Lunar Dust Distributions From So
Infrared Absorption Measurement
With a Fourier Transform Spectrometer

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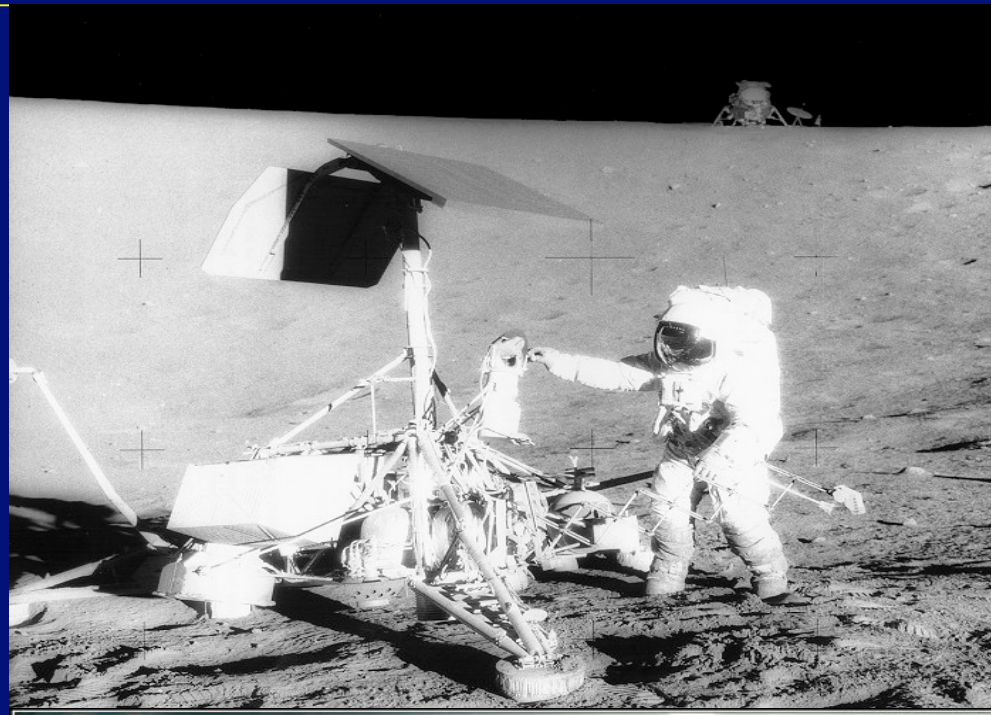
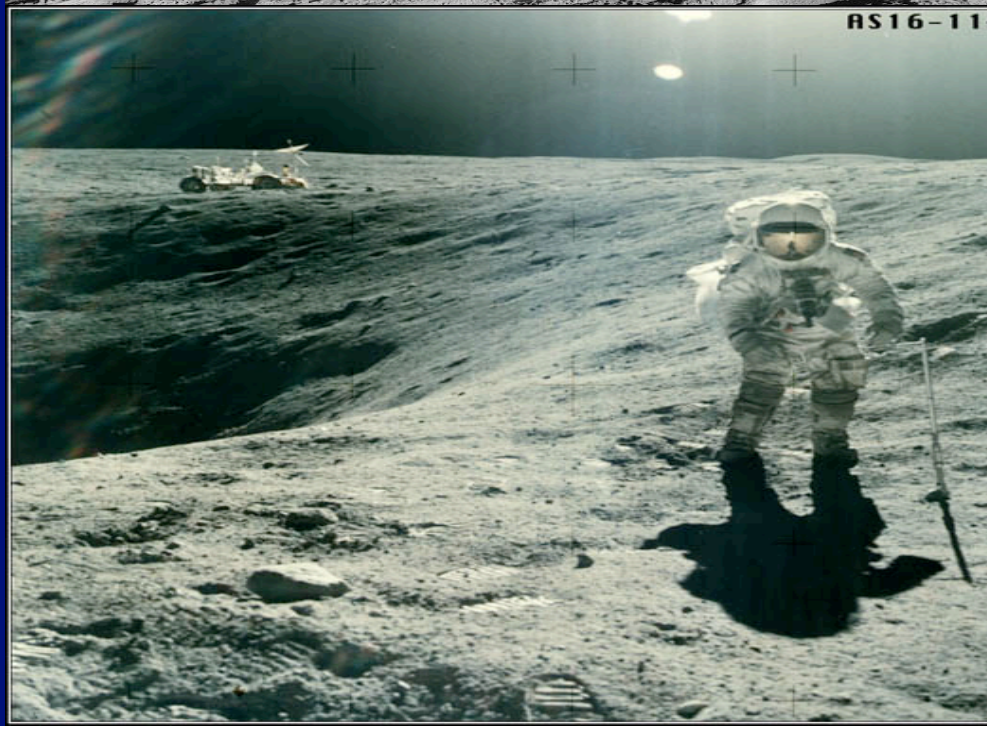
Lunar Regolith & Dust Formation Processes

- The lunar regolith is formed by impact of meteorites, high velocity micrometeorites, cosmic rays, and the solar wind, over billions of years.

- Composed of irregularly shaped fine and coarse dust grains with size distribution in the range of nano-meter, sub-micron, centimeter size or larger.





Dusty Environment on the Moon

- **Grain size distribution of the lunar samples:**

  Apollo and Luna missions indicate the regolith to be:

  ~ 20 wt%, of < 20 μm

  ~ 10 wt %, of < 10 μm

- **A smaller fraction of sub-micron size grains.**

Compositio	% wt
SiO_2	4
TiO_2	
Al_2O_3	1
Fe_2O_3	
FeO	1
MgO	
CaO	1
Na_2O	
K_2O	
MnO	
Cr_2O_3	
P_2O_5	

Observed Lunar Dust Phenomena

- The astronauts found the lunar dust to be unexpectedly high in its **adhesive characteristics**, sticking to the suits, instruments, and the lunar rover.
- Lunar Surveyor Spacecraft, and the Lunar Ejecta & Meteorite Experiment on Apollo 17 indicated the presenc of **transient dust clouds** in the lunar environment.
- A **horizon glow over the lunar terminator and high altitud streamers** were observed by the astronauts on the Apollo spacecraft.
- This glow phenomenon was observed during the lunar sunrise and sunset by astronauts both on the surface and the spacecraft in orbit.
- Clementine Spacecraft (1994) also detected the lunar glow phenomenon at high altitude.

Observed Lunar Dust Phenomena (contd.)

Electrostatic Nature of Dust Phenomena

With virtually no atmosphere and no global magnetic field, the observed lunar dust phenomena is attributed to electrostatic processes:

- **Dust Charging**: Lunar surface and the dust grains are charged by:

  Photoelectric emissions, Electron/ion collisions

  Secondary electron emissions; Triboelectric charging

- **Levitation:** The charged dust grains are levitated under repulsive forces larger than gravity.

- **Transportation:** Large electric fields created over the terminator, and Dust grains are assumed to be transported - producing dust clouds that are observe as a glow with the sunlight scattered over the horizon.

Measurements of the Lunar Dust

- Although the influence of the above processes is well recognized, the basic natu and a quantitative assessment of the lunar dust environment remains very uncertain.
- There are no reliable measurements of the fields, density and size distributions dust deposition on the lunar surface, near surface altitudes, and at higher altitu to validate the observed lunar dust phenomena.

Required Lunar Dust Measurements

The following measurements are needed to determine the nature and extent of the issues of lunar dust phenomena for developmen of effective dust mitigating strategies for a variety of objectives.

(a) Density and size distribution of:

Dust collected on the lunar surface

By devices such as Quartz Crystal Microbalances (QCM's).

(b) Density and size distribution as a function of altitude for:

Dust levitated in the near lunar surface

(c) Density and size distribution as a function of altitude for:

Dust transported to higher lunar altitudes.

(d) Adhesion and dust mass coverage on surfaces of various materials to investiga triboelectric charging effects.

(e) Electron densities and electric fields in the near surface environment by Langmuir probes.

Remote Sensing of Dust Distributions at Near Lunar Surface and at High Altitudes

- We investigate a well proven technique for determination of lunar vertical dust distribution profiles from infrared solar absorption measurements of dust with a Fourier transform spectrometer.

Modes of Solar Observations

- From Lunar Surface: at various zenith angles.

  Analysis of the observed spectra provide information about lunar dust density at low altitudes, with some limited information about vertical density profiles.

- From a Lunar Orbiter: Limb observations at various tangent heights.

  Analyses of the observed spectra provide dust density profiles with spatial resolution determined by the number of tangent height and the field-of-view of the instruments

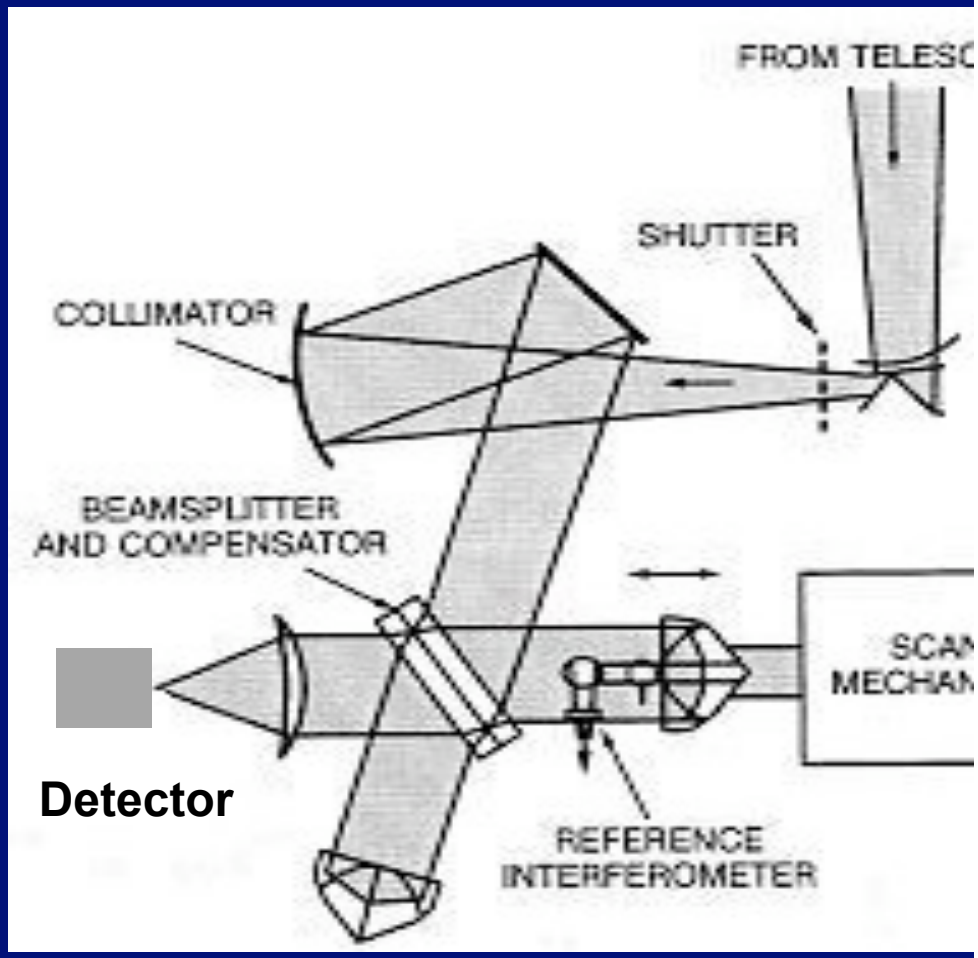
Fourier Transform Spectrometer For Remote Sensing of Lunar Dust

Instrument Specifications:

- Fourier Transform Spectrometer.
- Spectral range

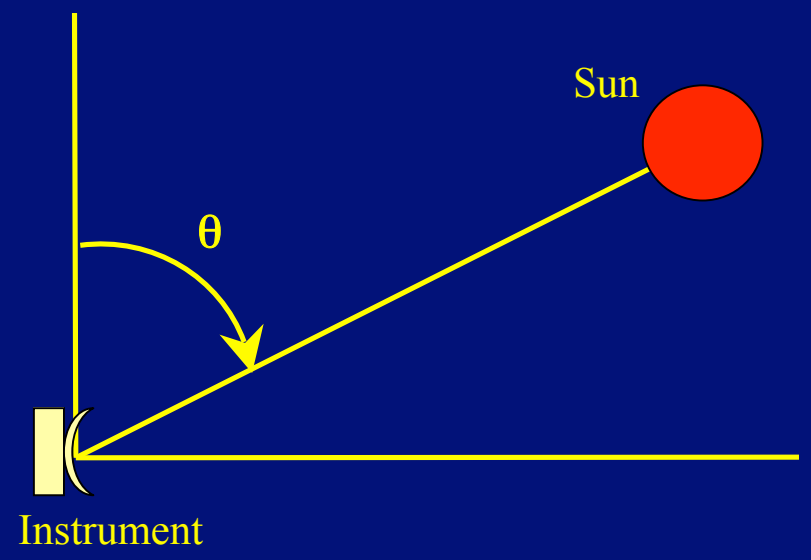
  ~ 5 -25 μm (400 – 2000 cm^{-1})
- Spectral Resolution

  ~ 10-20 cm^{-1}
- Fore-Optics and Sun-Tracker for Solar Observations

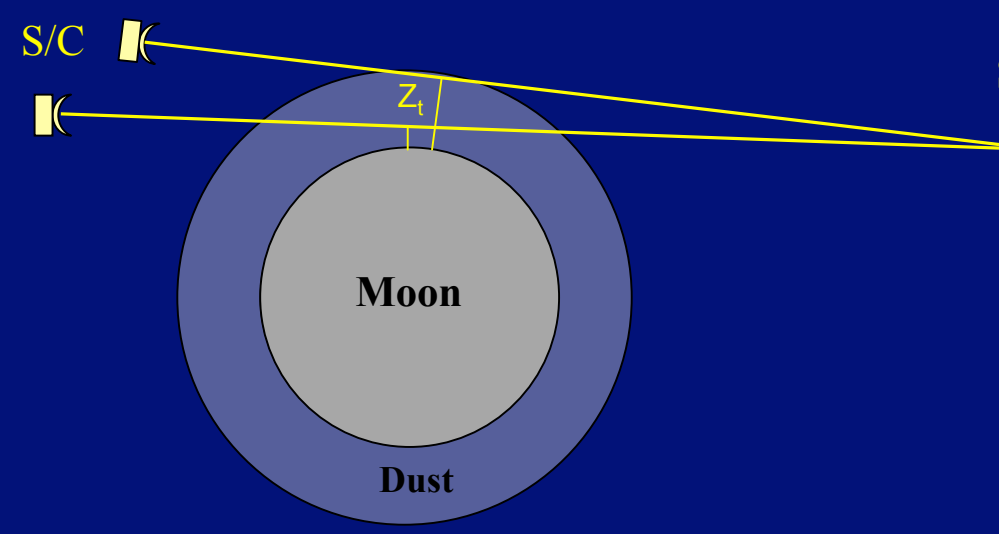


Lunar Dust Distributions by Solar Absorption Measurement with a Fourier Transform Spectrometer

Infrared Solar Absorption Measurements from the lunar surface: Made as a function of the solar zenith angle, provides dust distributions in the near surface environment.

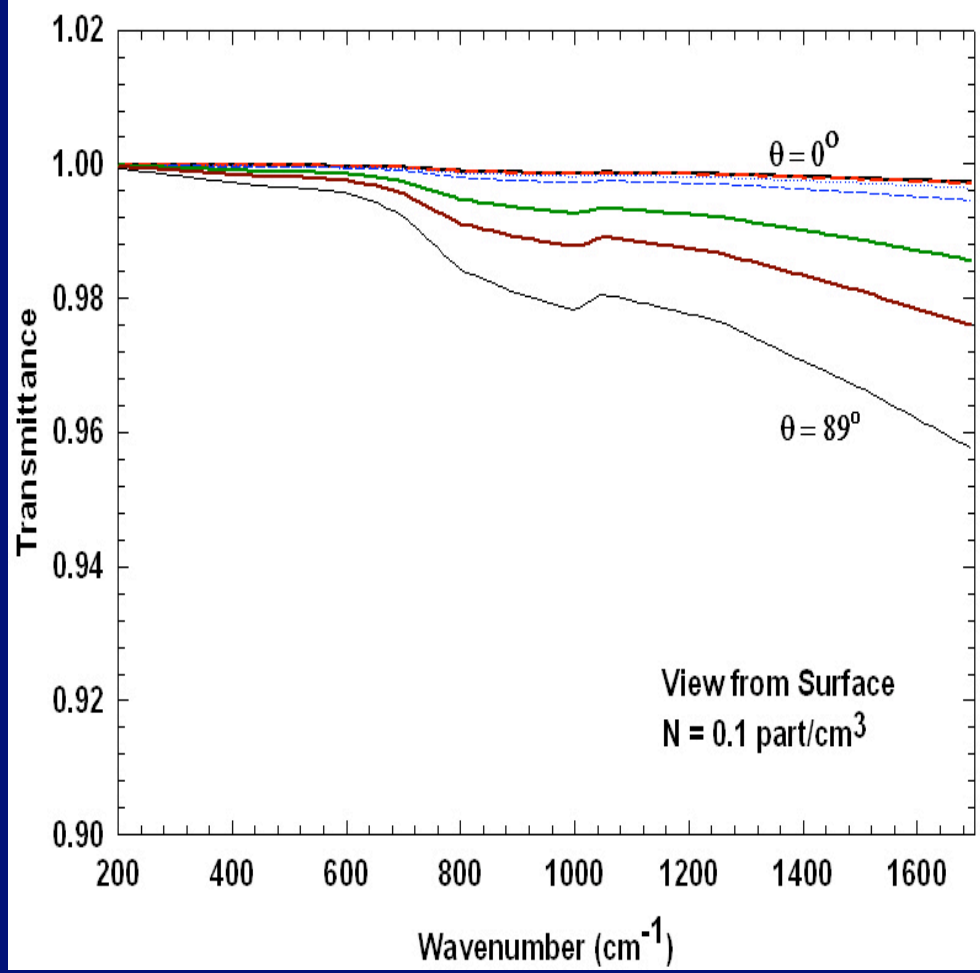


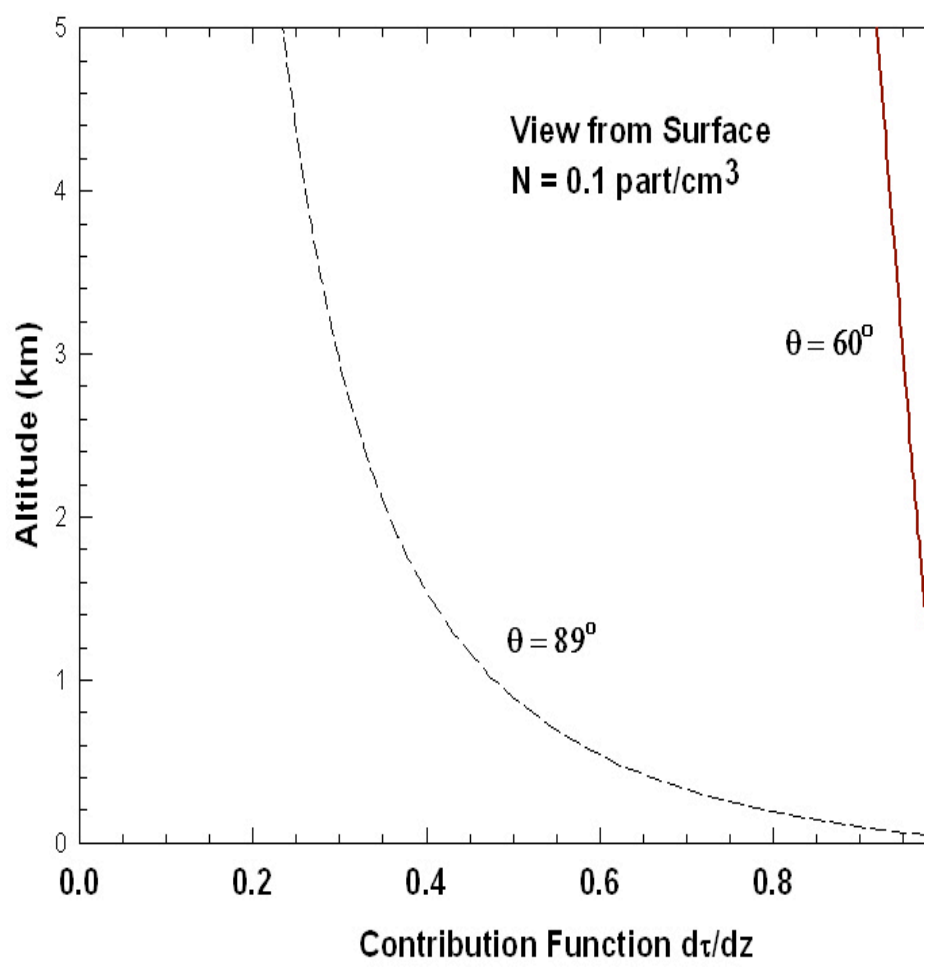
Limb Observations from a Lunar Orbiter: Made at several angles corresponding to a range of tangent heights. Sharply peaked contribution functions provide vertical dust density profiles.



Remote sensing of Lunar Dust Environment with an Infrared Fourier Transform Spectrometer

Calculated infrared dust transmittances and contribution functions for sola observations at various zenith angles from the lunar surface, for dust density, N = 0.1 cm^{-3}.





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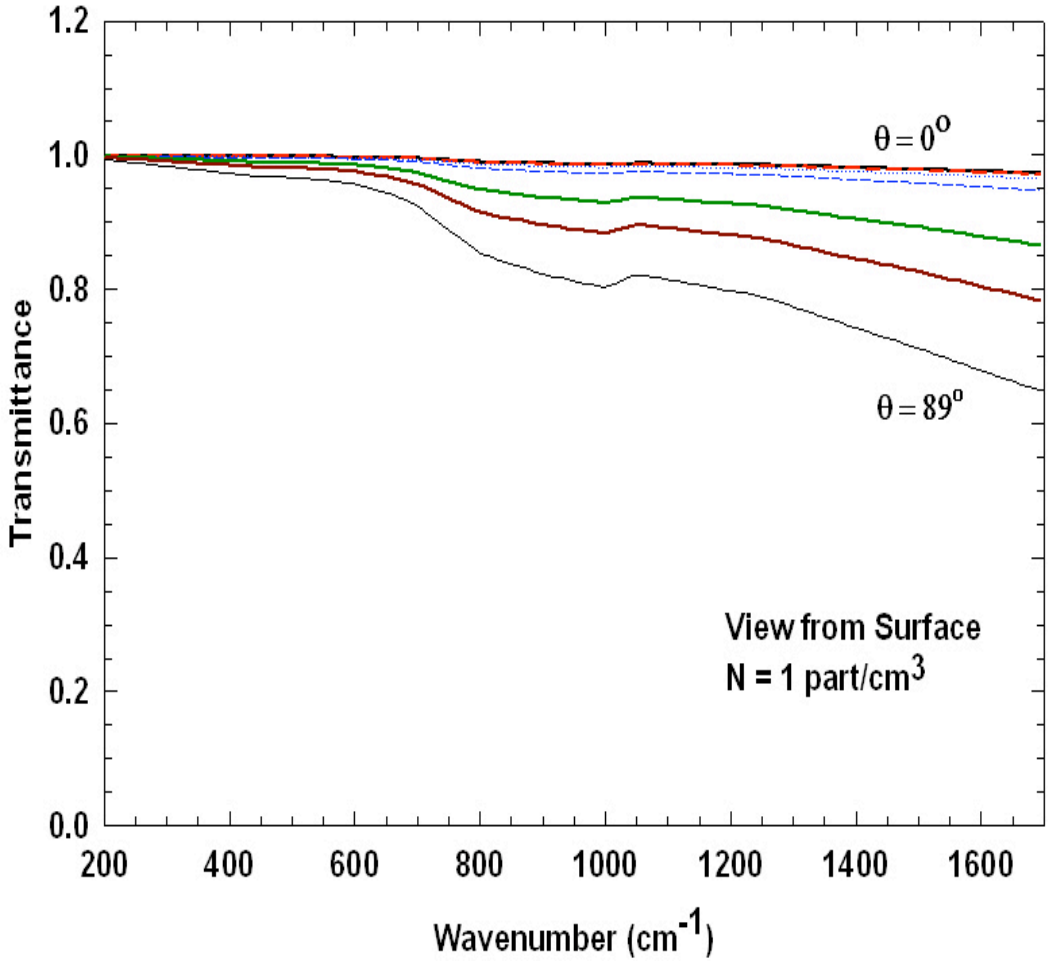

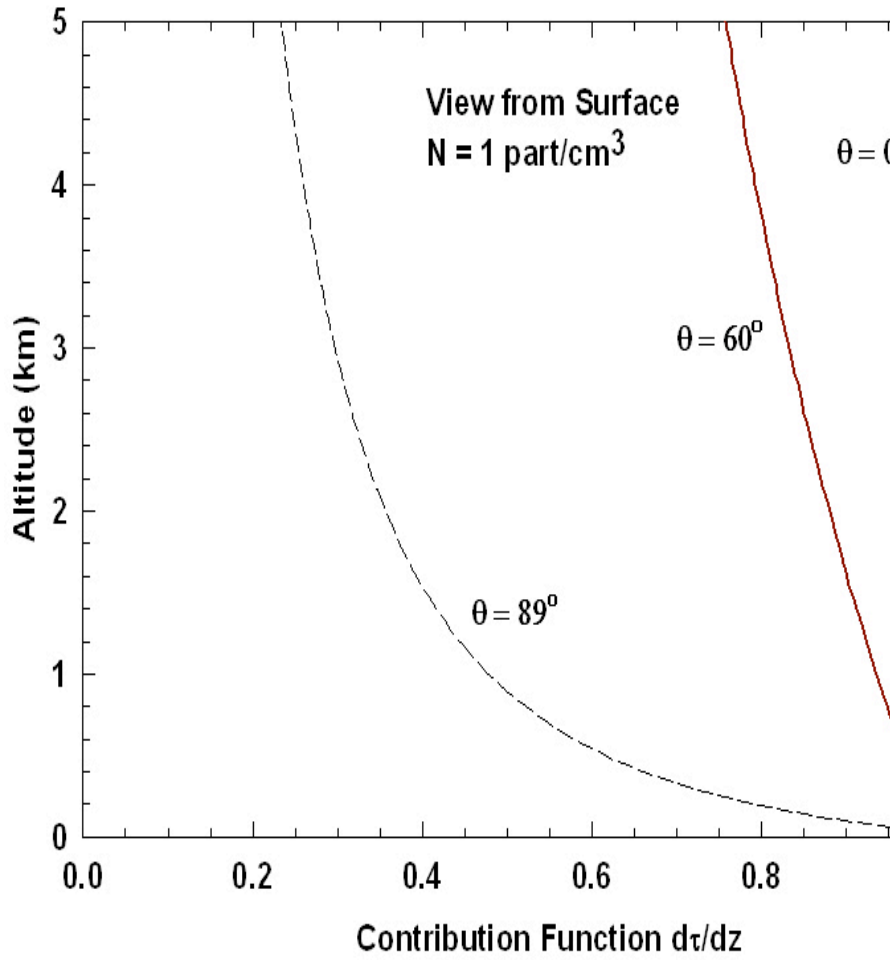

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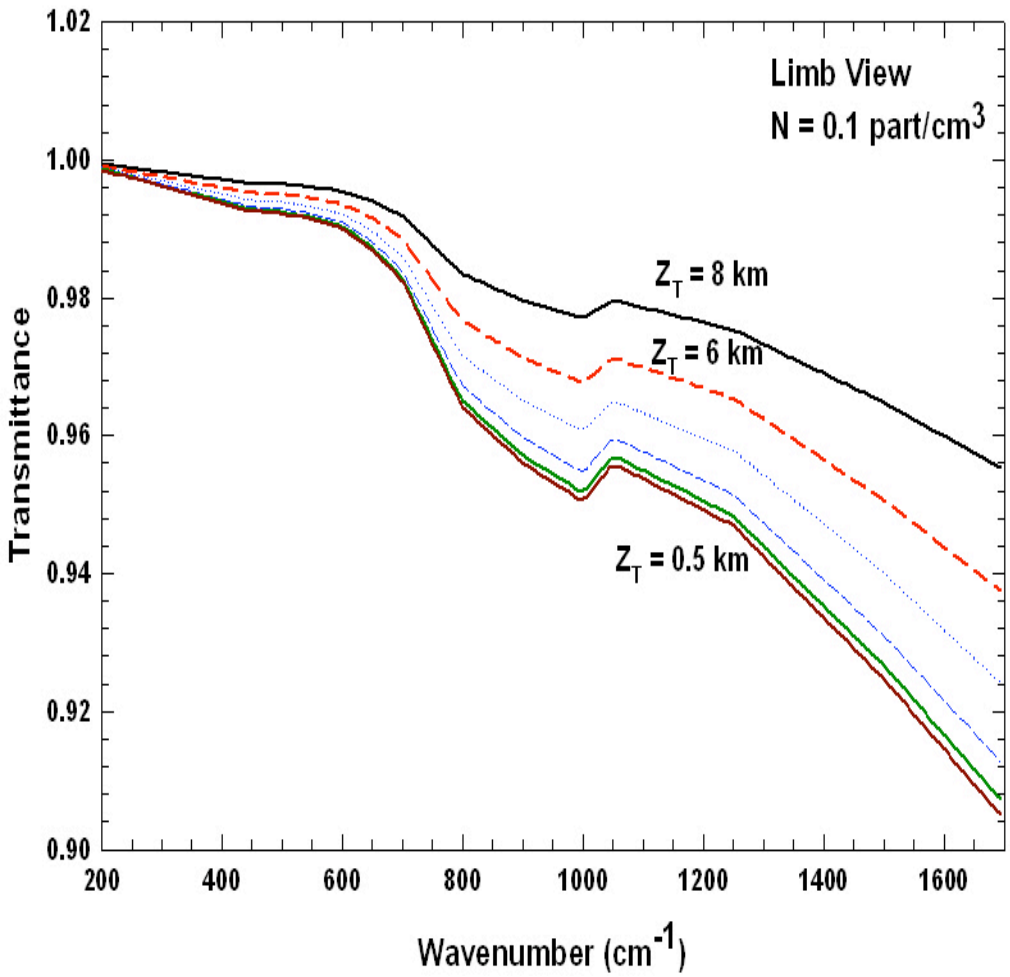

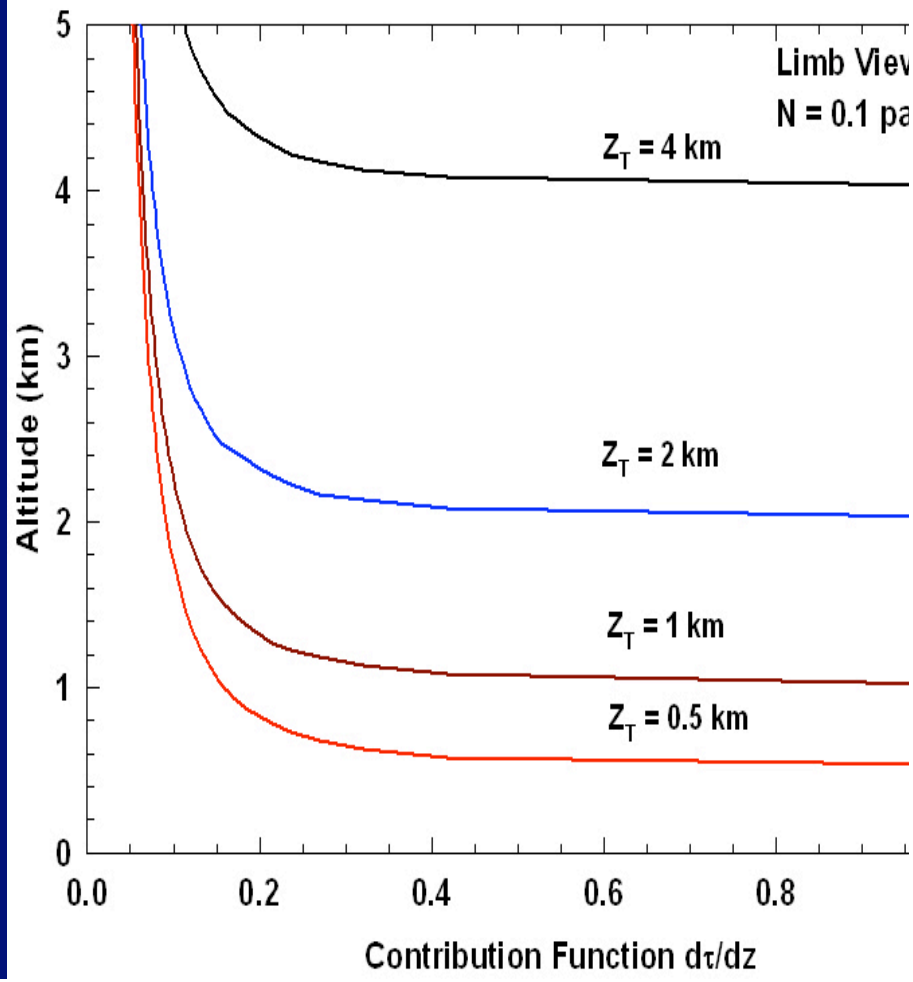

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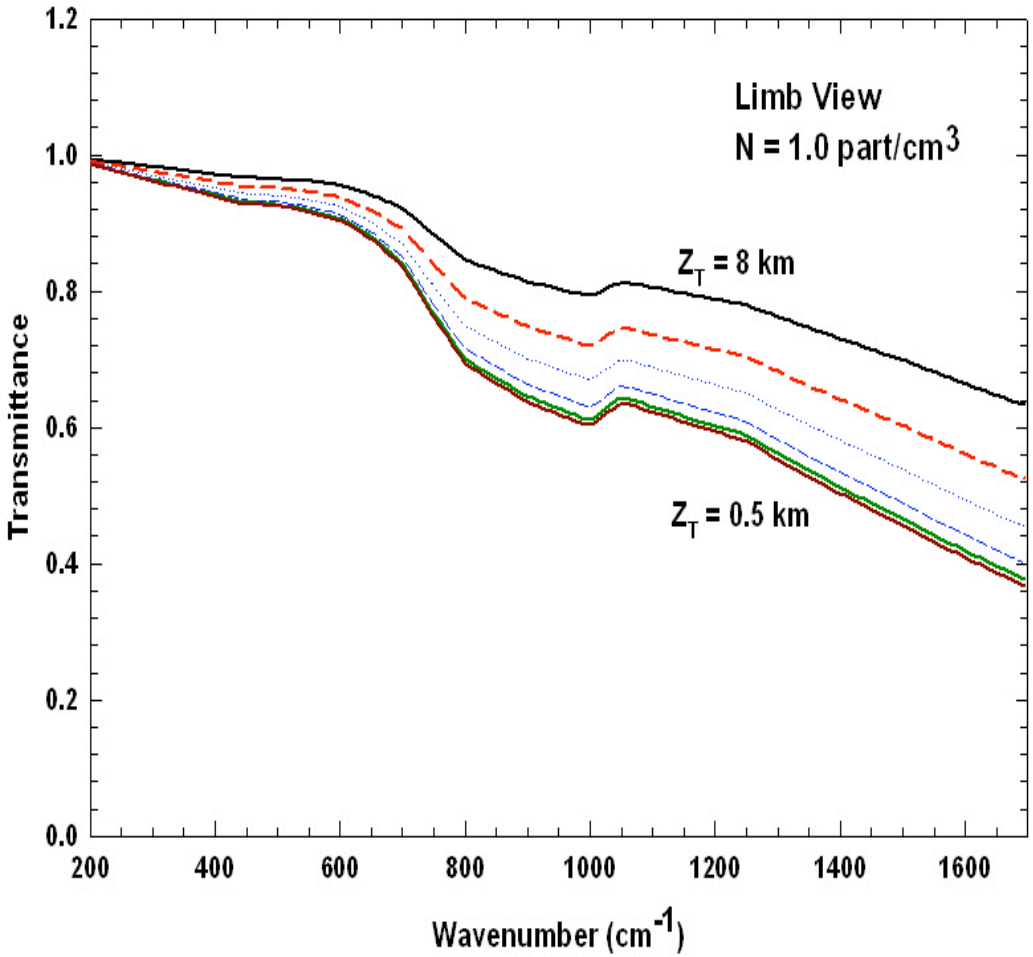
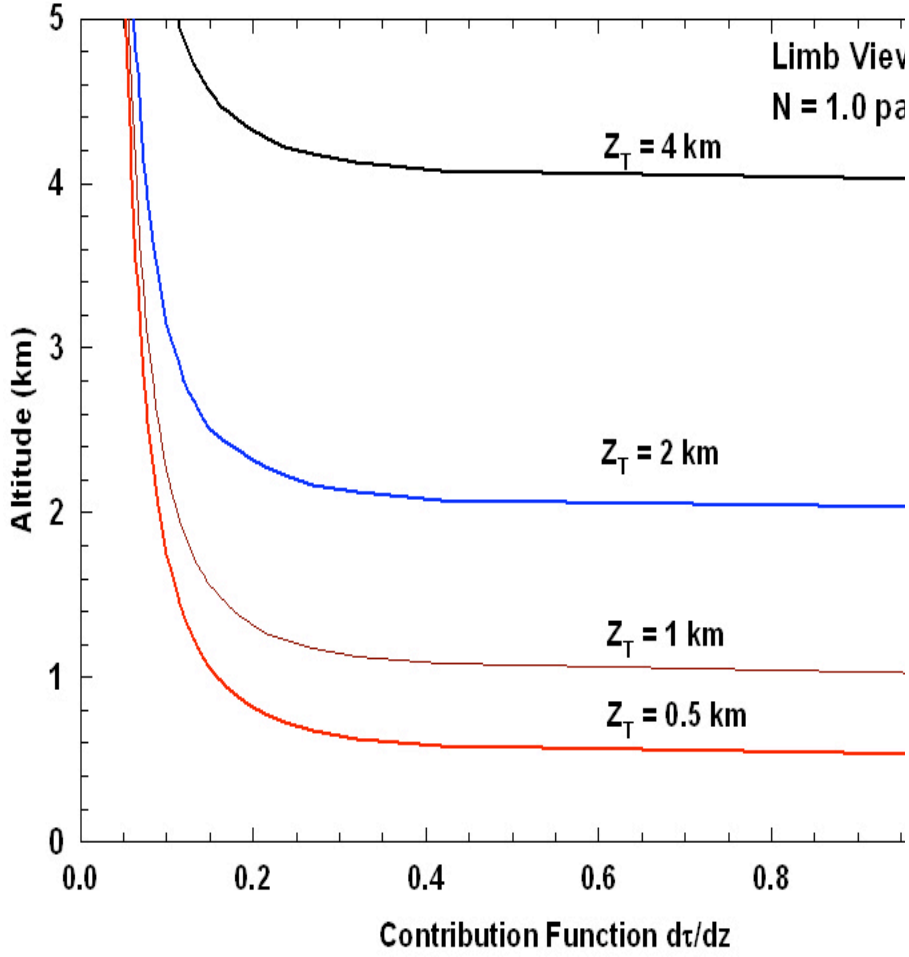


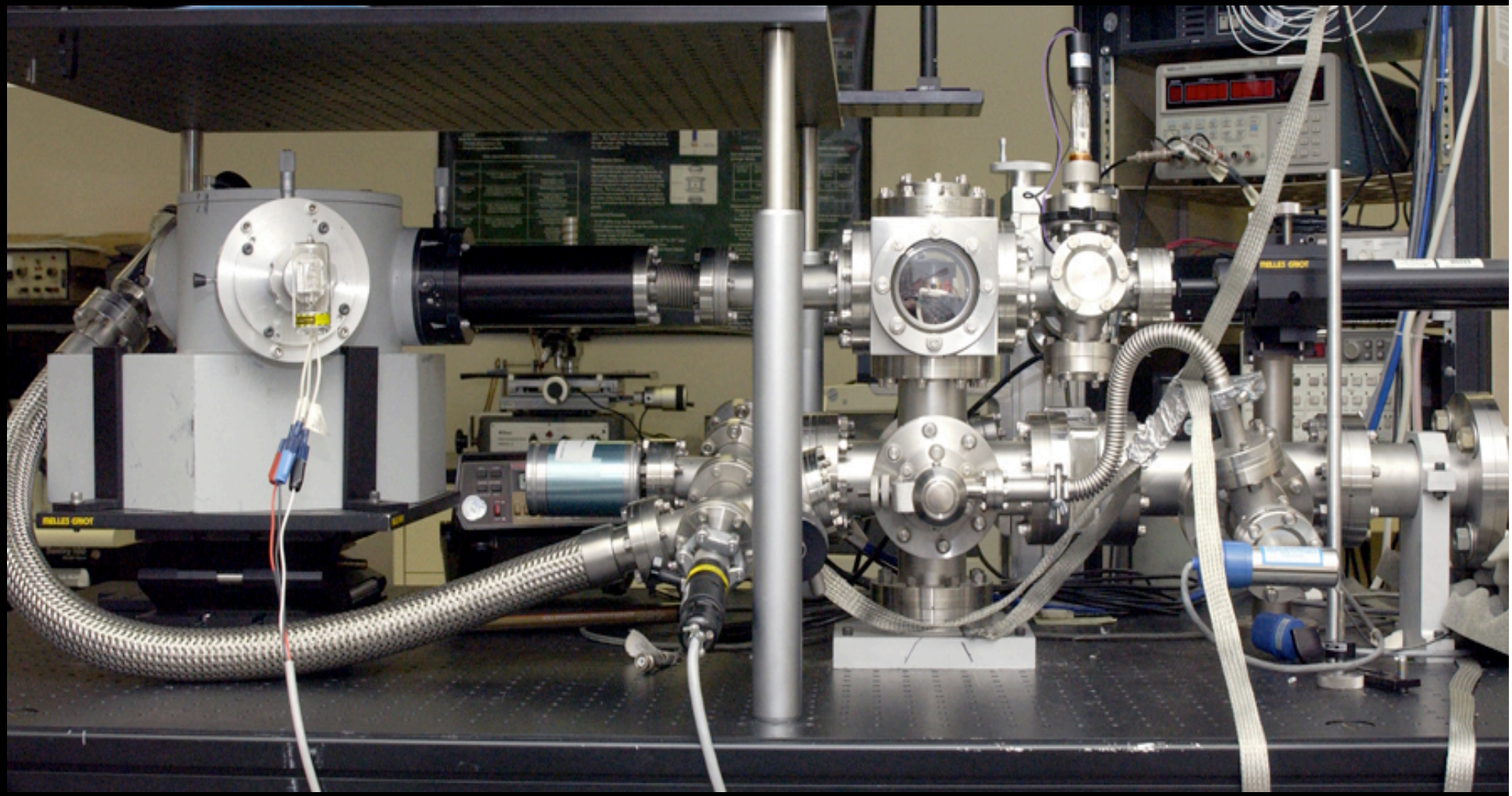


Laboratory Measurements of Infrared Extinction Coefficie of Lunar Dust Grains

- The extinction coefficients of Apollo 11, 12, 14, 15, 16, an 17 dust grains at infrared frequencies will be determined experimentally.
- These measurements will be made on an Electrodynamic Balance in a laboratory facility at NASA/MSFC. This facility has been employed for measurements of the charging properties of individual levitated lunar dust grains by photoelectric emissions, and is currently being used for studies of charging properties by electron impac
- The infrared extinction properties will be determined by using a Nicolet-Fourier transform spectrometer in the the 5-25 μm spectral region.

Laboratory Facility for Measurements of Optical Properties of Individual Dust Grains:

Electrodynamic Balance



Conclusions

- Measurements of lunar dust density and size distributions at the surfa near surface, and at higher altitudes are needed to characterize the lunar dust environment for design and implementation of satisfactory dust mitigation strategies for a variety of engineering and science objectives.

- Dust measurements on the lunar surface carried out with in-situ device do not provide vertical dust density and size distributions.

- A Fourier transform spectrometer, Solar Infra-Red Absorption of Dust (SIRAD), is proposed as a highly sensitive instrument for remote sensing spatial and temporal variations of lunar dust density and size distribution

- Near surface measurements may be made from dust solar absorption measurements from the lunar surface.

- Higher altitude dust density vertical profiles may be determined from solar absorption measurements in the lunar limb-viewing mode.