Getting the temperature right

Thermophysical and spectral properties of planetary surfaces using infrared measurements

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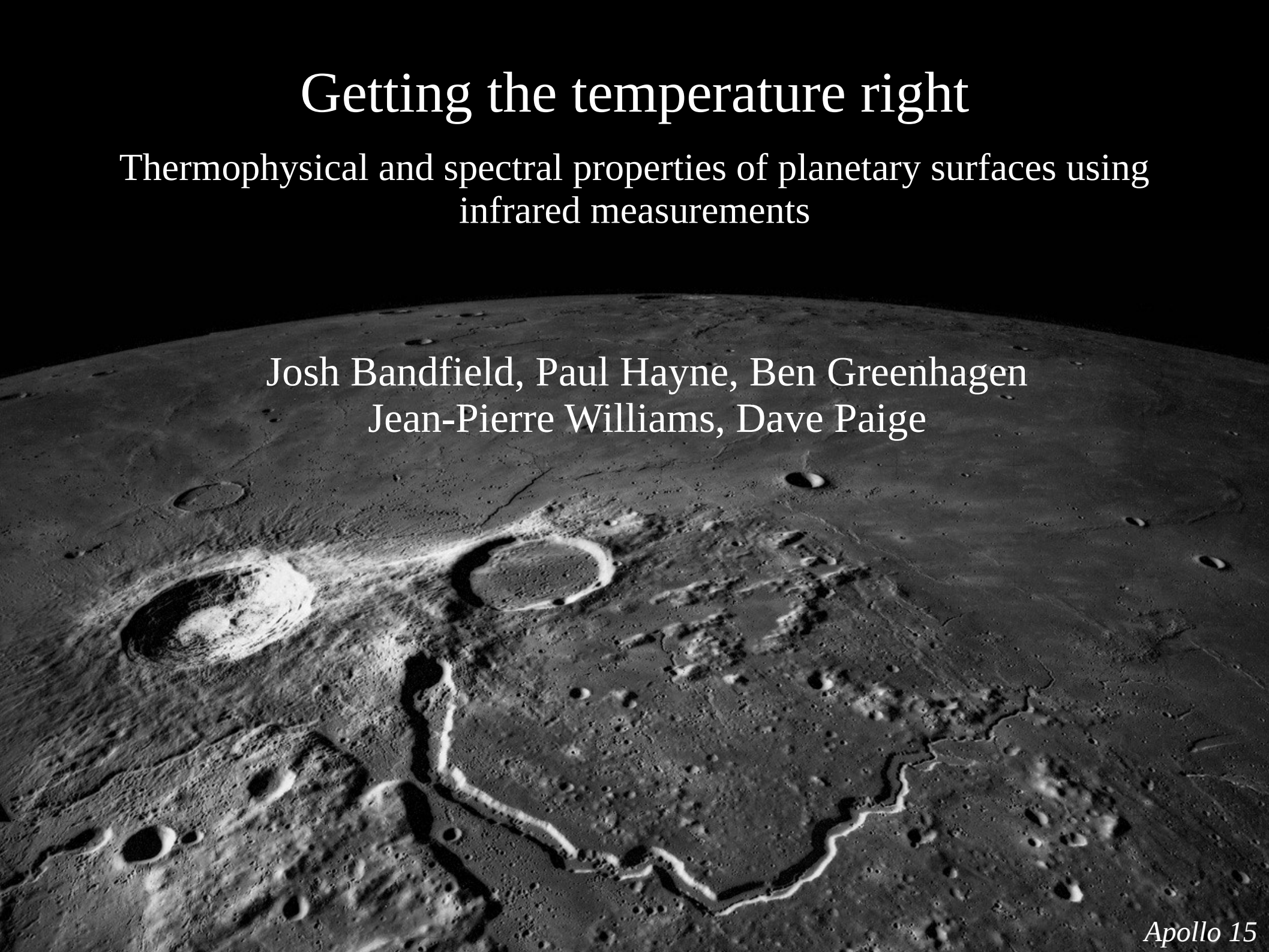

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The Main Point

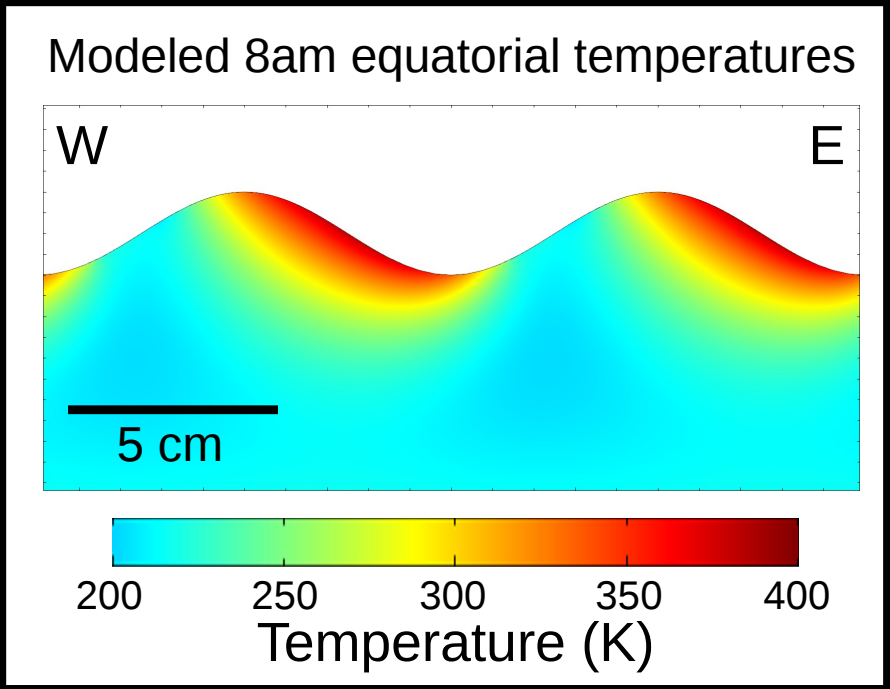
- Thermal emission from airless bodies is often dominated by effects due to surface roughness and rock abundance
- These surfaces are composed of a wide range of temperatures that cannot be approximated by a single temperature, which can lead to significant errors
- LRO Diviner has begun a campaign to fully characterize thermal emission from the lunar surface, serving as a baseline for investigations throughout the Solar System

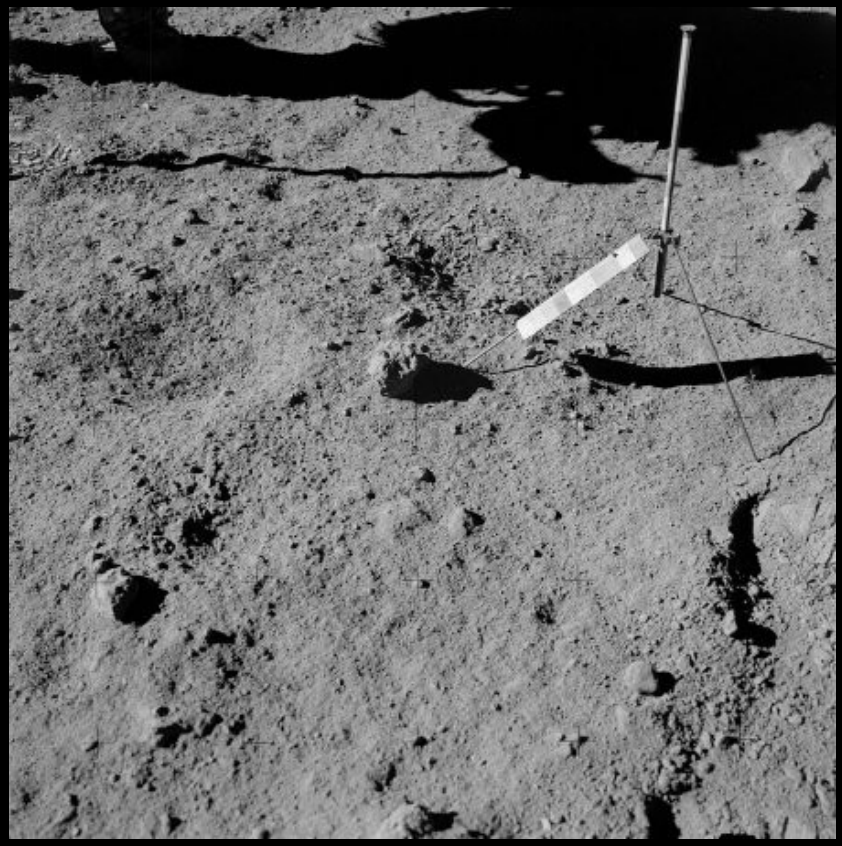
Surface Roughness

- Small-scale features dominate surface roughness measurement sensitivities
- Surfaces separated by just a few cm can vary by 200 K!

Why??

- Rough
- Highly insulating
- Vacuum environment





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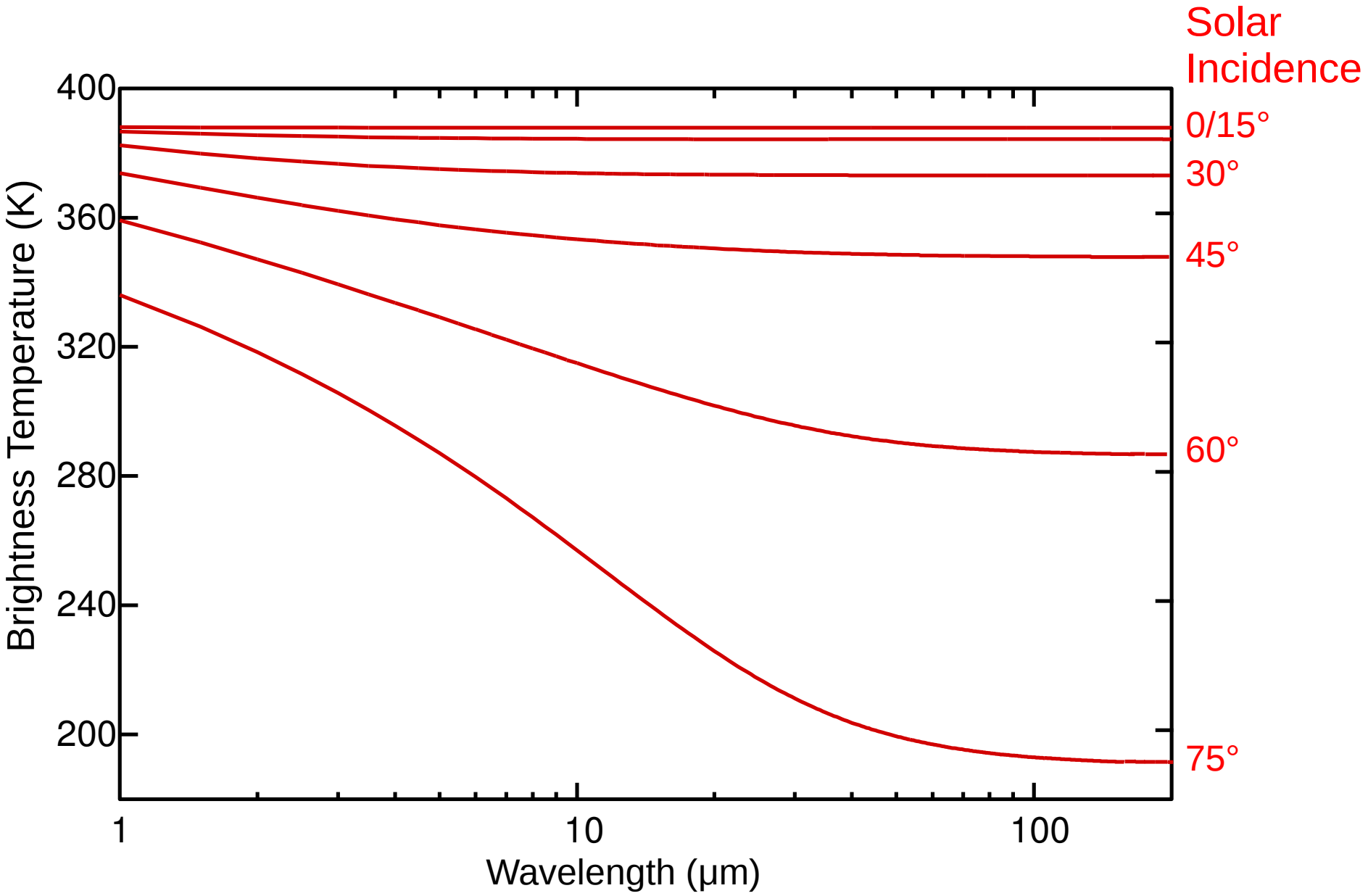
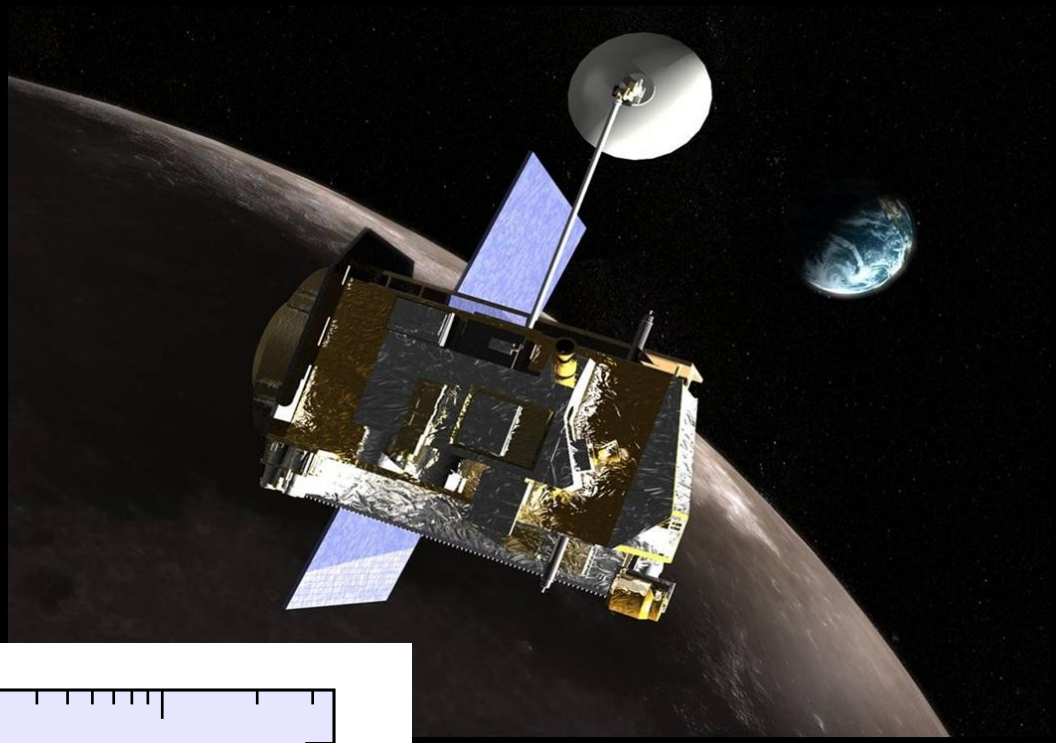
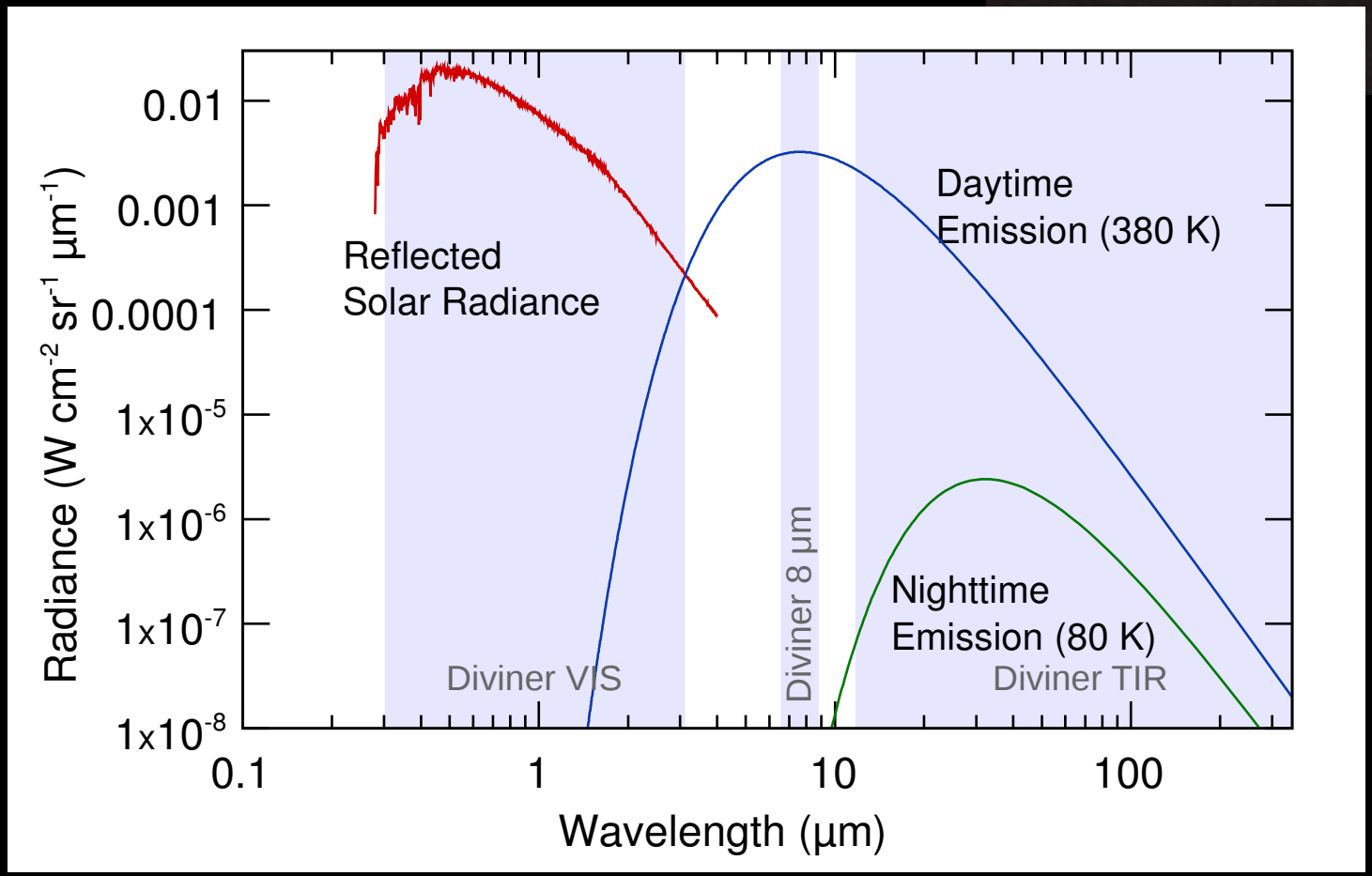
Surface Roughness and Brightness Temperatures



Modeled nadir lunar brightness temperatures for 25° RMS slope distribution

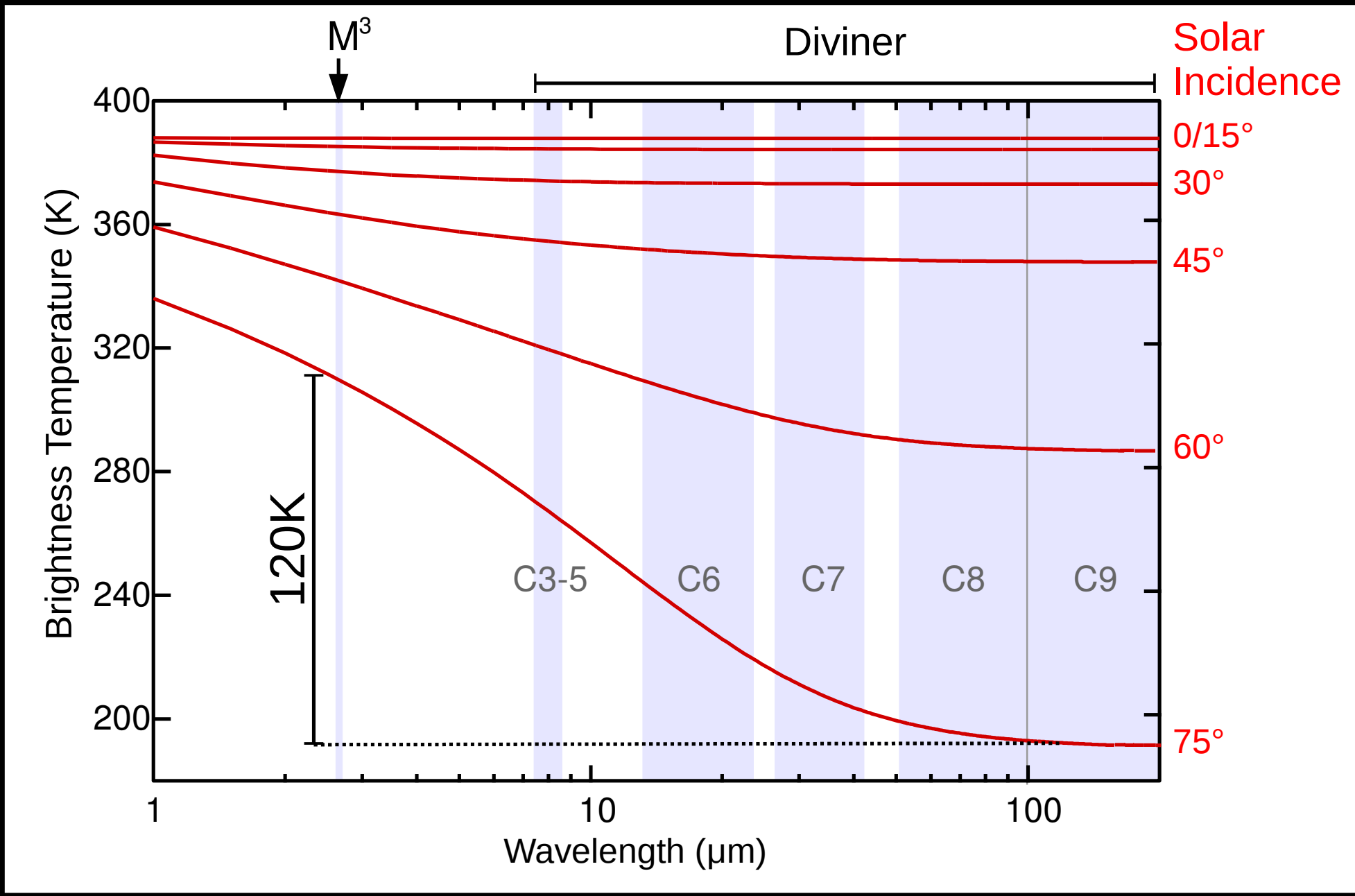
LRO Diviner: A Uniquely Complete Set of Measurements





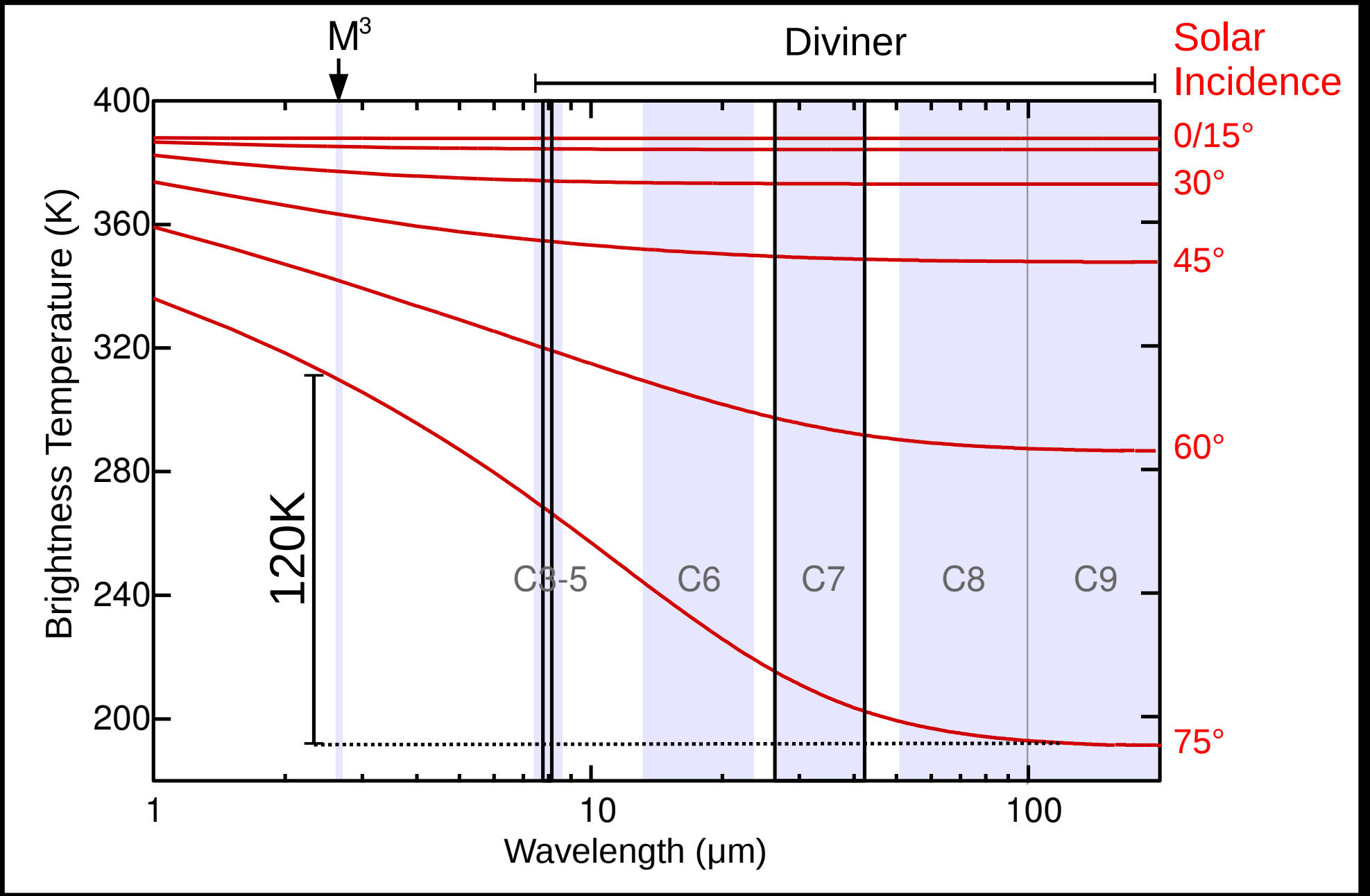
Diviner can measure most emitted and reflected light from most angles at all times of day

Surface Roughness and Brightness Temperatures



Modeled nadir lunar brightness temperatures for 25° RMS slope distribution

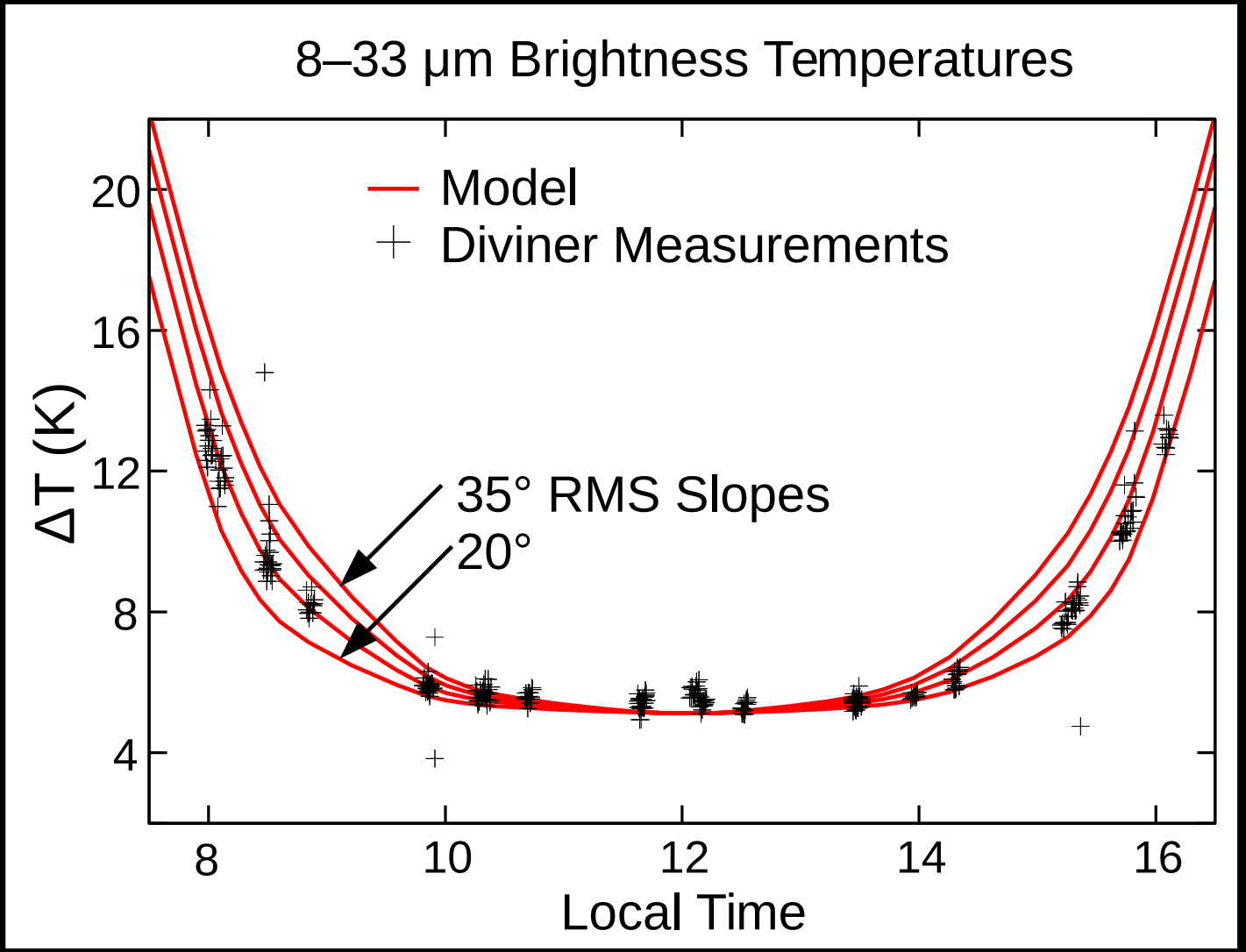
Surface Roughness and Brightness Temperatures



Modeled nadir lunar brightness temperatures for 25° RMS slope distribution

Lunar Surface Roughness

- Anisothermality is closely predicted using a ~25° RMS slope distribution (*Bandfield et al.*, 2015)

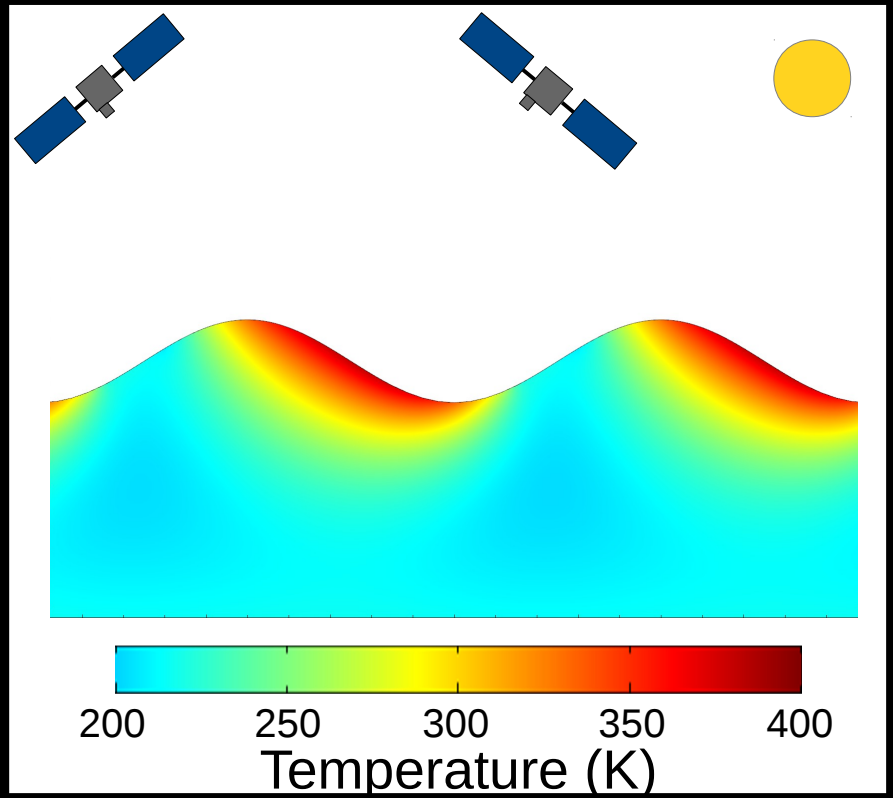


Diviner Nadir Observations (300-315E, 1S-1N)

LRO Diviner Phase Function Observations

- Two types of observations:
  1) Nadir spectral observations – measure spectral differences at a variety of solar incidence angles
  2) Multiple emission angle observations – measure surfaces from multiple angles at one or many solar incidence angles

- These two observation types provide complementary information and both are being collected by Diviner



Initial analysis published in *Icarus* (*Bandfield et al.*, 2014)

LRO Diviner Observations: Surface Phase Function Measurements

Goals:

- Define Vis and TIR phase function as completely as possible over representative surface units
  - Full diurnal coverage
  - Up/Down track and previous/post orbit cross-track observations
- Characterize the radiative balance of the lunar surface
  - **TIR coverage will be an unprecedented dataset**
  - There is also significant value in Vis observations that complement LROC
- Map variations in surface properties by collecting sustained off-nadir observations

LRO Diviner Observations: Surface Phase Function Measurements

Benefits:

- Determination of cm-scale physical properties to help determine the history and development of the lunar regolith

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LRO Diviner Observations: Surface Phase Function Measurements

Benefits:

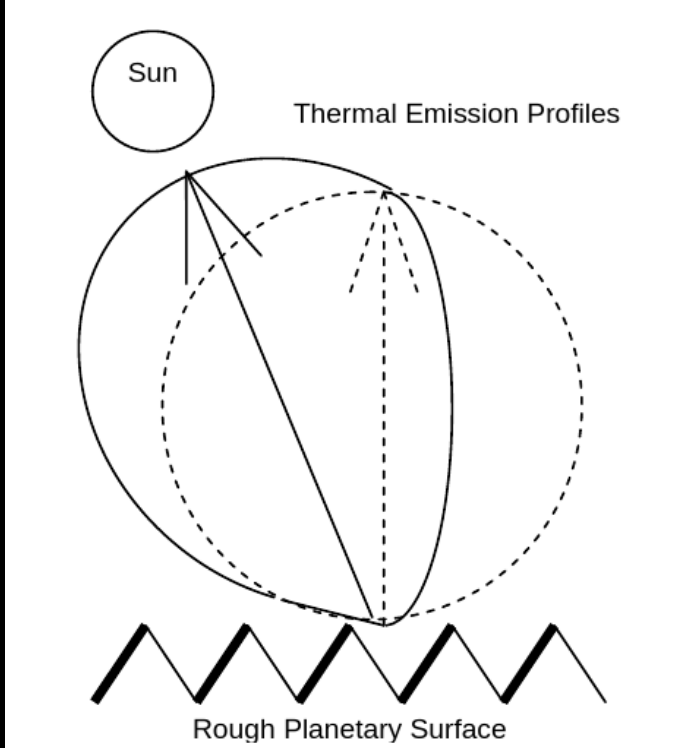
- Improved understanding of disk-integrated and limited measurements of airless bodies
  - Example: Estimation of asteroid size depends on “beaming”, which accounts for roughness properties towards the limb

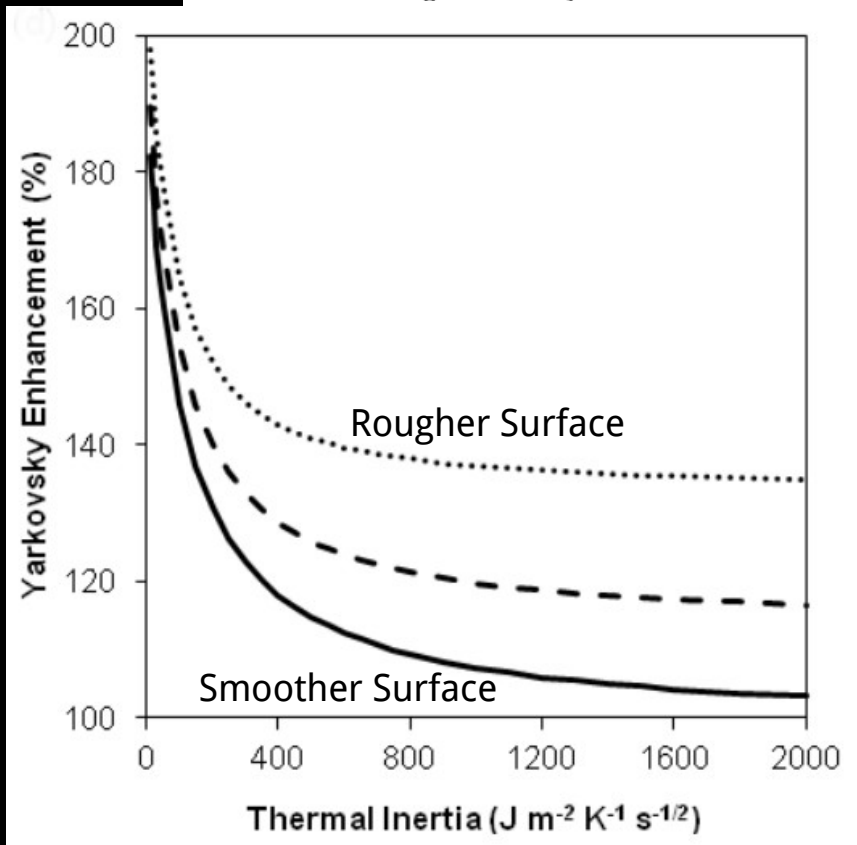
Wide-field Infrared Survey Explorer
NASA/JPL

LRO Diviner Observations: Surface Phase Function Measurements

Benefits:

- Improved determinations and understanding of Yarkovsky and YORP effects
  - Example: Non-lambertian emission greatly skews direction of emitted radiance



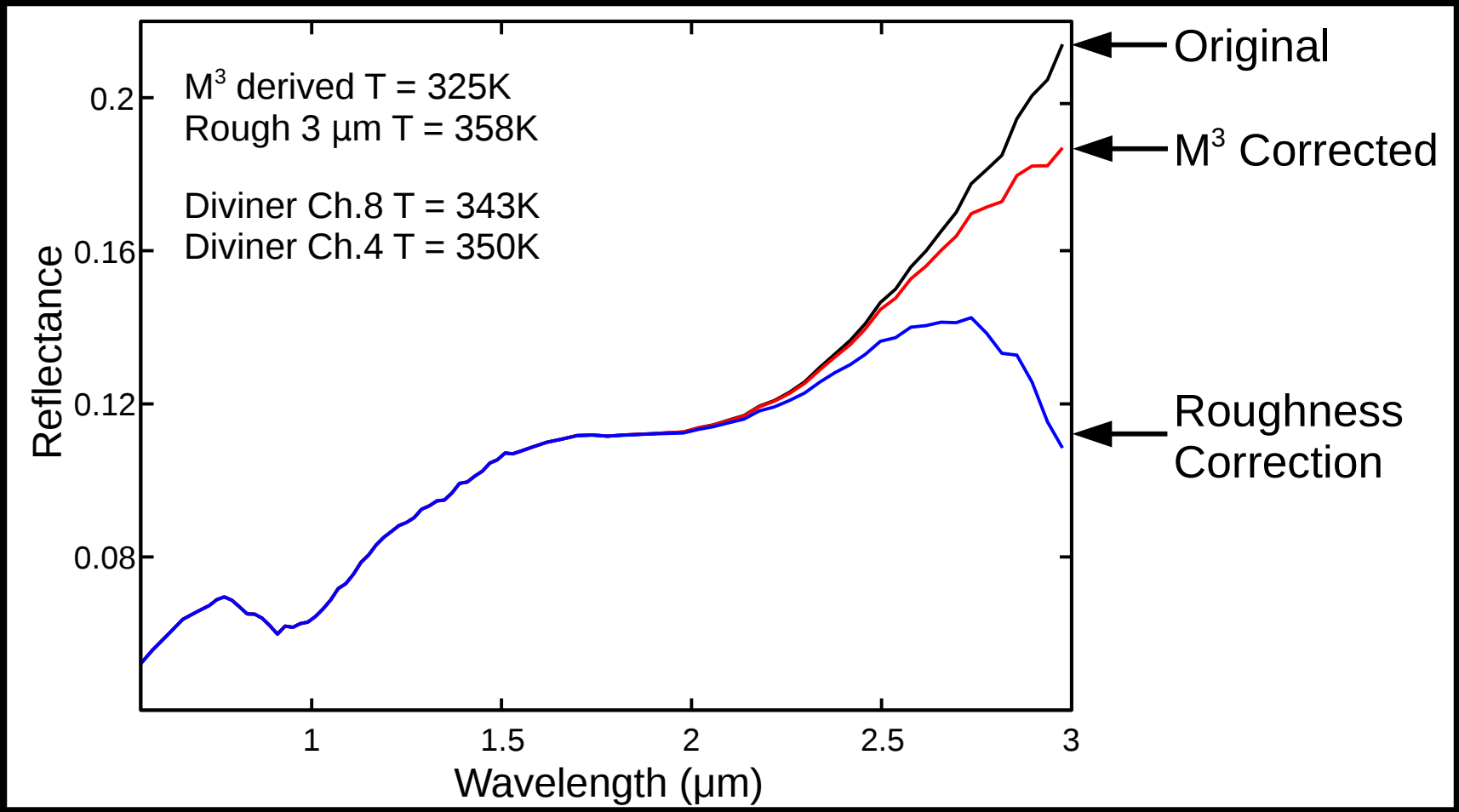


Rozitis and Green (2012)

LRO Diviner Observations: Surface Phase Function Measurements

Benefits: Improved thermal corrections for infrared spectroscopy

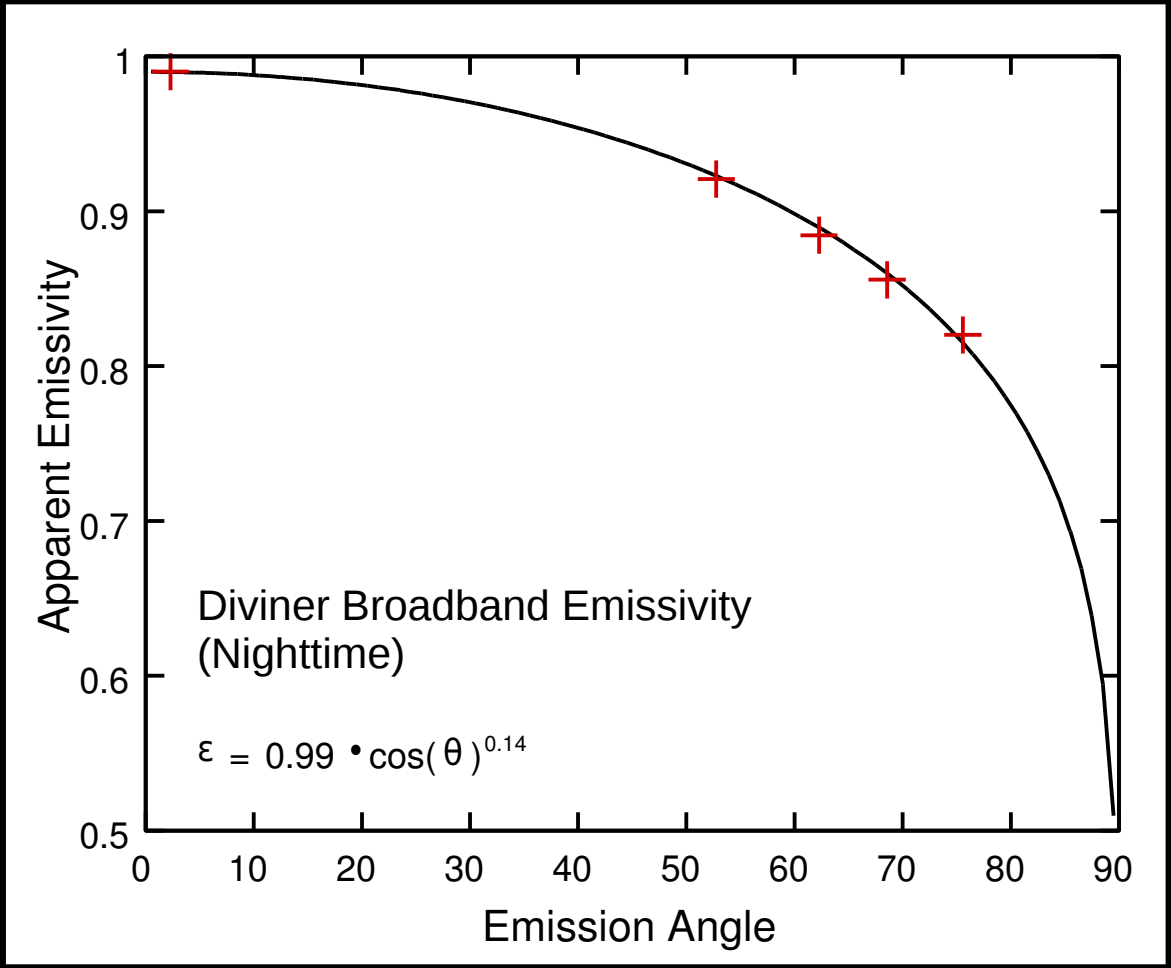
- Example: M^3 OH^-/H_2O absorption is much more prominent when accounting for roughness



LRO Diviner Observations: Surface Phase Function Measurements

Benefits:

- Characterization of radiative balance for improved thermal modeling
  - Example: Lunar hemispherical emissivity is lower than nadir directional emissivity resulting in warmer temperatures both day and night



LRO Diviner Observations Can Be Used To Better Understand Many Infrared Datasets

Dawn at Ceres

Examples:

Current/Recent Telescopes

- Spitzer, Herschel, SOFIA, WISE, IRTF

Current/Recent Spacecraft

- Dawn, LRO, Cassini, MESSENGER, Chandrayaan-1

Future Spacecraft

- BepiColombo, OSIRIS-REx, Hayabusa-2, Europa Clipper

Hayabusa-2
1999 JU3