Comparing the Radar Shape Model of 101955 Bennu with Ground Truth from OSIRIS-REx

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INTRODUCTION

- Nolan et al. (2013, Icarus) https://dx.doi.org/10.1016/j.icarus.2013.05.028 determined the shape and surface properties of Bennu using RADAR observations from the Arecibo and Goldstone planetary radar systems in 1999 and 2005 combined with optical lightcurve observations. We compare their results to initial observations by the OSIRIS-REx spacecraft.

NOLAN ET AL. (2013) PREDICTIONS

1. Size and shape: Fairly smooth, spinning top shape
2. Pole and obliquity: nearly retrograde, 177 degrees obliquity
3. Less prominent equatorial ridge than 1999 KW4 and 2008 EV5
4. One large boulder (10-20m), but no other large features.
5. Smoother than Eros and Itokawa at 3-12 cm scales
   - No dramatic textural changes between 3.5 and 12 cm scales
6. No satellites > 1-5 m
7. Variable block distribution across the surface
8. Surface particle density ~ 1800 kg/m²

PREDICTED IMAGERY AND LIGHTCURE

- Radar Shape Model
- 2000 Facets

- SPC Shape Model
- 3000 Facets
- 200000 Facets

SHAPE MODELS

- The shape models from radar modelling (Nolan et al. 2013) and Stereophotoclinometry (SPC) based on OSIRIS-REx Imagery (Barnouin et al., 2019 Nature Geosciences https://dx.doi.org/10.1038/s41561-019-0380-x) appear below.
- The renderings show the North (positive rotation) pole on top, then four views around the equator, then the South pole.
- The Arecibo and Goldstone planetary radar systems are shown approximately to scale.

POLARIZATION AND ROUGHNESS

- Radar Polarization has been interpreted as related to the surface roughness at wavelength-scales. Radar observations at 13-cm and 3.5-cm wavelength showed similar behavior at those scales. Nolan et al. (2013) interpreted this to suggest that
- This MapCam image of Bennu taken 2019 Feb 20 at 12 cm/px shows that most of the surface area in this region appears to be covered in ~m-scale or larger rocks, so that the radar reflectivity is probably dominated by the surface properties of the rocks rather than the grain size of any smaller pebbles. Phase angle is ~ 90 degrees, strongly emphasizing roughness.
- We now interpret rock textures (rather than surface grain textures) to be similar at 3-cm and 10-cm scale based on the radar.
- The low polarization ratio may be due to composition rather than roughness

COMPARISON BETWEEN RADAR PREDICTION AND SPACECRAFT IMAGING DERIVED SHAPES

- The overall “spinning top” shape prediction was correct. It is smooth in the sense that it does not have large shape protrusions that are not boulders, but is not smooth a few m scales.
- Axis lengths and overall size are correct to within 2%
- Pole estimate was off by 6 degrees (1.5 sigma). Obliquity within 1 degree
- Equatorial ridge even less pronounced than predicted.
- Largest boulder predicted to be 10-20 m, Largest observed boulder ~30m tall and 50m across. It is in the southern hemisphere as predicted.
- Other large boulders appear as topography in the shape model, but not as discrete objects: The model smooths topography.
- The “bumpiness” on the radar model is a reasonably accurate representation of the surface at ~ 20-m scales (the resolution of the model): the features seen are not noise in the model.
- We don’t yet know the roughness at cm-scales compared to Eros and Itokawa, but there are no large pond areas like on Itokawa.
- Comparison of scattering at different radar wavelengths suggested that the particle distribution is similar at 3- and 13-cm scales.
- Probably looking at texture of ~1-m boulders rather than grain distribution at smaller sizes.
- No large satellites
- Variable block distribution across surface
- Surface particle grain density not yet known, but radar properties may indicate relatively low-density boulders.
- Radar modelling that also uses lightcurve observations should pay careful attention to the assumed optical scattering function, especially if there are a wide variety of observing geometries.