MIRS: The infrared spectro-imager aboard the Martian Moon eXploration mission to study the evolution of Phobos, Deimos and Mars.

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Introduction:

The origin of Phobos and Deimos remains unknown, with two leading hypotheses to explain their existence. The Martian Moons 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 Martian Moon eXploration mission developed by JAXA [1] will be launched in 2026 to investigate the Martian system and in particular decipher the origin of Phobos and Deimos. The MMX probe will sample the surface of Phobos and return samples to Earth in 2031. MMX also includes an instrumental suite to study Phobos, Deimos and Mars from remote sensing observations within the Martian system [1]. Among its instrumental suite, MMX will hosy the infrared spectro-imager, MIRS (MMX InfraRed Spectrometer) [2].

MIRS instrument: MIRS is an infrared imaging spectrometer using push-broom scanning built at LESIA-Paris Observatory in collaboration with other French laboratories and CNES, and in close partnership with JAXA and MELCO. MIRS will operate from 0.9 to 3.6µm range with a spectral resolution ≤ 22 nm up to 3.2 µm and a SNR ≥ 100 in the 2.7 - 3.2 µm wavelength range. MIRS instantaneous Field of View for 1 pixel is ≤ 0.35 mrad and the field of View (FoV) is +/-1.70°[3]. To support MMX objectives, MIRS will characterize Phobos and Deimos surfaces as well as Mars atmosphere composition by monitoring diagnostic features in the near-infrared spectral range.

Phobos observations: MMX orbits will be located in the equatorial plane of Phobos at different altitudes, from 100km down to 7km depending on the stage of the mission. MIRS investigations will allow to obtain global mapping of Phobos surface and to study 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. If present, MIRS would be able to detect and characterize the presence of water (ice) (through its bands at 1.5, 2.0 and 3.0-3.2 µm), hydrous silicate minerals (2.7-2.8 µm, and minor overtones at 1.4 and 1.8 µm), anhydrous silicates (0.9-1.0 and 2.0 µm regions) and organic matter (3.3-3.5 µm). In addition to surface composition mapping, MIRS obsverations will also allow to retrieve Phobos thermal inertia with different sets of local time and phase angle.

Deimos observations: Throughout the stay of MMX in the Martian system, the probe will perform several flybys of Deimos, during which MIRS will be able to observe the smallest Martian moon. These observations will allow comparing Deimos surface composition to that of Phobos.

Mars observations: MIRS will also perform observations of the Martian atmosphere to investigate temporal and spatial changes. To do so, we will take advantage of the quasi-equatorial spacecraft orbits, allowing for in-depth local time dependencies studies. These observations, at a spatial resolution down to 2.5 km, will be crucial to better constrain the relations in the dust and water cycles in Mars atmosphere in the mid- and low-latitudes. MIRS will monitor water vapor through its 2.6µm band and atmospheric aerosols (dust and water ice) using either the continuum spectrum or their effect on the 2.0 and 2.7µm CO_2 bands. MIRS spectra could also give us insights on the water adsorbed on Mars' surface regolith. Given the equatorial orbit of MMX, MIRS will be able to investigate in depth the local time dependency of the retrieved quantities 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 potentially expected 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 provide extremely useful context information regarding the samples that will be bring back to Earth, with observation with only a few cm spatial resolution. Identification and mapping of different minerals on the surface of Phobos will also bring constraints to its origin and help achieve the mission objectives to decipher the Martian moons origin. The surface thermal inertia of Phobos will also provide insights on the physical properties of the regolith. MIRS spectral maps of Deimos acquired during its flybys will allow looking for similar features as the ones observed on Phobos. MIRS observations will also provide information on space weathering processes on airless small bodies through the observation of recent small craters. Investigations regarding space weathering by escaping ions from Mars atmosphere could also help probe the history of this escape through several million years. 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, in cooperation with the ones returned by the OROCHI (Optical Radiometer composed of Chromatic Imagers) and the TENGOO (Telescopic Narrow Angle Camera) instruments will provide numerous insights on the surface characterization of the two Martian 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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References:

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