1969 MARINER MARS INFRARED SPECTROMETER: LESSONS FOR FUTURE EXPLORATION.

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Introduction: Spectra returned by the 1969 Mariner Mars Infrared Spectrometer (IRS, 1.8 - 14.2 µm) have been used in a range of studies of the surface composition of Mars. IRS measured a wide spectral range with good spectral resolution and excellent signal to noise ratio (SNR). Table 1 lists spacecraft spectrometers that have returned spectra of Mars.

IRS results, as well as a comparison of IRS, the 1971 IRIS, 1989 ISM, and 1997 TES spectra show that an unambiguous examination of the surface mineralogy of Mars requires: (*1*) high spectral resolution (~2-5 cm^{-1} in the thermal region, and ~10-20 cm^{-1} in NIR); (*2*) high SNR (>600); and (*3*) continuous spectra measured of the VIS-NIR, overtone, and fundamental regions. Radiometer measurements, such as those provided by Viking IRTM and the proposed 2001 THEMIS, can be used to map spectral type regions. However, fully utilizing a radiometer data set will require complementary high quality spectra for an unambiguous examination of the minerals present.

Instrument: IRS used two circular variable interference filters with ~1% resolution to scan continuously two channels, from 1.8 to 6.0 µm and 3.7 to 14.2 µm [1]. Each spectrum contains approximately 1340 discrete measurements, scanned every ten seconds.

Continuous spectrum: Huguenin [2] noted that the assignment of a single band is frequently ambiguous, while the assignment of a suite of bands is generally not. Continuous spectra such as those recorded by IRS allow an examination of more than one spectral region and feature, and so the least ambiguous study of surface mineralogy.

Spectral range: The infrared spectrum can be divided into three approximate ranges that exhibit distinct behavior: *VIS-NIR*, (0.4 - ~3 µm); *overtone*, (~3-7 µm); and *fundamental*, (~7-50 µm). Each region contains complementary information. The information content of a spectrum increases significantly when it covers more than one spectral range.

VIS-NIR region. This region measures mainly reflected light (0.4 - 3 µm). It is simpler to use for quantitative measurements of mineral abundance, and atmospheric corrections are also simpler than for thermal wavelengths. IRS shows that this range can be combined with thermal wavelengths to provide more information on the surface than either wavelength range alone [3].

Overtone region. This region (~3 - 7 µm) is particularly important for studies of Mars because finely-particulate minerals, such as those predicted to occur on Mars, commonly have strong, diagnostic overtone features, but very weak fundamental features (which occur at longer wavelengths) [4]. This region is analogous to the hydrogen-oxygen overtone region at shorter wavelengths.

IRS spectra provide unique, high quality coverage of 3 to 7 µm, and they show this region is relatively uncomplicated by aerosol dust features. For thermal infrared studies of Mars, the aerosol dust greatly complicates an investigation of the fundamental regions, especially ~8-13 µm, where the aerosol has a particularly strong band. However, in the overtone region, silicates lack strong transmission features. This simplifies any study of this spectral region, and increases confidence in the results. The composition and particle sizes present can be better constrained using a combination of the overtone and other spectral regions than it can using only one region.

Fundamental region. Finely particulate materials such as those predicted to be present on Mars commonly have very weak fundamental features (~7-50 µm). Fundamental bands generally become weaker as particle size decreases, while overtone bands become stronger [4]. The fundamental region is most suitable for examining the mineralogy of larger particle sizes, while the overtone region is better for finely particulate materials.

Spectral resolution: Atmospheric constituents interfere with measurements of the surface spectrum, but the interference decreases with increasing spectral resolution. Measurements with higher spectral resolution contain additional detail that allow the best separation of atmospheric and surface absorptions, and the most accurate definition of band shape, center, and width (Figure 1). Figure 1 shows that the 12.6 µm (790 cm^{-1}) atmospheric CO_2 band broadens and distorts spectra with decreasing spectral resolution. As a second example, an examination of TES spectra in the 18-23 µm region requires an atmosphere removal [5], while IRIS spectra can be examined more directly.

A correction can be applied to reduce the distortion of surface features by atmospheric bands, but such corrections are never perfect. The accuracy and reliability of the correction decreases with decreasing spectral resolution, and it is especially difficult to apply to data returned by a radiometer. An atmosphere removal complicates the data processing; makes it more costly to perform; makes it take longer to obtain results; limits the accuracy and acceptance of the results; and it limits the number of researchers who have the time and resources to utilize the spectra. The most timely and accurate results are obtained with spectral resolution high enough to measure points that “see between” the atmospheric gas features, and thus have minimal interference from atmospheric gases. This allows a more direct fingerprinting of the mineral present.

Signal to noise ratio: Spectra should have sufficient SNR so features present in a single spectrum can be trusted. The alternative is averaging the spectra, but this decreases their spectral or spatial resolution. For example, IRS spectra remain of great value because of their high SNR, especially for <7 µm. TES has lower SNR, and struggles at the shorter wavelengths. IRIS has the lowest SNR, and usually requires some form of averaging even for day measurements. The 2001 THEMIS should have a SNR comparable to IRIS [6].

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Table 1: Spacecraft spectrometer parameters.

	1989 ISM[f]	1969 IRS	1971 IRIS[b]	1997 TES[c]	2001 THEMIS[k]
wavelength range (µm)	0.77 - 3.1	1.8 - 14.4	5 - 50	~6 - 50	6.5-15.5
spectral resolution at 10 cm^{-1}	–	10 cm^{-1} (1%)	[h]1.2 cm^{-1} (0.12%)	[h]10 or 20 cm^{-1} (1 or 2%)	
optical path difference (cm)	–	–	0.85	0.1 or 0.05	–
measurements per spectrum	64	1340	1500[g]	143	9
approx. measurements per resolution element	2	5	2	2	
spatial resolution (km)	25	130-500[b]	125-1000	3[d]	0.1
SNR (2.2 µm)[a]	400	190	–	–	–
SNR (6 µm)[a]	–	340	18[e]	low	
SNR (10 µm)[a]	–	600	100	400	
SNR (25 µm)[a]	–	–	400	good	–

[a]Value is rms at 270K (thermal), or for a typical bright region (NIR). [b][7]. [c]TES also has one thermal and one reflectance broadband channel [8]. [d]From mapping orbit of 350 km. [e]IRIS SNR from [9]. [f][10]. [g]IRIS measured interferograms with 4096 points [7], but these have been lost; what remains are spectra with 1500 points per spectrum. [h]IRIS and TES values are unapodized, both calculated as 1/optical path difference. [k][6].

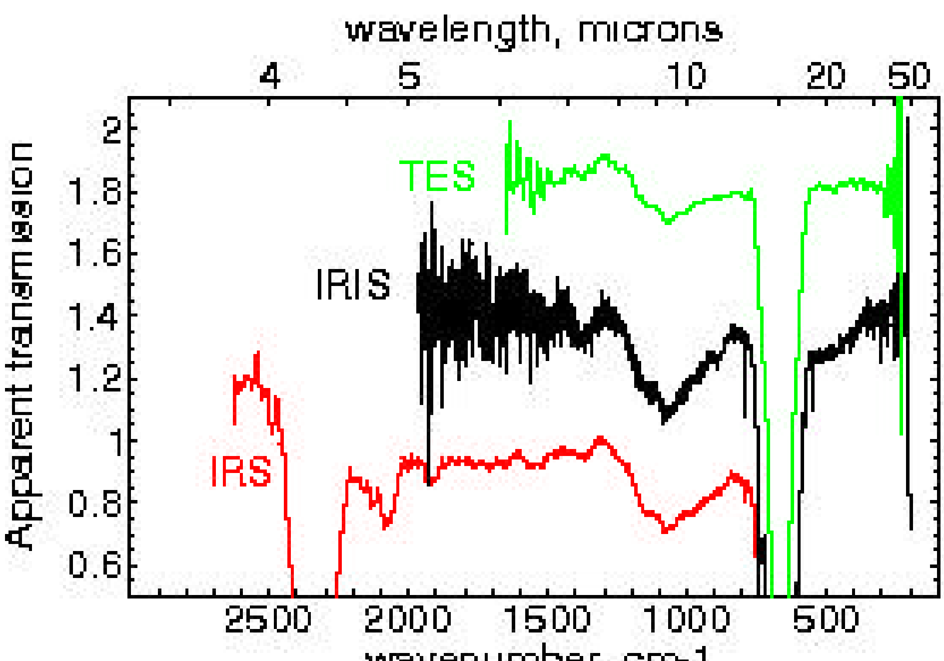

Figure 1: Comparison of typical IRS, IRIS, and TES spectra. IRS has the highest signal-to-noise ratio, especially at the shorter wavelengths. IRIS has the highest spectral resolution, which can be seen here by the sharp atmospheric lines present in IRIS spectra. For example, note the difference in appearance of the CO_2 gas feature at 12.6 µm (790 cm^{-1}) between the different data sets. IRS also measures to 1.8 µm (5500 cm^{-1}), but the spectra are not yet calibrated. TES measures with the highest spatial resolution.