Laboratory laser reflectance measurement and applications to asteroid surface analysis

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Introduction Laboratory reflectance measurement of asteroid analogs is an important tool for interpreting the reflectance of asteroids. One dominant factor affecting how measured reflectance changes as a function of phase angle (180° minus the scattering angle) is surface roughness [1], which is related to grain size. A major goal of this study is to be able to use the angular distributions (phase functions) of scattered light from various regions on an asteroid surface to determine the relative grain size between those regions. Grain size affects the spectral albedo and continuum slopes of surface materials, has implications in terms of understanding geologic processes on asteroids and is also valuable for the planning and operations of upcoming missions to asteroids, such as the New Frontiers OSIRIS-REx sample return mission to the asteroid (101955) Bennu [2]. Information on surface roughness is particularly powerful when combined with other datasets, such as thermal inertia maps (e.g., a smooth, low-backscatter surface of low thermal inertia likely contains fine grains).

Approach To better constrain the composition and surface texture of Bennu, we are conducting experiments to investigate the laser return signature of terrestrial and meteorite analogs to Bennu. The objective is to understand the nature of laser returns given possible compositional, grain size and slope distributions on the surface of Bennu to allow surface characterization, particularly surface grain size, which would significantly aid efforts to identify suitable sites for sampling by the OSIRIS-REx mission.

Setup A 1064-nm laser is used to determine the reflectance of Bennu analogs and their constituents (1064 nm is the wavelength of many laser altimeters including the one planned to fly on OSIRIS-REx). Samples of interest include serpentinites (greenalite, etc.), magnetite, and shungite.

To perform the experiments, a goniometer has been built. This instrument allows reflectance measurements at various illumination and viewing geometries. The goniometer has an an arm and a caddy that travels the length of an arc. Both the caddy and arm can accommodate either a source or detector. The arm rotates in azimuth and elevation, allowing data acquisition over the whole hemisphere. The optical assembly that we mount on the caddy for the first two sets of experiments described below has also been built.

Experiments We have determined a series of three sets of experiments for measuring reflectance as a function of grain size while successively broadening the range of illumination and viewing geometries: 1) The first set of experiments involves measuring reflectance of a set of samples, each of a different grain size, at constant viewing and illumination geometry (nadir for both). 2) The second set of experiments involves a similar set of measurements, but this time the incidence angle will be varied, while keeping the phase angle constant (at zero, i.e., the lidar geometry). The results will be important for calibrating OSIRIS-REx Laser Altimeter (OLA) data, including separating the contributions of range, surface roughness, and surface composition. 3) The third set of experiments builds on the previous experiments by also allowing phase angle to vary, resulting in phase function (angular scattering intensity distribution) measurements. These data are particularly useful for the interpretation of OSIRIS-REx Visible and IR Spectrometer (OVIRS) and OSIRIS-REx Camera Suite (OCAMS) data taken at varying illumination and viewing geometries. These datasets can then be analyzed together with the OLA dataset for a more complete picture of surface reflectance characteristics.

Conclusion The experiments outlined above and the resulting database are intended to benefit 1) proper interpretation of photometric data to determine surface roughness and 2) generation of albedo maps from laser altimeter measurements of planetary surfaces, such as that of Bennu. We have built a facility to collect this database of reflectance measurements, and the facility has already seen ”first light” with measurements of greenalite calibrated against Spectralon® targets. Measurement error (2σ) is 0.01 in I/F and 0.003 in BRDF (bidirectional reflectance distribution function).

References: [1] Shaw et al. (2013), *J. Geophys. Res., 118*, 1–19. [2] Lauretta et al. (2012) *LPS XLIII*, Abstract #6345. [3] Shaw et al. (2013), *LPS XLIV*, Abstract #1584.