DIVINER EMISSION PHASE FUNCTION (EPF) TARGETING CAMPAIGN.

K. A. Bennett[1], E. Foote[2], C. Gallinger[3], T. Powell[4], E. Jhoti[2], J.-P. Williams[2], F. Leader[5], and D. Paige[2]. [1]U.S. Geological Survey, Astrogeology Science Center, Flagstaff, AZ, 86001. [2]Department of Earth, Planetary, and Space Sciences, University of California Los Angeles. [3]Department of Earth Sciences, University of Western Ontario. [4]Applied Physics Laboratory, Johns Hopkins University. [5]Jet Propulsion Laboratory. (kbennett@usgs.gov)

Introduction: The Diviner Lunar Radiometer Experiment (Diviner) onboard the Lunar Reconnaissance Orbiter (LRO) has continuously been acquiring thermal and solar data since mid-2009. Throughout that time, Diviner has been conducting both global and targeted off-nadir observations to investigate the lunar emission phase function (EPF). These EPF observations provide valuable information about the angular infrared emissivity of the lunar surface. Analyzing the EPF can yield constraints on the lunar surface roughness and composition. Additionally, having an accurate model of the lunar EPF will be important for any future instruments with off-nadir temperature measurements that must be normalized to a standard viewing angle. Here we describe the targeted Diviner EPF campaign and provide an update regarding recent targets and strategies.

Background: Diviner nominally operates nadir-pointing in a pushbroom fashion to map and characterize the thermal and photometric environments and characteristics of the lunar surface [1]. However, it also has the capability to acquire off-nadir data by using elevation and azimuth actuators that move the instrument independent of the spacecraft orientation [1]. In addition to the planned off-nadir observations Diviner acquires, it also periodically obtains off-nadir data when the LRO spacecraft slews to enable off-nadir observations for other LRO instruments.

Diviner has been using this observation technique in two modes: a global off-nadir campaign [2,3] and a targeted EPF campaign [4,5]. In the global mode, Diviner is slewed off-nadir at a fixed angle and continuously takes data for an amount of time (usually several weeks). Due to the long duration of the experiment, data have only been acquired from a few angles. Multiple repeated observations of each target are necessary to capture a range of emission, azimuth, and incidence angles (i.e., Figure 2). Once sufficient coverage has been obtained, the EPF of each target can be compared to characterize differences in surface roughness and composition.

Targets and Data Acquisition: To build an EPF dataset, Diviner must obtain multiple observations of a location at many different viewing and illumination angles. This can be operationally intensive; therefore, a set of high-priority science targets have been selected for these observations.

The original set of ten test targets was selected in 2012 and included typical mare and highlands (both at the equator and at high latitudes), pyroclastics, impact ejecta (Kepler crater), impact melt (King crater), a cold spot (Chaplygin B), and a lunar swirl (Reiner Gamma) [5]. Preliminary analyses of the typical mare and highlands targets showed no statistically significant difference between the EPFs of each feature [4,5]. As EPF is influenced by surface roughness at cm-scale [4], this could imply that the mare and highlands have similar roughness at this scale.

Based on these results, additional targets were added during the previous LRO extended science missions (ESM4) that are thought to have anomalous roughness. By selecting targets with “extreme” examples of surface roughness, we will be able to test whether any features on the lunar surface exhibit variable roughness and variable EPFs at the spatial scale that is probed with Diviner. These targets included pyroclastic deposits (demonstrated to be relatively “smooth” compared to typical regolith), impact melt (with variable roughness properties depending on the dataset/wavelength investigated), cold spots (anomalously “fluffy” surface properties), and young (less than 10 years old) craters (which have not had time for space weathering to homogenize the surface). Additionally, the Apollo landing sites were added as targets because the photometry experiments conducted during those missions could provide important ground truth. Analysis of these datasets is underway.

During LRO’s current extended science mission (ESM5), two sets of Diviner EPF targets have been added. The first set is polar targets that were selected to take advantage of the “ring of fire” – a ring around the poles where LRO has enhanced repeat coverage as a result of its growing orbital inclination moving LRO away from a polar orbit [6]. Targets are focused on the south to provide coverage over several of the Artemis candidate landing regions. Targets include “typical” polar terrain, paired targets inside and outside permanently shadowed regions, and Artemis candidate landing regions. Additionally, Diviner is taking part in the ESM5 LRO Multi-Instrument Photometry Campaign [7]. Eleven targets were added to address science goals related to impacts, volcanism, and composition, as well as provide support for future landed lunar missions. Coordinating these observations across LRO instruments will result in a cohesive and complementary multi-instrument dataset that can robustly characterize how the lunar surface reflects, absorbs, and emits radiation at various viewing geometries and wavelengths.

The locations of 51 high-priority targets described above are shown in Figure 1. The original ten targets have the most complete coverage across the lunar day and across viewing angles (Figure 2A). The ESM4 targets have moderate coverage (Figure 2B), and the ESM5 targets have sparse coverage as there has not yet been sufficient time to build the dataset.

Highlighted Targets: Figure 2A shows an example of brightness temperature as a function of azimuth and emission angle at noon for the high-latitude highlands target. This site has sufficient angular coverage to show consistent trends in directional emission. In general, the observed brightness temperature is elevated when viewing at low phase angle, likely due to preferential viewing of sub-pixel sunlit surfaces. Figure 2B shows a similar plot for the Sulpicius Gallus pyroclastic deposit, a more recently added target (ESM4). Though fewer observations have been accumulated to date, the directional emission behavior is broadly similar. Continued accumulation of EPF will allow detailed comparison between sites to identify differences in roughness between features.

Expected Dataset and Future Plans: The targeted EPF observations being collected by Diviner represent a unique dataset to study the photometry and emissivity of the lunar surface, which is key to understanding the Moon's thermal environments. While this data is currently available in the Diviner data archive at the PDS, at present there is no way to easily identify EPF observations. Work is currently underway to isolate the EPF observations and make a separate dataset readily available to the planetary science community.

References: [1] Paige et al. (2010) *Space Sci Rev* **150**, 125–160. [2] Greenhagen et al. (2017) AGU Fall Meeting, #P41D-2850. [3] Rubanenko et al. (2020) *JGR: Planets*, vol. 125, 6. e2020JE006377. [4] Bandfield et al. (2015) *Icarus, 248, 357–372.* [5] Warren et al. (2021) LPSC #1890. [6] Petro et al. (2022) LPSC, #2326. [7] Bennett et al. (this conference) LPSC.

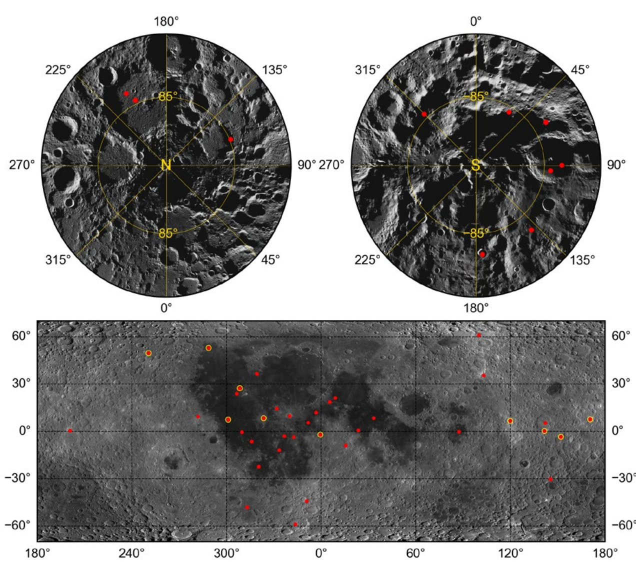

Figure 1: Red dots show locations of all 51 Diviner EPF targets. The original 10 targets selected in 2012 are circled in yellow in the equatorial plot.

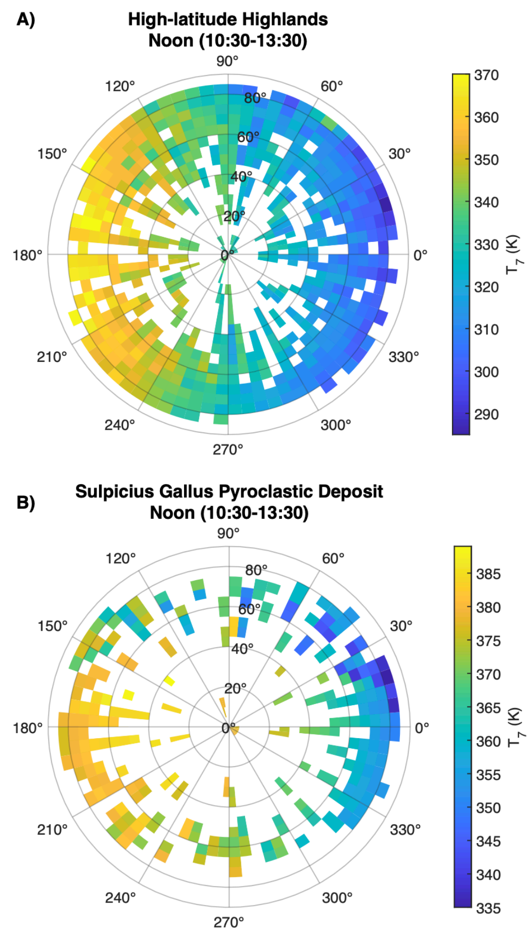

Figure 2. Channel 7 brightness temperature as a function of viewing geometry at noon for the high-latitude highlands (49.55˚N, -109.55˚E) and Sulpicius Gallus pyroclastic deposit (21.28˚N, 8.82˚E) targets. Azimuth angle is relative to north.