MIRS : MMX INFRARED SPECTROMETER TO MARTIAN SYSTEM.

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Introduction: MIRS (MMX InfraRed Spectrometer) is an imaging spectrometer on board of the JAXA sample return MMX (Martian Moon eXploration) mission [1]. MMX spacecraft will be launched in 2026 to Martian system to carry out three years observations of the Martian moons, and to bring back samples (>10 g) from Phobos to Earth in 2031. The spacecraft will arrive at Mars system in 2027, injected into Phobos co-orbit and then in orbit around Mars like a Martian Moon in the so-called quasi-satellite orbits (QSOs) to observe Phobos monitor Mars' atmosphere and observe Deimos by several tens of fly-bys. The QSOs will be settled in the equatorial plane of Phobos with several stages of decreasing altitude, from 100km to 7km to obtain global mapping at different spatial resolutions and characterize the selected landing sites. The 20 best landing candidate regions will be selected for finer observations during lower altitude QSOs. Along with Phobos composition, MIRS will perform Phobos thermal inertia observations at specific sets of local time and phase angle. Multiple flybys of Deimos will be also performed to compare its surface composition to that of Phobos with observations at similar spatial resolution. A complete characterization of the global composition is important to identify and evaluate the properties and geologic context of different materials to select the best landing sites. Observations of the Martian atmosphere will also be performed to investigate temporal and spatial changes taking the advantage of quasi-equatorial spacecraft orbits.

MIRS instrument: The MIRS imaging spectrometer has been designed to accomplish MMX's scientific objectives. MIRS was built [2] at LESIA-Paris Observatory in collaboration with other French laboratories and CNES with close collaboration with JAXA. The MIRS Proto Flight Model (PFM), before to be delivered to JAXA, is shown in Fig. 1. MIRS uses the push-broom acquisition principle and works in the spectral range 0.9 -3.6 µm. The measured spectral resolution is ≤ 22 nm up to 3.2 µm and the SNR: ≥ 100 in the region 0.9 - 3.2 µm. The instantaneous Field of View (iFoV) is ≤ 0.35 mrad, the field of View (FoV) is +/-1.65°.

MIRS is composed of three main components (Fig.1): the electronic box (EBOX), the optical box (OBOX) and the harness between EBOX and OBOX.

The EBOX contains two electronics boards: i) the Low Voltage Power Supply (LVPS) board that generates all power supply voltages and ii) the Instrument Control Unit (ICU) board that controls all the subsystems (detector assembly, shutter, scanner, dust cover, calibration lamp). This board communicates with MMX MDP (Mission Data Processor).

The OBOX contains all the subsystems: a telescope to image the scene on a field stop, which is the spectrometer slit; a spectrometer to disperse the light and form the image on the focal plane; a detector assembly (cooled down to 110K using an integrated cryocooler to limit its dark current) and its proximity electronics to acquire and digitalize the images; the along-track scanner; a shutter to close the spectrometer cavity and record background images; a dust cover to protect the OBOX entrance window during Phobos descent phases; a calibration lamp to perform spectral registration and relative radiometric calibration in-flight; thermal hardware to ensure the instrument remains in its allowable flight temperature range (a survival system based on heaters and mechanical thermostats to keep the OBOX above -40°C, and a set of two radiators to passively cool down to limit the thermal background emission of the spectrometer).

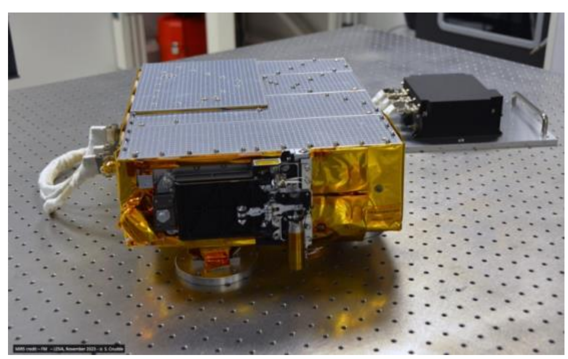

Fig. 1: MIRS PFM before its delivery to JAXA

MMX objectives: The mission is devoted to study the origin of Martian moons, to enlarge the knowledge

of the Martian system and to assess the possibility of Martian life, and to support future crewed exploration.
The major goals of the mission [2] are 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. From the Martian moon Phobos, MMX will investigate the transport of water and organic materials across the Solar System and explore how life and habitable environments were created. The mission will clarify the driving mechanism of the transition of the Mars-moon system and add new knowledge to the evolution history of Mars.

MIRS objectives: To achieve the objectives of the mission, MIRS is expected to remotely characterize Phobos and Deimos surfaces and Mars atmosphere composition to identify diagnostic features in the near-infrared spectral range. 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.

Conclusions: MIRS observations will allow to characterize the surface composition and to detect all spectral absorption features and their variations on the Phobos and Deimos surfaces. After the insertion to QSO, for Phobos, MIRS will acquire spectra from High, Medium and Low altitude and characterize the surface of the preselected landing/sampling sites at lower altitude with spatial resolution of few meters up to few cm for the two selected sampling sites. 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 (3.3-3.5 µm). Unique identification of different mineral phases on the surface of the Martian moons can set main constrains to their origin and evolution. Moreover, MIRS will be able to measure the spectral radiance of the surface within the instrument footprint. MIRS data can be used to derive the surface temperature and its spatial and temporal variations. The surface thermal inertia of Phobos will be derived at the instrument spatial resolution from temperature measurements. To constrain the surface composition of Deimos, MIRS is expected to spectroscopically map during several fly-bys major regions of the moon at a spatial resolution better than 100 m and detect the same major absorption bands as observed in Phobos. The dataset acquired by MIRS will also favor the search for heterogeneity that could be linked to topography.
MIRS observations will also allow to investigate 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.

In summary, MIRS will help to decipher whether Phobos composition is closer to primitive dark asteroids or composed by more evolved material. In the first case we expect a surface similar to carbonaceous chondrites with possible presence of organics and/or ices which will imply an asteroid capture origin. On the other side, if the surface contains high-temperature phase materials, even if in small quantity, representing a mixture of Martian silicates, it would imply an origin by giant impact.

Concerning Mars atmosphere, MIRS will be able to give new insight about the history of the Martian environment observing dust and water transport processes in the Martian atmosphere, by monitoring the distributions of dust content and storms, water ice clouds and water vapor. MIRS will observe the 2.0 µm band to monitor CO_2, the 2.6 µm band to monitor water vapor. 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 and to investigate short lifespan events in Martian atmosphere. MIRS, in close collaboration with the on-board cameras OROCHI and TENGOO, will help, thanks to long monitoring, in better understanding the presence of water, CO_2 and dust cycles.

MIRS will contribute together with the returned sampling to clarify the origin of the Martian moons and to improve the knowledge of the evolution history of Mars.

Acknowledgements: MIRS is built at LESIA-Paris Observatory in collaboration with CNES, four other French laboratories (LATMOS, LAB, OMP, IRAP), and close collaboration with JAXA. MMX is developed and built by JAXA, with contributions from CNES, DLR, ESA and NASA. We thank the MMX JAXA teams for their efforts and CNES for the financial support and collaboration to build MIRS instrument.

References :

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