Mid-Infrared Spectral Effects of Thermally Isolated Dust Coated Surfaces

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Introduction

- Thin mantles of dust are recognized as the cause of an unexpected spectral contribution in measurements of rocks and soils taken by the Miniature Thermal Emission Spectrometer (Mini-TES) instruments on the Mars Exploration Rovers (MER; Spirit and Opportunity)
- If not corrected, spectral effects caused by thin mantles of dust can greatly hinder mineralogical interpretation of rock surfaces (Fig. 1).
- Here we present preliminary results of laboratory and modeling efforts to understand the effects of thin dust mantles on planetary surfaces to aid in the interpretation of spectroscopic data.

I. Background: Mini-TES data

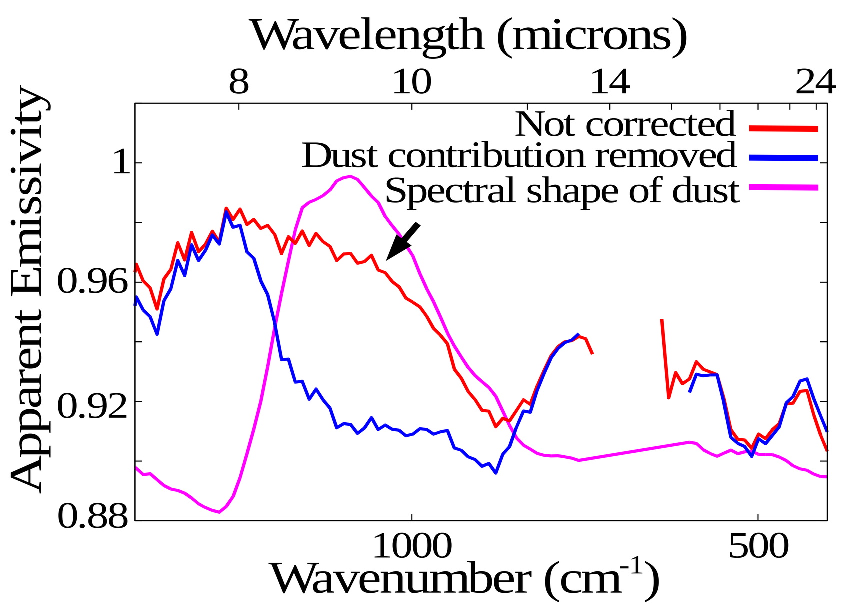

Figure 1. Mini-TES spectra of Adirondack Class olivine rich basalts. The spectral character of the contribution caused by thin dust mantles is observed as a convex-up shape between 8-10 μm. The emission feature at 8-12 μm coincides with an absorption feature of Olivine and without a correction the absorption feature would not be identifiable.

- Thin dust coatings (<~ 5μm) have been considered negligible until recently in mid-infrared measurements (MIR, $\sim 200-2000 cm^{-1}$)
- Thin mantles of dust contribute spectral features to Mini-TES spectra that are similar to those caused by downwelling radiance from atmospheric dust and were initially attributed as such by [4].
  - ⇒ The radiative effects of atmospheric dust and cannot solely account for the magnitude of the spectral features.
  - ⇒ They also lack the radiative effects of atmospheric CO2, which should also be present if atmospheric dust is responsible for the observed spectral features.
- To contribute spectral features to the measured spectra, the dust (temperature $= T_2$), must be thermally isolated from the substrate (temperature $= T_1$).
- Thick dust coatings (>~ 5μm) produce different spectral effects → result in a reduction of spectral contrast.

II. Goals

Our goal is to combine both laboratory measurements and modeling to better understand the behavior and underlying physics of how thin dust coatings can affect TIR spectral measurements. **This information will aid in the interpretation of spectroscopic data.**

III. Motivation

- The spectral effects of thin dust coatings present in Mini-TES data have yet to be observed in the laboratory.

Possible Reasons:

1. Previous investigations did not control for dust particle size such that large clumps (>> 5 μm in diameter) were deposited on surfaces (Fig. 2a) → linear mixing effects
2. The dust and substrate were not thermally isolated, so that the dust and the substrate had the same temperature → no net effect on measured radiance

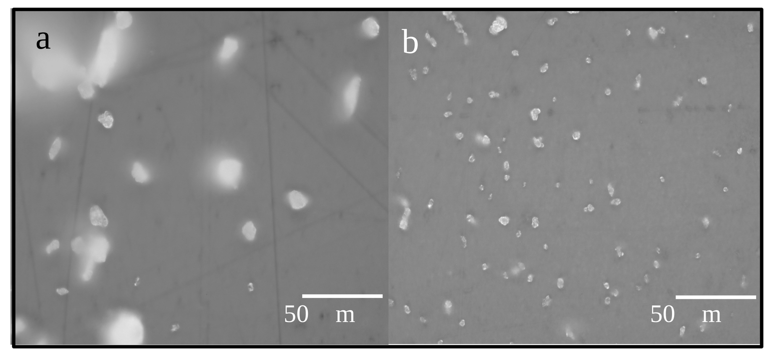

Figure 2. (a) Without controlling for particle size, dust coating experiments include surfaces dominated by dust particles of different sizes and particle clumping is present, (b) experiments done here restrict the particle size and clumping is minimal.

IV. Thermally Isolated Surfaces

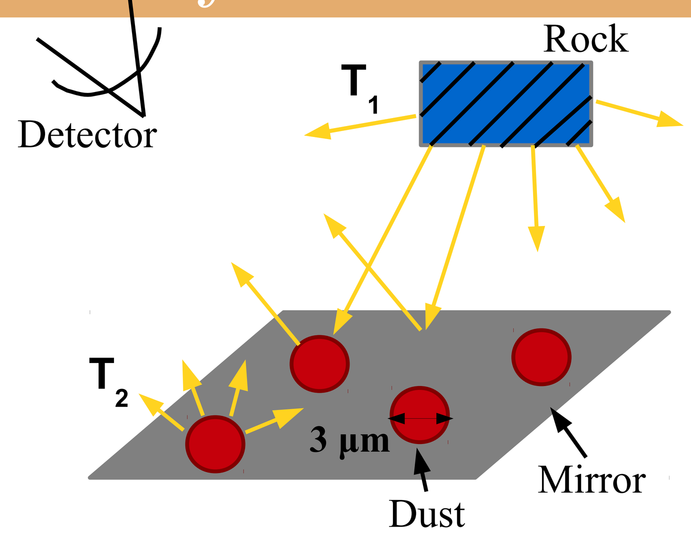

Figure 3. Schematic of observations of target through a dusty mirror

- A similar spectral contribution is due to dust deposited on the periscope mirror through which Mini-TES makes all of its observations.
  - ⇒ Because the dust and the rock are not in contact they can have two distinct temperatures.
- Laboratory measurements of dusty mirrors will allow us to understand some of the underlying physics of how thin dust coatings can affect spectral measurements.(Figure 3, Results in box Vc).

V. Laboratory Measurements

- Updated the laboratory set-up of [2] to include a cover above the substrate. Set-up consists of a hand pump or compressed air and a plastic box (Figure 4). The pump is used to disperse dust into the air within the box. A rock (or other) surface is then mantled by the dust that settles out.
- From the settling velocities, times can then be calculated for which it is necessary to remove the cover to limit the deposition of particles of a given size
- Substrates were deposited with increasing quantities of dust to see what effects particle size, thickness and surface coverage have in MIR spectra.

Va. Laboratory Set-up

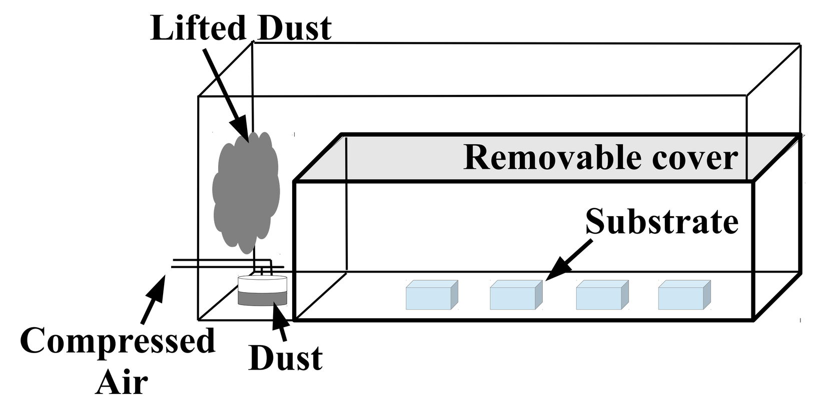

Figure 4. Schematic of laboratory set-up used here for dust deposition.

- Substrates:
  - ⇒ Rocks of basaltic composition (Results in box Vb)
  - ⇒ Parabolic Mirror (Results in box Vc)
- Dust: Na-Montmorillonite (phyllosilicate)

VI. Radiative Transfer Modeling

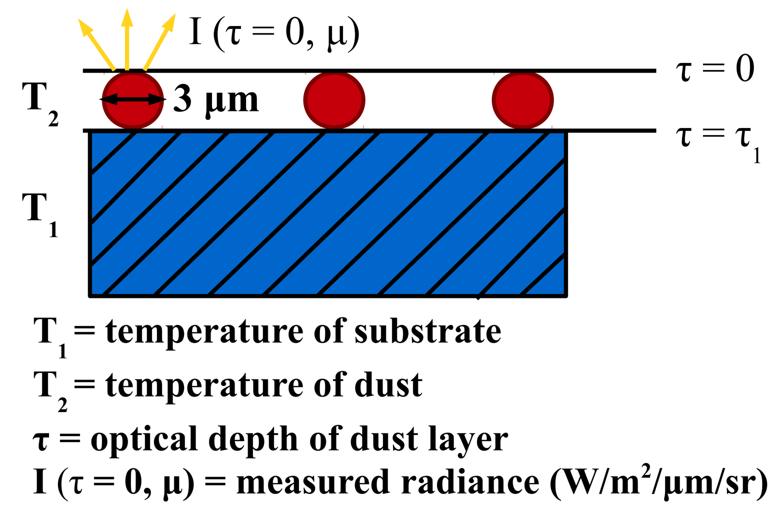

Figure 7. Basic schematic highlighting main parts of RT model.

- We started by using a similar radiative transfer approach used to model atmospheric dust due to their similar spectral behavior.
- The radiative transfer (RT) model accounts for radiance emitted by the substrate and dust, and radiance absorbed and scattered by the dust (Figure 7).
- We model a thermally isolated mono-layer of spherical particles above a blackbody surface (Figure 7).
- A two/four-stream approximation as outlined by [8] is used to calculate the modeled radiance using scattering parameters calculated from Mie theory [7]. Apparent emissivities are then calculated from these values.

Vb. Preliminary Lab Results: Dust Coated Rocks

- Even with visible amounts of dust no apparent trends were seen in this particular dataset.

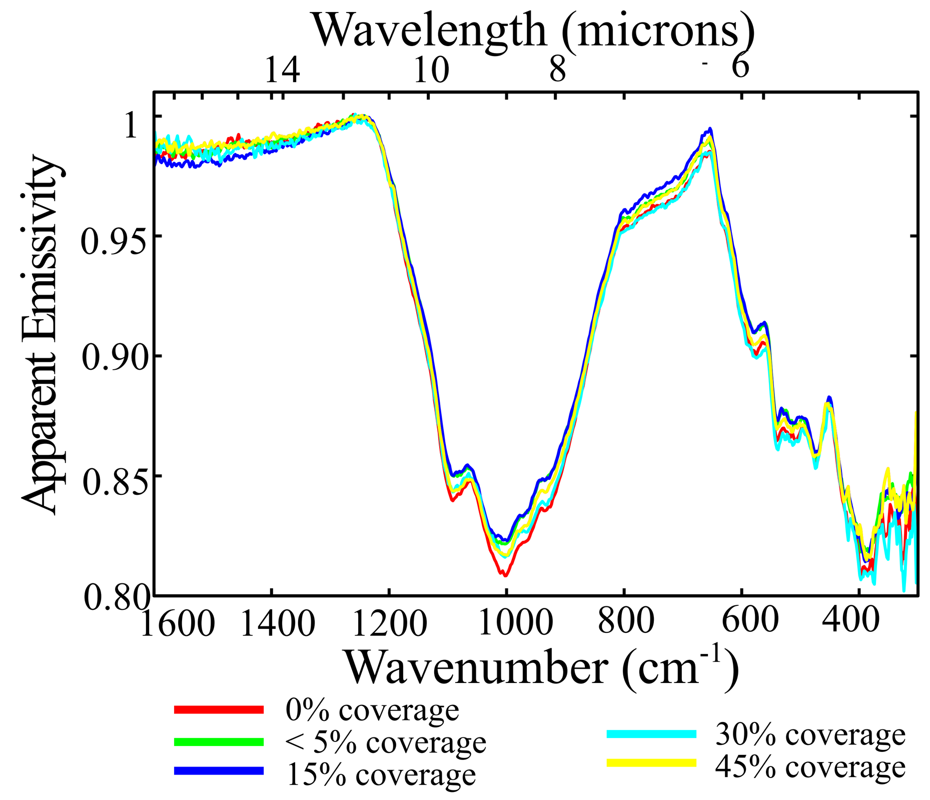

Figure 5. Preliminary results from laboratory measurements of basaltic rocks coated with Montmorillonite dust dominated by ~ 3μm diameter particles.

Vc. Preliminary Results: Dust Coated Mirrors

- The temperature contrast between the dust and the target mimic effects similar to those caused by thin mantles of dust in Mini-TES observations.

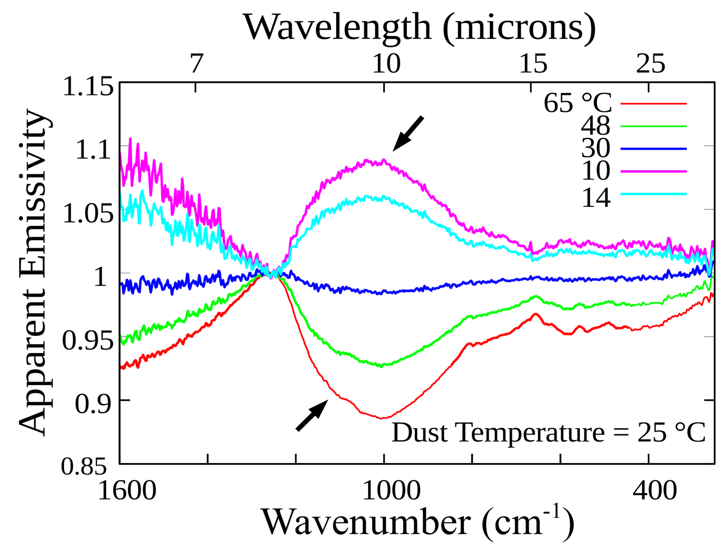

Figure 6. Spectra acquired of dusty mirror looking at blackbody substrate. Arrows point to spectral features that are similar to those seen in Mini-TES spectra.

VIa. Preliminary Results: RT-Modeling

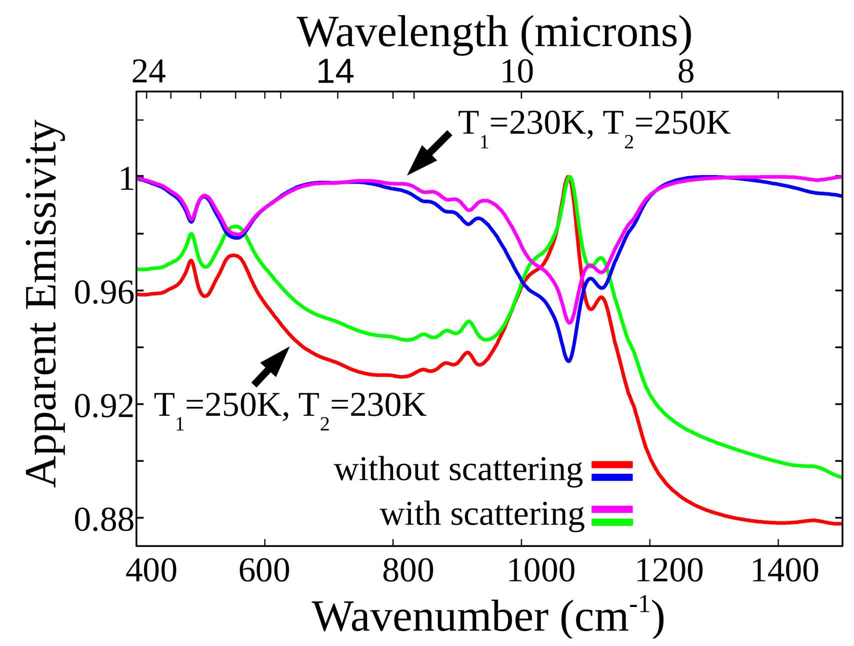

Figure 8. Example output from RT model. Arrows point to features similar to those caused by thin mantles of dust in Mini-TES observations. Optical constants of Montmorillonite were used to calculate the scattering parameters and a gamma function with an effective radius of 1.5 μm and an effective variance of 0.2 was used to describe the particle size distribution of the dust.

References

[1] Ruff, S.W., and P.R. Christensen (2002) JGR, 107, 512710.1029/2001JE001580. [2] Johnson, J.R., P.R. Christensen, and P.G. Lucey (2002) JGR, 107, 503510.1029/2000JE001405. [3] Graff, T. (2003) M.S. thesis, Arizona State University. [4] Ruff,S.W., et al. (2006) JGR, 111, 1210.1029/2006JE002747. [5] Ruff, S.W. and J.L. Bandfield (2010) LPSC, 41, 2411. [6] Hamilton, V.E. and Ruff, S.W. (2012) Icarus, 218, 2, 917-949, 10.1016/j.icarus.2012.01.011. [7] Maetzler, C., University of Bern, Institut für Angewandte Physik, Research Report No. 2002-08. [8] Fu, Q., et al. (1997) JAS, 54, 2799-2812.