LUNAR DUST DISTRIBUTIONS FROM SOLAR INFRARED ABSORPTION MEASUREMENTS WITH A FOURIER TRANSFORM SPECTROMETER

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Introduction: The lunar surface is covered with a thick layer of micron/sub-micron size dust grains formed by meteoritic impact over billions of years. The fine dust grains are levitated and transported on the lunar surface, as indicated by the transient dust clouds observed over the lunar horizon during the Apollo 17 mission [1-5] Theoretical models suggest that the dust grains on the lunar surface are charged by the solar UV radiation as well as the solar wind. Even without any physical activity, the dust grains are levitated by electrostatic fields and transported away from the surface in the near vacuum environment of the Moon [6-8]. Since the abundance of dust on the Moon's surface with its observed adhesive characteristics has the potential of severe impact on human habitat and operations and the lifetime of a variety of equipment, it is of paramount importance to investigate the dust size and density distributions, and the lunar dust levitation and transportation phenomena in order to develop appropriate mitigating strategies. This critical information is essential for understanding the lunar environment.

This white paper addresses the critical need for measurements of the dust vertical density and size distributions in the lunar environment. The proposed technique for evaluation of the vertical density distribution is based on solar infrared absorption measurements with a Fourier transform spectrometer in the middle infrared spectral region (5-25 μm; 400-2000 cm^{-1}) with a spectral resolution of ~ 10 cm^{-1}.

Measurement Objective:

The solar infrared dust absorption spectra may be obtained in the following two observational modes.

(a) Measurements from the lunar surface: These measurements made over a range of elevation angles will provide information about the near surface dust density profiles, as well as possible detection of out-gassing in the lunar hot spots and flares.

(b) Measurements from a lunar orbiter: Solar absorption measurements of the lunar limb with viewing angles over a range of tangent heights will provide vertical dust density profiles with high spatial resolution.

The observed dust spectra may be analyzed to retrieve the vertical distribution of dust densities by utilizing the spectral inversion techniques well developed for infrared remote sensing of the Earth and planetary atmospheres in order to understand the nature and extent of the lunar dust transport phenomena [e.g., 9-12]. Information about the dust size distribution may also be obtained with parallel laboratory measurements of the extinction coefficients of individual micron or submicron size dust grains.

The proposed measurements will fulfill a critical need to fully understand the nature and extent of the lunar dust phenomena in order to develop satisfactory mitigating strategies.

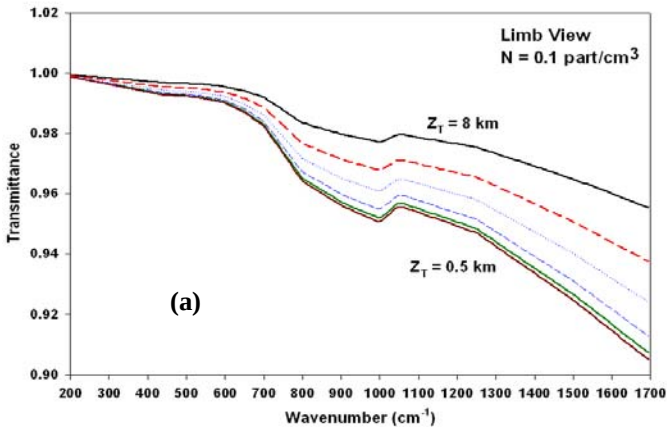
Solar Infrared Absorption Spectrometer for Dust Measurements:

With the primary objective of broadband dust measurements, a Fourier transform spectrometer with a spectral resolution of ~ 10 cm^{-1} in the 400-2000 cm^{-1} region would provide absorption spectra suitable for retrieval of dust distributions. The following Fourier transform spectrometers would serve as models for the lunar based spectrometer: (1) ATMOS/JPL middle infrared solar absorption spectrometer by Gunson et al. [13] flown on Spacelab 3 and Atlas/Shuttle missions for measurement of trace gas species in the Earth's upper atmosphere. (2) TES (Mars Global Surveyor mission), and Mini-TES (Mars Rover), thermal emission Fourier Transform spectrometers, employed for Mars exploration (3) Nicolet- FTIR, a commercial off-the-shelf laboratory middle infrared Fourier transform spectrometer. The design for the lunar spectrometer will incorporate features suitable for lunar dust measurements by solar absorption mode, involving a sun-tracker, fore-optics, interferometer, and electronics. The physical model developed by this study would be based on an autonomous instrument concept and will include size, cost, data acquisition, power, and telemetry requirements.

Analytical Techniques:

Some selected model calculations for retrieval of lunar dust distributions from solar infrared dust absorption spectra using an algorithm employed in infrared remote sensing of the Earth's and the planetary atmospheres [9-12] were carried out with assumed dust density and infrared extinction data shown in Figs. 1-2. . The extinction coefficients in the middle infrared spectral region (200-1700 cm^{-1}) are assumed to be the similar to those for planetary

dust/aerosol [14] for particles of all size. The dust content is specified by number density cm^{-3} with uniform distribution at all altitudes. Numerical calculations for the limb-viewing mode of observations are shown in Figs. 1-2 with plots of the dust transmittances and contribution functions for retrieval of dust density distributions.



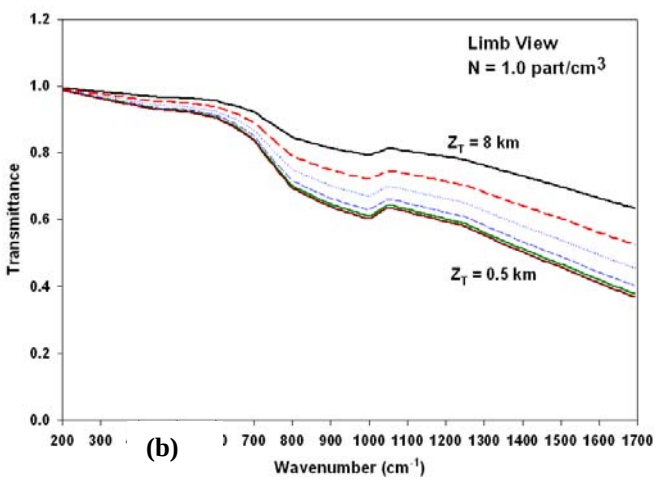


Figure 1.a-b. Dust transmittances for limb-view paths with tangent-heights of 0.5, 1, 2, and 4 km., with dust densities (a) N = 0.1 cm^{-3} (b) N = 1.0 cm^{-3}

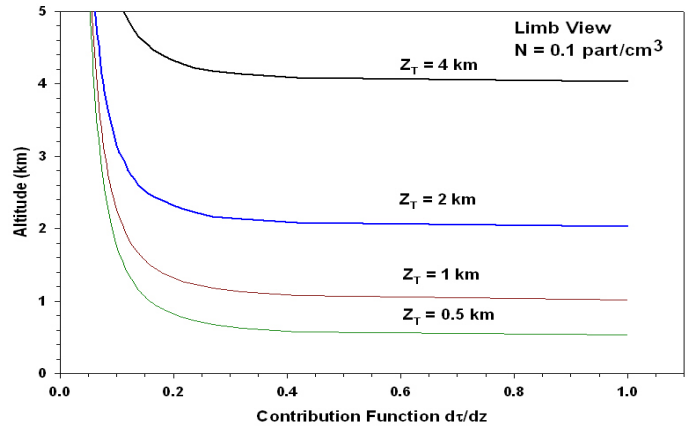


Fig. 2. Contribution functions for limb-view paths with tangent-heights of 0.5, 1, 2, and 4 km.

Conclusion: Model calculations based on assumed dust density and extinction coefficients indicate the capability of solar infrared absorption measurements with a Fourier transform spectrometer as very useful technique for remote sensing of the lunar dust distributions in the near surface as well as the high altitude environments.

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