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Solar Reflectance Measurements of Apollo Lunar Soils

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Abstract

The moon is the one planetary object from which we have returned samples. The goal of this work is to analyze and understand the solar reflectance of the Moon. Our approach is to compare Lunar Reconnaissance Orbiter (LRO) Diviner orbital solar albedo measurements at the Apollo soil sample sites with laboratory bidirectional reflectance measurements. CAPTEM provided us with five representative lunar soil samples: a typical low albedo mare sample (10084, Apollo 11), a low titanium basaltic sample with impact breccias (12001, Apollo 12), an Apollo 15 sample (15071), a high albedo lunar highlands soil (68810 & 61141, Apollo 16) and an Apollo 17 soil sample (70181). The laboratory and Diviner datasets provide complementary and independent insights into the photometric properties of the lunar surface. We have made the most extensive set of laboratory bidirectional measurements of lunar soil to date and have successfully fit photometric models to the laboratory data.

1. BRDF Measurements

We used the Bloomsburg University Goniometer (BUG) to make the Bidirectional Reflection Distribution Function (BRDF) measurements on the suite of Apollo samples exposed to standard ambient laboratory conditions. The BUG instrument consists of a filtered, chopped and collimated light source and a solid-state detector [1]. The source is a 100 W quartz halogen bulb and is attached to an arm that moves 0-65º degrees in incidence and 0-180º degrees in azimuth, 60 cm away from the sample. The detector has a 1 cm field of view for normal viewing geometry. It is attached to an arm that moves 0-80º in emission angle, 80 cm away from the sample. The source and detector move along three independent axes [1]. Figure 1 shows the Apollo 11 soil sample with the BUG setup.

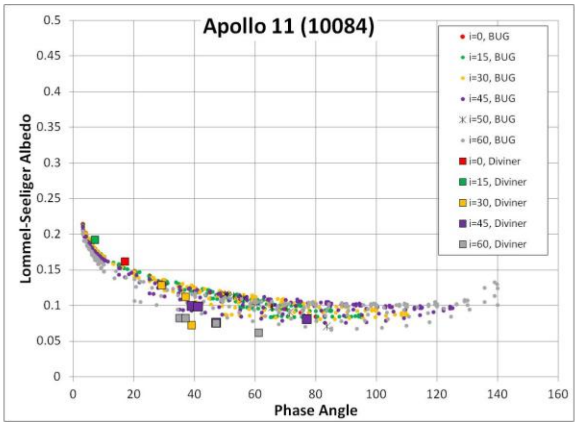
We collected two different types of reflectance datasets. The standard set of BUG BRDF measurements include incidence angles (0º < i < 60º), emission angles (0º < e < 80º), and phase angles (3º < g < 140º), which provided us with 680 measurements per wavelength (Figure 2). We also obtained BUG data at high-incident angles. These measurements were acquired along and perpendicular to the principal plane axis and include incidence angles 0º < i < 75º and phase angles 3º < g < 155º, which gave us an additional 89 points per wavelength (for a grand total of 769 angle combinations). We used 6 spectral filters to obtain these data, 450, 550, 700, 750, 850 and 950nm.

Figure 1: BUG Experimental Setup. (left) Full bidirectional reflectance measurements are performed using 28g of lunar soil in a circular dish at incidence angles ranging from 0° to 60°. (right) By placing the same soil sample in an elongated rectangular trough, bidirectional reflectance measurements are performed inside and perpendicular to the principal plane at incidence angles of 70° and 75°

2. Diviner Observations

The Diviner Lunar Radiometer Experiment on the Lunar Reconnaissance Orbiter is an infrared and solar radiometer with nine spectral channels (ranging from 0.35 to 400 microns) [2]. Diviner is currently collecting data from an orbit of 100 kilometers above the lunar surface and an orbital period of two hours.

The instrument has obtained solar reflectance measurements of the Moon in a broadband solar channel, Channel 1, from 0.3 to 3.0 microns wavelength. Most of these measurements have been acquired in a nadir pushbroom mapping mode near e=0. The solar channel on Diviner is calibrated once per orbit and is done so by rotating the instrument toward space and looks at an aluminum calibration target for 30-50 seconds.



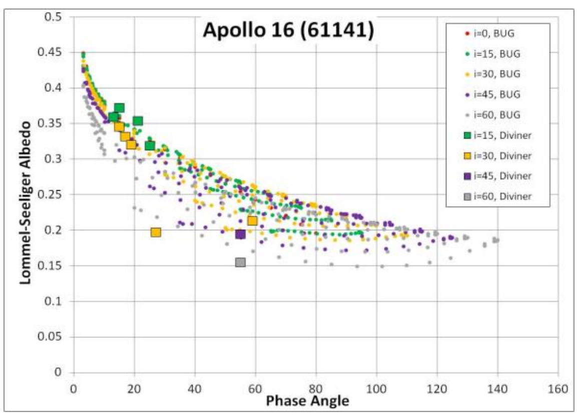


Figure 2: The BUG Apollo sample measurements and the Diviner solar channel data acquired within 0.5 km lat/lon boxes centered on the Apollo 11 (top), and 16 (bottom) and landing sites. The Lommel-Seeliger Albedo corrects for first order photometric variations due to incidence and emission angle. The Lommel-Seeliger albedo (A_{ls}) is related to the Lambert Albedo (A_L) by $A_{Ls}=A_L(\mu_0+\mu)$. The plots show a strong dependence on measured reflectance with phase angle.

In addition to the calibration procedure, the LRO spacecraft is routinely rolled to obtain high-resolution Lunar Reconnaissance Orbiter Camera (LROC) stereo images of the Apollo landing sites and other areas of interest on the lunar surface, thus providing more complete BRDF coverage. Figure 2 shows the Diviner solar channel data acquired within 500 m lat/lon boxes centered on the Apollo 11 and Apollo 16 and landing sites.

The Diviner team has recently designed a targeting tool that has enabled us to use Diviner's internal off-nadir pointing capability to obtain a more extensive and complete set of bidirectional reflectance measurements of selected regions of interest these include the Apollo landing sites and sample sites which has greatly improved our photometric coverage. The limited bidirectional reflectance measurements obtained by Diviner at the Apollo 11, 12, 15, 16 and 17 landing sites thus far are in good general agreement with laboratory goniometer measurements at the same angles, especially at low phase angles. At higher phase angles, the Diviner measurements are lower, suggesting that roughness and shadowing at spatial scales smaller than the Diviner footprint are a significant factor. We will continue to use Diviner's pointing capabilities to target the Apollo sites. We will soon expand our Diviner targeting campaign to study other diverse and interesting Lunar features, such as swirls, melt ponds, pyroclastic deposits and low thermal inertia areas.

References

[1] Shepard, M. K., 32nd Lunar and Planetary Science Conference, Houston, TX, USA, Abstract #1015, 2001.
[2] Paige et al. Space Sci. Rev. 150, 125, 2010.