Bennu orbit and hazard assessment based on OSIRIS-REx data

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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.

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References


