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CONSTRAINING THE ORBITAL PARAMETERS OF THE DIDYMOS-DIMORPHOS SYSTEM: LIGHTCURVE OBSERVATIONS IN PREPARATION FOR AIDA/DART

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The binary near-Earth asteroid (65803) Didymos is the target for the Asteroid Impact and Deflection Assessment (AIDA) mission, which is a concept with two primary spacecraft: NASA's DART (Double Asteroid Redirection Test) impactor and ESA's Hera orbiter (Cheng et al. 2018; Michel et al. 2018). DART is NASA's first planetary defense mission and will be the first demonstration of asteroid deflection by a kinetic impactor. The DART spacecraft is designed to impact Dimorphos, the secondary in the Didymos system, and modify its orbit through momentum transfer. DART will launch in late 2021 and is scheduled to impact in fall 2022. The DART spacecraft will carry ASI's LICIACube (Light Italian Cubesat for Imaging of Asteroids, Dotto et al. 2021) to observe the DART impact event and the resulting impact ejecta.

A key scientific goal of the DART and Hera missions is to measure and characterize the deflection caused by the DART impact. The impact will change the satellite orbit period, which will be measured by ground-based facilities in the post-impact period. In order to correctly interpret the data from the impact epoch, we need to understand the baseline, unperturbed dynamics of the system. The DART/Hera Observations Working Group is tasked with characterizing the Didymos-Dimorphos system properties with sufficient accuracy to measure the change in the binary orbital period to within 7.3 seconds. This measurement is a small, but observable fraction of the current orbital period of the satellite (P_{orb}=11.92 hours). The observed period change is a critical input to the calculation of the momentum transfer enhancement parameter, "Beta" (β).

We obtained lightcurve observations during the recent apparition (December 2020 to March 2021) to further characterize the system. During our observing window, occultations and eclipses were observable because the Earth and Sun were close to the orbital plane of the binary system. These events are collectively known as "mutual events" and we characterize this small binary system through their observation (e.g., Pravec et al. 2006). Mutual events result in a distinctive signature superimposed on the rotational lightcurve of the binary system, providing crucial clues to characterize the system (Figure 1).

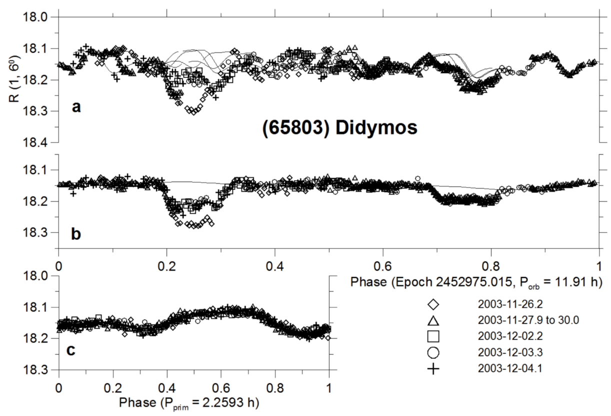

Figure 1: The folded lightcurve of Didymos from 2003 (panel a) can be decomposed into a contribution from the rotation of Didymos (panel c) and a contribution due to mutual events with Dimorphos (panel b). From Pravec et al. (2006).

Modeling of the 2003-2019 lightcurve observations found three possible BYORP solutions (-1.8, 0.1, and +2.1°/yr^2) resulting in a 3-σ uncertainty on the true anomaly of Dimorphos at the time of impact of ± 65 degrees. The DART mission required our 2020-2021 observations to reduce the Dimorphos true anomaly at impact to within ± 45 degrees by mid-February 2021. The preliminary results presented here are the result of that February analysis.

We had two goals for our 2020-2021 Didymos observing effort: (1) Measure the amount of Binary YORP (BYORP) torque occurring in the system and (2) Establish whether or not the secondary is in synchronous rotation. An international group of observers affiliated with DART and Hera obtained time at 11 different facilities over the time period from December 2020 to March 2021. We combined these new observations with past data to provide us with the opportunity to further understand the state of the system before impact to a high level of precision.

To meet our scientific objectives, we required multiple mutual event observations over different lunations with minimum observing periods of 6 hours. We also had strict requirements on the precision of our photometry. All observations needed photometry with RMS ~ 0.01 mag (SNR ~ 100) and a time cadence of exposures every ≤3 minutes. These requirements limited our observational effort to medium and large ground-based due to the faintness of the Didymos system (V=18.9-20.2).

Details about the observing effort including telescopes used, dates scheduled, and whether a given run was successful can be found on our coordination site: https://sites.google.com/view/didymosobs/home

Our preliminary analysis includes data from the Lowell Discovery Telescope and Keck Observatory obtained in December 2020 and January 2021. We are continuing our data reduction efforts and anticipate a full analysis of the data set to be published later this year in a set of papers.

The 2020-2021 data enabled the determination of a single BYORP value (0.13 ± 0.14 °/yr^2) and a refined pole solution for the binary orbit. The single BYORP solution resulted in a calculated true anomaly (3-σ) at the time of impact to within ± 10 degrees.

The photometric data quality was not sufficient to meet our second observing goal of determining if the secondary was in synchronous rotation. Understanding the shape and rotational properties of Dimorphos will be a key scientific goal of our 2022 observations prior to the DART impact.

References:
Pravec, P. 2006. Photometric survey of binary near-Earth asteroids. Icarus 181, 63-93.