THERMAL REMOVAL FROM MOON MINERALOGY MAPPER (M^3) DATA.

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Introduction: Near-infrared spectra of the Moon contain a mixture of reflected sunlight and thermal emission caused by heating of the surface from the sun at wavelengths beyond about 2 microns [1].

Thermal emission is a factor in analyzing data from the Moon Mineralogy Mapper (M3) instrument, C. Pieters, PI, now orbiting the moon on Chandrayaan-1. Background info can be found in [2, 3] and initial results are presented in [4].

Reflectance and Thermal Emission:

Following equation 9 from [1], the apparent reflectance measured by a spectrometer on a planetary surface is:

$$R_o' = R_o + r_o^2 B_o(e,T)/F_{sun}, \qquad \text{(eqn 1)}$$

where R_o' is the reflectance + thermal emission, R_o is the reflected solar fraction, r_o is the distance from the sun to the planetary surface (the moon in this case), B_o is the Planck black body equation with emissivity e and temperature T. F_{sun} is the solar flux / pi at 1 AU.

Equation 1 is simplified compared to working in radiance, which requires the field of view and distance to the observer. Ratioing to the sun cancels some terms, simplifying the equation.

Real World Thermal Emission

An imaging spectrometer measures a grid of points on the surface, each with an average slope, and possible complications due to sub-pixel slopes or roughness. Equation 1 does not include these effects. In practice, to compute the thermal component, one would need a high resolution digital elevation model (DEM) and accurate registration of the DEM with the imaging spectrometer data set. Such DEM does not yet exist for the moon that could be used with M3 data, thus we have employed a simple empirical approach.

We found that an extrapolation of the apparent reflectance of the lunar continua at about 1.55 and 2.35 microns to 3 microns provides a first order estimate of the lunar reflectance at 3-microns. Subtraction of that estimate, equivalent to R_o in equation 1, from the observed data, R_o', gives an estimate of the thermal emission, $r_o^2 B_o(e,T)/F_{sun}$ at 3-microns. The temperature is then derived and the thermal spectrum computed and removed from the observed data to give a first order lunar reflectance spectrum without thermal emission.

Example spectra from single M3 pixels are shown in Figure 1. Curves A-C show different albedo surfaces in full sunlight with derived temperatures of 403 to 424 K. Curve D shows a surface tilted away from the sun. Such a surface appears similar to a low albedo surface but receives less sunlight and therefore less heating, with less thermal emission and a lower temperature of 357K. Also note that the temperature in spectrum C is lower than that in spectrum B even though the apparent albedo (I/F) is lower in spectrum C. This is another indicator that the area covered by spectrum C is sloping away from the incident sunlight.

Derived temperatures (Figure 2) from the first image cube obtained by M3 range from about 340K to over 450 K. The hottest temperatures are seen in craters where surfaces are heated by direct sunlight plus sunlight reflected off of nearby crater walls. The peak temperature occurs opposite the direction to the sun.

Figure 1. M3 apparent reflectance spectra as measured with the thermal component (red dashed lines) and after thermal removal (solid lines).

Figure 2. Left: M3 apparent reflectance at 0.75 microns. The image has a non-linear stretch to show surface contrast. Middle gray scale temperature map. Right: color codes temperature map.

References:

[1] Clark, R. (1979) Icarus **40**, 94-103.
[2] Pieters *et al.* (2006) XXXVII, #1630.
[3] Pieters *et al.* (2007) LPSXXXVIII #1295.
[4] Pieters *et al.*. (2009) these volumes.

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Figure 1.

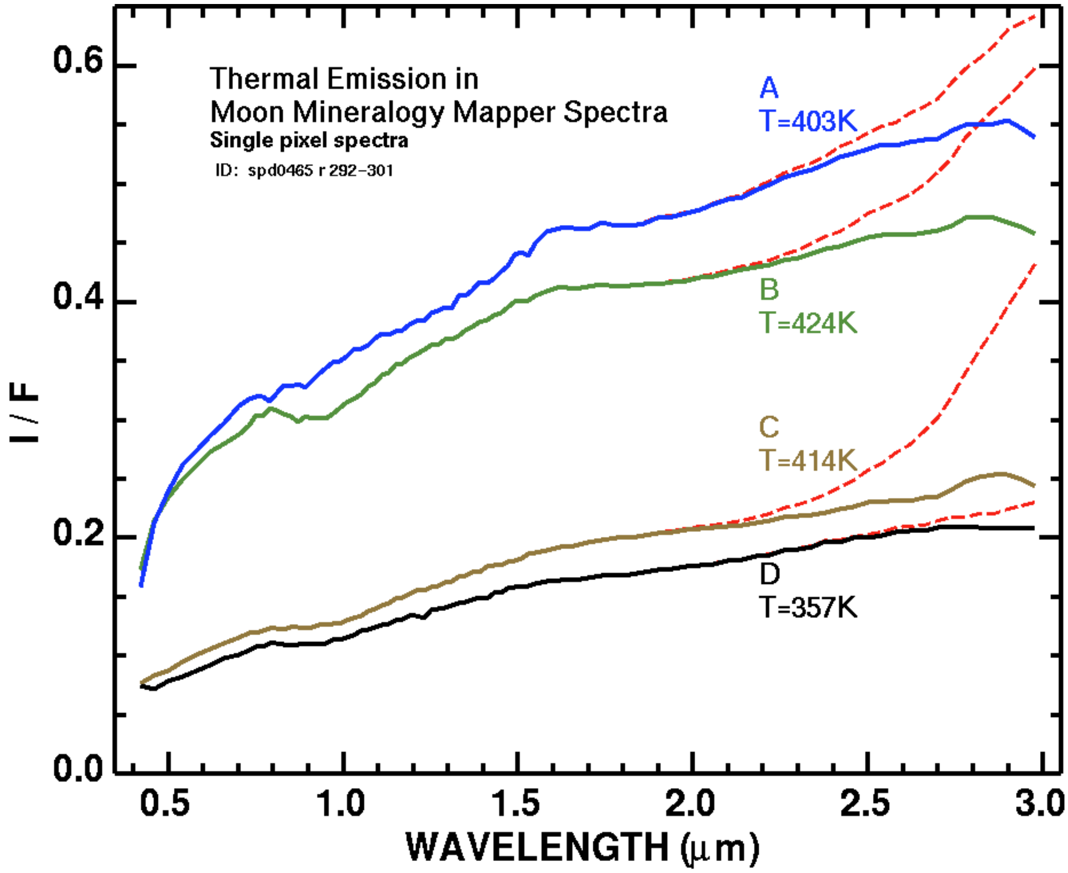

Figure 2.