between 0.9 and 3.6 μm will allow to study water ice clouds. MIRS should also be able to detect CO at 2.35 μm and O_2 at 1.27 μm. MIRS spectra will also allow to estimate the water adsorbed in the surface regolith. MIRS in close collaboration with the on-board cameras [6] will be able to investigate short lifespan events in Martian atmosphere as well the investigation of CO_2 clouds following the procedure proposed by Vincendon et al. [7] for Mars Express observations. The described observations will give new insight about the history of the Martian environment.

Conclusions: MIRS observations will allow to characterize the global composition of Phobos and Deimos surface and subsurface. MIRS will help to decipher whether i) Phobos composition is closer to primitive dark asteroids, similar to carbonaceous chondrites with possible presence of organics and/or ices which will imply a capture origin or ii) containing high-temperature phase materials, even if in small quantity, representing a mixture of Martian silicates [8] which would imply an origin by giant impact. MIRS, together with OROCHI and TENGOO, will help in better understanding the presence of water, CO_2 and dust cycles, thanks to long term monitoring.

MIRS together with the MMX payload and sampling return will be able to clarify the origin of the Martian moons and the process of the evolution of the Martian environment.

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