CONSTRAINING THE ORBITAL PARAMETERS OF THE DIDYMOS-DIMORPHOS SYSTEM: LIGHTCURVE OBSERVATIONS IN PREPARATION FOR AIDA/DART. Cristina A. Thomas[1], Andrew S. Rivkin[2], Nicholas A. Moskovitz[3], Petr Pravec[4], Petr Scheirich[4], Julia de Leon[5], Elena Mazzotta Epifani[6], Mirel Birlan[7], Benoit Carry[8], Steven Chesley[9], Elisabetta Dotto[6], Tony Farnham[10], Dora Fohring[11], Mikael Granvik[12,13], Ellen Howell[14], Simone Ieva[6], Matthew M. Knight[10,15], Monica Lazzarin[16], Fiorangela La Forgia[16], Erin May[2], Alessandra Migliorini[17], Shantanu Naidu[9], Marcel Popescu[18], [1]Northern Arizona University (cristina.thomas@nau.edu), [2]Johns Hopkins University- Applied Physics Laboratory, [3]Lowell Observatory, [4]Astronomical Institute, Ondrejov Observatory, [5]Instituto de Astrofísica de Canarias, [6]INAF-Osservatorio Astronomico di Roma, [7]IMCCE, Observatoire de Paris, [8]Observatoire de la Côte d'Azur, [9]Jet Propulsion Laboratory, California Institute of Technology [10]University of Maryland, [11]University of Hawaii, [12]University of Helsinki, [13]Luleå University of Technology, [14]University of Arizona, [15]United States Naval Academy, [16]Università degli Studi di Padova, [17]INAF-IAPS Roma, [18]Astronomical Institute of the Romanian Academy

Introduction: 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 [1], [2]. 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 mid-2021 and is scheduled to impact in fall 2022. It will carry ASI's LICIACube (Light Italian Cubesat for Imaging of Asteroids, [3]). The Hera mission will arrive in 2027 to further characterize the Didymos system and the effects of the DART impact.

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 are obtaining additional lightcurve observations during the current apparition (December 2020 to March 2021) to further characterize the system. Combining these observations with past data will provide us with the opportunity to establish the state of the system before impact to a high level of precision.

Past Observations: Most system information was determined from lightcurve and radar measurements made during a close pass to Earth in 2003 (e.g., [4], [5]). Observations of Didymos between 2003 and 2019 were limited. One partial lightcurve was obtained in 2015 and partial nights were obtained during the spring 2017 apparition, but both 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 remained.

The DART/Hera Observations Working Group obtained lightcurve observations in early 2019 to improve the orbit characterization. A key goal of the 2019 observations was to reduce the number of possible BYORP solutions for the Didymos system. BYORP is a non-gravitational force due to anisotropic reradiation 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 had occurred since the 2003 lightcurve measurements. Prior to our 2019 observations, there were 5 possible BYORP solutions. Using the data obtained in 2019, we were able to eliminate two of the possible BYORP solutions.

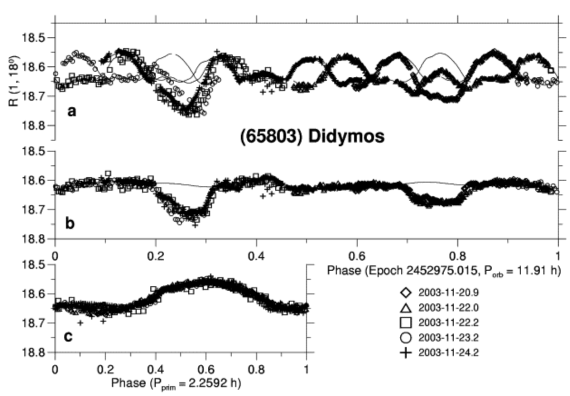

Figure 1: The folded lightcurve of Didymos from 2003 (panel a) can be decomposed into a contribution from the rotation of Didymos A (panel c) and a contribution due to mutual events with Didymos B (panel b). From Pravec et al. (2006), [4].

Observation Goals: We have 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. Under favorable geometric conditions, as seen 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 binary system through their observation (e.g., [4]). Mutual events result in a distinctive signature superimposed on the rotational lightcurve of the binary system, providing crucial clues to characterize the system (see Figure 1).

2020-2021 Observations: Additional measurements from the 2021 apparition will enable the determination of a single BYORP solution and will reduce the uncertainties of other parameters in the secondary orbit solution. Constraining BYORP is particularly critical because a solution is necessary to separate the DART induced orbital change from any naturally-occurring change (i.e., BYORP).

We determined the necessary precision and time cadence to address our stated scientific goals. We require high precision observations (RMS=0.01, 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. Given the relative faintness of Didymos during our 2020-2021 apparition (V>18.9), this limited our observations to medium and large telescopes (aperture greater than approximately 3-4 meters).

An international group of observers affiliated with DART and Hera proposed for observing time on various telescopes around the world. We have obtained time at 11 different facilities around the world throughout the time period from December 2020 to March 2021.

We will discuss our state of knowledge from previous observations (through 2019) and selected preliminary results from our 2020-2021 observations.

References: [1] Cheng, A. F. et al. (2018) *PSS, 157,* 104-115. [2] Michel, P. et al. (2018) *Advances in Space Research, 62*, 2261-2272. [3] Dotto, E. et al. (2021) *PSS,* in press. [4] Pravec, P. et al. (2006) *Icarus, 181,* 63-93. [5] Naidu et al. (2020) *Icarus, 348*, 113777.