Comparison of Thermal Infrared Spectral Data Sets of Mars: 1969 IRS, 1971 IRIS, and 1996 TES.

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Summary. Three spacecraft spectrometers have returned spectra of Mars of the thermal emission wavelength regions: the 1969 Mariner 7 IRS, (1.9-14.4 µm); the 1971 Mariner 9 Infrared Interferometer Spectrometer (IRIS, 5-50 µm); and the Global Surveyor Thermal Emission Spectrometer (TES, 6-50 µm). Each instrument measured spectra with different characteristics, so each data set provides complementary information that can be used to examine the composition of the aerosol dust and surface materials. Any interpretation produced using TES spectra should be consistent with spectral information provided by IRS and IRIS.

Here we discuss the strengths of the different data sets, lessons learned and how they should be applied to future spectral instruments, and we will present newly recovered IRS long path cell laboratory spectra.

Data sets. IRS measured with the highest signal-to-noise ratio (SNR) at the shorter wavelengths, and includes unique coverage of the informative overtone spectral region from ~3-7 µm (Figs. 1,2). IRIS measured with the highest spectral resolution, which allows the best separation of surface and atmospheric features, and the best definition of band shape. TES measures with the highest spatial resolution, which allows the most detailed mapping of spectral types. Table 1 gives instrument parameters.

IRS long path cell spectra. We recently recovered IRS spectra of Mars that measured from 3.7-14.2 µm from the original data tapes, calibrated, and released them to the community [1]. We are now recovering laboratory spectra recorded of gases and minerals under the original IRS investigation, and these will also be freely released to the community.

To examine the surface mineralogy of Mars, the signature of the atmospheric features must be separated from the surface features. This separation is a problem for any infrared data set of Mars, and unique long path length gas measurements made by IRS may help resolve this problem.

The spare flight IRS, Flight C, measured gas samples using a one-of-a-kind, temperature controlled long path cell, with path lengths up to 2540 meters (Fig. 3) [2]. The long path length is necessary to permit measurement of gas spectra at the low pressures typical of Mars. Gases measured include CO_2, CO, CH_4, NO_2, N_2O, OCS, O_3, and NH_3. The temperature controlled cell was used with Flight C to record spectra of gases at the ambient temperature and pressure of Mars, thus producing the most accurate characterization of Martian atmospheric absorptions. These spectra remain unique, and they may be used to verify modeling of predicted atmospheric absorptions under Martian conditions. They may also be used directly with IRS to detect and remove the signature of atmospheric gases.

References: [1] Forney P. B. and Kirkland L. E. (1997) *LPSC XXVIII*, 373-374. Kirkland L. E. et al. (1999) *LPSC XXX, abs. 1693*. [2] Horn D. and Pimentel G. (1971) *App. Op. 10*, 1892-1898. Horn et al. (1972), *Icarus 16*, 543-556. McAfee J. M (1974) *thesis*, Interpretation of the infrared spectra of the Martian atmosphere obtained by the Mariner 6 and 7 Infrared Spectrometers.

Table 1: Instrument characteristics.

	1969 IRS	1971 IRIS[d]	1996 TES[c]
wavelength range (µm)	1.8 - 14.4	5 - 50	~6 - 50
spectral resolution at 10 µm	10 cm^{-1} (1%)	[e]1.2 cm^{-1} (0.12%)	[e]10 or 20 cm^{-1} (1 or 2%)
measurements per spectrum	1340	1500[f]	143
spatial resolution (km)	130-500[c]	125-1000	3
SNR at 2.2 µm[a]	190	–	–
SNR at 6 µm[a]	253	18[g]	33
SNR at 10 µm[a]	711	100	345
SNR at 25 µm[a]	–	400	388

SNR = signal-to noise ratio. [a]Values are rms at 270K (thermal), or for a typical bright region. [c][*Christensen et al.*, 1992]. [d][*Hanel et al.*, 1972a, b]. [e]IRIS and TES values are unapodized, calculated as 1/optical path difference. [f]IRIS measured interferograms with 4096 points [*Hanel et al.*, 1972a, b], but these have been lost; what remains are spectra with 1500 points/spectrum. [g]*Roush et al*. [1993].

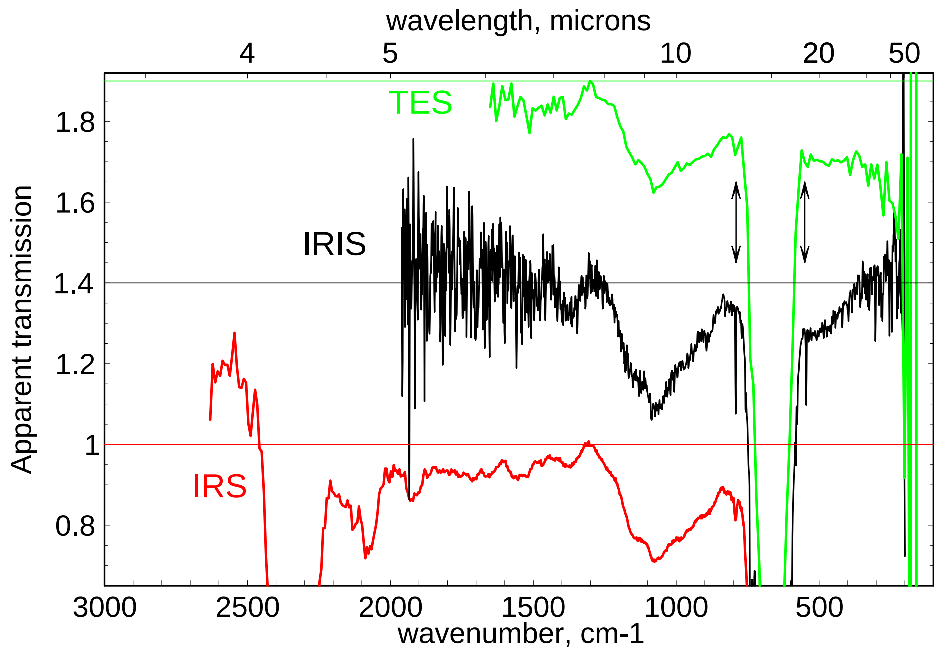

Figure 1: Typical IRS, IRIS, and TES spectra. IRS has the highest signal to noise ratio at the shorter wavelengths. TES measures with the highest spatial resolution. IRIS has the highest spectral resolution, seen here by the sharp atmospheric lines. For example, note the difference in appearance of the sharp CO_2 gas feature at 12.6 µm (790 cm^{-1}) and 18.2 µm (550 cm^{-1}) between the different data sets (marked with reference arrows). However, noise causes most of the 1971 IRIS spectral detail at the shortest wavelengths. The 1969 IRS also measures to 1.8 µm (5500 cm^{-1}), but the spectra are not yet calibrated. The conversion to apparent transmission used here accounts only for the emitted energy, so reflected light causes the increasing values in IRS spectra at wavenumbers greater than ~2500. TES offset +0.9 and IRIS +0.4 for clarity. More information is at: http://www.lpi.usra.edu/science/kirkland/

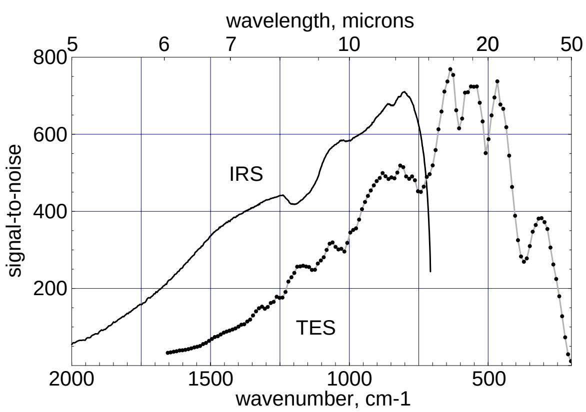

Figure 2: SNR for IRS and TES. Shown are the signal to noise ratio values for IRS (line) and TES (points) when measuring a blackbody at 270K. Higher values represent higher quality. Detector response and the Planck radiance signal cause the broad shape of the two curves, while instrument absorptions cause the finer detail. This noise calculation uses individual deep space spectra, which are not available for IRIS. However, its response should be broadly similar to TES, but offset so that the SNR is ~100 at 1000 cm^{-1}.

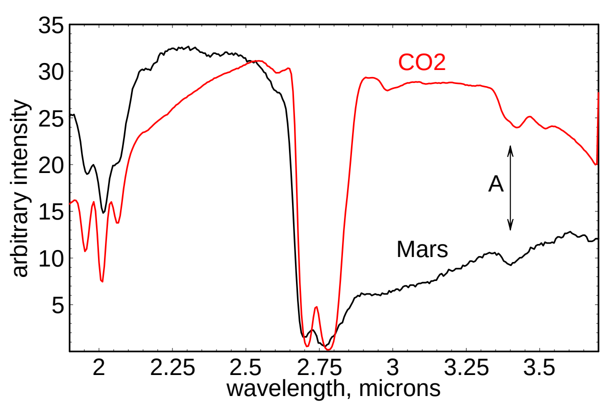

Figure 3: Long path cell spectra. The red trace shows long path cell spectrum #72801, CO_2 gas at 200K measured by the spare flight IRS. The black trace shows a typical spectrum of Mars (IRS7-92). Both are in arbitrary intensity units (instrument response unremoved). The long path length and temperature control permitted spectra to be recorded of gases under a range of simulated Martian conditions. These unique spectra may be used to help detect and compensate for atmospheric bands in spectra recorded of Mars. Arrow "A" marks an instrumental absorption.