



Observation opportunities for Mars atmosphere with the MIRS instrument aboard the Martian Moon eXploration mission

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The Martian Moon eXploration mission (MMX), currently developed by the Japan Aerospace Exploration (JAXA) will aim at studying Mars satellites and return samples from Phobos to decipher the history of the Martian system. MMX mission is to be launched in September 2024 and arrive in Mars system on August 2025, will stay three years in Quasi Satellite Orbits (QSO) around Phobos, and will land for several hours on Phobos to collect at least 10g of Phobos regolith before returning to Earth.

Among the mission instrument suite is the near-Infrared Spectrometer MIRS (MMX InfraRed Spectrometer) provided by CNES and built at LESIA-Paris Observatory in collaboration with four other French laboratories (LAB, LATMOS, LAM, IRAP-OMP) and in close collaboration with JAXA and MELCO. MIRS is an imaging spectrometer from 0.9 to 3.6 μm , with a spectral resolution better than 20 nm. The IFOV is 0.35 mrad and FOV of $\pm 1.65^\circ$. The SNR is higher than 100 up to 3.2 μm in a maximum integration time less than 2s. For Mars observation MIRS is expected to perform observations at 10 km spatial resolution, with a spectral radiometric absolute and relative accuracies of 10% and 1% respectively.

Given MIRS spectral range, expected Signal-to-Noise ratio, and observation windows, a certain numbers of high priority targets have been set to achieve MMX goal of *Constrain transport processes for dust and water near the Martian Surface, continuous observations of the mid-to low-latitude distributions of dust storms, ice clouds and water vapor in the Martian atmosphere* (Barucci et al. 2021, Ogohara et al. 2021), summarized in Table 1. Simulated spectra of Martian atmosphere as observed by MIRS are provided in Figure 1.

Table 1: List of MIRS main science targets for Mars observations (adapted from Barucci et al. 2021).

Target	Parameters	Spectral range
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Ice cloud formation and evolution
 Dust clouds / storms formation and evolution

1.5, 2 and 3 μm
 CO_2 band @ 2.7 μm

Water cycle
 Atmospheric dynamics and composition

0.9-3.6 μm continuum
 2.6 μm
 CO_2 band @ 2.0 μm

H_2O vapor
 Surface pressure
 CO
 Limb observations for middle atmosphere

1.27 μm

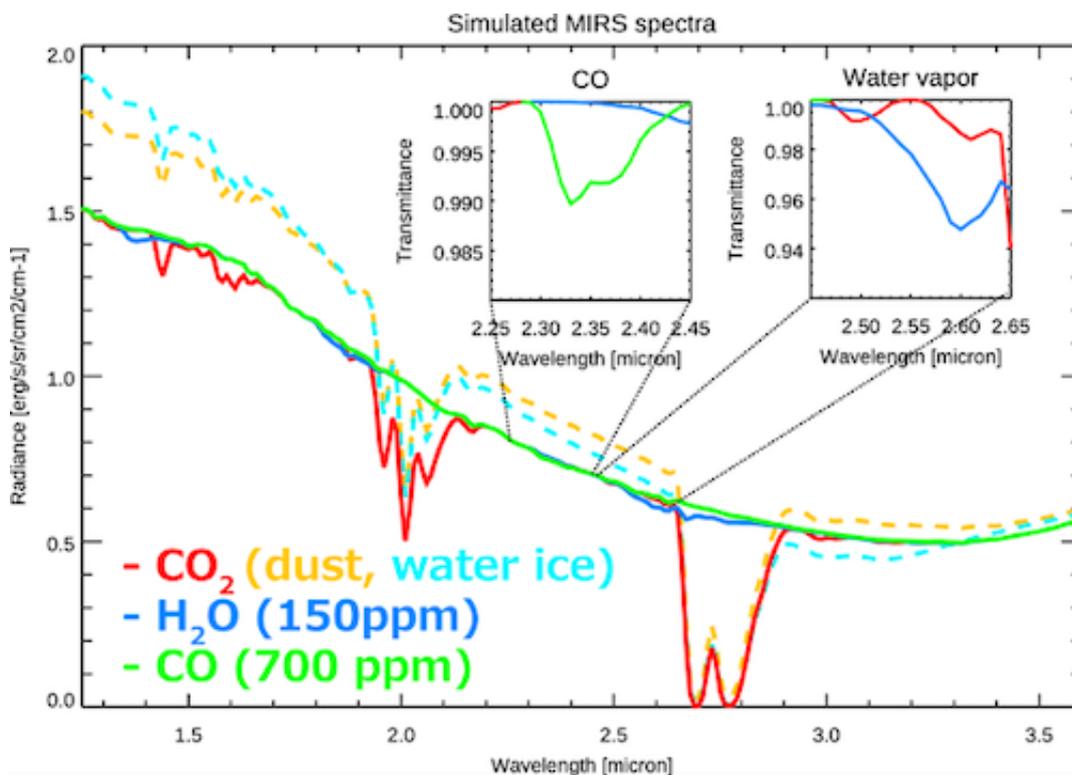


Figure 1: Simulated MIRS spectra for typical Mars observation (from Barucci et al. 2021). Plain curves correspond to clear sky conditions, and the dashed ones include the effects of dust or water ice clouds. For gases, CO₂, CO, and water vapor are calculated separately and reported in red, orange, and blue curves, respectively.

MMX QSO around Phobos will result in a quasi-circular orbit around Mars with a period of $\sim 7\text{h}$, providing more than 3 hours window to Mars observation when Phobos observation is not possible. Several observation strategies, still in discussion, will be possible to maximize either temporal or spatial coverage of Mars and its atmosphere by MIRS. These strategies span from observations with a 30 minutes temporal resolution of a limited zone, to a complete coverage for low and mid latitude in a few orbits (Ogohara et al. 2021, Barucci et al. 2021). Limb observations may also be performed to obtain high vertical resolution observations of the Martian atmosphere.

MIRS observations will provide further constraints on dust and water transport processes in the Martian atmosphere, by monitoring the distributions of dust content and storms, water ice clouds and water vapor. CO₂ (and thus pressure) will be monitored through the CO₂ 2.0 μm band. Water vapor will be monitored on a daily basis using its 2.6 μm band (Maltagliati et al. 2008) and water ice clouds through their spectral features between 0.9 and 3.6 μm (Olsen et al. 2019). MIRS should also be able to detect CO 2.35 μm and O₂ at 1.27 μm . MIRS spectra will also allow for estimations of the

water adsorbed in the surface regolith. Finally, MIRS will be operated in close collaboration with the OROCHI (Optical Radiometer composed of Chromatic Imagers) and TENG00 (Telescopic Narrow Angle Camera) instruments. This will enable efficient monitoring and reactivity to investigate short lifespan events in Martian atmosphere. This will also render possible the investigation of CO₂ clouds following the procedure proposed by Vincendon et al. 2011 for Mars Express observations.

The reflectance spectrum from the light backscattered by atmospheric aerosols can be obtained by comparing successive observations of identical zones on Mars within a short time and with varying phase angles. Such a set of measurements permits to decorrelate the surface reflectance signal from the light scattered by the aerosols suspended in the atmosphere and gives information on the aerosols size and their composition properties averaged over the line of sight. Previous measurements showed a particle size distribution having an effective radius of $1.2 \pm 0.2 \mu\text{m}$ (Erard et al. 1994). The retrieved parameters include the scattering albedo, the phase function of the aerosols, the optical thickness, τ , of the atmosphere at the time of observation and the aerosols size distribution.

In summary, MIRS observations, together with the ones from MSA, OROCHI and TENG00, will help better understand the interdependencies of species and their roles in the Martian water, CO₂ and dust cycles, thanks to long term monitoring of these key constituents of Mars atmosphere.

References

Barucci et al. 2021, *MIRS an Imaging Spectrometer for the MMX mission*, accepted for publication in Earth Planets and Space

Erard, S., Mustard, J., Murchie, S., Bibring, J. P., Cerroni, P., & Coradini, A. (1994). Martian aerosols: Near-infrared spectral properties and effects on the observation of the surface. *Icarus*, 111(2), 317-337.

Ogohara et al. 2021, *The Mars system revealed by the Martian Moons eXploration mission*, accepted for publication in Earth Planets and Space

Vincendon et al. 2011, *New near-IR observations of mesospheric CO₂ and H₂O clouds on Mars*, *JGR Planets* 116, 0-02.

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