**WHAT ISM TOLD US ABOUT MARS.** S. Erard, *I.A.S., bât.121, 91405 Orsay campus, France.* Erard@ias.fr.

**Introduction.** ISM was the imaging spectrometer of the Phobos-2 mission, the first space-borne instrument of this type to return scientific data from the planets. The instrument was developed by IAS and DESPA in France, with support from CNES. Between January and March 1989, it returned ~80Mbit of data consisting mainly in 9 medium resolution (25km) and 2 high-resolution (7km) image cubes of Mars. All observations were performed in the equatorial regions, and span the 0.73-3.15 µm domain in 128 spectral channels. ISM also acquired one image cube of Phobos at 700m resolution, and various limb observations of Mars. Although the spectral resolution of ISM is comparable to that of previous ground-based observations, its angular resolution (12'x12') and signal-to-noise ratio (up to 1500) are much better than those of any other spectral measurement on Mars, and remain unchallenged in this spectral range.

The public release of the PDS-formatted data set is expected in 1999 (CNES Planetary data base). A preliminary version of the archive, including calibrated and derived data, has been widely distributed for several years directly by IAS. Information can be found at:

http://www.ias.fr/cdp/ISM/welcome.html

**Instrument principle.** The dispersive system is a grating, the first two orders of which are separated by a beam-splitter and focused onto two PbS arrays. Each array consists of two rows of 32 detectors, looking in directions that differ by ~23'. A complete spectrum is acquired at each time step. The image format of the data results from both the orbital motion of the spacecraft and the scanning motion of an entrance mirror. The integration time (ranging from 0.125 to 1 s) is selected to get a limited drift during acquisition, and depends mainly on spacecraft altitude. The number of pixels per line is then selected to get a one-pixel shift between two lines, and an analog gain is used to optimize the signal to noise ratio.

The limiting steps in the calibration process are the correction of spectral orders overlap (due to imperfect transmission of the bean-splitter), focal plane temperature variations, and transfer function. Channel-to-channel relative accuracy is comparable to that of the most accurate telescopic spectra, typically 3-5%. However, the real limit of data analysis is imposed by the signal to noise ratio, on the order of 0.3% in most of the spectral range (~3% above 2.8 µm).

**Atmospheric studies.** Gaseous absorptions were used 1) to study surface topography (using $CO_2$ bands), and 2) to study minor atmospheric species (CO, $H_2O$).

Topography was measured by fitting the profile of the 2.0 $CO_2$ band of ratioed spectra with a ratio a synthetic spectra computed with the semi-empirical band model of [1], the GEISA library, surface pressures and a temperature profile from Viking [2, 3]. The relative accuracy was estimated between 100 and 300 m, depending on altimetry. Therefore this method provides better results than stereophotogrammetry in regions with slow topographic variations (on the order of 1 km). The absolute accuracy however is limited to 700 to 2000 m. The data base contains a topographic map of all regions observed at a resolution of 0.3° in longitude and latitude. The largest difference with Viking topographic map is observed between the western and eastern sides of Olympus Mons (ISM altitudes differ by ~2 km, while Viking altitudes are similar). The discrepancy could result from the inherent cumulative error of the stereophotogrammetric method.

The most accurate results concerning $H_2O$ and CO distributions were published by [4]. The average water content is ~11 pr-µm, with diurnal and latitudinal variations globally consistent with Viking MAWD observations in 1976-79 [5]. The average value is larger than that observed by Viking (~8 pr-µm in similar conditions), but agrees with telescopic data of 1988 of [6]. Variations of water vapor with altitude show an excess of water vapor atop the volcanoes. Two mechanisms were proposed to explain the difference in water exchange between the volcanoes and the surrounding plateaus ([7] [8]): the first one implies a difference of adsorptive properties (clays on the volcanoes, basalt on the plateau); the second one relies on the difference of thermal properties (relatively low albedo and very low thermal inertia on the volcanoes, resulting in higher noon temperatures).

Studies of CO by [4, 7] showed an apparent inconsistency over the volcanoes between ISM observations and Earth-based estimates of the CO / $CO_2$ mixing ratio. If surface properties (composition, grain size…) are constant with altitude, CO may be constantly depleted above the volcanoes. A possible mechanism is related to CO trapping by aerosols: laboratory measurements by [9] suggest that CO mostly recombines on the airborne dust below an altitude that depends on the dust optical depth; this relationship would be complicated by the coupling between dust vertical distribution and surface elevation. Therefore heterogeneous processes could contribute to the CO depletion, that would be somehow correlated to concentrations of airborne dust. However, these measurements are sensitive to instrumental artifact, and higher spectral resolution measurements are required.

**Aerosols**. Spectra of aerosols were derived by [10] and [11]. The first attempt permitted to estimate particles distribution, and yielded an effective radius

$r_{eff}$ ~ 1.25 µm. This particle size is only half of that measured by Mariner 9 ($r_{eff}$ ~ 2.75 µm, [12]) and the distribution is twice as narrow ($v_{eff}$ = 0.25 versus 0.418), but this result agrees with those of Auguste, KRFM and Termoskan on board Phobos-2, although there seems to be a rather large uncertainty on the width of the distribution [13].

[11] applied the same model to areas that were observed twice under different viewing geometries. The scattering continuum derived agrees with that of [10] and with optical parameters derived from Viking IRTM (w ~0.9, g ~0.6, [14]). In addition, continuum-ratioed spectra allowed analysis of aerosols absorptions up to 2.5 µm. Most of them were ascribed to $H_2O$ ice, except a small absorption at 1.8 µm observed only in some hydrated clay minerals and in gypsum, but in no other usual Martian analog material. [11] also found that the vertical aerosols opacity is largely independent of surface elevation. This result is consistent with an observation of Olympus Mons by IRTM, showing an increasing dust-to-$CO_2$ mixing ratio above 10 km elevation ([14]). Such a vertical structure, consistent with that inferred from Viking by [15], could bear some relationship with the CO distribution discussed above, would CO recombination be catalyzed by airborne dust or ice crystals.

A major conclusion concerns the effect of aerosols scattering on observation of the surface. The contribution to the overall signal is very large (up to 25% of the reflected light at 1 µm, consistently with estimates from IRTM [14]), and deeply modifies the apparent surface absorptions (negative spectral slope, reduced contrast, and shift to longer wavelengths).

**Surface features.** The main signatures of surface materials have been discussed by [16]. Apart from albedo and spectral slope, they consist in hydration band at 2.7-3.15 µm and Fe-related absorptions at 0.8-1 and 2.2 µm. More subtle features have been identified in limited areas. The very high signal to noise and the imaging capacity make it possible to interpret spatial variations at the level of ~0.5%.

Variations in spectral slope have been studied extensively by [17], who ascribe them to ferric coatings of variable thickness in some areas (in particular on the flanks of Olympus Mons). The 3 µm $H_2O$ band depth was found to be highly correlated to reflectance. In bright regions, it corresponds to a weight fraction of ~2% water [18].

Bright region have characteristics of hydrated, poorly crystalline, iron oxides. Subtle local variations indicate that some bright materials are not remobilized and mixed. Most of these variations are ascribed to differences in particle size or degree of crystallization, but some small areas could have high concentrations of other alteration materials, phyllosilicates or sulfates [19].

Dark areas have been studied specifically by [20-22]. Fresh dark materials of various ages were interpreted as two pyroxenes basalts, with spectral characteristics close to the basaltic SNCs (Shergotty, Zagami…). This suggests that SNCs are relevant to large regions of Mars and large periods of time. In older areas, these materials have been interpreted as komatiites, warm and fluid lavas formed deep in the mantle [23].

Other, “anomalous”, materials are observed. In particular, an unusual material found in the layered deposits of Valles Marineris, with both mafic and hydration characteristics, suggests that hydrovolcanism was an important factor in the development of this area [24, 25]. A possible signature of carbonates was observed in Lunae Planum, an old dark area [26].

ISM data were also used to build composite spectra in the 0.4-5.7 µm domain, together with telescopic spectra and IRS observations of the same regions [27]. These composites are currently used in a spectral model of Mars to prepare future observations by OMEGA on-board Mars-Express.

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