OBSERVATIONS OF DIDYMOS IN SUPPORT OF DART AND HERA.

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Abstract: 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 spacecraft: NASA's DART (Double Asteroid Redirection Test) impactor and ESA's Hera orbiter. The DART spacecraft is designed to impact the secondary in the Didymos system, whose 160-meter size is typical of the size of asteroids that could pose a more common hazard to Earth, and modify its trajectory through momentum transfer. The Hera spacecraft would then visit Didymos to survey the diverted secondary, measure its mass and perform high-resolution mapping of the crater left by the DART impact. A key scientific goal of both AIDA missions is to measure and characterize the deflection caused by this impact. The DART impact planned for 2022 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 Investigation Team is tasked with characterizing the Didymos system properties with sufficient accuracy to measure the change in the binary orbital period. The observed period change is a critical input to the calculation of the momentum transfer enhancement parameter (β).

We will present an up-to-date knowledge of the system parameters obtained using lightcurve observations from 2019 and from previous apparitions.

Introduction: Most system information was determined from lightcurve and radar measurements made during a close pass to Earth in 2003. Observations of Didymos since 2003 were limited. One partial lightcurve was obtained in 2015 and partial nights were obtained during the spring 2017 apparition, but both recent campaigns were plagued by poor weather and Didymos' faintness (V > 20.5 in 2015, V > 20.2 in 2017). These measurements were sufficient to establish a pole position for the Didymos system, but important uncertainties remain.

To further characterize the system from lightcurve observations, we observed the Didymos system during the 2019 apparition (January-April) and are planning additional observations during the 2020-2021 apparition. These observations will provide us with the opportunity to establish the state of the system before impact to a high level of precision. We had three goals for our 2019 Didymos observing campaign: 1) Measure the amount of Binary YORP (BYORP) torque occurring in the system, 2) Establish whether or not the secondary is in synchronous rotation; and 3) Constrain the inclination of the secondary orbit. Under favorable geometric conditions, as we have for Didymos during the 2019 (V > 19.8) and 2020-2021 (V > 18.9) apparitions, the Earth and Sun are close to the orbital plane of the binary system such that occultations and eclipses can occur. These are collectively called "mutual events" and we characterize this small binary system through their observations [1]. 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).

2019 Observing campaign: A key goal of the 2019 observing campaign was to reduce the number of possible BYORP solutions for the Didymos system. BYORP is a non-gravitational force due to anisotropic re-radiation of thermal energy in a binary asteroid system, leading to a change in the orbit size. The data prior to the 2019 apparition defined allowed values for BYORP, depending on the number of satellite orbits that occurred since the first lightcurve measurements in 2003. Prior to our 2019 observations, there were 5 possible BYORP solutions in a range of allowed values of the secondary orbital drift in mean anomaly from -2.3 to +3.2 deg/yr^2. Simulations of further observations indicated that additional measurements from multiple lunations in both 2019 and 2021 will eliminate 4 of the 5 possible BYORP values and reduce the uncertainties of other parameters in the remaining secondary orbit solution. Constraining BYORP will be necessary to separate the DART induced orbital change from any naturally-occurring change.

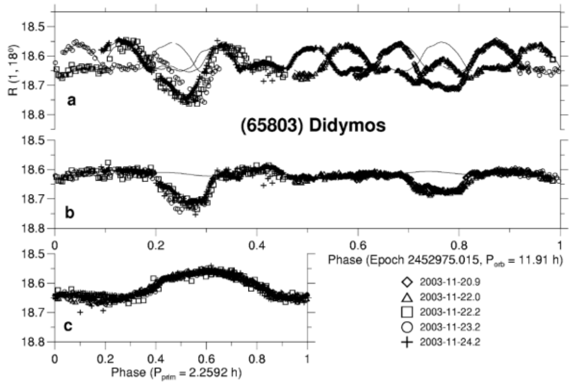

Figure 1: The folded lightcurve of Didymos from 2003 (panel a) can be decomposed into a contribution from the rotation of Didymos A (panel c) and a contribution due to mutual events with Didymos B (panel b). From [1].

We calculated the necessary precision and time cadence to address our stated scientific goals, specifically our goal of eliminating possible BYORP solutions. We required high precision observations (RMS error = 0.01 mag, i.e., S/N ~ 100) over the full orbital period with a time cadence of exposures every ≤3 minutes during mutual event passages to discriminate between the primary and secondary eclipses. Ideally these would be over multiple lunations within our observing windows. Additionally, we require successful observations during both the 2019 and 2020-2021 apparitions. Given the relative faintness of Didymos during our 2019 apparition (V > 19.8), this limited our observations to large telescopes (aperture > 4 meters).

An international group of observers affiliated with DART and Hera proposed for various telescope around the world. We obtained time at 6 different facilities with apertures ranging from 4.3 meters to 10.4 meters and spread over three lunations (January-April) available during this apparition (Table 1).

We created a website[1] to help with the coordination of many observers across three different continents. Our site includes timelines for proposals and approved observations, an observation report form to communicate how each night went, and a place to see an overview of what observations have already occurred.

Telescope & Location	Total duration
Discovery Channel Telescope (4.3m) Arizona	7.3 h
MMT Observatory (6.5m) Arizona	1.8 h
Magellan (6.5m) Chile	19.2 h
Gemini-North (8.1m) Hawaii	7.0 h
VLT-UT1 (8.2m) Chile	12.2 h
Gran Telescopio Canarias (10.4m) Spain	17.4 h

Table 1: Observations of Didymos taken during January-April 2019.

Results: We will reduce, analyze and model the obtained data during May-June 2019. At the EPSC-DPS meeting, we will present an up-to-date knowledge of the Didymos system parameters. We will also discuss observing plans for the 2020-2021 apparition and the 2022 impact apparition.

Acknowledgements: The work at Ondřejov was supported by the Grant Agency of the Czech Republic, Grant 17-00774S. Access to computing and storage facilities owned by parties and projects contributing to the National Grid Infrastructure MetaCentrum provided under the programme ”Projects of Large Research, Development, and Innovations Infrastructures” (CESNET LM2015042), and the CERIT Scientific Cloud LM2015085, is greatly appreciated.

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[1] https://sites.google.com/view/didymosobs/home