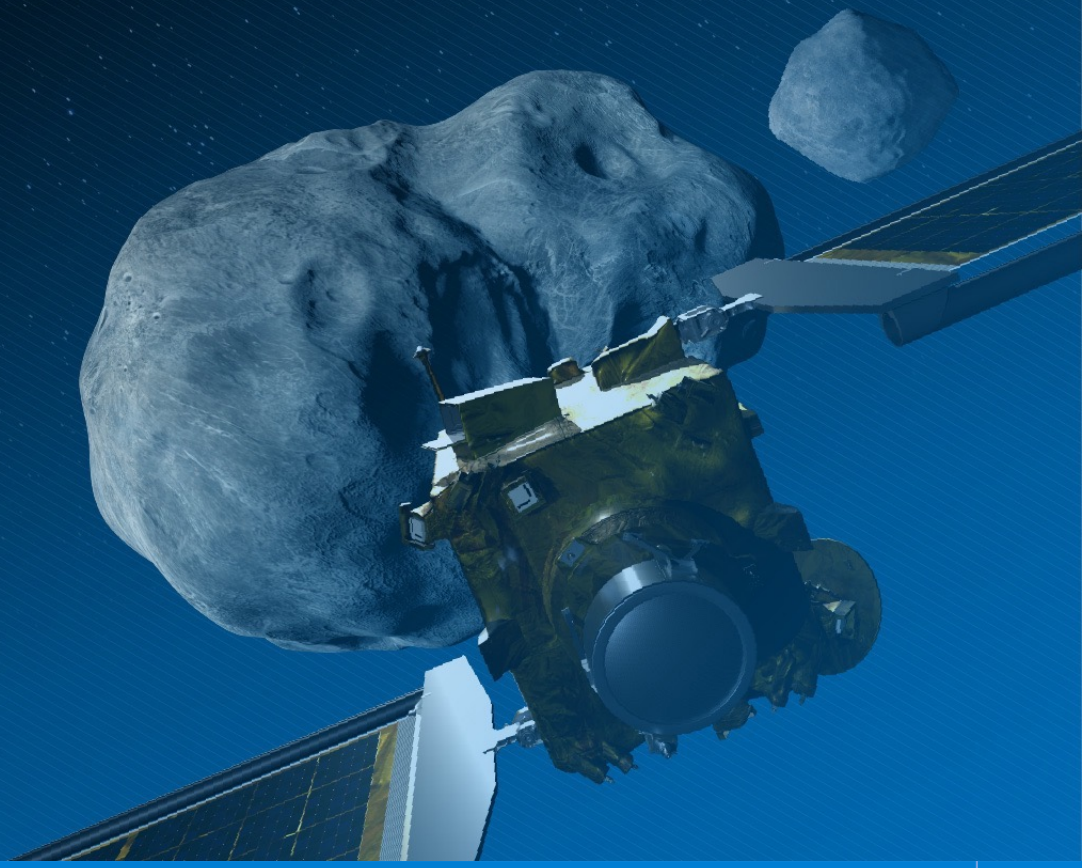
DART

JOHNS HOPKINS APPLIED PHYSICS LABORATORY

NASA

Double Asteroid Redirect Test (DART) Mission Status

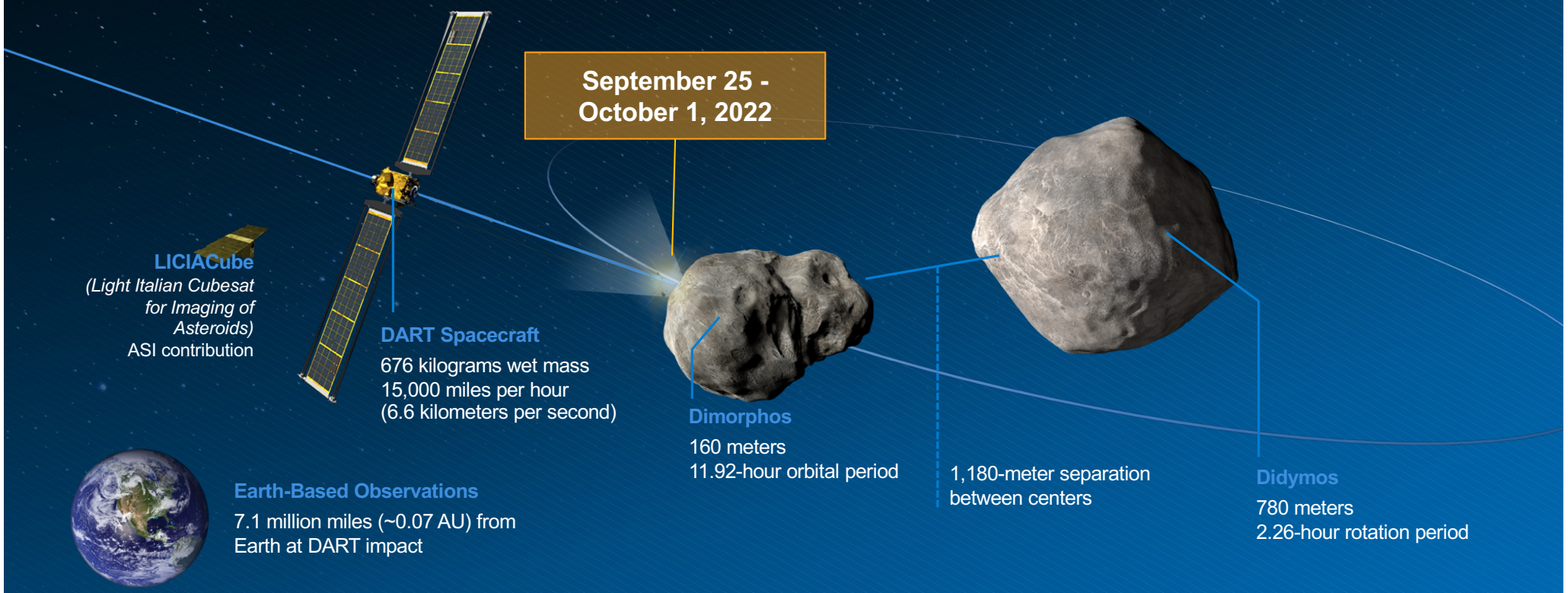
Dr. Elena Adams
Elena.Adams@jhuapl.edu
26 April, 2021



Launch

November 18, 2021 – February 15, 2022

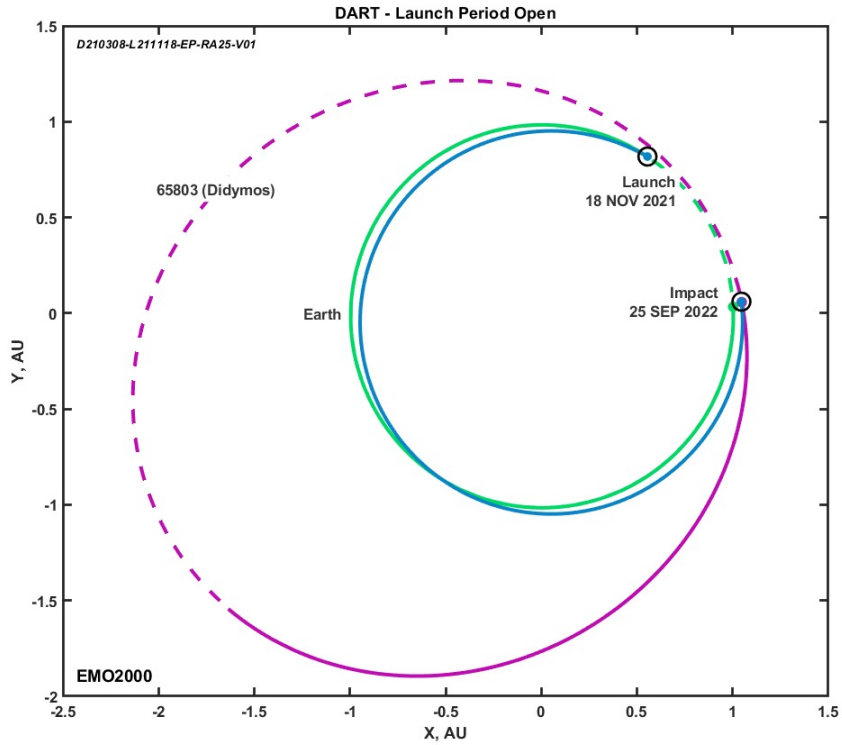
- Target the binary asteroid Didymos system
- Impact Dimorphos and change its orbital period
- Measure the period change from Earth



DART moves to the secondary launch opportunity

- DART was directed by NASA to move to secondary launch opportunity with baseline **launch readiness date: 18 November, 2021**

- This secondary opportunity allows DART to meet its launch and objectives
  - Launch ground coverage becomes simpler, as DART will have a good contact with ESTRACK's New Norcia ground station
  - Cruise portion of the mission is a few months shorter
  - Impact geometry and velocity is comparable
  - Spacecraft still arrives at Dimorphos near the asteroid's closest approach to Earth, and guarantees good ground telescope and radar coverage
    - New impact dates: 25 Sept, 2022- 01 Oct, 2022



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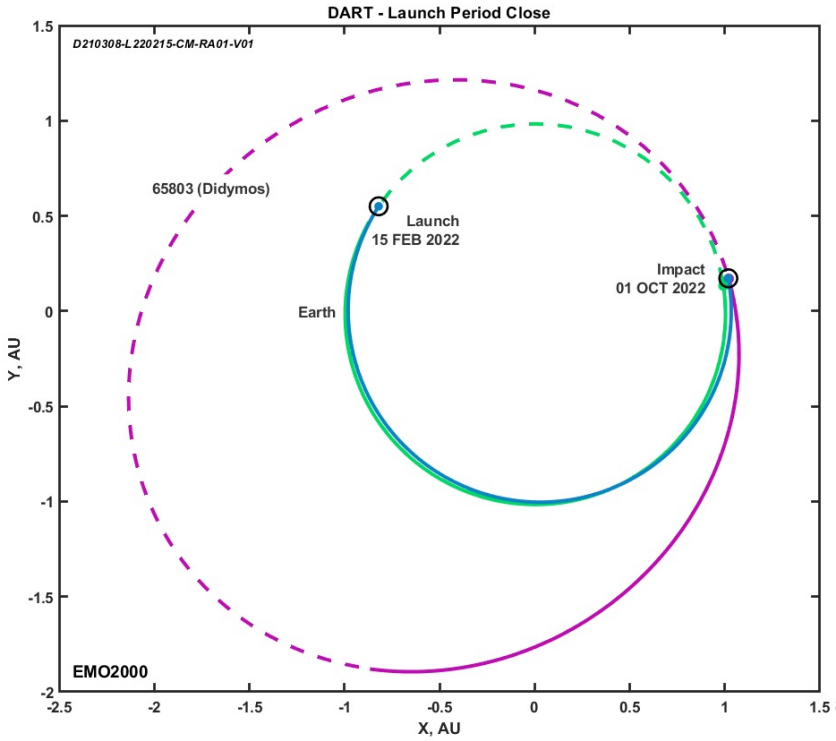

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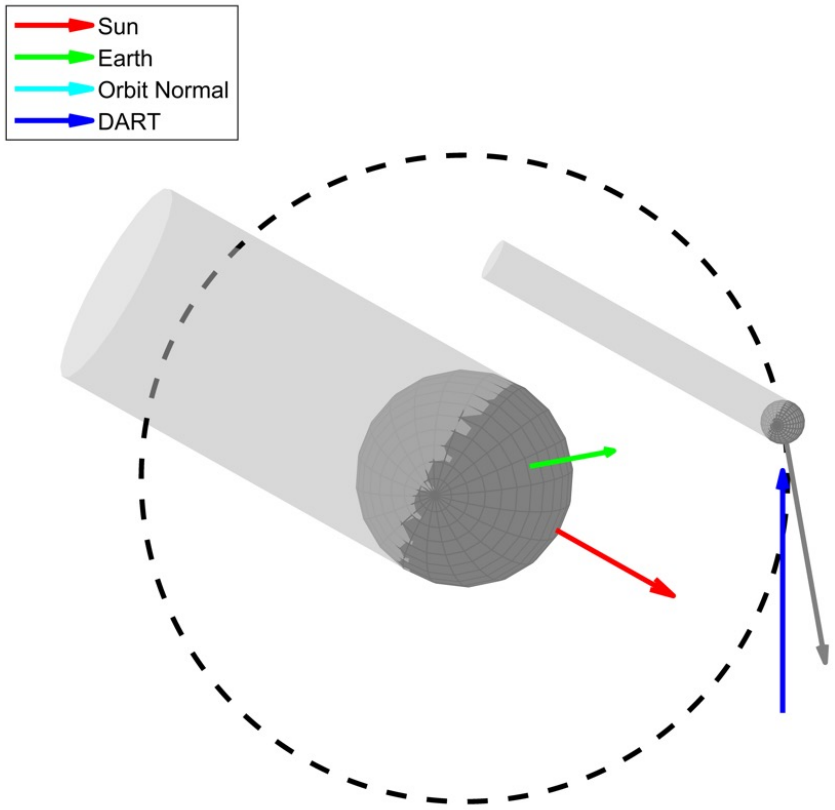
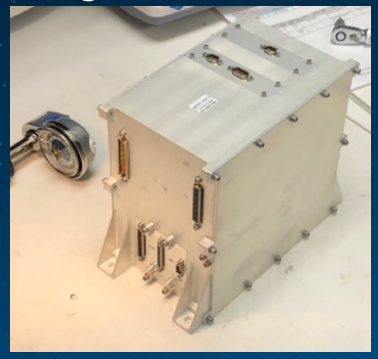


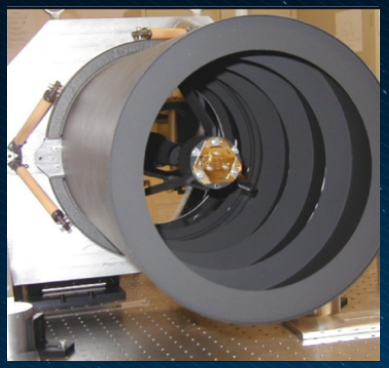
DART: Key and New Technologies

DART will mature key new technologies for future planetary missions

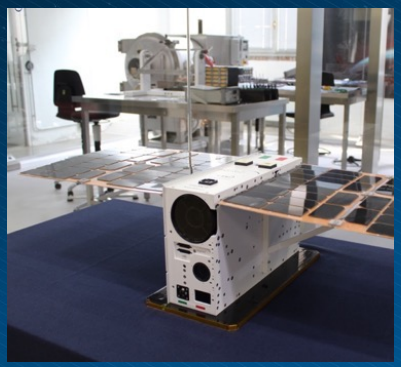
Autonomous Navigation using SMART Nav



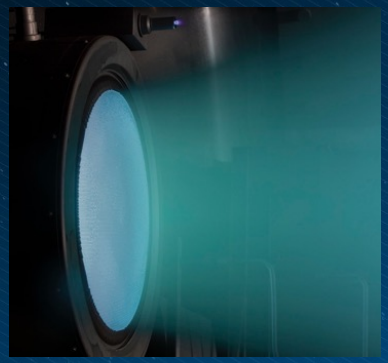
Coresat Avionics



DRACO Telescope



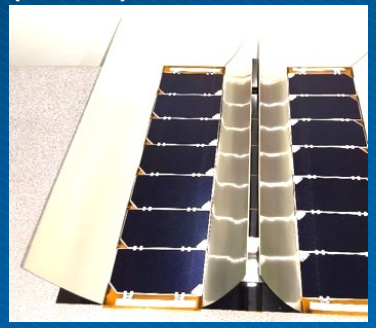
LICIACube Cubesat



Ion Propulsion Engine (NEXT-C)

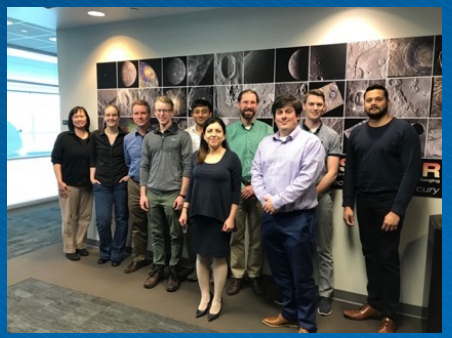
Radio Line Slot Array

Roll Out Solar Arrays (ROSA)



Transformational Solar Array Concentrators

Integrating and Testing Spacecraft Getting Ready for Launch This Year

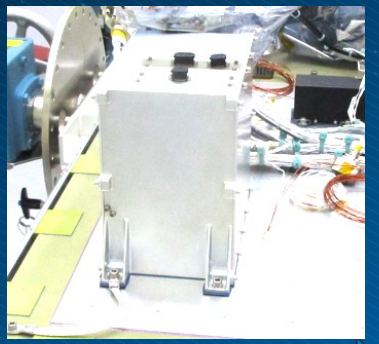


DART mission status overview

- **Spacecraft integration and test is proceeding, even in COVID-19 environment**

DART in thermal chamber

Timeline to Launch



Integration Readiness Review ✓

March 2020

NEXT-C Delivered ✓

April 2020

Panels/Harness Delivered, I&T began! ✓

April 2020

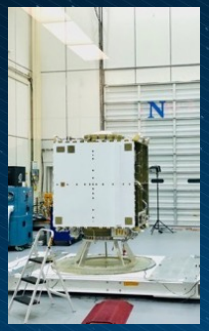
Spacecraft Core Delivered ✓

May 2020

Coresat Avionics Delivered and Integrated ✓

June 2020

Timeline to Launch



Solar Arrays Engineering Unit Deployed (@ DSS)
Jul 2020 ✓

Comprehensive Performance Test (CPT) 1
Aug 2020 ✓

Mission Simulation (MSIM) 1
Aug 2020 ✓

Closed S/C Panels
Sept 2020 ✓

DSN Compat Testing
Oct 2020 ✓

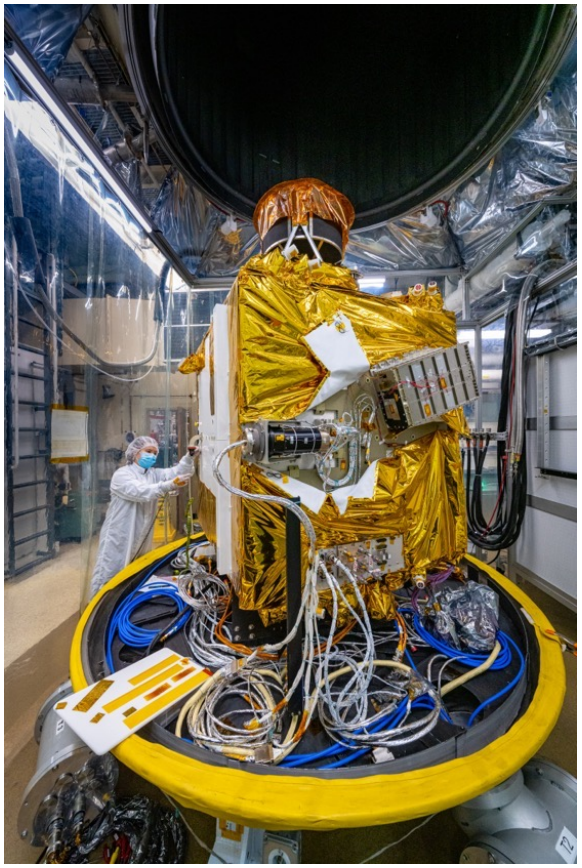
NEXT-C Integration
Oct 2020 ✓

CPT 2 MSIM 2
Dec 2020 ✓

PER
Jan 2021 ✓

DART mission status overview

- **Spacecraft integration and test is proceeding, even in COVID-19 environment**
- Move to the secondary launch opportunity is caused by waiting on two hardware articles to be delivered to the spacecraft: the DRACO telescope and the Solar Arrays
  - Spacecraft structural testing cannot commence without them
- DRACO telescope had a mirror failure during vibration of a spare flight telescope, and the failure investigation board concluded that the flight telescope mirror mounts needed redesign to ensure that the flight telescope survives spacecraft testing and launch. Redesign was completed, and new mirror mounts manufactured. **Telescope is expected to arrive for integration in June 2021**
- **Rollout Solar Arrays (ROSA)** have experienced delays in the build due to COVID and as part of the new technology development, but now **have been received at APL for integration on the spacecraft in May 2021**



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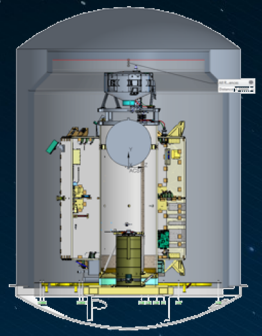
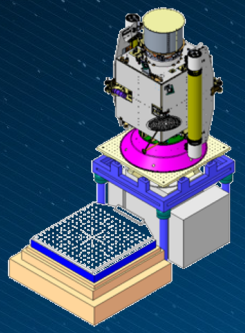




Thermal Tests (CPT3, MSIM3) ✓

Feb-Mar 2021

Solar Array Delivery ✓

Apr 2021

DRACO telescope Delivery

Jun 2021

Structural Tests (Vibe, Shock)

July 2021

Pre-Ship Review

Sept 2021

Ship to Vandenberg Air Force Base

Oct 2021

Launch!

Nov 2021

DART

Double Asteroid Redirection Test

DART

NASA

APL JOHNS HOPKINS APPLIED PHYSICS LABORATORY

DART: How will we know what we've done?

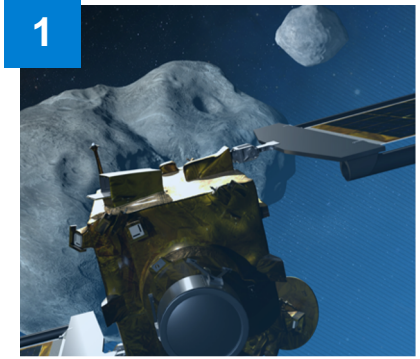
Observations and Dynamics

Andy Rivkin
DART Investigation Lead

DART's Level 1 Requirements

Defining the Mission's Planetary Defense Investigation

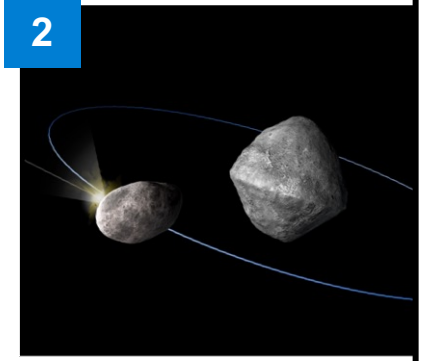
1



Impact Dimorphos

During its Sept/Oct 2022 close approach to Earth

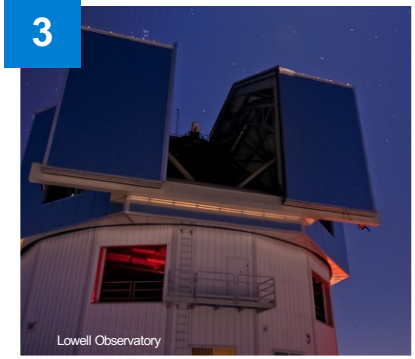
2



Change the binary orbital period

Cause a ≥73-second change in the orbital period of Dimorphos

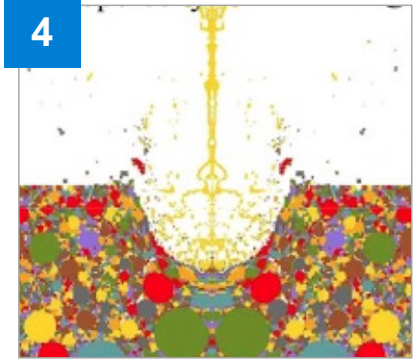
3



Measure the period change

To within 7.3 seconds, from ground-based observations before and after impact

4



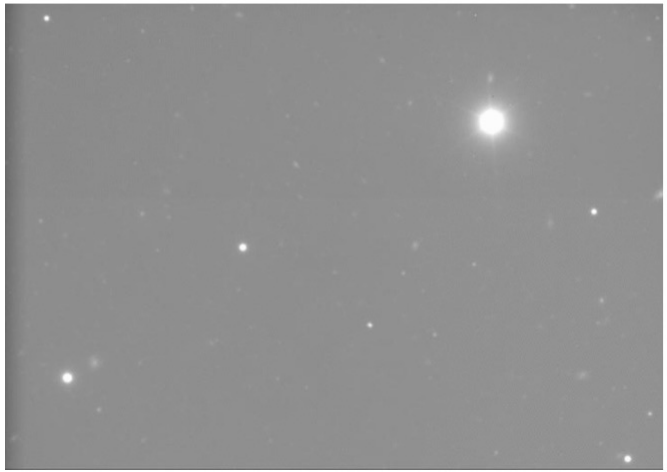
Measure "Beta" and characterize the impact site and dynamics

Beta = *the momentum enhancement factor*

I'll be talking mostly about #3, just touch on #4

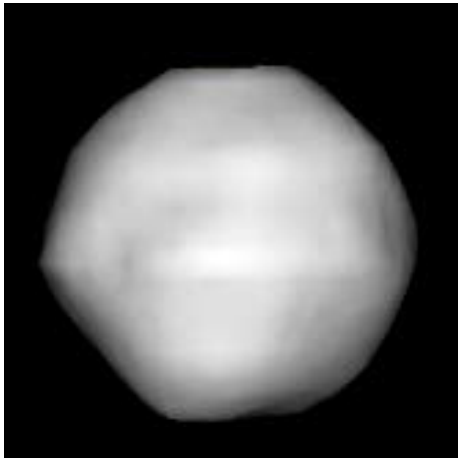
Current Knowledge about Didymos

Lightcurves



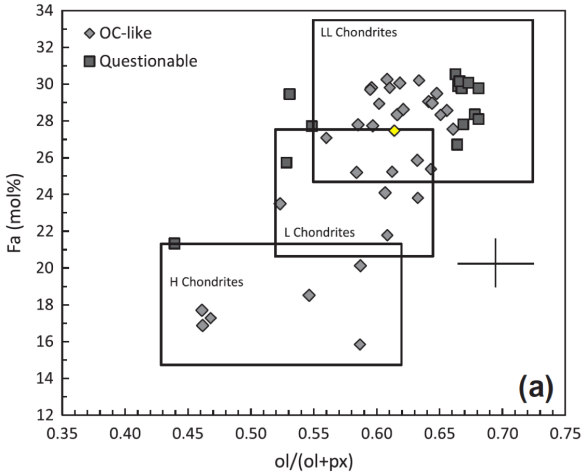
Didymos, moving through star field
Taken from Keck Observatory, January 2021

Radar Shape Model



Shape model of the Didymos primary asteroid from combined radar and light curve data (Naidu et al. 2020)

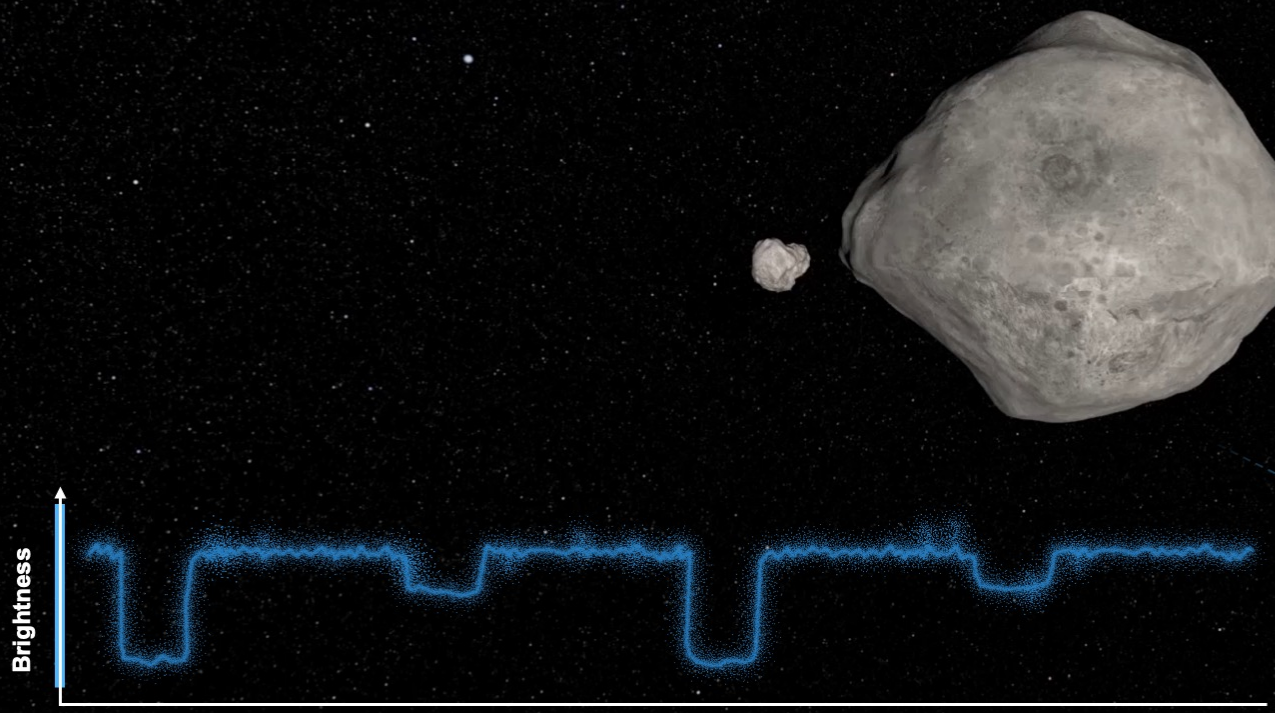
Composition



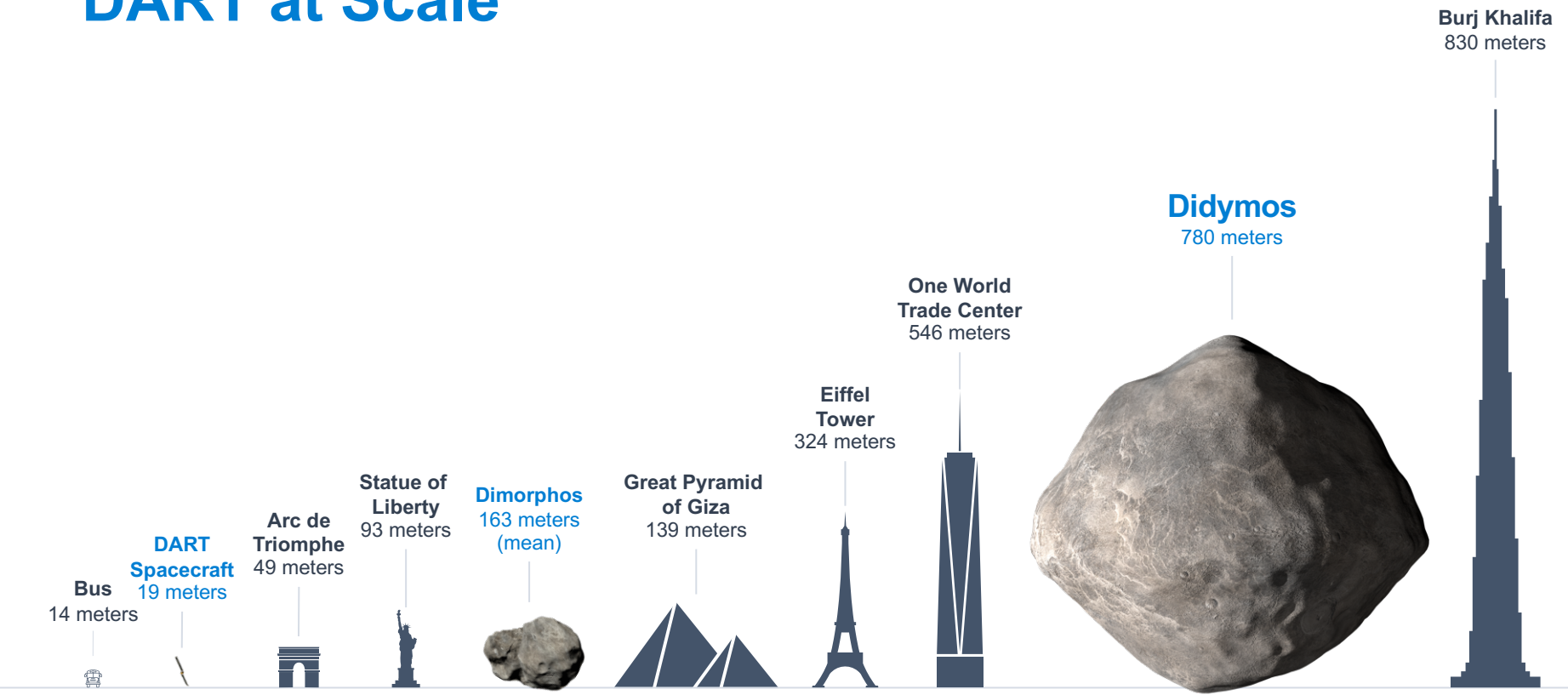
Spectral parameters from observations by de Leon et al. (2009) (yellow diamond) found by Dunn et al. (2014) to be most consistent with L/LL meteorites.

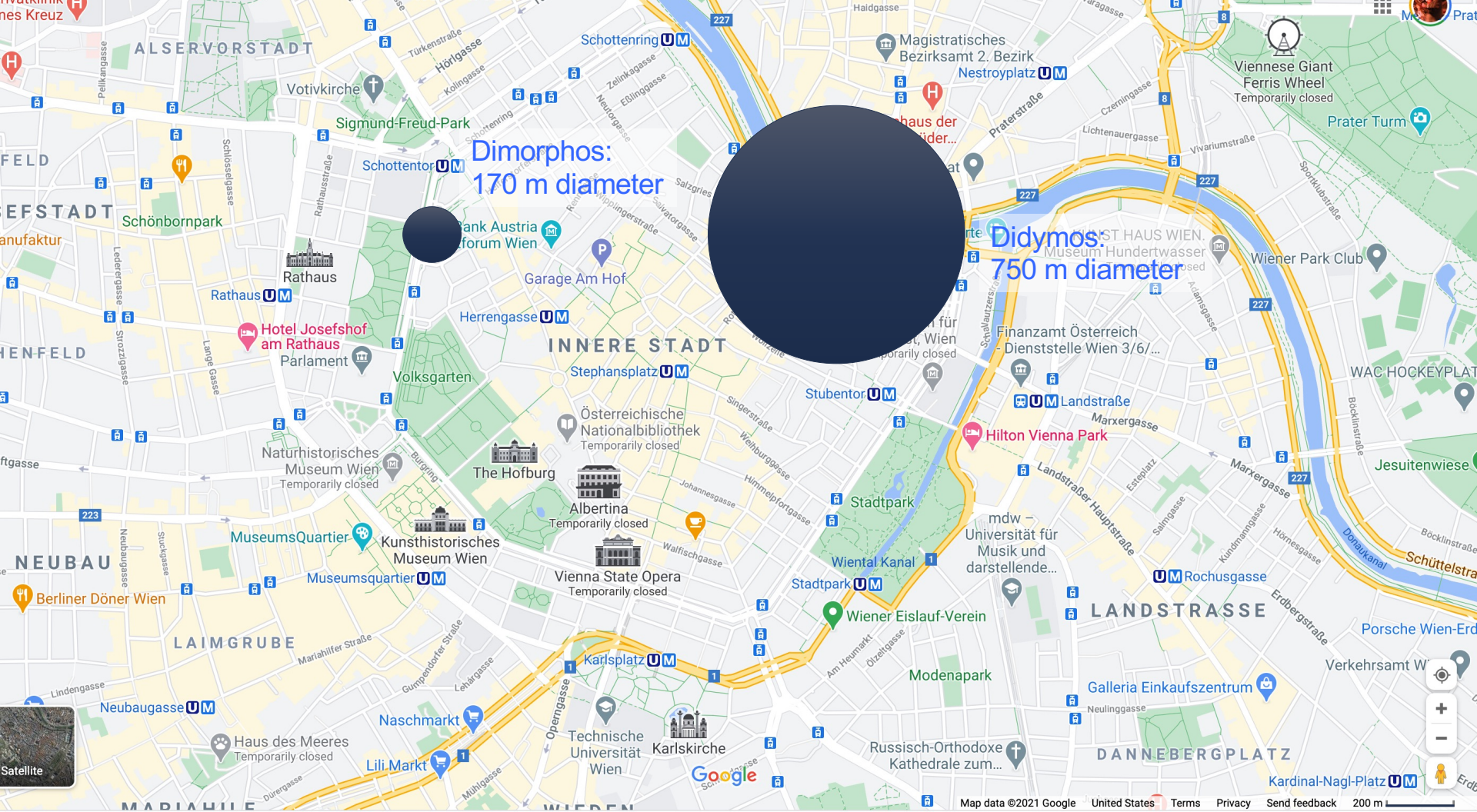
Measuring the Binary Asteroid System from Earth

Dimorphos Orbiting about Didymos



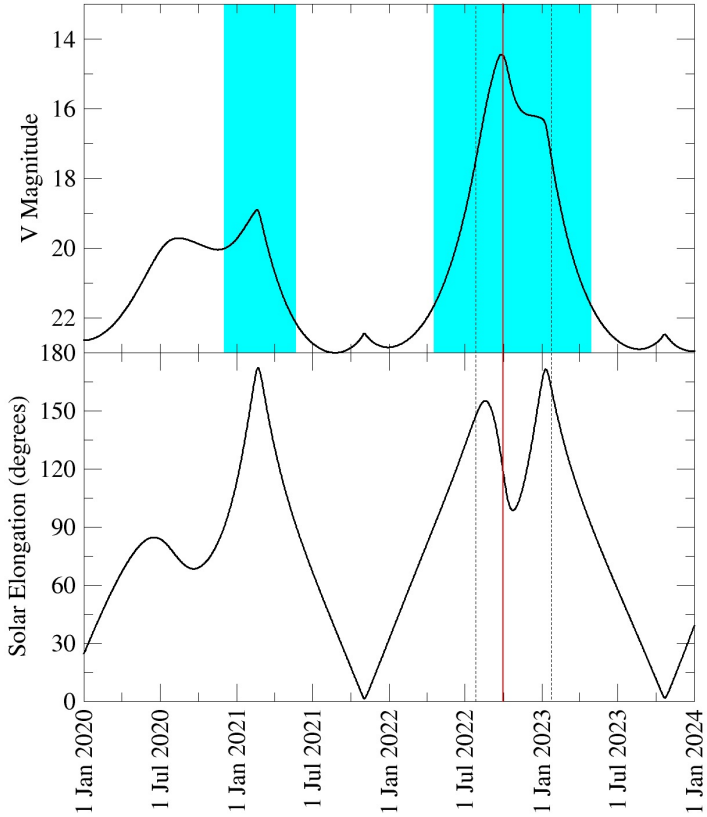
DART at Scale




Dimorphos:
170 m diameter
Didymos:
750 m diameter
ALSERVORSTADT
INNERE STADT
NEUBAU
LAIMGRUBE
LANDSTRASSE
DANNEBERGPLATZ
Votivkirche
Sigmund-Freud-Park
Schottenring
Schottentor
Schönbornpark
Rathaus
Rathaus
Hotel Josefshof am Rathaus
Parlament
Volksgarten
Herrengasse
Garage Am Hof
Stephansplatz
Österreichische Nationalbibliothek
Temporarily closed
The Hofburg
Naturhistorisches Museum Wien
Temporarily closed
Albertina
Temporarily closed
MuseumsQuartier
Kunsthistorisches Museum Wien
Museumsquartier
Vienna State Opera
Temporarily closed
Berliner Döner Wien
Karlsplatz
Technische Universität Wien
Karlskirche
Naschmarkt
Lili Markt
Haus des Meeres
Temporarily closed
Neubaugasse
Magistratisches Bezirksamt 2. Bezirk
Nestroyplatz
Viennese Giant Ferris Wheel
Temporarily closed
Prater Turm
Praterstraße
Wiener Park Club
Finanzamt Österreich - Dienststelle Wien 3/6/...
Stubentor
Landstraße
Hilton Vienna Park
Stadtpark
Wiental Kanal
Stadtpark
Wiener Eislauf-Verein
mdw – Universität für Musik und darstellende...
Rochusgasse
Modenapark
Galleria Einkaufszentrum
Russisch-Orthodoxe Kathedrale zum...
Kardinal-Nagl-Platz
Satellite
Google
Map data ©2021 Google
United States
Terms
Privacy
Send feedback
200 m

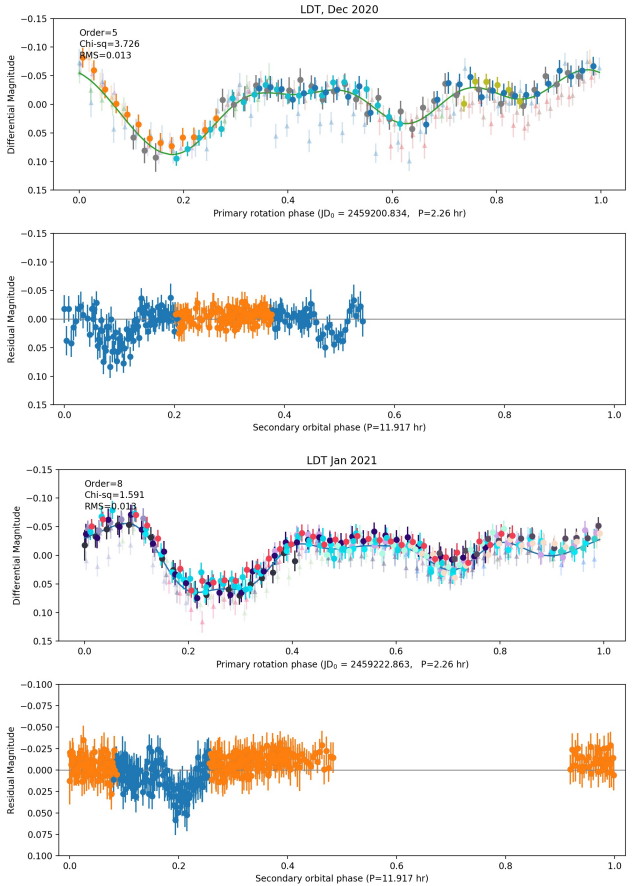
The 2020-2021 Apparition

- Focused on improving precision of Dimorphos' orbit to allow extrapolation and targeting of a particular orbit phase at time of DART arrival
- Observing season December 2020—March 2021
  - Early observations only had short observing window per night
- Deadline-driven data analysis included observations from LDT and Keck
  - Only data reduced through mid-January included in current fits
  - Additional observations still under analysis



The 2020-2021 Apparition

- New data reduces the uncertainty on Dimorphos' orbit period to 0.01 seconds
- 3-σ uncertainty on Dimorphos orbit phase < 7° when extrapolated to time of DART arrival
- GM value corresponds to mass of roughly 5.5 x 10^{11} kg
  - 95%+ of mass in Didymos, remainder in Dimorphos
  - Density 2170 ± 350 kg/m^3
- Best estimate for binary YORP ("BYORP") is small but non-zero.



Lowell Discovery Telescope, December 2020 & January 2021
Nick Moskovitz, Matthew Knight, Tony Farnham

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Parameter	Value	1σ uncertainty
M_0 (°)	78.9	1.9
Period (h)	11.9216287	0.0000031
n_0 (rad s^{-1})	1.46400235e-04	0.00000038e-4
$\dot{n}$ (rad s^{-2})	4.9e-18	1.1e-18
Epoch (TDB)	2011-08-21.5	
χ^2	20.0	
χ^2_ν	0.42	
$(\lambda, \beta)°$	$(320, -79)°$	
GM_{sys} (m^3 s^{-2})	37.0362739237411501789	

The 2020-2021 Apparition

- New data reduces the uncertainty on

Also see e-Lightning Talks:
"Constraining the Orbital Parameters of the Didymos-Dimorphos System: Lightcurve Observations in Preparation for AIDA/DART" by Thomas et al.
"Estimation of orbital parameters of Dimorphos from lightcurve mutual events" by Naidu et al.

  - Density 2170 ± 350 kg/m^3

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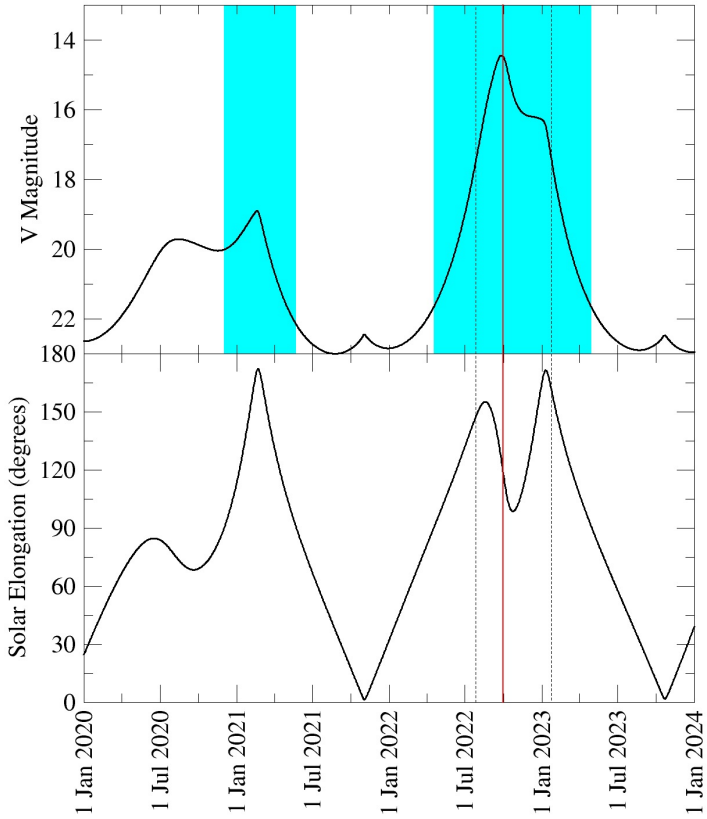
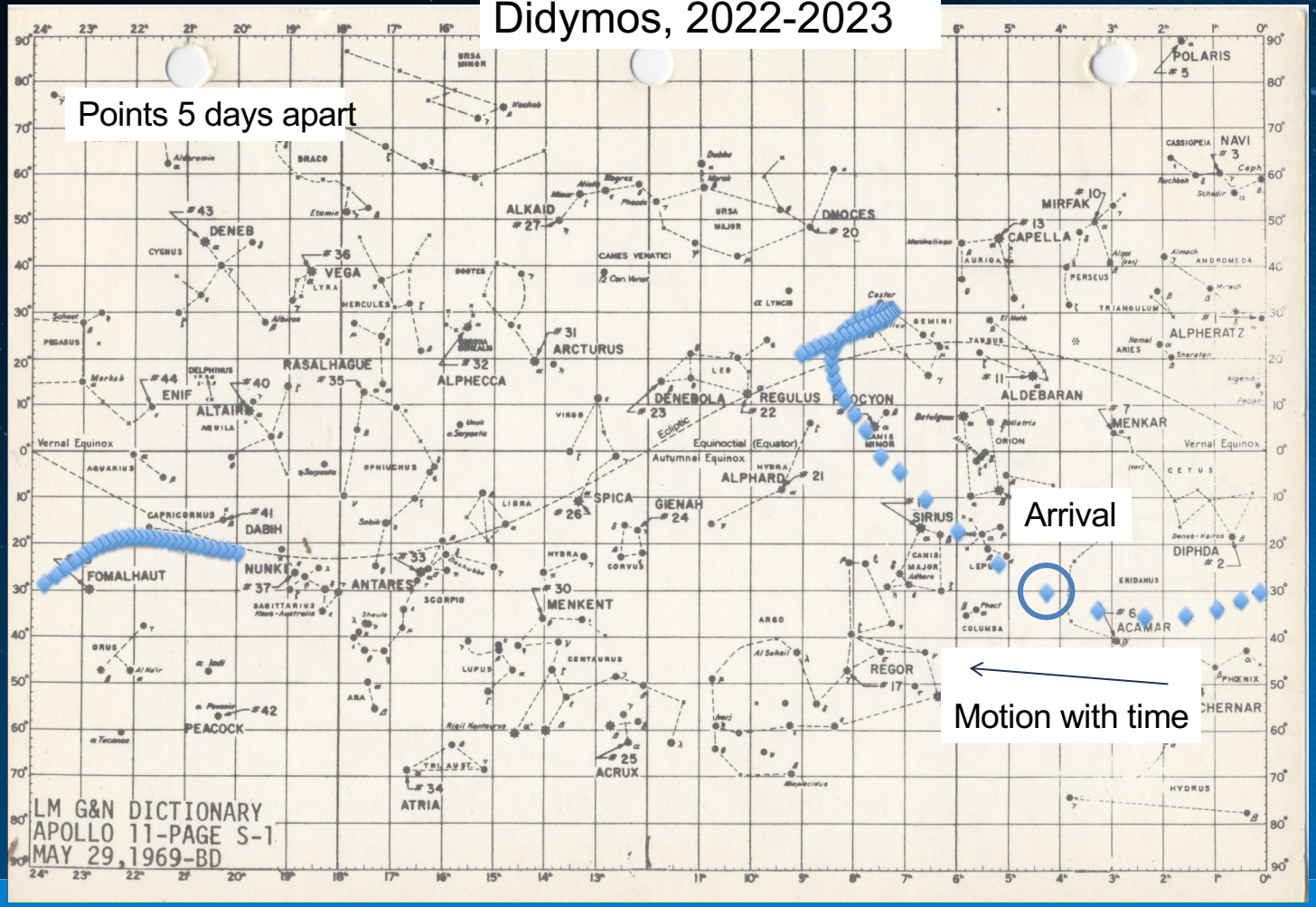
The 2022-2023 apparition

- Didymos spends very long period at >90° solar elongation, roughly 6 months at V < 17.5
  - At V < 17.5 should be able to get good lightcurve data with m-class telescopes
- DART supporting observations from 4 observatories
  - Lowell Observatory
  - Magdalena Ridge Observatory
  - Las Cumbres Observatory (network)
  - Las Campanas Observatory
- Access to additional observatories through team membership around the world
- At time of DART arrival, Didymos is in southern skies. It moves north rapidly over following weeks
  - Distribution of supported telescopes allows good coverage during entire period
- Anticipate reaching required precision on period change by end of calendar year 2022



Didymos, 2022-2023



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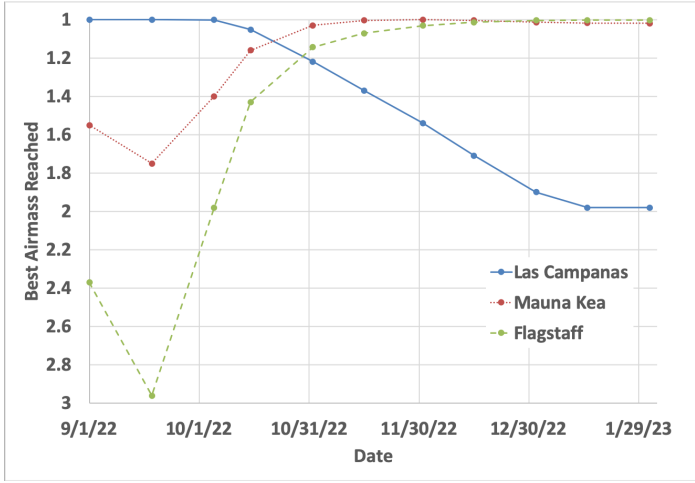

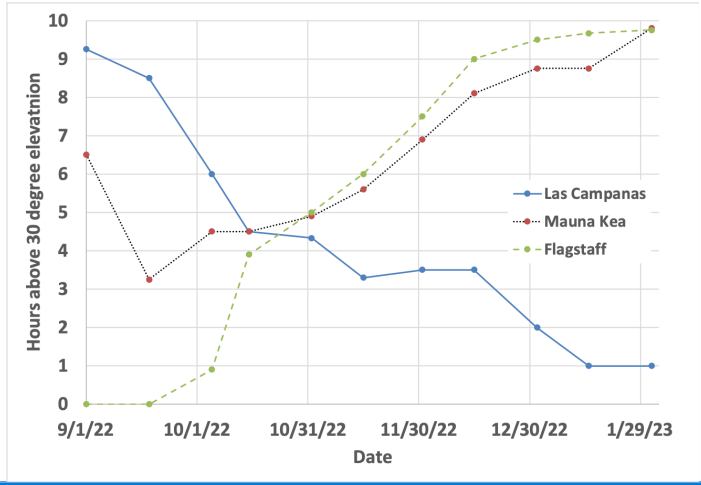

Additional measurements

- Radar: High SNR measurements available from Goldstone 2-16 October 2022, 150 m/pixel monostatic, 75 m/pixel bistatic with Green Bank possible.
  - Can potentially measure offset between Dimorphos position and unperturbed position within a few days of DART impact
- Ejecta:
  - Visualization models still being run for LICIACube and other observing platforms
  - Expect brightening of system while ejecta is still unresolved within same pixel as Didymos (duration dependent upon imaging system used as well as ejecta model)
  - Hope to study the ejecta evolution from Earth-based systems, which will help constrain particle sizes and ejecta mass

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Also see e-Posters:
"Dynamics of ejecta plume after the DART impact on Dimorphos" by Ferrari et al.;
"Non-spherical dust dynamics of the ejecta plume in support of DART/LICIACube mission" by Ivanovski et al.
"Incorporating a gravity field model based on radar observations into the rebound ejecta dynamics package" by Larson et al.
e-Lightning talks: "Simulating planned LICIACube imagery of DART impact ejecta based on ejecta dynamics simulation output" by Fahnestock et al.;
"Influence of the body composition on the evolution of ejecta in the Didymos-Dimorphos binary system" by Rossi et al.

Dynamical Possibilities

- The impact into Dimorphos will inevitably cause librations
  - Even if perfectly circular/perfectly tidally locked pre-arrival, DART will cause some amount of eccentricity and thus libration
- The amount of libration is dependent upon Dimorphos' shape
  - Not clear if likely amounts of libration will be observable from Earth
  - May be observable with Hera's arrival
  - If observable, will provide information about Dimorphos' interior
- Dynamics of system very sensitive to initial conditions, shape of Didymos and Dimorphos
  - Close enough to one another that they do not appear as point sources for gravitational purposes
- Hera's visit to Didymos will enable dynamical models to be tested
  - Another case were the combined data sets will be "more than the sum of parts"

Dynamical Possibilities

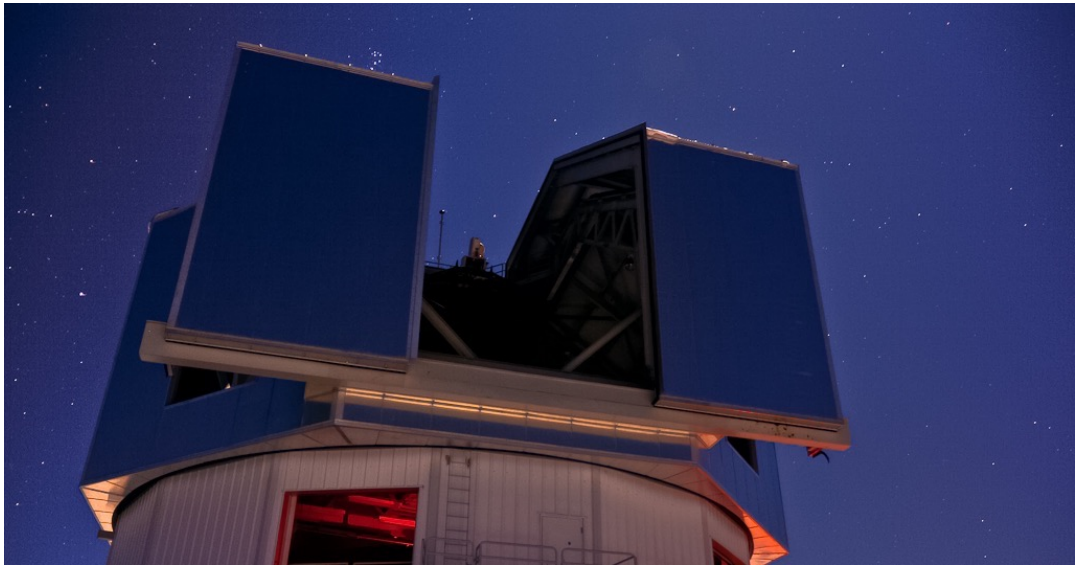
- The impact into Dimorphos will inevitably cause libration

Also see e-Lightning talks:
"Consequences of the DART impact on Dimorphos' spin state and surface mass", Benavidez et al.;
"On the post-impact spin state of the secondary component of the Didymos-Dimorphos binary asteroid system" by Agrusa et al.;
"Changing the heliocentric orbit of the Didymos system with DART" by Makadia et al.

- Hera's visit to Didymos will enable dynamical models to be tested
  - Another case were the combined data sets will be "more than the sum of parts"

Summary

- Telescopic observations of the Didymos system are integral to the DART project
- Dynamical studies have been showing what can/can't be extrapolated or determined from 1st principles, and studying the lifetime of DART effects
- Observations prior to DART's arrival are necessary to characterize its undisturbed nature and to enable targeting at a desired Dimorphos orbit phase
- Observations subsequent to DART's arrival are how the experiment will be evaluated
- Preparations for the 2022-2023 observations are beginning, with opportunity to participate



Lowell Discovery Telescope (credit: Lowell Observatory)

DART

Double Asteroid Redirection Test