COMPARING THE ESTIMATED DYNAMICAL ENVIRONMENTS AND MASS DISTRIBUTIONS OF BENNU AND RYUGU

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Summary

A direct comparison of the dynamical environments and mass measurements of asteroids (101955) Bennu and (162173) Ryugu are made, leveraging recently published data for both bodies as well as the latest results. The comparisons are of interest both for the design of close proximity operations and for the geophysical analysis of these bodies. The motivation for this discussion is to provide better insight into the diversity of small, primitive small bodies. Even though these two asteroids share many similarities, they are also individual worlds to be explored, with their own unique attributes.

Introduction

The year 2018 was a banner year for asteroid exploration, with the Hayabusa2 [1] and OSIRIS-REx [2] missions achieving rendezvous with their target asteroids, (162173) Ryugu and (101955) Bennu, respectively. Both missions will stay in rendezvous with their respective asteroids for an extended period of time, characterizing the environment before making descents to the surface to sample the regolith. Ultimately, both spacecraft will bring their samples back to Earth.

In this paper we combine published information on these bodies to outline the similarities and differences between their dynamical and geophysical environments. Such a comparison is especially relevant given their similar spectral types. Several papers and presentations have already given the basic computations about these individual bodies. This presentation is an opportunity to make direct comparisons of the dynamical quantities that can be directly computed given their mass, shape, spin state and heliocentric orbit. The information we use for the asteroid Bennu was published in several papers, specifically an overview paper [3], a paper on the mass of the asteroid [4], a paper on the asteroid shape [5], and one that covers the spin state and other observations [6]. The information for the asteroid Ryugu was presented in two main papers [7,8]. The presentation will also take advantage of updates to these published values. All of these results have also been shown in special sessions at the 2018 DPS, 2018 AGU, 2019 LPSC and 2019 EPSC/DPS conferences.

This abstract presents the basic parameters for both of the bodies. The presentation will compare these and describe the orbital environments about both bodies, ranging from near-surface motion out to their respective Hill spheres. The presentation will also focus on their surface environments, including surface slopes, accelerations, escape speeds, and geopotentials. Even though the two bodies have qualitatively similar shapes, we find substantial differences which will lead to different dynamical environments about these bodies. These are mostly driven by the bodies having spin rates that differ by a factor of 2 and sizes that differ by a factor of 2.

Properties of Bennu and Ryugu

Table 1 presents the main properties of these two bodies, as extracted from the indicated papers. Some important points of comparison can be made. First, the estimated densities of the bodies are the same, within published error bars (not shown in these tables). While this may be expected as Bennu and Ryugu have been classified as similar types, it is still a remarkable fact given the many differences between these bodies as studied in [9,10]. Another point of comparison can be made with the gravity field coefficients predicted from the shape and assuming constant density. These non-dimensional numbers are also remarkably consistent, showing that the bodies have a clearly similar oblate shape. Ryugu has more asymmetry in its north-south shape, as correlated with its larger C_{30} coefficient.

Table 1: Bennu Parameters [3] (left) and Ryugu Parameters [7] (right). Gravity coefficients are computed from the published shape model using a constant density assumption.

Bennu Parameters				Ryugu Parameters			
Parameter	Value	Units	Comments	Parameter	Value	Units	Comments
μ	4.892	m^3/s^2	gravitational parameter	μ	30.01	m^3/s^2	gravitational parameter
ρ	1.190	g/cm^3	bulk density	ρ	1.190	g/cm^3	bulk density
T	4.296057	h	rotation period (J2000)	T	7.63262	h	rotation period (J2000)
RA	85.65	deg	right ascension (J2000)	RA	96.40	deg	right ascension (J2000)
DEC	-60.17	deg	declination (J2000)	DEC	-66.40	deg	declination (J2000)
ϵ	177.6	deg	computed obliquity	ϵ	171.64	deg	computed obliquity
q	.896894	AU	perihelion	q	.963308	AU	perihelion
Q	1.355887	AU	aphelion	Q	1.415893	AU	aphelion
P	1.07963	AU	orbit parameter	P	1.146554	AU	orbit parameter
	Constant Density Gravity Coefficients				Constant Density Gravity Coefficients		
C_{20}	-0.05812		oblateness coefficient	C_{20}	-0.05394		oblateness coefficient
C_{22}	0.00320		ellipticity coefficient	C_{22}	0.00266		ellipticity coefficient
C_{30}	0.00062		latitudinal asymmetry coefficient	C_{30}	0.00307		latitudinal asymmetry coefficient
C_{40}	0.03768		oblateness coefficient	C_{40}	0.04209		oblateness coefficient
R	0.245023	km	normalizing & mean radius	R	0.448442	km	normalizing & mean radius
A_s	0.782	km^2	surface area	A_s	2.734	km^2	surface area

Discussion

The presentation will focus on these above basic parameters of the system and use them to discuss the relative equilibria and their manifolds, the Roche Lobes of both bodies and other dynamical phenomenon of interest.

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