EPSC Abstracts
Vol. 13, EPSC-DPS2019-225-1, 2019
EPSC-DPS Joint Meeting 2019

EPSC
EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

Reflective surface texture through OCAMS and OVIRS on-board OSIRIS-REx: What can shadow effects tell us about the surface of (101955) Bennu?

P. H. Hasselmann (1), S. Fornasier (1), M. A. Barucci (1), A. Praet (1), B. E. Clark (2), J-Y Li (3), X.-D. Zou (3), D. N. DellaGiustina (4), V. E. Hamilton (5), A. A. Simon (6), D. Golish (4), D. S. Lauretta (4), and OSIRIS-REx team.
(1) LESIA, Observatoire de Paris-Meudon, Meudon, France (**pedro.hasselmann@obspm.fr**). (2) Department of Physics and Astronomy, Ithaca College, Ithaca, NY, USA. (3) Planetary Science Institute, Tucson, AZ, USA. (4) Lunar Planetary Laboratory, University of Arizona, Tucson, AZ, USA. (5) Southwest Research Institute, Boulder, CO, USA. (6) NASA Goddard Space Flight Center, Greenbelt, MD, USA.

Abstract

Bennu's rough surface is a challenge for radiance modeling of OSIRIS-REx's spectro-photometric and spectroscopic near-infrared data. We developed a technique to model the sub-pixel visible roughness parameters on a facet basis. We presented the first results for different quasi-analytical shadowing models applied to OCAMS and OVIRS data. The ultimate goal is to improve the radiative estimation of roughness for resolved surfaces and provide a roughness map for Bennu.

1. Introduction

Since November 2018, the OSIRIS-REx mission has revealed a very rough surface for the asteroid (101955) Bennu, presenting a challenge for photometric modeling. High-resolution images show terrains ranging from multi-size boulders to fine regolith, indicating varied relief distribution at local scale. The general approach to model roughness through reflected light is to use disk-integrated phase curves and approximate the roughness distribution for Gaussian [1,2] or pre-fractal surfaces [3,4]. This approach, however, generally diverges for phase angles larger than ~50-60° [5] when the body is non-spherical or its reliefs are non-Gaussian [6]. As Labarre et al. [7] have recently shown, many collected rough surfaces also diverge from the Gaussian assumption, motivating us to seek a more generalized approach.

In the scope of OSIRIS-REx mission, Bennu's topography will be determined with precision thanks to an on-board altimeter (OLA [8]) and camera (PolyCam [9]). With accurate topography, we can directly compute the full illumination and observation conditions into the bore-sight of OVIRS [10] and into OCAMS "distanced images". Our ultimate goal is to characterize the roughness distribution at scale of the smallest surface element in a shape model (the facet), and understand the role of roughness shadow effects in the modeling of reflected radiance.

2. Data

We will use X-filter (0.860 microns) MapCam images and OVIRS spectra at the same wavelength from data obtained during the Preliminary Survey phase (distance of ~20 km, December, 2018). We aim at determining the roughness map using both instruments.

MapCam is a medium-range camera with four wide-band filters ranging from blue (0.470 microns) to near-infrared (0.860 microns). Its field of view (FOV) is 0.068 mrad [9].

OVIRS is a VIS-NIR point spectrometer ranging from 0.4 to 4.7 microns. Every point spectra is obtained in a circular FOV of 4 mrad [10].

3. Methodology

The average single-scattering phase function of Bennu [11] will be used to derive the average roughness slope distribution for a given surface. Then, the methodology consists of the following:

a) The most precise NAIF SPICE kernels and DTM shape model are ingested into a ray-tracing code for rendering shaded images for Bennu's surface. This make sit possible to discount for the effects of macroscopic shadows, leaving only the sub-facet texture to be modeled [Fig. 1].

b) Every facet is represented by an average roughness slope distribution [12]. At first, our modeling will be focused on radiative transfer outcomes from random slopes simulated by

Gaussian distribution or pre-fractal properties. Pre-fractal surfaces mimic roughness by reproducing a same given noise into a decreasing self-similarity size scale. These cases already have a quasi-analytical solution [1-4]. In the future goal, we aim obtaining the radiance from any given roughness slope distribution [Fig. 2] by generalizing the Van Ginneken et al. statistical model [2].

c) The modeled radiance factor (I/F or RADF) from every facet in the FOV is convolved with the instrument efficiency curve per solid angle. This final convolved signal is compared to the image or spectral observations. The L-BFGS-B minimization algorithm [13] is used for inversion and obtaining the best roughness parameters.

4. Perspectives

By modeling roughness, we expect to measure the “viewed” sub-facet roughness at different scales and at different instrument settings. This kind of approach has never been applied for space mission data out of Hapke’s photometric modeling scope [14]. A by-product is the composition of a roughness map for the surface of Bennu. Such a map will help us understand the correlations among albedo, visible colors, near-infrared spectra, and temperature.

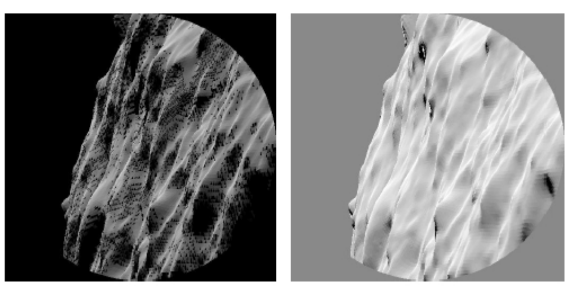

Figure 1: Generated images with Bennu’s surface as “seen” by OVIRS boresight with (a, left) and without (b, right) ray-trace shadowing. We used the Lommel-Seeliger scattering law to model the disk function per facet. Bennu’s surface is represented by a stereo-photo-clinometric shape model of 3 million facets.

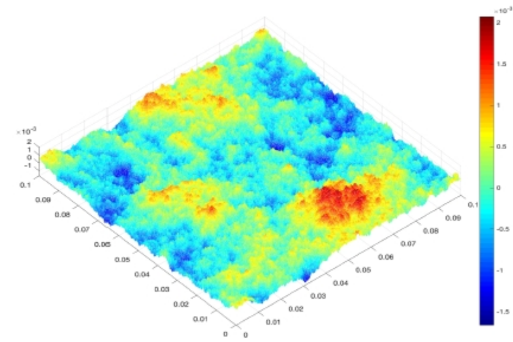

Figure 2: Example of randomly generated multi-scale relief. The surface is pre-fractal and non-Gaussian. Generated using Hurst coefficient of 0.3 and height scale of 5 mm [4].

Acknowledgements

This material is based on work supported by NASA under Contract NNM10AA11C issued through the New Frontiers Program. The authors also extend their gratitude to the following people without whom this work would not have been possible: the instrument teams at NASA Goddard Spaceflight Center (GSFC) and Arizona State University; the spacecraft teams at GSFC, KinetX and Lockheed Martin; the science planning and operations teams at the University of Arizona; and the Science Processing and Operations Center staff at the University of Arizona. PHH, SF, MAB, AP acknowledge funding support by CNES. PHH acknowledges funding provided by Ile-de-France & Dim-ACAV+.

References

[1] Hapke, B. *Icarus* **59**, 41-59,1984.
[2] Van Ginneken, B. et al. *Applied Optics,* **37**, 130-139, 1998.
[3] Shkuratov, Y. et al.. J. *Opt. Soc. Am.* **20**, 2081-2092, 2003.
[4] Shepard, M. K. & Campbell, B. *Icarus* **134,** 279-291, 1998.
[5] Li, J-Y. et al. *Icarus* **188**, Issue 1, 195-211, 2007.
[6] Davidsson, B. et al. *Icarus* **201,** 335–357, 2009.
[7] Labarre, S. et al. *Icarus* **290**, 63-80, 2017.
[8] Daly, M. G. et al. , *Space Sci. Rev*. **212**, 899–924 , 2017.
[9] Rizk, B. et al.. *Space Sci. Rev.* **214**, 26, 2018.
[10] Reuter, D. C. et al. , *Space Sci. Rev.* **214**, 54, 2018.
[11] DellaGiustina et al., *Nat. Astron.* **3,** 241-351, 2019.
[12] Shepard, M. K. et al. *JGR* **106**, No. E12, p. 32.777-32.795, 2001.
[13] Byrd, R. H. et al. *SIAM Journal on Scientific Computing,* ***16*** (5), 1190–1208, 1995.
[14] Hasselmann, P. H. et al. *Icarus* 267, 135-153, 2016.