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Diviner Lunar Radiometer Highlights from the LRO Cornerstone Mission

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Abstract

After over nine years in operation NASA's Lunar Reconnaissance Orbiter (LRO) Diviner Lunar Radiometer (Diviner) continues to reveal the extreme nature of the Moon's thermal environments, thermophysical properties, and surface composition. Diviner is the first multispectral thermal infrared instrument to globally map an airless body with relatively high spatial and temporal resolution. Thus Diviner observations form a cornerstone of thermal infrared studies of the Moon and airless bodies with important considerations for future datasets from the Moon, Mercury, small bodies, and icy satellites.

1. Diviner Lunar Radiometer

To date, Diviner has acquired observations over 18 complete diurnal cycles and 8 seasonal cycles. Diviner daytime and nighttime observations have essentially global coverage, and more than 90% of the surface has been measured with at least 8 different local times. Diviner's extended operations have also enabled observations of the lunar surface with a wide range of viewing geometries. The spatial resolution during the mapping orbit was ~200 m and now ranges from 150 m to 1300 m in the current elliptical orbit. Calibrated Diviner data and maps of visible brightness, temperature, rock abundance, nighttime soil temperature, and silicate mineralogy are available through NASA's Planetary Data System Geosciences Node.

Diviner was designed to accurately measure temperatures across a broad range from midday equatorial regions such as the Apollo sites (around 400K), typical nighttime temperatures of less than 100K, and extreme permanent shadowed regions colder than 50K. The coldest multiply-shadowed polar craters may have temperatures low enough constrain lunar heat flow [1]. Nighttime temperatures are driven by the thermophysical properties, including rock abundance and soil thermal inertia, which are used to investigate impact crater formation and evolution processes [2]. Multichannel infrared spectroscopy can constrain silicate mineralogy, including compositional heterogeneity in the lunar crust [3]. In addition to lunar properties, during the current LRO Cornerstone Mission (CM), we use new observation campaigns to characterize thermal emission behaviour fundamental to airless bodies with fine-particulate surfaces, including epiregolith thermal gradients and thermal-scale surface roughness.

2. Cornerstone Mission

With a vast dataset of nadir-pointing diurnal data on hand, we now look to use Diviner's spacecraft-independent gimballing capabilities to make special regional and global observations. Approximately half of Diviner data from the CM are one of four types of special observations: Lunar eclipse, twilight campaigns, targeted off-nadir EPFs, and global off-nadir campaigns.

2.1 Lunar Eclipses

The sharp thermal pulse associated with lunar eclipse provides the best opportunity to study the thermophysical structure of the upper few cms on the regolith. However, eclipses are infrequent and observations are limited to areas around the LRO ground track. Additionally, Diviner is no longer allowed to make measurements during total lunar eclipses due to spacecraft power restrictions. Therefore during the CM, we focus on partial lunar eclipses where these key observation can be for the portion of the Moon that is in total Earth shadow. We observed one partial eclipse on 7 August 2017 and will observe a second one in July 2019.

2.2 Twilight Campaigns

While there are limited opportunities to view lunar eclipses, all areas on the Moon experience rapid temperature drops immediately after local sunset. However, this analysis requires very high temporal density coverage across lunar "twilight." During the CM, we target ROIs for repeated observation on adjacent orbit tracks (~4 lunar minutes apart) during the 17:45 to 18:45 time period. The LRO orbit affords us opportunities to makes these measurements nearly globally and in many areas there are multiple opportunities.

2.3 Targeted Off-Nadir EPFs

The lunar surface is both very rough and highly insulating on scales of mm to cm, which produces range of temperatures (i.e. anisothermality) within any scene [4]. To fully characterize this behaviour requires multispectral thermal infrared observations with systematically varying viewing and illumination geometries. The improved understanding of the lunar regolith emission phase function (EPF) will feed directly into models of heat transfer on airless bodies and volatile transport and sequestration. During the CM, we will measure EPFs for ten representative targets.

2.4 Global Off-Nadir Campaigns

During the CM we will produce global maps with approximately 50 degree emission angles, both low and high phase at eight different local times (four day and four night). These data compliment an existing 70 degree emission angle, low phase campaign and enable an extension of the targeted EPF science to global scales.

3. Summary

This presentation will focus on recent Diviner results addressing a diverse range of scientific questions and will highlight exciting new observations from LRO's Cornerstone Mission.

References

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