Composite spectra of Mars, 0.4-3.7 μm.

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Background and abstract. Spectroscopic measurements of Mars are key observations to identify both ferric/ferrous minerals (from the 0.8-1.2 μm range) and alteration minerals (from the 2.2-5 μm range) present on the surface. The first space borne instrument to span this complete spectral range will be OMEGA/Mars 96, scheduled for July, 1997. However, IRS/Mariner in 1969 and ISM/Phobos-2 in 1989 performed observations of quality that partially cover the spectral range. This first comparison between the two data sets is intended to assess ISM calibration's accuracy at longer wavelengths, to check the permanency of shallow spectral features, and to look for possible differences in areas observed by the two instruments.

Data used, uncertainties. Data in the 1.9-3.7 μm range are from the short wavelength IR segment of IRS on Mariner 7. Spectral information is acquired in sequence while the spacecraft is moving, with a spectral resolution of ~1.5%; the corresponding footprint is ~200x15 km^2. The relative uncertainty is limited by instrumental noise (0.5-10% depending on spectral reflectance); a spectral calibration uncertainty of up to 2% remains in spectra used here (see [1] for details). Observations were performed at large incidence, emergence and phase angles (~50°). Absolute calibration of these data is not available.

The spectral range 0.77-3.14 μm was spanned by ISM on-board Phobos-2. 64 among 128 channels are used to preserve accuracy, yielding a spectral resolution of ~5%; those measurements are acquired at once and correspond to a given area on the surface of ~20x20 km^2. Observations used here are performed at relatively large incidence and emergence angles (i, e ~35°) and small phase angle (<5°). Up to 2.7 μm, data are calibrated using telescopic observations by [2]; both telescopic and ISM spectra used for calibration are taken in areas different from that studied here (see [3] for details on calibration). Absolute uncertainty (*i.e.*, on the average reflectance) is about 15%; relative uncertainty (*i.e.*, on channel ratios) is determined by reference spectra rather than by signal-to-noise, and is of the order of 3%. Above 2.7 μm, calibration relies on both ground-based measurements and a spectral model for Phobos; uncertainty is thus larger, on the order of 10-20%.

Regions of overlap. IRS and ISM observations overlap in two areas: first from Lunae Planum to Margaritifer Sinus, through Aurorae Planum and Capri-Eos chasmata; second, in southern Arabia Terra. Composite spectra of bright and darker materials observed in this latter area are presented here. Registration of both data sets is on the order of 0.5° on the surface. IRS footprints are located in homogeneous areas, which insures that spectra essentially correspond to a single type of material. Unfortunately these spectra were not fully calibrated in previous studies of the data set, and a relative uncertainty of several percents remains above to 2.7 μm.

Composite spectra. The bright area observed by IRS falls a little north of ISM's Arabia image cube; thirty ISM pixels covered by IRS footprint were averaged, then IRS was scaled to ISM level at 2.45 μm. Another area observed by IRS in this image cube corresponds to a darker surface in ISM image cube, although not to the darkest type on Mars. Furthermore, this region exhibit different albedo patterns in Viking maps and the ISM image, and the area may actually have been covered by brighter material at the time of IRS observations. ISM spectra in a similar, nearby, area were previously integrated with telescopic observations from 0.4 to 1.1 μm in Oxia Palus [4]; the same data are plotted here, scaled to ISM reflectance at 0.9 μm, to complete the composite spectrum of dark areas.

Results. While reflectance calibration of both data sets is completely independent, the spectra appear in very good agreement in the range of overlap: they are nearly identical in the atmospheric continuum from 2.2 to 2.7 μm; inflexions at 2.4 and 2.52 μm in particular are similar. Another inflexion at 2.95 μm visible in IRS spectra is found also in ISM data. The main differences consist in 1) deeper atmospheric bands at 1.9-2.15 μm and 2.65-2.85 μm for IRS, related to larger observations angles (the difference in band profiles is related to spectral resolution). 2) a substantially larger reflectance level in the hydration band above 2.8 μm in ISM spectra. 3) a narrow CO_2 atmospheric feature at 2.15 μm present in IRS spectra, not resolved by ISM. Instrumental artifacts are: the feature at 3.4 μm (absorption in IRS filter); the shape of ISM spectra at the very end of the spectral range (the last two channels are noisy).

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Interpretation. The main discrepancy, that concerns the reflectance level in the hydration band, can be ascribed mainly to the difference in phase angles: spectral contrast is usually increased at large phase angles, because larger multiple scattering occurs in the continuum, and results in more isotropic phase functions. However, a systematic error in ISM calibration (relying in this domain on ground-based calibrations) and a possible attenuation by IRS's CVF at high wavelengths could also account for a part of this difference. The feature in the 2.3-2.45 µm domain has been ascribed both an atmospheric [5] and a surface origin [6] [1]; the similarity of profiles in the composite bright spectrum is a validation of ISM calibration at long wavelengths. The presence of this feature in the IRS component of the darker spectrum may be an indication that superficial deposits have actually shifted during the 20-years period; in this case, the high-wavelength range would correspond to bright material, while the telescopic-ISM range would represent terrains of intermediate albedo.

Conclusion. This first comparison between IRS and ISM spectra demonstrates a remarkable consistency between two data sets acquired at 20 years of difference, and calibrated independently. The similarity in bright areas demonstrates the accuracy of ISM calibration above 2.2 µm, like [4] demonstrated at shorter wavelength. Future works will focus on 1) extending this comparison to other areas of data overlap so as to encompass a larger range of reflectance/composition variation on Mars, and 2) integrating the long wavelength segment of IRS as well, so as to correlate 1 µm-iron features and possible hydrous carbonates features at 5.4 µm. Such composite spectra would be interesting simulations of Martian observations by OMEGA on board Mars-96.

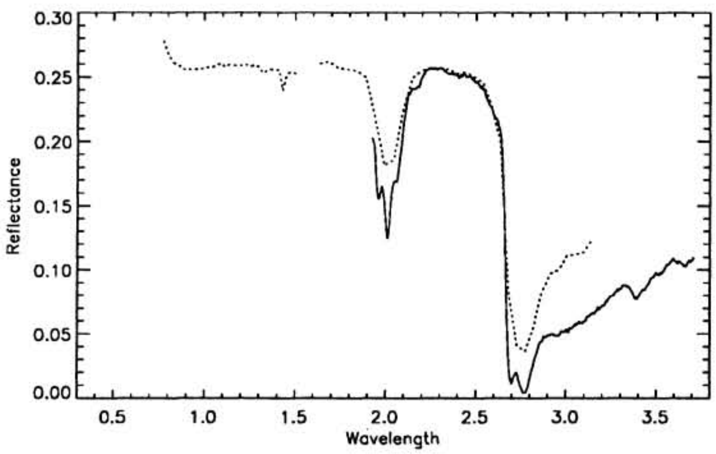
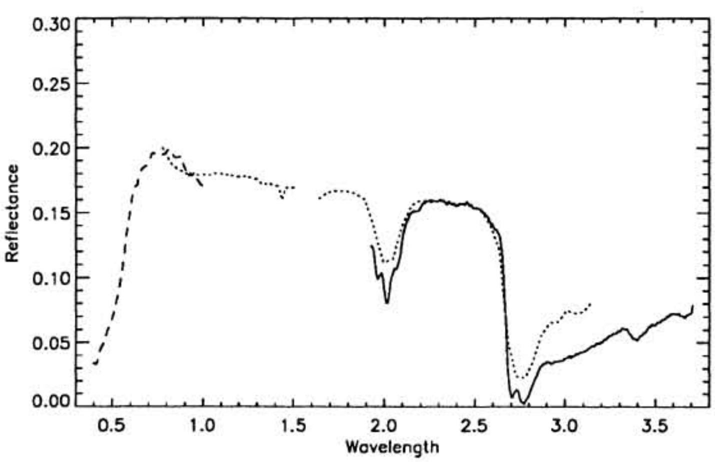


Fig. 1: Composite spectra in Arabia Terra from ISM data and IRS/Mariner-7 spectra 94 and 98 (up: bright material; bottom: material of intermediate albedo). The visible data are from [4], acquired during the 1988 opposition.



References:
[1] Calvin *et al.*, *J.G.R.* 99, 14659-14675 (1994)
[2] McCord *et al.*, *J.G.R.* 87, 3021-3032 (1982)
[3] Erard *et al.*, *Icarus* 111, 317-337 (1994)
[4] Mustard and Bell, *G.R.L.* 21, 353-356 (1994)
[5] Encrenaz and Lellouch, *J.G.R.* 95, 14589-14594 (1990)
[6] Singer, *Adv. Space Res.* 5, 8/59-8/68 (1985)