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Investigating Thermal Emission from the Epiregolith: Lunar Lessons for Applications to Airless Bodies

Benjamin Greenhagen (1), Parvathy Prem (1), Kerri Donaldson Hanna (2), Neil Bowles (3) and Paul Lucey (4)

(1) Johns Hopkins Applied Physics Laboratory, USA, (2) University of Central Florida, USA, (3) University of Oxford, UK, (4) University of Hawai'i, USA (Email: benjamin.greenhagen@jhuapl.edu)

Abstract

Thermal gradients in the uppermost portion of the regolith greatly affect lunar thermal emission spectra. A multimodal study using remote sensing, laboratory, and modeled datasets can improve our understanding of the phenomenon and the possible implications for other airless bodies.

1. Introduction

On the Moon, near Earth asteroids, and the moons of Mars, the uppermost portion of regolith, the "epiregolith", represents the boundary layer between the surface and space that dominates spectral observations from far-ultraviolet reflectance to far-infrared emission. On the Moon, this layer is typically less than 2 mm in thickness and is characterized by significant thermal gradients (~60K / 100 µm). These thermal gradients make spectral emission from the Moon wholly different from Earth and Mars (where the epiregolith is essentially isothermal) and complicate the interpretation of spectral emission remote sensing data (Fig. 1). Therefore, thermal infrared (TIR) spectroscopy experiments measured in ambient laboratory conditions are not comparable to remote sensing datasets of airless bodies that contain significant emission components (Fig. 2). Here we use orbital data from the Lunar Reconnaissance Orbiter Diviner Lunar Radiometer (Diviner), experiments in simulated lunar environment, and radiative transfer models to investigate the thermal structure of and spectral emission from the epiregolith.

2. Diviner Lunar Radiometer

Diviner is a multispectral radiometer that has observed solar reflectance and TIR emission from the Moon at a wide range of illumination and viewing geometries to constrain radiative balance and spectral emission [1].

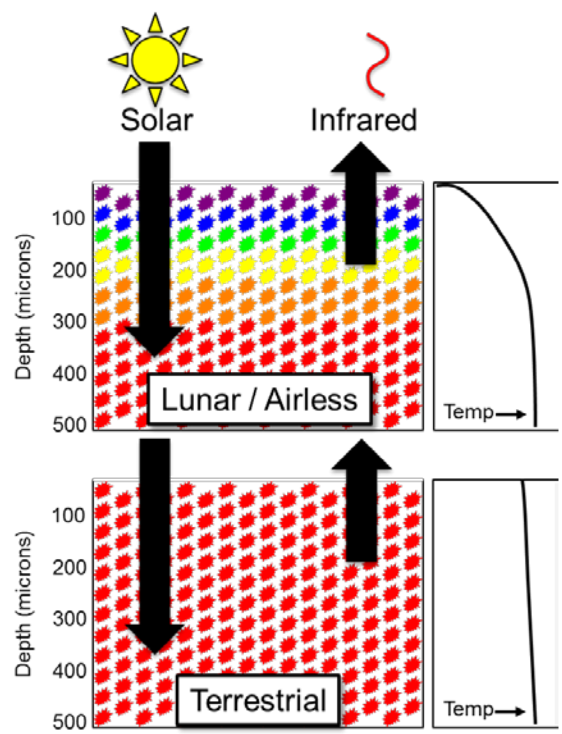

Figure 1: The lack of heat convection via atmospheric gases causes thermal gradients seen on airless bodies not found in terrestrial environments.

3. Simulated Lunar Environment

To simulate a relevant thermal environment we use the Simulated Lunar Environment Chamber (SLEC) and Planetary Analogue Surface Chamber for Asteroids and Lunar Environments (PASCALE) at University of Oxford's Planetary Spectroscopy Facility and the Simulated Airless Body Emission Laboratory (SABEL) at Johns Hopkins Applied Physics Laboratory. In these chambers, a particulate sample is heated (by conduction and illumination) within a cold radiation shield, and under vacuum. SLEC, PASCALE, and SABEL can create thermal gradients of variable magnitude and simulate the wide range of temperatures relevant to a wide range of studies [2-4]. Our experiments include relevant silicate minerals (anorthite, clinopyroxene, orthopyroxene, and olivine), lunar analogs, and lunar soils.

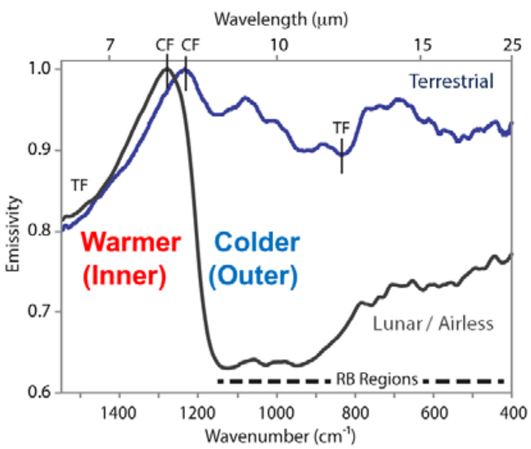

Figure 2: TIR spectral features are significantly altered by the presence of thermal gradients [after 2].

4. Thermal Models

Radiative transfer thermal models have been used to predict the behavior observed by Diviner and laboratory experiments [5-6]. We are implementing a new approach incorporating Monte Carlo methods to approximate scattering with significant benefits in required processing time. The increase speed of this code will enable additional investigations across a broader parameter space.

5. Summary and Conclusions

Insights gained from this study will improve interpretations of Diviner, future TIR lunar datasets, and improved thermal corrections of near-infrared datasets. Furthermore, epiregolith thermal gradients may also be significant on other airless bodies. The VORTICES node of SSERVI is specifically tasked with this type of multimodal data analysis and we hope to use our results to improve modelling of orbital and ground-based observations of the Moon, near Earth asteroids, and the moons of Mars.

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