OSIRIS-REx Laser Altimeter 1064-nm Reflectance Investigation at Bennu

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Introduction

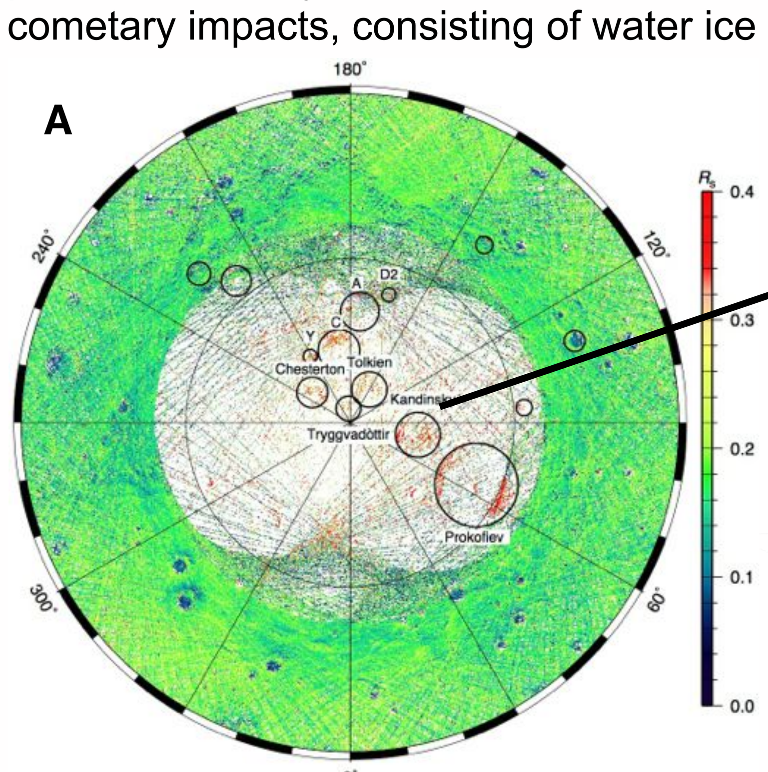
The purpose of the OSIRIS-REx mission is to characterize and successfully return to Earth a geologically representative portion of the surface of asteroid Bennu. The touch-and-go (TAG) sampling of this small asteroid (~250 m in radius) will entail a detailed survey to select a sampling site. The data required to ensure TAG success will be provided by a scientific payload that includes a powerful dual-range scanning laser altimeter [1] (OLA) contributed by the Canadian Space Agency. **The laser altimeter will also measure the intensity of the returned pulses and thereby the normal albedo, independent of illumination geometry, the first such lidar radiometric measurements of an asteroid.**

This investigation, as part of the Altimetry Working Group (AltWG) team, seeks to provide a global calibrated reflectance map of Bennu at high resolution. **We will apply algorithms successfully employed at NASA GSFC to recover the reflectance at Bennu, and pursue its implications for modeling the radiation pressure of the reflected light on the orbital (Yarkovsky) and rotational (YORP) dynamics.**

Background

➜ **Previous work at Mercury** Persistently shadowed regions (PSRs) at both poles of Mercury have been found to harbor volatiles [2], likely deposited by cometary impacts, consisting of water ice and larger organic molecules.

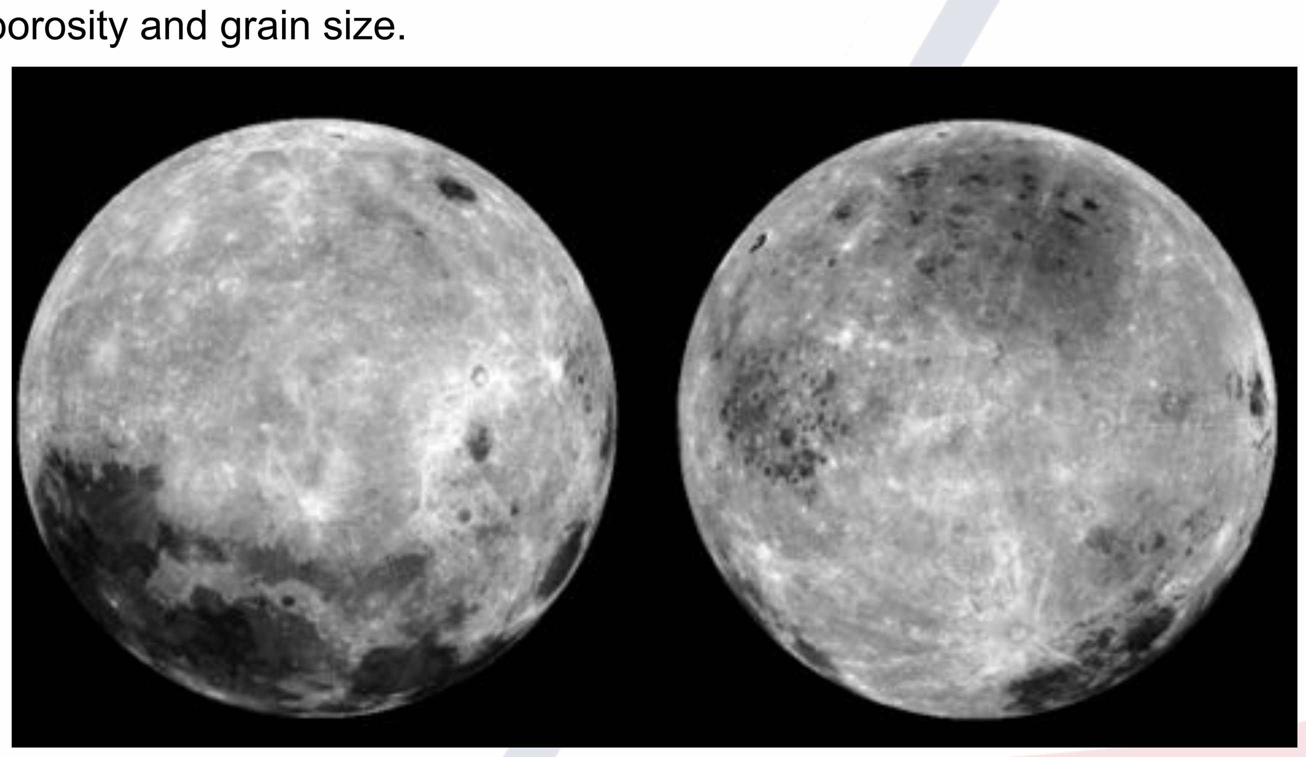
A



B

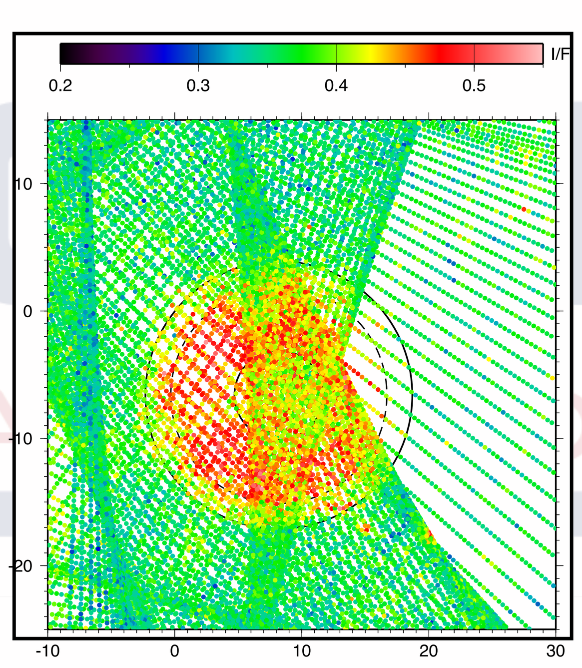
High Mercury Laser Altimeter reflectance (**A**) where model predicts that temperatures remain below 100 K [2,3]. Low reflectance at temperatures between ~150-200 K is interpreted as a carbon-rich sublimation lag.
B Artist's depiction of icy deposits.

➜ **Previous work at the Moon** The Moon's 1.54° axial tilt drives temperatures within the shadowed interior of polar craters well below 100 K, in fact, as low as 25 K, and many volatile species including water were detected in the LCROSS experiment impact plume. At most a diffuse signal of surface frost has been detected however in Lyman Alpha and 1064 nm wavelengths [5]. The low obliquity of Bennu also raises the possibility of PSRs near the poles, in which temperature and space weathering will differ markedly and produce latitudinal variations in surface properties such as single-scattering albedo, porosity and grain size.



Normalized global albedo map from the Lunar Orbiter Laser Altimeter [6] shows a nearly 3-fold variation in albedo but little polar brightening.

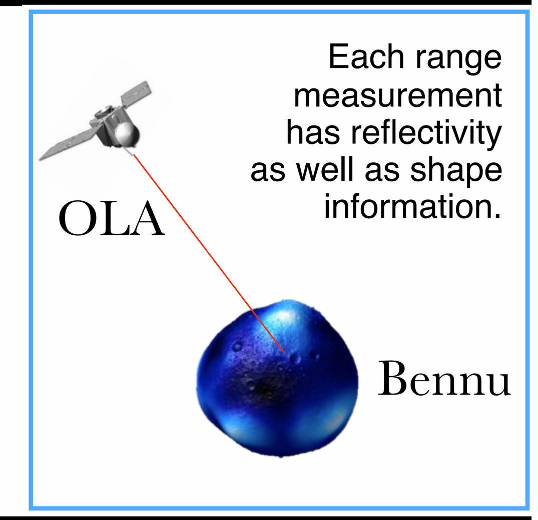
Shackleton Crater on the south pole of the Moon has been permanently shadowed since its formation. Topography of the interior shows slopes at an angle of repose and signs of mass wasting. LOLA found a ~20% brightening within the interior, interpreted as decreased space weathering after downslope transport and/or 15-20% pore ice [4]. N. polar PSRs showed evidence of frost at maximum temperatures < 156 K [5]. Fisher et al. [6] established a clear link between 1064 nm reflectance and stability zones of water ice below 110 K.



LOLA 1064-nm reflectance in the 20-km-diameter Shackleton crater.

OLA and spatial variations in reflectance of Bennu.

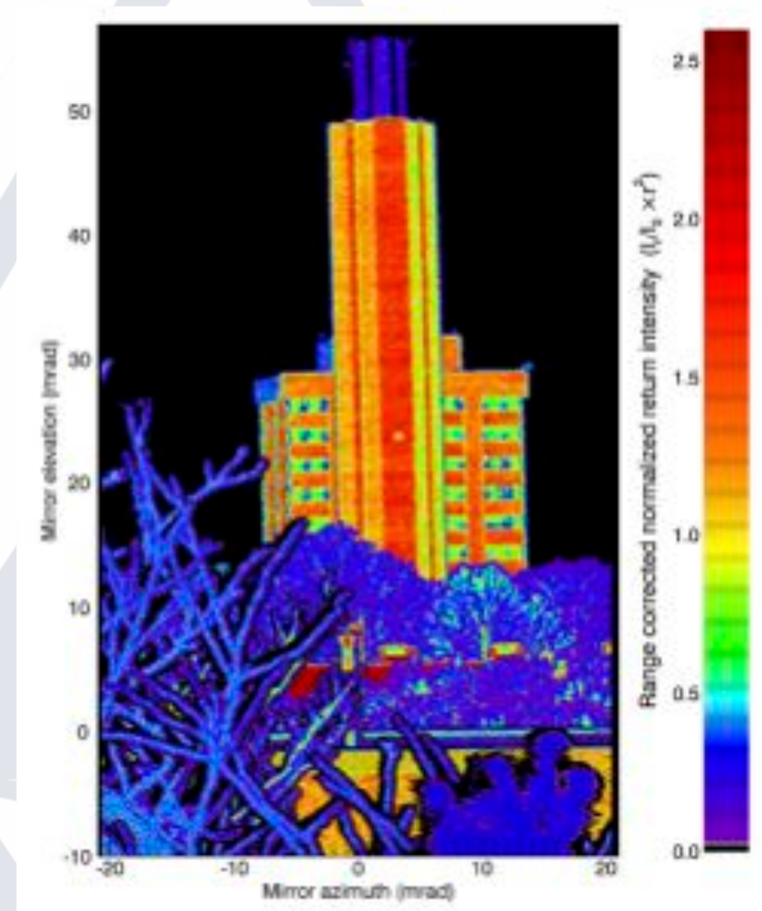
➜ **Bennu's spin axis is perpendicular to its orbital plane within ± 4°.** Due to Bennu's small size and collisional history there is considerable uncertainty in its rotational parameters and possibly up to 1° of axial wobble. It is unlikely that long-term temperatures have remained cold enough for water ice to be stable on the surface for geological time, but Bennu may have preserved primordial ices from an earlier era in the outer Solar System, which could be detectable on the surface, something that could be detectable in the reflectance data.



Tasks

1 - **Calibration of intensity telemetry to produce 1064-nm maps of normal albedo using test data and crossover analysis.**
The OVIRS spectrometer will be used to calibrate the absolute reflectance at 1064nm in the Approach and Preliminary Survey mission phases, within 5% using internal and external sources. We will use such data to explore nonlinearities and systematic changes with temperature, instrumental alignment and space environment over a large dynamic range. Preliminary Survey maps will aid in mission planning.

A

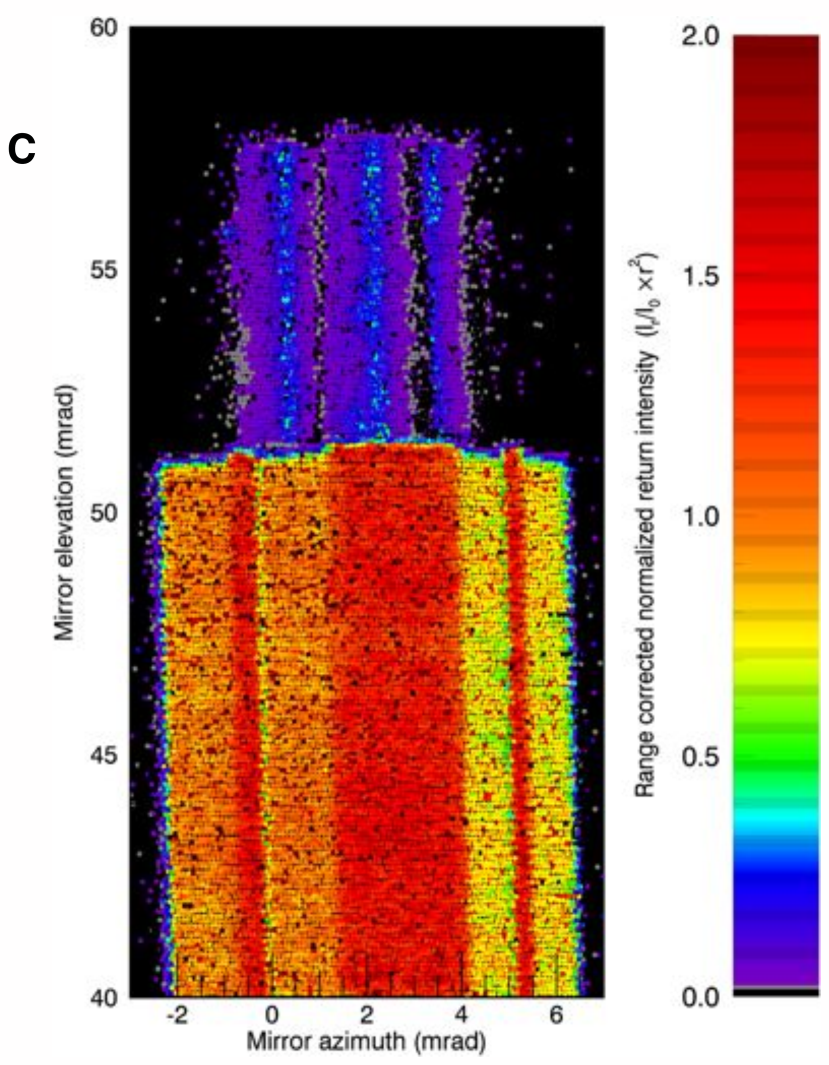


A. Range-corrected normalized return intensity test data [1] up to a distance of 1200 m from a Low Energy raster scan.

B

B. York University long-range test facility smoke stack.

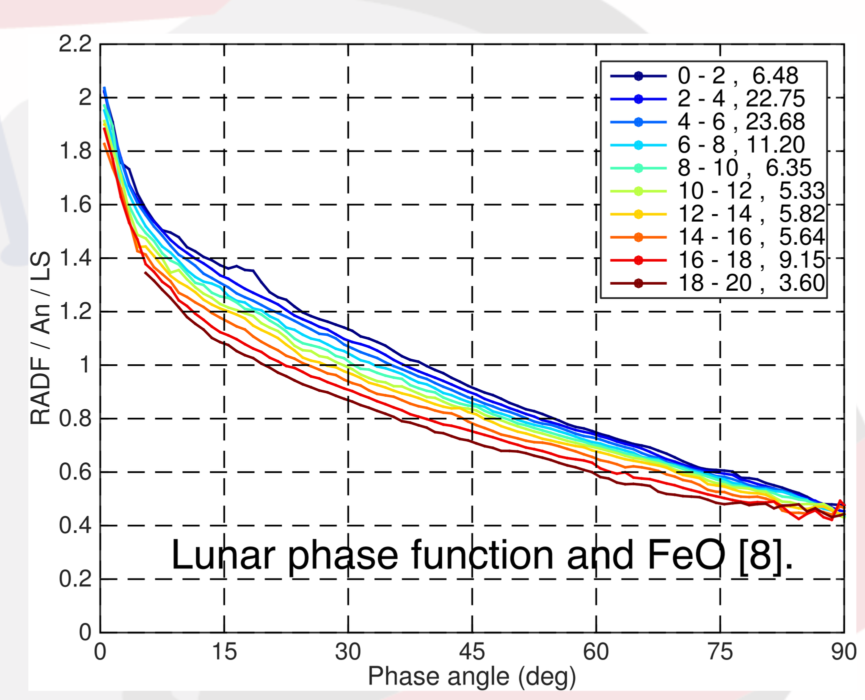
C



C. Intensity image from the OLA High Energy raster scan at 900 m, showing potentially useful signal in these derived data.

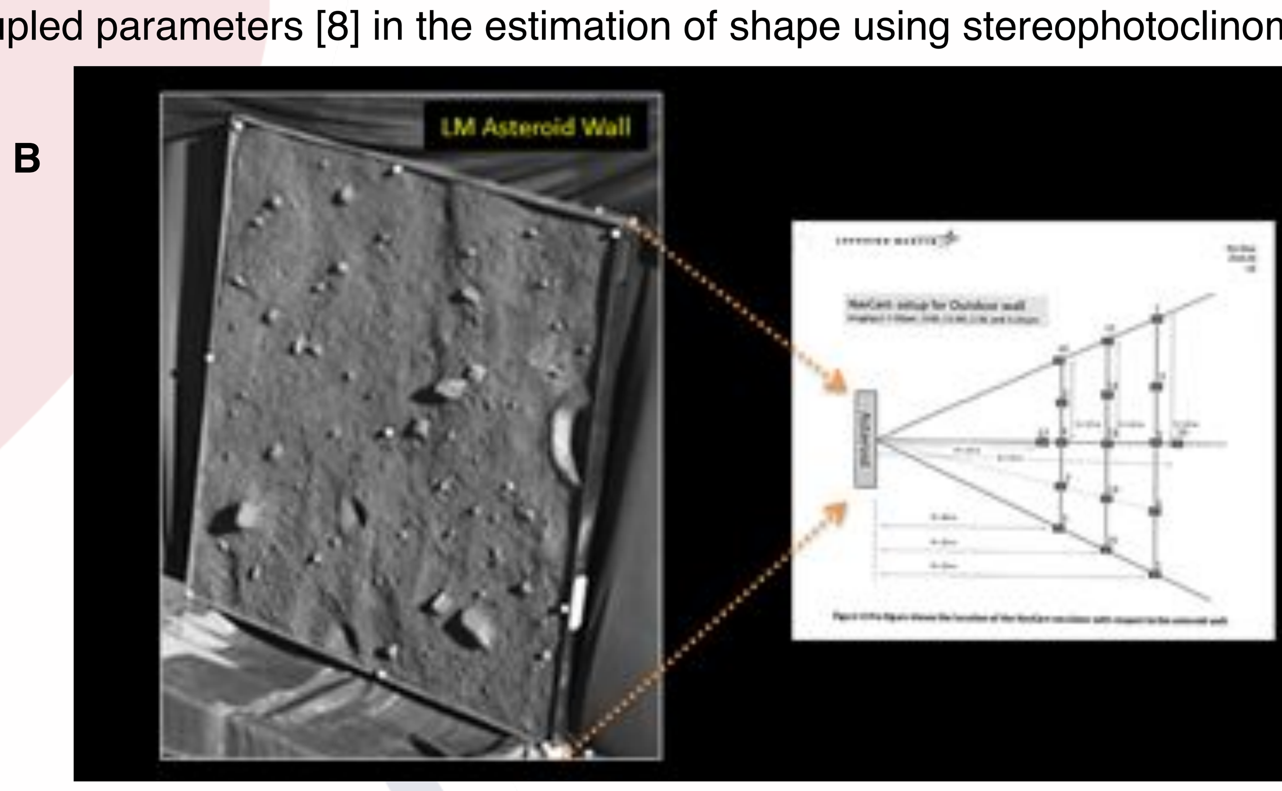
2 - **Photometric modeling and assessment of surface properties: Regolith, volatiles, permanently-shadowed regions**.
The opposition effect is an indicator of grain-scale properties, especially in B-type asteroids. We use normal albedo at zero phase measured by OLA to anchor Hapke models of photometric functions (**A**) and eliminate coupled parameters [8] in the estimation of shape using stereophotoclinometry (**B**).

A



Lunar phase function = radiance factor normalized by LOLA normal albedo and Lommel-Seeliger law (to correct for varying geometries).

B

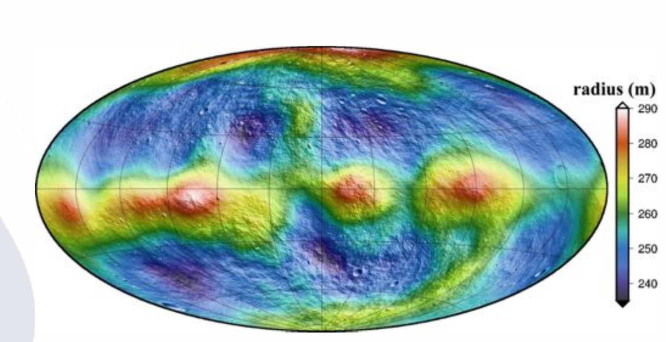


Lockheed Martin simulated Bennu surface [9].

3 - **Dynamical implications of normal albedo for modeling YORP effects.**
We will generate smoothed, interpolated global products and spherical harmonic expansions for radiation pressure modeling. The global normal albedo map at 1064 nm will be an input to a numerical model to compute reflected solar radiation pressure on the spacecraft for navigation purposes. OLA shape models aligned with the global normal albedo map as inputs to models of the differential radiation pressure on Bennu will provide an assessment of the YORP effect on rotational dynamics [10]. YORP spin-up, impact and/or tidal-derived seismic processes are important to interpret the samples returned to Earth accurately.

Acknowledgements - We thank the OSIRIS-REx Participating Science Program for this opportunity to contribute to the science of this exciting mission and instrument suite.

Sample shape model by R. Gaskell derived from stereophotoclinometry simulations used to model torques from reflected light [10].



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