UTILIZING NIGHT SPECTRA OF MARS FOR MINERALOGY.

L. E. Kirkland[1], K. C. Herr[2], and J. M. McAfee[3] [1]Lunar and Planetary Institute, Houston, TX, <kirkland@lpi.jsc.nasa.gov>; [2]The Aerospace Corp., El Segundo, [3]CA; Los Alamos Nat'l Lab, NM.

Summary. Thermal infrared spectra measured of the night side of Mars have advantages over day measurements for examining the aerosol dust mineralogy because they contain fewer atmospheric gas and surface features. Despite the advantages night spectra offer, they have rarely been utilized because the methodology to convert them to transmission was poorly understood. Here we present a method for converting night and day spectra to apparent transmission. We also discuss the advantage for mineralogical studies of apparent transmission vs. apparent emissivity.

Background. In 1969, IRS returned high quality spectra of Mars covering the wavelength region 1.8 - 14.4 µm. These spectra have recently been recovered from the original data tapes and calibrated from 5 - 14.4 µm with heavy involvement from members of the original IRS team [1, 2, 3]. We use these spectra here because IRS has the high signal-to-noise ratio needed for night measurements.

Previous aerosol studies. Previous studies have used only day spectra from IRS or 1971 Mariner IRIS to examine the composition of the aerosol dust. These studies presented a wide variety of results, concluding that the aerosol dust consists mainly of an oxidized tholeiitic basalt [4]; rock of intermediate [5] or felsic composition [6]; montmorillonite [7]; a mixture of basalt and clay [8]; or palagonite [9].

All those studies concluded that the aerosol consists of particles < 10 µm in size. Widely separated particles this small behave in a manner similar to a gas [10, 11, 12], so their transmission (τ) and emission (ε) spectra have the same shape, although bands that appear as transmission troughs appear as emission peaks ($\tau = 1 - \varepsilon$).

Night spectra advantages. Night measurements contain less contribution from atmospheric gases and the surface, which allows a more direct examination of the aerosol signature. Night spectra have received less attention mainly because it was not clear how to convert them from radiance to transmission.

Since the atmosphere is so cold at night, night spectra contain very little contribution from atmospheric hot bands (which are from transitions from an excited state rather than the ground state). The population of higher energy states decreases exponentially with temperature (Boltzmann distribution), so the intensity of a hot band decreases rapidly with decreasing temperature.

Apparent transmission. Mineralogical studies using thermal infrared spectra of Mars typically use spectra converted from radiance to apparent emissivity (ε_A) [10]. However, ε_A spectra have two undesirable artifacts:

1. The spectral contrast depends on the background temperature for both day and night spectra, even though a true measure of transmission does not have this dependence.
2. Restrahlen bands in night ε_A spectra have an emissivity greater than 1, which is clearly incorrect.

Apparent emissivity is calculated by dividing the spectrum measured of Mars by the Planck radiance curve at the surface temperature, taken as the brightness temperature (T_B) at 7.75 µm. Figs. 1 and 2 show typical day and night IRS spectra, with the surface 7.75 µm T_B curve shown as a solid line.

Day measurements are dominated by atmospheric transmission and surface emission features, which have restrahlen bands (e.g. the 9 µm band) that appear as troughs relative to the surface 7.75 µm T_B Planck curve (fig. 1).

However, night spectra have restrahlen bands that appear as peaks relative to the surface 7.75 µm T_B Planck curve (fig. 2). Thus night ε_A spectra appear "upside down" relative to day spectra, and have $\varepsilon_A > 1$. This is because single particle re-emission features dominate night spectra, so restrahlen bands appear as peaks rather than troughs. An apparent emissivity calculation fails glaringly in this case because it does not account for the re-emission of the dust. Since the process involved is highly non-linear, the problem cannot be fixed simply by inverting the night ε_A spectra.

To address this problem, we use a method similar to [13] to convert the spectra from radiance to apparent transmission (τ_A):

$$\tau_A = \frac{\mathrm{Mars} - \mathrm{aerosol}_{BB}}{\mathrm{background}_{BB} - \mathrm{aerosol}_{BB}}$$

and

$$\tau_{A_0} = 1 - \left\{ (1-\tau) \times \log_{10}\left[10 \times \cos\Theta \right] \right\}$$

where $\tau_{A0} = \tau_A$ normalized for atmospheric path length; Mars = radiance spectrum measured of Mars; $\mathrm{aerosol}_{BB}$ = Planck radiance curve at the temperature of the aerosol dust; source_{BB} = Planck radiance curve at the temperature of the surface; Θ = emission angle.

The log term in the τ_{A0} equation accounts for absorptions adding logametrically rather than linearly (Beer's Law). The surface temperature is taken as the brightness temperature at 7.75 µm. The aerosol temperature is derived iteratively, and incorporates the brightness temperature from spectra measured at the terminator, where the flat spectral shape indicates the aerosol and surface temperatures are equal.

Discussion. The conversion to τ_A produces a more accurate spectral shape because it accounts for the re-emission of the aerosol, thus allowing a more accurate comparison to laboratory spectra for mineralogical studies of the aerosol. It also provides a method to utilize night spectra for mineralogical work. However, it assumes the emissivity of the surface is 1, so it does not work well where there are strong surface emissivity features. Nonetheless, it works well for Mars, because transmission features dominate over the very subtle surface features. It is especially suited to night measurements, which have even less contribution from the surface.

References: [1] Forney P. B. and L. E. Kirkland, (1997) *LPSC XXVIII*, 373. [2] Kirkland *et al*. (1998) *XXIX*, abs.1516. [3]Kirkland *et al*. (1999) *XXX*, abs.1693. [4] Herr K. C. *et al*. (1971) *BASS 3*, 466. [5] Hanel R. *et al.*, (1972) *Icarus 17*, 423. [6] Aronsen J. R. and A. G. Emslie (1975) *JGR 80*, 4925. [7] Hunt G. *et al*. (1973) *Icarus 18*, 459. [8] Toon O. B. *et al*. (1977) *Icarus 30*, 663. [9] Clancy *et al*. (1995) *JGR 100*, 5251. [10] Conel J. (1969) *JGR 74*, 1614. [11] Hunt G. R. and L. M Logan (1972) *Appl. Optics 11*, 142. [12] Logan *et al*. (1973) *JGR 78*, 4983. [13] Polak M. et al. (1995) *Ap. Opt. 34*, 5406.

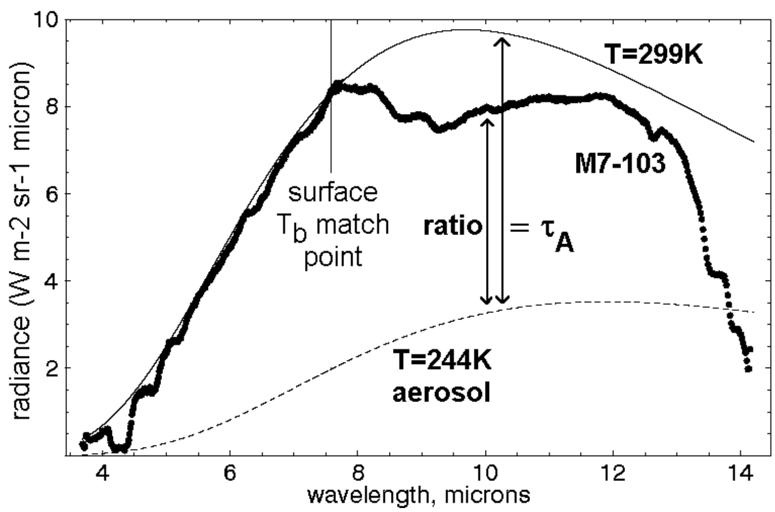

Fig. 1: Conversion of day spectrum to apparent transmission. This shows a typical IRS spectrum measured of Mars during the day. To convert to apparent transmission, the spectrum is referenced to both the Planck blackbody curve of the background (solid line) and the zero reference line (dashed line). The background is the surface, which is assumed to behave as a perfect blackbody with an emissivity of 1. The zero reference line is set at the assumed temperature of the aerosol, and is value that would be seen if the transmission of the aerosol is zero.

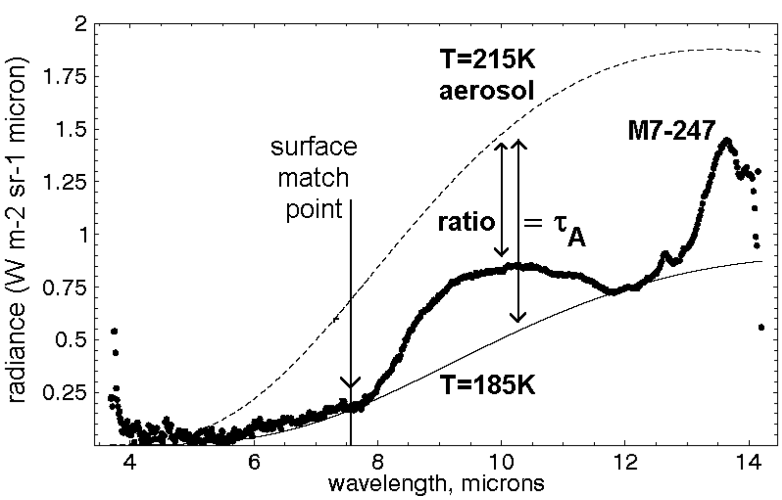

Fig. 2: Conversion of night spectrum to apparent transmission. This shows a typical IRS spectrum measured of Mars at night. The spectrum is converted to apparent transmission as described above. However, in night spectra, the background (surface, solid line) is colder than the zero reference line (dashed). The zero reference line gives the value that would be seen if the aerosol transmission is zero.