THE GRAVITY AND GLOBAL GEOPHYSICAL ENVIRONMENT OF (101955) BENNU.

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Introduction: The OSIRIS-REx spacecraft's initial encounter with asteroid (101955) Bennu yielded the total mass, shape and spin state of this body. These results are outlined herein, and the global geophysical implications and observations based on these measurements are outlined. This abstract combines the models developed by multiple teams on the OSIRIS-REx mission, most specifically from the Radio Science Working Group (WG), the Flight Dynamics team, the Altimetry WG and the Regolith Development WG. The values and observations provided herein are current as of early 2019, but are expected to be refined and expanded by the time of the LPSC meeting.

Mass Measurement: Between December 4 and 16, 2018 the OSIRIS-REx spacecraft performed five slow, hyperbolic flybys of the asteroid (101955) Bennu with closest approach distances of ~7 km and speeds of ~4 cm/s. The spacecraft was tracked during and around these flybys using the DSN, acquiring Doppler shift data that could detect the small deflection of the spacecraft velocity due to the asteroid's gravity, on the order of 3.5 cm/s. See [1] for a discussion of the estimation process. Based on these measurements the gravitational parameter of the asteroid was determined to be 4.89 ± 0.03 m^3/s^2 (giving a mass of $7.327 \pm 0.006 \times 10^{10}$ kg). When combined with the volume determined from the shape [2] this yields a bulk density of 1189 ± 7 kg/m^3, consistent with that of asteroid (162173) Ryugu reported by the Hayabusa2 mission [3]. Given the analog meteorite type, this yields a porosity of 25-50% [4], establishing Bennu as a rubble pile asteroid. Our density estimate is consistent with the previous Bennu density estimate (1260±70 kg/m3), which was based on the Yarkovsky effect rather than gravitational perturbations, thereby validating this novel approach to density estimation based on remote observations [5].

Geophysical Models: When the asteroid density is combined with the Bennu shape and rotation rate the geophysical environment of Bennu can be evaluated under a constant density hypothesis. Doing so yields a range of important parameters that provide insight into the dynamical environment of this asteroid. This is of importance for understanding and constraining its history and geology, and also for the design and implementation of the future sampling of the asteroid surface. The methods used to carry out these computations were previously applied and discussed for the pre-arrival model [6]. Our current results are consistent with these previous computations, but are now known to a much higher precision and accuracy. Several global constraints that were only hinted at in the pre-arrival model are now clearly visible and will be discussed.

A brief summary of some of the major findings are listed below and will be presented and discussed with the most current shape and gravity field model:

- The Bennu orbital environment and stability properties of the trajectories of material lifted from the Bennu surface (Fig. 1).
- Description of the Roche Lobe of Bennu and identification of where it intersects the shape, coupled with the observed changes in the global slope distribution that are evident at this transition.
- Global acceleration profile across the Bennu surface, which ranges from 3-8 microG and definitively shows Bennu to be a micro-gravity aggregate.
- Global geopotential across the surface, including a detailed presentation of the energetically favorable directions for migration of surface material.
- Global slope structure of Bennu and as a function of latitude, which shows clear transitions at specific latitudes across the surface.
- Investigation of possible past global failure conditions as a function of strength in order to understand possible formation conditions for the bulge and the low slope region within the Roche Lobe.

References: [1] McMahon et al. 2019. 50th LPSC Meeting. [2] Barnouin et al. 2019. 50th LPSC Meeting. [3]Yoshikawa et al. 2018. DPS Meeting. Abstract 501.01. [4] Walsh et al. 2019. 50th LPSC Meeting. [5] Chesley et al. 2014. *Icarus* 235: 5-22. [6] Scheeres et al. 2016. *Icarus* 276: 116-140.

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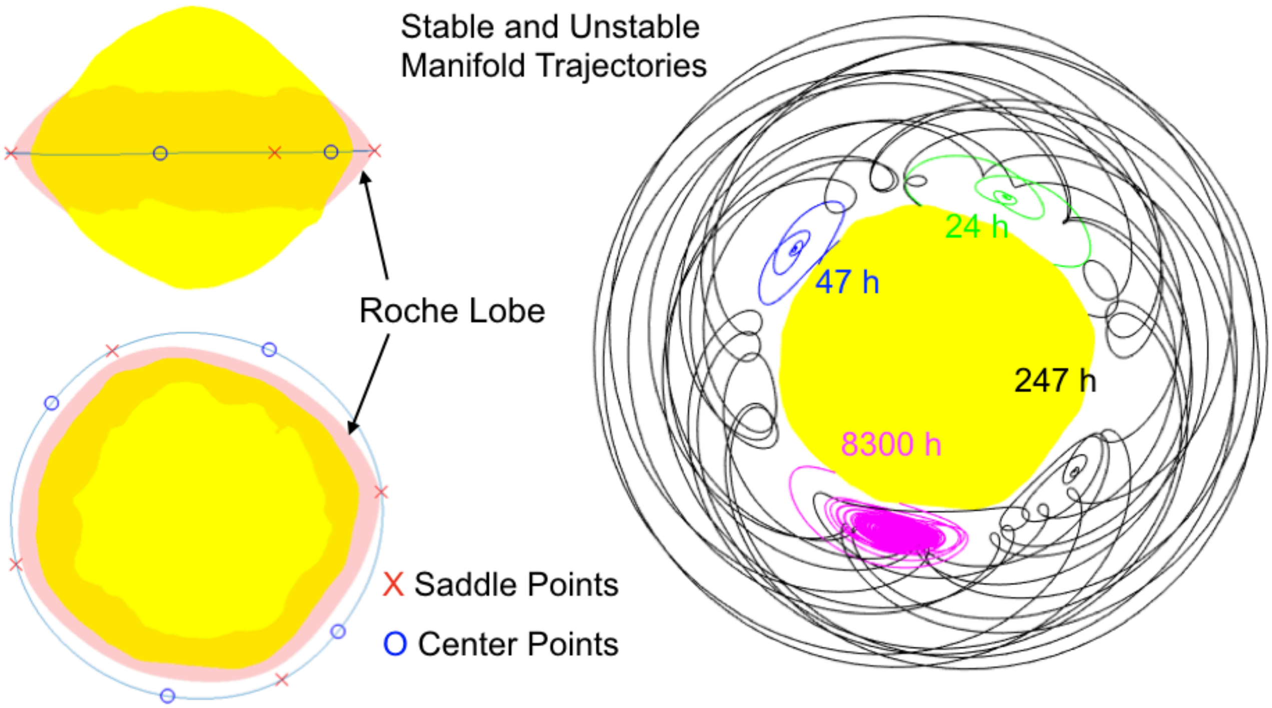

Figure 1: Bennu Equilibrium points, Roche Lobe and near surface trajectories. The stability properties of the equilibrium points control the dynamics of material lifted from the surface and cause it to be ergodically distributed. The lowest energy point also defines the energy level of the Roche Lobe.