EPSC Abstracts
Vol. 13, EPSC-DPS2019-158-1, 2019
EPSC-DPS Joint Meeting 2019

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

Bennu orbit and hazard assessment based on OSIRIS-REx data

Davide Farnocchia (1), Steven R. Chesley (1), Yu Takahashi (1), Alex B. Davis (2), David Vokrouhlický (3), Ryan S. Park (1), Brian P. Rush (1), Nickolaos Mastrodemos (1), Brian M. Kennedy (1), Julie Bellerose (1), Daniel P. Lubey (1), Dianna Velez (1), Benjamin Rozitis (4), Joshua P. Emery (5), Dante S. Lauretta (6) and the OSIRIS-REx Team
(1) Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, USA, (2) University of Colorado, Boulder, Colorado, USA, (3) Charles University of Prague, Prague, Czech Republic, (4) The Open University, Milton Keynes, UK, (5) University of Tennessee, Knoxville, Tennessee, USA, (6) Lunar and Planetary Laboratory, University of Arizona, Tucson, Arizona, USA (Davide.Farnocchia@jpl.nasa.gov)

Abstract

We present an updated estimate of the trajectory of Bennu based on OSIRIS-REx data collected through the Orbit B phase of the mission. These data greatly improve our knowledge of the future orbit of Bennu but also require an unprecedented fidelity for the modeling of an asteroid's trajectory. We analyze future close approaches of Bennu with Earth and revise the hazard assessment for a potential collision late in the 22nd century.

Introduction

The orbit of the near-Earth asteroid (101955) Bennu is well-constrained from ground-based observations. The wealth of ground-based optical and radar data collected since its discovery in 1999 over about 15 years allowed an estimate of the semimajor axis accurate to within 20 m. The data also allowed a 200-sigma detection of the Yarkovsky effect acting on Bennu as well as deterministic ephemeris predictions through the Earth close approach in 2135 [1].

OSIRIS-REx data

The OSIRIS-REx mission to Bennu [3] has provided data that further constrain the asteroid's trajectory to an unprecedented level. On 2018-08-17 Bennu was first detected with OSIRIS-REx's PolyCam [4], and optical navigation measurements [5] during the Approach phase constrained the location of Bennu in the OSIRIS-REx plane of sky to within a few kilometers [2]. Upon arrival, the OSIRIS-REx spacecraft started operating in Bennu's proximity, with radio ranging data [6] that measured the distance between Earth and Bennu to within a few meters for several months.

High-fidelity trajectory modeling

While these data greatly improve the knowledge of Bennu's trajectory, they also require high-fidelity modeling of Bennu's dynamics. For example, the fit to OSIRIS-REx ranging data is sensitive to short-term perturbations caused by the Yarkovsky effect, which is proportional to Bennu's thermal inertia. Therefore, accurately tracking the motion of Bennu provides an indirect, but completely independent, estimate of Bennu's thermal inertia that can be compared to OSIRIS-REx's direct thermal measurements. Moreover, radiation effects such as the Poynting-Robertson drag [7], so far only considered for interplanetary dust dynamics, now become a consideration for modeling the trajectory of a 500-m asteroid.

Hazard assessment

Bennu is a potentially hazardous asteroid and, based only on ground-based data, there is about 0.04% probability of an Earth impact between 2175 and 2196 [1]. We will show how the OSIRIS-REx mission data through the Orbital B phase change the statistical assessment of the possibility that Bennu reaches the Earth late in the 22nd century. While many potential impacts previously detected can now be ruled out, we identify those that might persist and refine the estimated impact probability.

Acknowledgements

We are thankful to W. Folkner and A. Konopliv for helpful discussions. Part of this research was conducted at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with NASA. This material is based upon work supported by NASA under Contract NNM10AA11C issued through the New Frontiers Program.

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