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**MIRS: An infrared spectro-imager aboard the Martian Moon eXploration mission to study Phobos, Deimos and Mars.** T. Gautier<sup>1,2</sup>, M.A. Barucci<sup>1</sup>, P. Bernardi<sup>1</sup>, J.-M. Reess<sup>1</sup>, S. Fornasier<sup>1</sup>, F. Merlin<sup>1</sup>, G. Poggiali<sup>1</sup>, G. David<sup>1</sup>, A. Doressoundiram<sup>1</sup>, Y. Leseigneur<sup>2</sup>, C. Donny<sup>3</sup>, M. Le Du<sup>3</sup>, V. Piou<sup>3</sup>, E. Sawyer<sup>3</sup>, T. Iwata<sup>4</sup>, H. Nakagawa<sup>5</sup>, T. Nakamura<sup>5</sup> and MIRS team, <sup>1</sup> LESIA-Observatoire de Paris, Université PSL, CNRS, Sorbonne Université, Université de Paris, 92195 Meudon Principal Cedex, France, [Thomas.gautier@latmos.ipsl.fr](mailto:Thomas.gautier@latmos.ipsl.fr) <sup>2</sup> LATMOS, CNRS, Université Versailles St-Quentin, Université Paris-Saclay, Sorbonne Université, 11 Bvd d'Alembert, 78280 Guyancourt, France <sup>3</sup>CNES, 18 Av. Edouard Belin, 31400 Toulouse, France ; <sup>4</sup>ISAS, JAXA, Kanagawa, 252-5210, Japan ; <sup>5</sup>Tohoku University, 6-3 Aramaki-aza-Aoba, Aoba-ku, Sendai, Miyagi, 980-8578, Japan.

**Introduction:** The origin of Phobos and Deimos remains debated, with two main hypotheses to explain their presence. They could have formed in the debris disk following a giant impact on Mars or could originally have been primitive asteroids (or even a binary comet) captured by Mars. The JAXA Martian Moon eXploration mission [1] will be launched in 2026 to investigate the Martian system and in particular is tasked to solve the origin of Phobos and Deimos. MMX will sample the surface of Phobos and return a sample to Earth in 2031 including an instrumental suite to study Phobos, Deimos and Mars from different orbits [1]. Among its instrumental suite, MMX will carry an infrared spectro-imager, MIRS (MMX InfraRed Spectrometer) [2]. MMX will be placed in an equatorial orbit around Mars adjusted to a quasi-satellite orbit (QSO) around Phobos.

**MIRS instrument:** MIRS is a push-broom infrared imaging spectrometer built at LESIA-Paris Observatory in collaboration with other French laboratories and CNES in close partnership with JAXA and MELCO. MIRS operates in the 0.9 to 3.6 $\mu\text{m}$  range with a spectral resolution  $\leq 22$  nm up to 3.2  $\mu\text{m}$  and a SNR  $\geq 100$  in the 2.7 - 3.2  $\mu\text{m}$  wavelength range. MIRS instantaneous Field of View for 1 pixel is  $\leq 0.35$  mrad and the field of View (FoV) is  $\pm 1.70^\circ$ [3]. In support of MMX objectives, MIRS will remotely characterize Phobos and Deimos surfaces as well as Mars atmosphere composition by monitoring diagnostic features in the near-infrared spectral range.

**Phobos observations:** MMX QSOs will be located in the equatorial plane of Phobos at different altitudes, depending on the stage of the mission, from 100km down to 7km. MIRS observations from QSOs will allow to obtain global mapping of Phobos surface at different spatial resolutions and characterize the selected sites for MMX surface sampling. MIRS will spectroscopically characterize the global surface material distribution of Phobos at spatial resolutions better than 20 m to support the sampling selection. In particular, the 20 best landing site candidate regions will be observed at highest resolution during lower altitudes co-orbits. If present, MIRS will be able to detect and characterize the presence of water (ice) (through its bands at 1.5, 2.0 and

3.0-3.2  $\mu\text{m}$ ), hydrous silicate minerals (2.7-2.8  $\mu\text{m}$ , and minor overtones at 1.4 and 1.8  $\mu\text{m}$ ), anhydrous silicates (0.9-1.0 and 2.0  $\mu\text{m}$  regions) and organic matter (3.3-3.5  $\mu\text{m}$ ). In addition to surface composition mapping, MIRS will also measure Phobos thermal inertia with different sets of local time and phase angle.

**Deimos observations:** Throughout the stay of MMX in the Martian system, several flybys of Deimos will be also performed during which MIRS will be able to observe the smallest Martian moon. These observations will allow to compare Deimos surface composition to that of Phobos with observations at a spatial resolution of about 100m.

**Mars observations:** Observations of the Martian atmosphere will also be performed to investigate temporal and spatial changes taking the advantage of quasi-equatorial spacecraft orbits. These observations will be key to better constrain the relations in the dust and water cycles in Mars atmosphere in the mid- and low-latitudes at a spatial resolution of up to 2.5km. Given its wavelength range, MIRS will be able to monitor water vapor through its 2.6 $\mu\text{m}$  band and atmospheric aerosols (dust and water ice) using either the continuum spectrum or their effect on the 2.0 and 2.7 $\mu\text{m}$  CO<sub>2</sub> bands. MIRS should also be able to detect and monitor CO at 2.35  $\mu\text{m}$ . MIRS spectra will also give us insights on the water adsorbed in Mars' surface regolith. It should be noted that given the equatorial orbit of MMX, MIRS will be able to investigate in depth the local time dependency of the retrieved quantities, and to sample dust and water content with a high temporal resolution (up to 15 min).

**Conclusions:** MIRS observations will allow to characterize the surface composition of Phobos and Deimos and to detect all spectral absorption features and their variations. MIRS will observe the surface of the candidate sampling sites at lower altitude with spatial resolution of few meters. For the final two selected sampling site, MIRS observations will have only a few cm spatial resolution, providing extremely useful context information regarding the samples that will be bring back to Earth. Identification and mapping of different mineral phases on the surface of the Martian moons will help establish strong constraints to the origin

of Phobos and Deimos. The surface thermal inertia of Phobos will also provide insights on the physical properties of the regolith.

Deimos flybys will be opportunities for MIRS to spectroscopically map regions of its surface and look for similar features as the ones observed on Phobos. MIRS observations will also provide information regarding space weathering processes on airless small bodies through the observation of recent small craters.

Mars observations at high temporal resolution will be particularly useful to decipher the interrelation between dust and water during the onset of local, regional or major scale dust storms.

Overall, MIRS data, especially in association with the ones returned by the OROCHI (Optical Radiometer composed of Chromatic Imagers) and the TENGOO (Telescopic Narrow Angle Camera) instruments will provide new insights on the surface characterization of these two moons and help constrain Phobos and Deimos surface composition. If they turn out similar to the one of primitive dark asteroids, with the possible presence of organics or ices, this will imply that Phobos and Deimos were asteroid captured into Mars orbit. On the other hand, the detection of more processed materials or phases demonstrating high-temperature heating in the past, would strongly hint toward their origin being due to a giant impact on Mars.

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