MICROMEGA: AN IR HYPERSPECTRAL MICROSCOPE FOR THE PHOBOS GRUNT LANDER.

C. Pilorget[1,α], J.-P. Bibring[1], M. Berthe[1] and the MicrOmega Team[1,2], [1]Institut d'Astrophysique Spatiale, Université de Paris Sud, 91405 Orsay, France, [2]Laboratoire d'Etudes Spatiales et d'Instrumentation en Astrophysique, Observatoire de Paris, 92185, Meudon, France, [α]cedric.pilorget@ias.u-psud.fr

Introduction: The coupling between imaging and spectrometry has proved to be one of the most promising way to study remotely planetary objects [1][2]. The next step is to use this concept for *in situ* analyses. MicrOmega IR has been developed within this scope in the framework of the Exomars mission (Pasteur paylaod). A demonstrator will be embarked on the Phobos Grunt mission. It is an ultra miniaturized near-infrared hyperspectral microscope dedicated to *in situ* analyses, with the goal to characterize the composition of Phobos soil at almost its grain size scale, in a non destructive way. It will provide unique clues to trace back the history of Phobos, and will possibly contribute optimizing the selection of the samples to return to Earth.

Phobos origin: The origin of Phobos remains controversial. Its composition truly differs from that of Mars and appears like that of a primitive body [2]. This similarity led to the assumption that Phobos could be an asteroid captured by Mars. However, calculations seem to prove that this expectation is rather unlikely [3]. Phobos could also result from an impact on Mars, that could have led to the accretion of small martian satellites, with Phobos and Deimos the latest remnants, accreted close to the co-rotational orbit. The similarity with primitive bodies would come from the lack of sufficient energy to enable a further differentiation to take place. Other scenarios for Phobos formation and evolution are still considered.

MicrOmega should greaty contribute deciphering Phobos origin. Since surface samples should be representative of the bulk of Phobos [4], the presence (or not) of mafic minerals, altered products and carbon compounds in the samples will provide important clues to answer these questions.

Instrument concept: MicrOmega acquires reflectance spectra of 5 mm-sized samples with a spatial sampling of 20 µm. A monochromator, based on an AOTF (Acousto Optical Tuneable Filter), illuminates sequentially the sample in up to 500 contiguous wavelength channels (spectral sampling of ~ 20 cm^{-1}) covering the spectral range of interest (0.9 - 3.2 µm). For each channel, an image is acquired on a 2D detector, building a tridimensional (x,y,λ) image cube.

One of the most critical devices in the instrument is the monochromator. We use an AOTF illuminated through a beam condenser by a white source from a tungsten filament lamp. The light is partly diffracted inside the AOTF when powered at a given RF and, in a given direction, distinct from that of the non diffracted (white) light, a monochromatic light exits the crystal, imposed by the wavelength of the acoustic wave. The functioning of this component is based on the anisotropic Bragg diffraction [5] and thus requires no moving part: the tuning of the RF triggers that of the monochromatic light.

MicrOmega Phobos Grunt: MicrOmega IR is currently developed at IAS to be implemented on board the Phobos Grunt lander (launch in 2011). Its spectral range (0.9-3.2 µm) is chosen to identify mafic minerals, ferric oxides and hydrated phases. It should also be sufficient to detect some organic compounds. The samples will be collected and delivered to the instrument by a robotic arm. They will be released on a sapphire window, on top of the MicrOmega instrument. A Sofradir MCT detector with a spectral range from 0.9 to 3.2 µm and a 30 µm pitch has been chosen. To get a 20 µm spatial resolution, the imaging optics has a magnification of 1.5. Since the spectral range extends to 3.2 µm, the detector will be actively cooled down to about 110 K, by a dedicated cry-cooler, in order to limit the dark current. Another feature related to the upper limit of the spectral range is the sensitivity to the thermal flux. Since the entire instrument cannot be cooled down, the field of view of the detector must be reduced. A cold baffle, cooled by the cryo-cooler, is mounted within the detector module and an aperture stop, passively cooled down 250 K (through a dedicated thermal screen), has been added between the detector and the imaging optics (composed of a telecentric objective). In this way, the thermal flux is limited to an acceptable level.

Instrument capabilities: A breadboard fully representative of the instrument has been implemented at IAS [6] and has been used to test the different subsystems and the performances of the instrument. MicrOmega has the capability to distinguish different minerals within the same sample (Fig. 1).

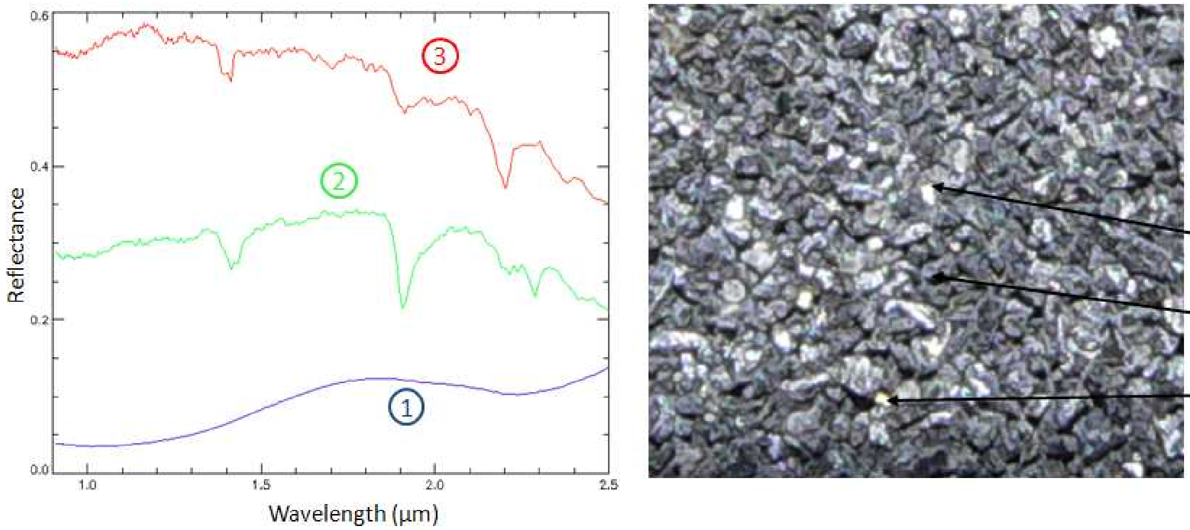

Fig. 1. *A sample made of pyroxene, kaolinite type clay and nontronite type clay, tested on MicrOmega breadboard. Blue: pyroxene spectrum (1) ; green: nontronite type clay spectrum (2) ; red: kaolinite type clay spectrum (3)*

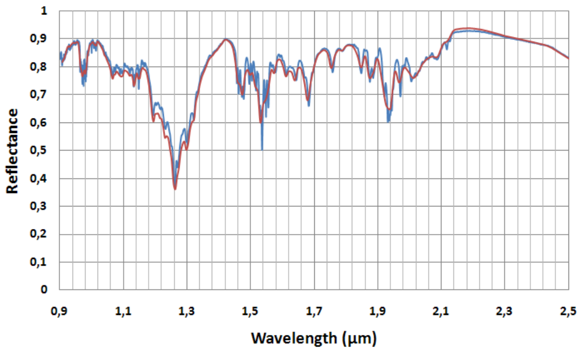

Fig. 2. *blue: Labsphere calibration standard spectrum acquired with a FTIR PerkinElmer spectrometer ; red: spectrum acquired with a representative breadboard of the MicrOmega instrument (each measure was acquired every 5 cm^{-1} with the FTIR spectrometer and every 37 cm^{-1} with the representative breadboard).*

We also acquired a spectrum of a reference sample (Labsphere calibration standard) with both a FTIR PerkinElmer spectrometer and the MicrOmega breadboard. Figure 2 shows that the spectrum is very well reproduced and that the spectral resolution of the instrument is sufficient to detect small typical spectral features, in each pixel.

Mars and beyond: After Phobos Grunt, MicrOmega will fly on the ESA ExoMars mission. Its spectral range will be extended to 3.5 µm in order to better detect and identify the possible organic compounds. Furthermore, the MicrOmega mapping capabilities will play a key role in the overall investigation protocole within the analytical laboratory. Samples will be first analyzed by MicrOmega, operating in a truly non destructive manner. The image-cubes will be processed onboard the rover to identify and locate areas of interest (e.g. with hydrated phases), to be further targeted by other instruments (such as the RAMAN spectrometer) with much smaller spots.. Algorithms are currently developed at IAS to perform this task.

References: [1] Bibring J.-P., et al. (2006), *Science*, 312, 400 – 404. [2] Murchie S. and Erard S. (1996), *Icarus*, 123, 63-86. [3] Szeto A. (1983), *Icarus*, 55, 133-168. [4] Langevin Y. (1988), *Phobos International Workshop on Phobos, Proceedings*. [5] Goutzoulis A.P. and Pape D.R. (1994), *Design and fabrication of acousto-optic devices*. Edited by Dekker Inc. [6]] Leroi V., Bibring J.-P. and Berthe M., (2009), *Planetary and Space Science*, Volume 57, Issues 8-9, 1068-1075