

EFFECTS OF AEROSOLS SCATTERING ON SPECTRAL CHARACTERIZATION OF THE MARTIAN SURFACE Stéphane Erard *IAS - Planetologia, viale dell'Università 11, 00185 Roma, Italy.*

Introduction. Near-IR spectral observation has proven to be one of the most efficient ways to characterize the mineralogy of planetary surfaces. However, the main mineralogical absorptions have a typical depth of 1%, and in the case of Mars may be easily masked or subdued by light scattered by airborne particles. An estimate of this aerosols contribution to the light measured between 0.77 and 2.6 μm was previously derived from ISM imaging spectroscopic data acquired from the Phobos-2 spacecraft in 1989 [1] [2]. It makes it possible to investigate the effect of scattering on spectral parameters used to characterize the surface mineralogy.

Aerosols contribution. The Martian aerosols being very bright and strongly forward-scattering in the near-IR, the radiance factor can be approximated under low opacity as the sum of surface reflectance and aerosols backscattering [3]. This model made it possible to derive an estimate of the scattered spectrum, taking advantage of multiple observations of the same region (W of Pavonis Mons) under different viewing geometries [1]. The main hypothesis are: (a) the detected photons are scattered at most once in the atmosphere (b) the aerosols contribution is neglected above 2.6 μm (c) the photometric function of the surface is assumed independent of the wavelength (d) the difference between extinction and forward-scattering is supposed to be small compared to backscattering. The estimated spectrum is consistent with results of Phobos-2/Auguste data acquired in the same period (opacity at 1.9 μm $\tau \approx 0.23$, effective radius $\approx 1.2 \mu\text{m}$, effective variance ≈ 0.2 [4]) and contains weak features related to water-ice and hydrated phyllosilicates [1].

The image-cube covering Syrtis Major and Isidis Planitia ($400 \times 3000 \text{ km}^2$) was used to test the effect of scattering on the spectra. Statistical analysis of these 3000 spectra showed that the vertical opacity can be considered uniform on the whole region ($\tau \approx 0.17$ at 1.9 μm), with no altimetric dependence. This correction is probably overestimated on the darkest areas.

Surface properties. The main six spectral parameters related to the surface materials are: the reflectance at 1.09 μm ; the spectral slope estimated here as the derivative between 1.84 and 2.35 μm ; the strength of the 2 μm -pyroxenes band; a measurement of the depth of the 0.88 μm -ferric oxides band; the surface of the Fe^{2+} band, integrated from 0.86 μm to 1.09 μm . They were computed for the whole image-cube on calibrated spectra and on spectra corrected from scattering (estimate of the surface alone); their values are given in Table 1. The last three parameters were also used to establish a classification of the calibrated spectra [5]; the main spectral types are given in Fig. 1a. The spectra of the same pixels were averaged after subtraction of the aerosols contribution, and are given in Fig. 1b.

Discussion. The level of the scattered spectrum below 2 μm ranges from 0.02 to 0.05, which represents 5 to 15% of the albedo of the bright areas, and 15 to 30 % of that of the dark regions. This large contribution of scattering is similar to those inferred from IRTM observations for "clear atmosphere" [6] and from independent ISM analysis [7]. The negative spectral slope often ascribed to dark materials appears to be largely due to the aerosols scattering continuum, although intrinsic variations are recognized on the data, for example between the eastern and western parts of Syrtis Major (even enhanced by the correction in this case; see Fig. 1).

Although they are slightly subdued and shifted to longer wavelengths, the Fe^{3+} and 2 μm -pyroxene bands do not appear very sensitive to the addition of a low-opacity scattered component: their spatial distribution and relative contrast aren't deeply modified. Conversely, the Fe^{2+} band area is reduced by almost a factor of two, although the transformation is almost a linear stretch of

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the scale. This reduction may help explaining why the $1\ \mu\text{m}$ -mafic feature is not always observed from the ground.

In the estimated surface spectra (Fig. 1b) the center of the $1\ \mu\text{m}$ band is systematically shifted by some tens of nanometers towards the short wavelengths with respect to the measured spectra. This method also results in band centers located at shorter wavelength than a simpler but less physical correction (division by a linear continuum fitted on the data [8]). However, this latter shift isn't large enough to change dramatically the mineralogical interpretation of the surface: the absorptions are still compatible with hematite on bright regions (center at $0.86\ \mu\text{m}$) and with calcic pyroxenes in Syrtis Major (center at $0.94\ \mu\text{m}$), though probably less rich in Ca than previously inferred from ISM ($\text{Ca}/(\text{Fe}+\text{Ca}+\text{Mg})\approx 0.20\pm 0.08$ instead of 0.275 ± 0.075 [8]). Very calcic pyroxenes may have their bands shifted up to $1.05\ \mu\text{m}$ by the addition of the scattered component, and could have been mistaken for olivine in early spectral data of Mars ranging only up to $1.1\ \mu\text{m}$.

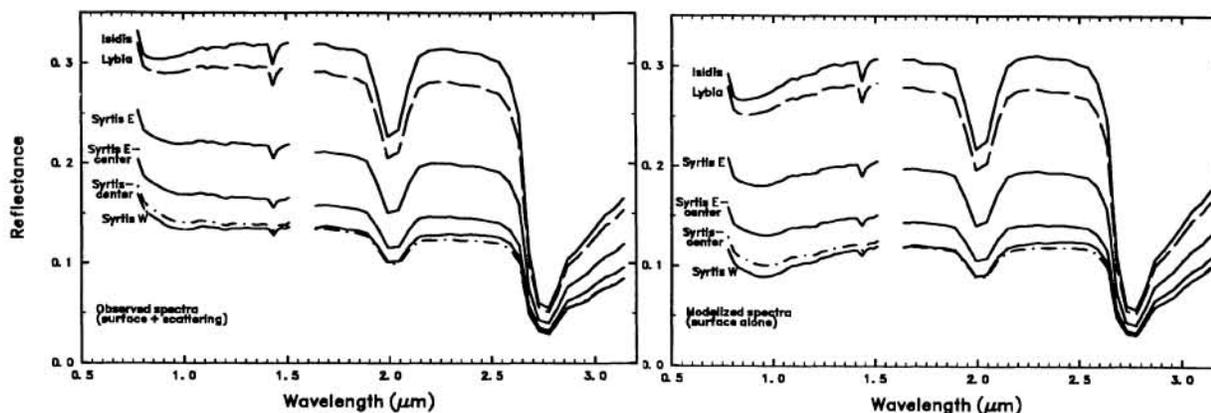


Figure 1. Average spectra of the six main spectral units in the Syrtis Major-Isidis Planitia image-cube: (a) calibrated spectra; (b) after removal of the estimated scattering.

Table 1: Range of variation of the spectral criteria in the Syrtis-Isidis image-cube.

	Surface + scattering (measured)			Surface alone (modeled)		
	min	max	Range/rms noise	min	max	Range/rms noise
Reflectance at $1.09\ \mu\text{m}$	0.115	0.33	1200	0.08	0.30	1200
Spectral slope refl. units/ μm)	-0.025	0.0002	35	-0.010	0.020	30
$2\ \mu\text{m}$ pyroxenes (band depth)	0.97	1.00	20	0.98	1.01	20
$0.9\ \mu\text{m}$ Fe^{3+} (band depth)	0.965	1.055	50	0.955	1.055	60
$1\ \mu\text{m}$ Fe^{2+} (band area)	0.0	0.40	85	0.0	0.70	150

References : [1] Erard *et al.*, *Lunar Planet. Sc. XXIV*, 445, 1993. [2] Erard *et al.*, *Icarus*, 1994, submitted. [3] Drossart *et al.*, *Annal. Geophys.* 9, 754, 1991. [4] Korablev *et al.*, *Icarus* 102, 76, 1993. [5] Erard *et al.*, *Lunar Planet. Sc. XXIV*, 443, 1993. [6] Clancy and Lee, *Icarus* 93, 135, 1991. [7] Erard *et al.*, *Lunar Planet. Sc. XXIII*, 335, 1992. [8] Mustard *et al.*, *J. Geophys. Res.* 98, 3387, 1993.