EPSC Abstracts
Vol. 13, EPSC-DPS2019-140-1, 2019
EPSC-DPS Joint Meeting 2019

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

New insights from (101955) Bennu's global digital terrain model

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Abstract

The shapes of asteroids are a product of their formation and evolution interplaying with their bulk properties. The OSIRIS-REx (Origins, Spectral Interpretation, Resource Identification, and Security—Regolith Explorer) measured the shape of Bennu using stereophotoclinometry and laser altimetry. Bennu is found to be a highly porous rubble pile with a top-like shape. Bennu's surface is dominated by boulders and craters. It exhibits a non-circular equatorial ridge and high-standing longitudinal ridges that, in some instances, span all latitudes. These structures suggest interior strength through friction or cohesive forces. Long surface lineaments and mass-wasting suggest recent activity by surface and, perhaps, interior processes. We report on global shape models that will undergo further improvements through the addition of higher resolution images and altimetric data. These results include global shape, spherical harmonic analysis, hypsometry, and a comparison to other asteroids – leading to additional insights into Bennu's history.

1. Introduction

The objective of the OSIRIS-REx mission is to return a sample from asteroid (101955) Bennu[1]. The spacecraft started its close-encounter with the asteroid in the fall of 2018[2]. The instruments aboard the OSIRIS-REx spacecraft are measuring the geophysical and geochemical state of this approximately 500 m diameter[3] carbonaceous asteroid.

Two of the instruments on the OSIRIS-REx spacecraft contribute to the measurement of the shape. The OCAMS (OSIRIS-REx Camera Suite)[4] is used in an imaging campaign to support a stereophotoclinometric (SPC) shape model[5]. The OSIRIS-REx Laser Altimeter (OLA)[6], a scanning laser rangefinder, is used to develop an independent shape model thereby allowing confidence assessments through cross-comparison.

2. Datasets

The global datasets available are currently at scales of 0.3 m resolution and uncertainties of approximately 0.5 m RMS with some locations on the OLA model available at higher or lower resolutions due to sampling and shadowing effects. The current OLA dataset is shown in Figure 1. The current SPC shape has been presented in Barnouin et al.[3].

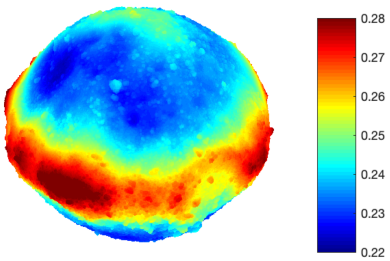

Figure 1: The shape of Bennu as seen by OLA. The scale is radial distance in metres from the centre of mass. The equatorial bulge is prominent.

3. Summary of Major Shape Characteristics

The major physical characteristics of Bennu are listed in Table 1. Bennu shows a characteristic top-like shape with a pronounced equatorial bulge (Figure 1). The major features include north-south ridges that are primarily responsible for the degree-4 sectoral terms in the spherical harmonic expansion shown in Figure 2. These ridges are associated with pronounced features on the equatorial bulge and are indicative of interior stiffness through friction or cohesion, which is notable as the bulk density of Bennu is compatible with a rubble-pile structure.

Table 1: Bennu's main shape parameters.

Parameter	Value
Average radius	244 ± 0.09 m
Best fit ellipsoid (x)	252.78 ± 0.05 m
Best fit ellipsoid (y)	246.20 ± 0.09) m
Best fit ellipsoid (z)	228.69 ± 0.12 m
Volume	$0.0615 \pm 0.0001\ \mathrm{km}^3$
Surface area	$0.782 \pm 0.004\ \mathrm{km}^2$
Bulk density	$1,190 \pm 13\ \mathrm{kg\ m}^{-3}$

4. Summary and Conclusions

The current shape models of Bennu are high-fidelity models that support detailed topographical assessments. The SPC shape model will undergo further improvements and the OLA dataset will grow from 10's of millions of measurements to 100's of millions of measurements. These improved models are expected to be at a resolution of better than 8 cm globally and will lead to improved interpretation of Bennu's global properties. This dataset will be used to refine the topography, spherical harmonic analysis and hypsometric comparisons with other asteroids.

Acknowledgements

The laser altimeter build and Canadian science support was provided by a contract with the Canadian Space Agency. The United States team contributions were supported by the National Aeronautics and Space Administration under Contract NNM10AA11C issued through the New Frontiers Program.

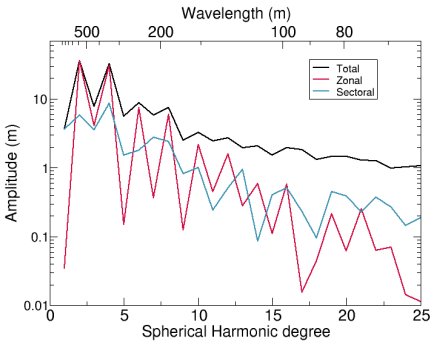

Figure 2: The amplitude spectrum of a spherical harmonic expansion for the GDTM. The black line indicates the total amplitude at each spherical harmonics degree. Zonal terms (red) describe contributions to the shape that vary only with latitude; sectoral contributions (blue) vary only with longitude. Spectral amplitude is dominated by zonal degree-2 and degree-4 terms from Bennu's top shape and equatorial ridge. The degree-4 sectoral terms capture the major north–south ridges (root-mean-square globally averaged amplitude of 8–10 m) that are separated by approximately 90 degrees of longitude.

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