THE BIDIRECTIONAL REFLECTANCE OF APOLLO 11 SOIL SAMPLE 10084.

E. J. Foote[1], D. A. Paige[1], J. R. Johnson[2], W. M. Grundy[3], and M. T. Shepard[4], [1]University of California, Los Angeles, Department of Earth and Space Sciences, 595 Charles Young Drive East, Los Angeles, CA 90095, efoote@ucla.edu, [2]USGS, [3]Lowell Observatory, [4]Bloomsburg University.

Introduction: Accurate models of the lunar thermal and illumination environment require a realistic treatment of scattered radiation at high incidence and emission angles. It has long been appreciated that the bidirectional reflectance of lunar soil is anisotropic [1], yet most lunar thermal models still assume that scattered radiation is isotropic. We recently measured the bidirectional reflectance of Apollo 11 soil sample 10084 using the Bloomsburg University Goniometer (BUG) [2] and fit the measured reflectances using Hapke's photometric model [3] that includes the effects of large-scale roughness [4]. Figure 1 shows the BUG experimental setup which was optimized for obtaining reflectance measurements at high incidence and emission angles.

Results: Figure 2 shows the BUG measurements of the full bidirectional reflectance of the Apollo 10084 soil sample at an incidence angle of i=60°. Figure 2 also shows the best fit bidirectional reflectance calculated at i=60° using Hapke's model employing the parameters and procedures decribed by Johnson et al. [4]. Figure 3 shows the measured and calculated reflectance of the sample at i=75° in and out of the principal plane. Using the Hapke's model allows us to extrapolate the bidirectional reflectance to higher incidence and emission angles than were measured by BUG in a physically plausible manner. Figure 4 shows the calculated integrated hemispherical reflectance of the sample as a function of incidence angle.

Discussion: The BUG 10084 measurements demonstrate that the bidirectional reflectance of lunar soil is anisotropic at high incidence and emission angles. These results have significant relevance for modeling illumination conditions and temperatures in shadowed regions such as those that exist at the lunar poles. They suggest that the flux of scattered solar photons within shadowed regions may be more than a factor of two higher than has been previously estimated. The next step in our analysis will be to fit the BUG bidirectional reflectance measurements to a set of simplified empirical functions that are less computationally intensive than Hapke's and then incorporate them into a in a 3-dimensional ray-tracing thermal model [5].

References: [1] Minnaert, M. Photometry of the Moon. in *Planets and Satellites*, University of Chicago Press, 1961; [2] Shepard, M. K. *Solar System Remote Sensing Symposium*, #4004, LPI, 2002; [3] Hapke, B. *Theory of Reflectance and Emittance Spectroscopy*, Cambridge University Press, 1993; [4] Johnson et al., this volume; [5] Paige et al., DPS meeting #38, #49.01, 2006.

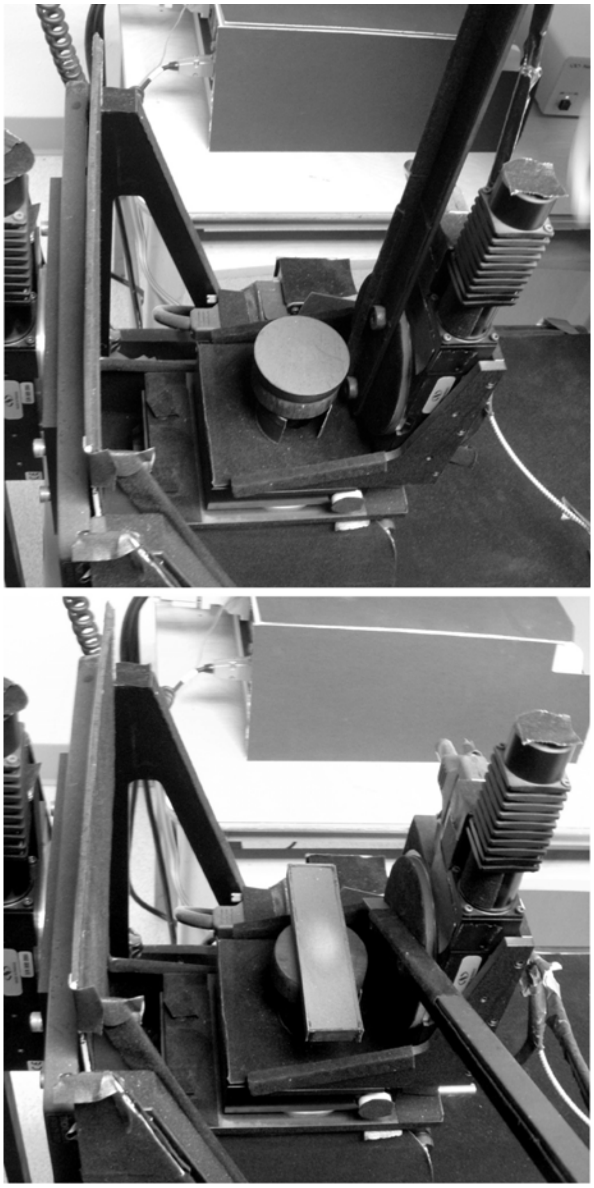

Figure 1. BUG Experimental Setup. (top) Full bidirectional reflectance measurements are performed using 28g of lunar soil in a circular dish at incidence angles ranging from 0° to 60°. (bottom) By placing the same soil sample in an elongated rectangular trough, bidirectional reflectance measurements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

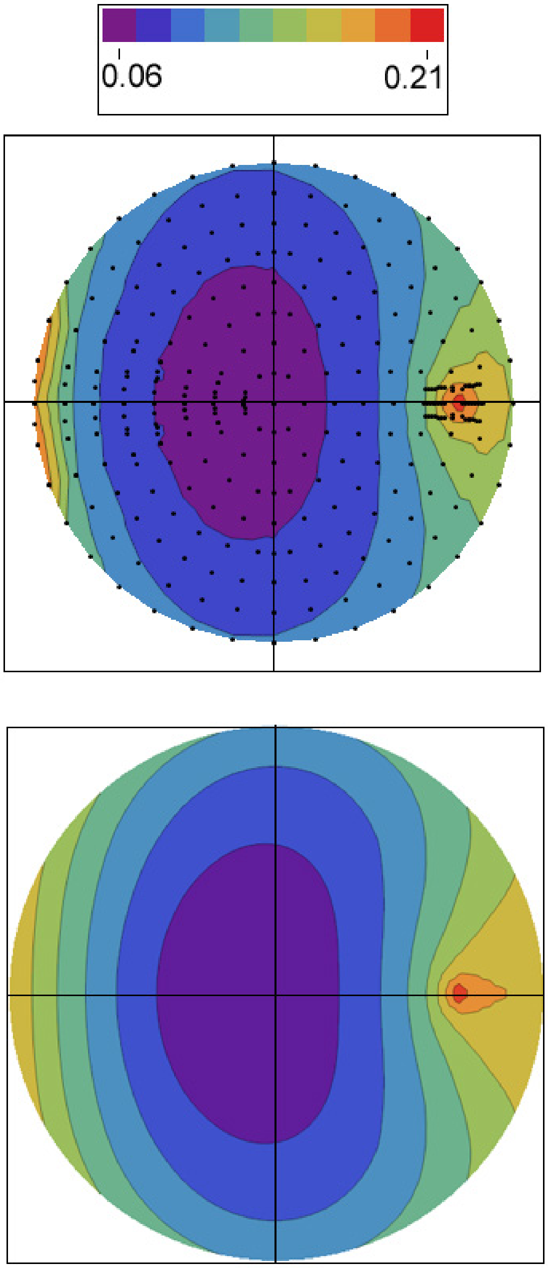

Figure 2. Measured (top) and calculated (bottom) bidirectional reflectance of the Apollo 10084 soil sample at 750nm at *i*=60°. The radial coordinate is emission angle (to 90°) and the azimuthal coordinate is azimuth angle. The principal plane is oriented along the *x* axis. The black dots indicate the angular positions of the BUG measurements (acquired to emission angles of 80°). The contoured quantity is the reflectance factor or Lambert Albedo, which is the measured reflectance divided by that expected for a perfectly diffusing reflecting surface under the same illumination conditions. The calculated bidirectional reflectances employ the best fit Hapke parameters from Johnson et al. [4] using two-term Henyey-Greenstein functions and accounts for large-scale surface roughness.

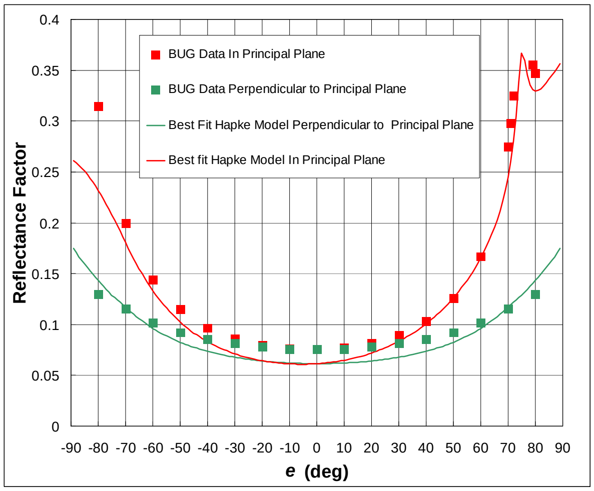

Figure 3. Measured and model-calculated reflectances at 750nm for *i*=75°. BUG measurements at this incidence angle were measured in the principal plane and perpendicular to the principal plane. The model results shown here employ an optimized set of Hapke parameters that were fit to a subset of the BUG dataset that included only data measured in the principal plane and perpendicular to the principal plane. Using the notation of Johnson et al [4], they are $w(hg2)$=0.33, $\theta(hg2)$=7, $h(hg2)$=0.017, $B_0(hg2)$=1.0, $b(hg2)$=0.308, $c(hg2)$=0.425.

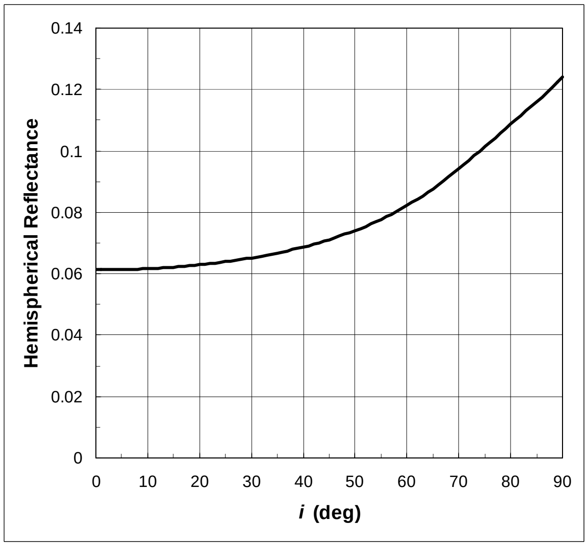

Figure 4. Hemispherical Reflectance. Calculated hemispherical reflectance of lunar sample 10084 as a function of incidence angle using Hapke model parameters described in Figure 3. This is the fraction of total incident photon energy at each incidence angle that is scattered by the sample.