

NASA Planetary Defense Missions

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Planetary Science Division
NASA Headquarters
Washington, DC

SMPAG Meeting #19
20 October 2022



NASA Missions of Interest

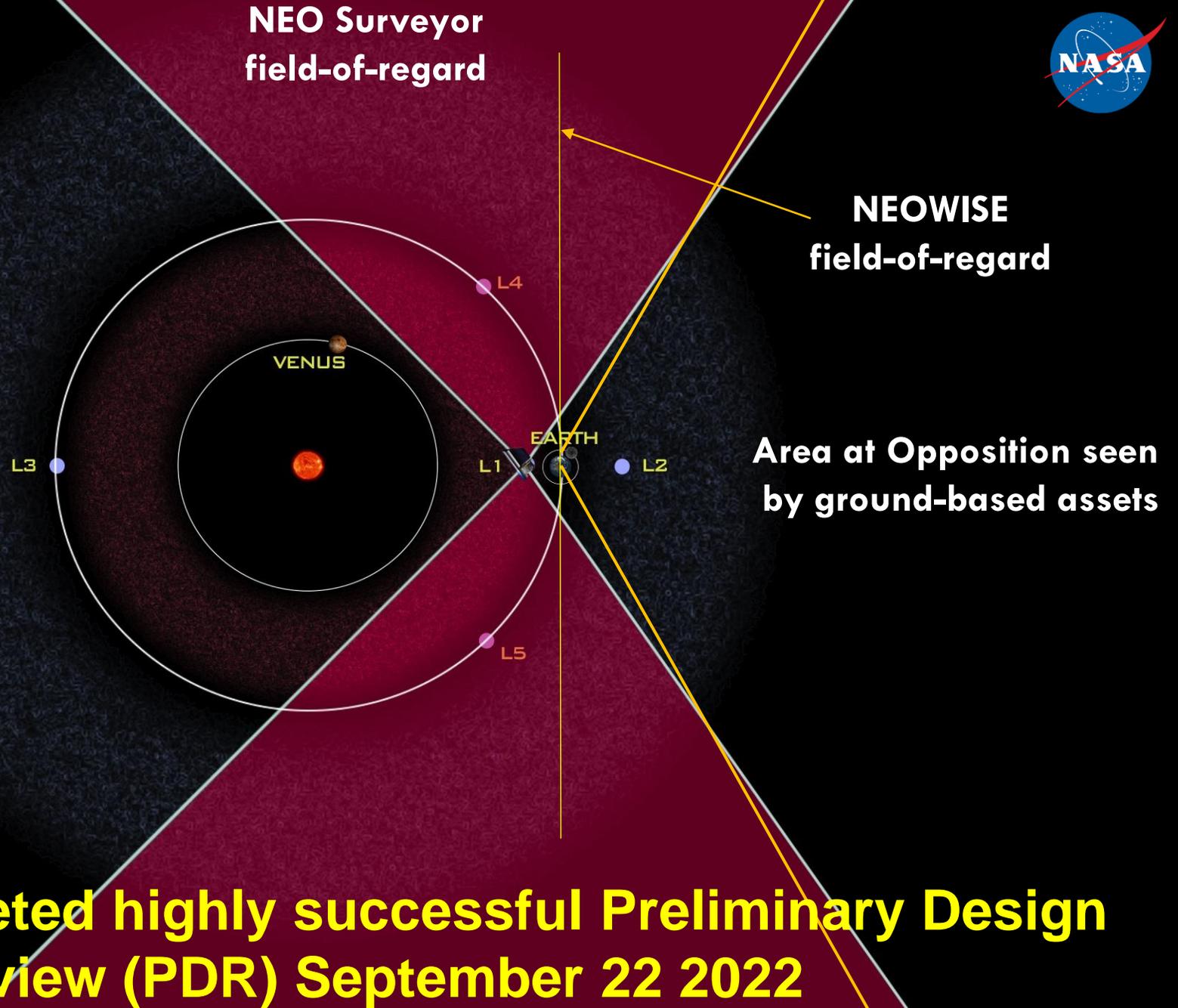
Planetary Science Missions to Asteroids

- **OSIRIS-REx – Sample Return from asteroid Bennu**
 - All nominal in cruise return to Earth – September 2023
 - Extended mission OSIRIS-APEX awarded by New Frontiers
- **Lucy – Mission to the Jupiter Trojans**
 - Successfully completed EGA 16 October 2022
- **Psyche – Mission to a “Metal World”**
 - Did not meet the August 2022 launch window
 - Continuation/Termination Review 25 October
- **Janus – SIMPLEx mission to two binary asteroids**
 - Awaiting decision on Psyche
- **NEO Scout – Destination 2020 GE**
 - Awaiting launch on Artemis 1

NEO Surveyor



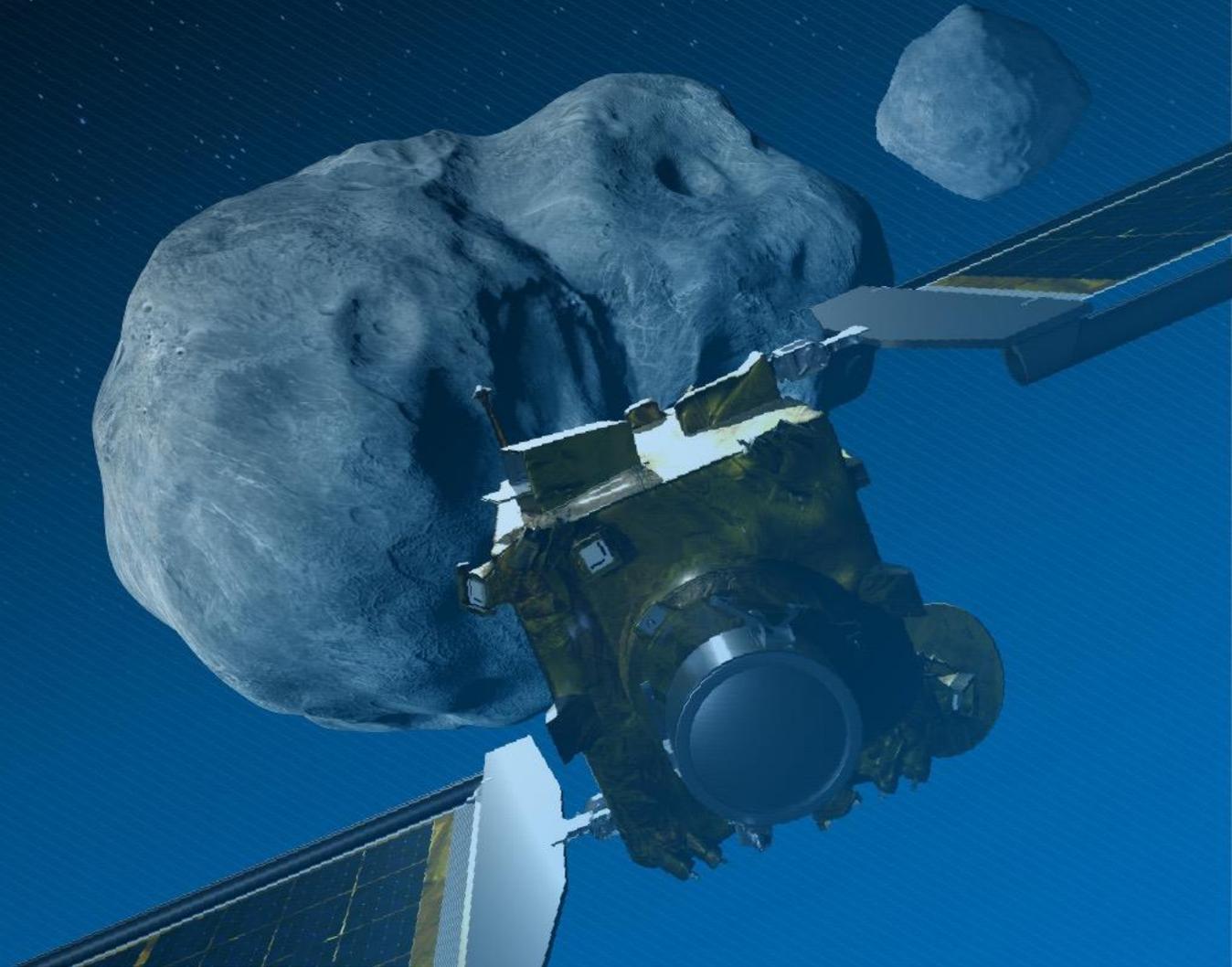
- Space-based infra-red telescope
- Objectives:
 - Find 65% of Potentially Hazardous Asteroids (PHAs) >140 m in 5 years (>90% in 10 years)
 - Estimate object sizes



Project completed highly successful Preliminary Design Review (PDR) September 22 2022



Double Asteroid Redirection Test Post- Impact Update



Launched on Nov. 24 EST

SpaceX Falcon 9
Vandenberg Space Force Base, CA

DART Mission:

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

IMPACT: 26 Sep 2022

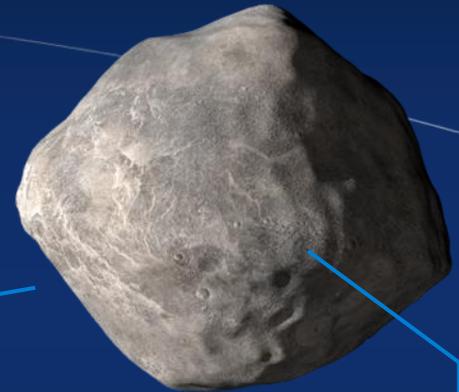
LICIACube
(Light Italian Cubesat
for Imaging of
Asteroids)
Italian Space Agency
contribution



DART Spacecraft
14,000 miles per hour



Dimorphos
160 meters
11.92-hour orbital period



1,180-meter separation
between centers

Didymos
780 meters



Earth-Based Observations
6.8 million miles (0.07 AU) from
Earth at DART impact

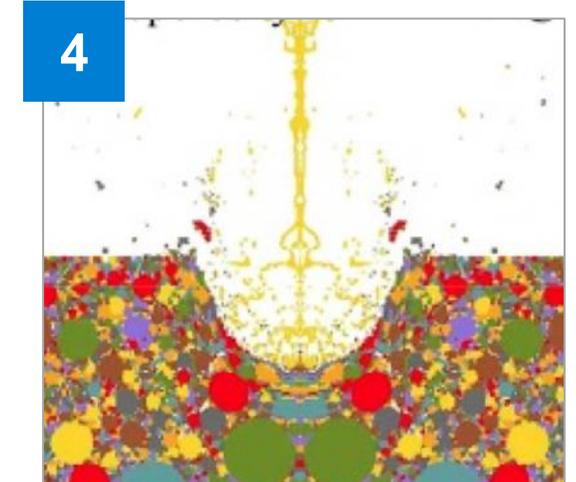
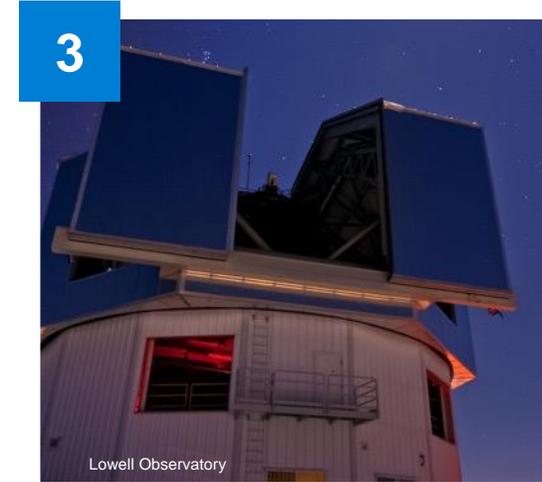
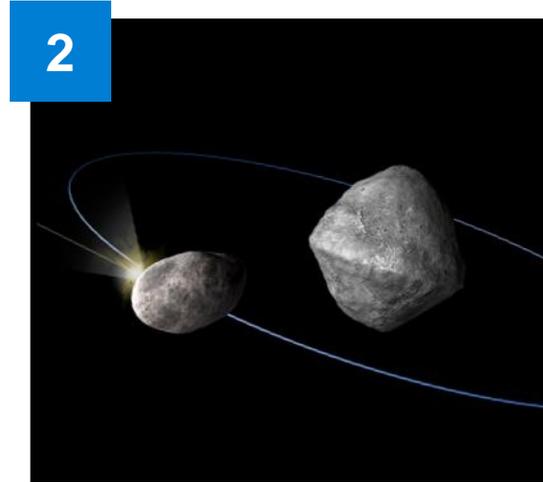


DART in
launch vehicle
fairing at
Space X
processing
facility



DART's Level 1 Requirements

Defining the Mission's Planetary Defense Investigation



Impact Dimorphos

During its Sept/Oct 2022 close approach to Earth

Change the binary orbital period

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

Measure the period change

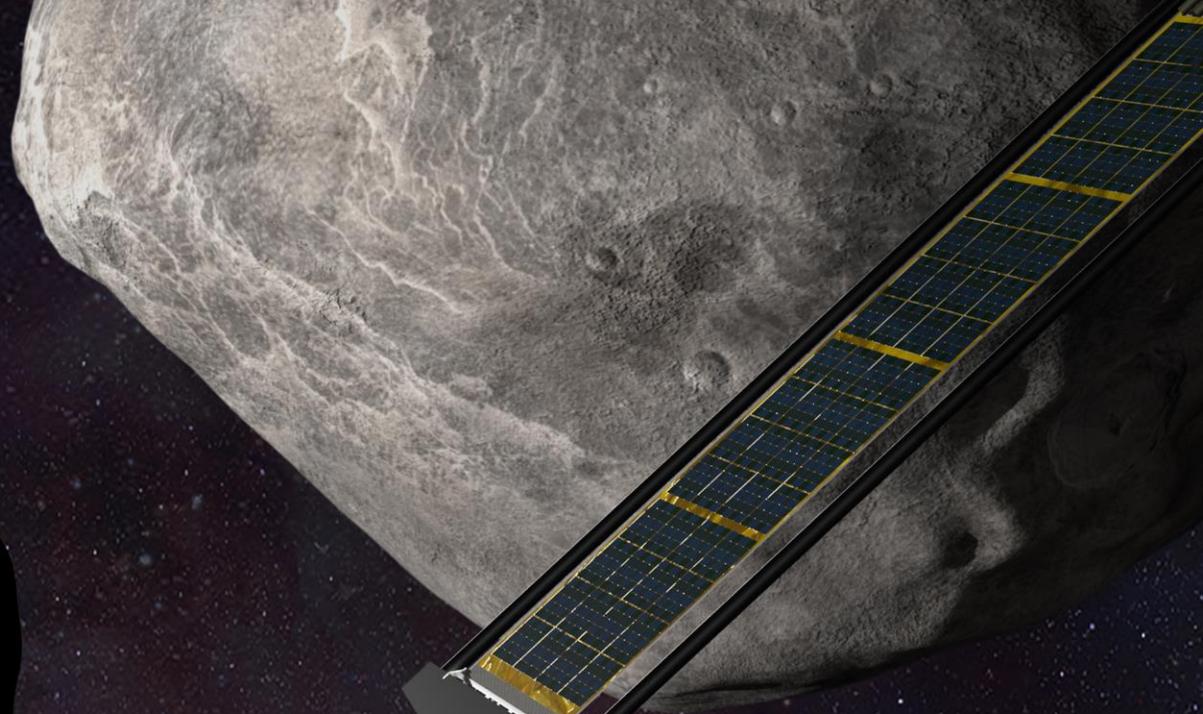
To within 7.3 seconds, from ground-based observations before and after impact

Measure "Beta" and characterize the impact site and dynamics

Beta = the momentum enhancement factor caused by crater ejecta



Impact! September 26, 2022

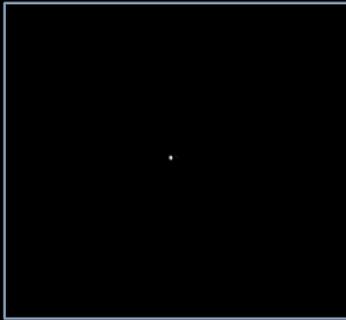


It allows a deflection demonstration on an asteroid of the relevant size by changing its orbital period by ~1% about the larger asteroid.



Earth-based observations

We won't see the target until almost time to hit it!



24,000 kilometers
Didymos – 6.5 pixel
Dimorphos – 1.4 pixel
Target becomes observable



1600 kilometers
Didymos – 99 pixel
Dimorphos – 21 pixel
Final divert maneuver corrections



800 kilometers
Didymos – 197 pixel
Dimorphos – 41 pixel
Divert maneuvers complete, drift to impact



130 kilometers
Didymos – N/A
Dimorphos – ~300 pixel
Pixel-scale requirements met



DART Impact Replay



WORLDWIDE
OBSERVING
CAMPAIGN **2022**
2023



Arizona

LDT (4.3 m)
Hall (1.1 m)

California

Goldstone
Palomar (5 m)
TMO (1 m)

Hawaii

IRTf (3 m)
ATLAS (0.5 m x 2)

New Mexico

MRO (2.4 m)

Texas

LCOGT (1 m)

West Virginia

Green Bank

Canary Islands

TNG (3.5 m)
NOT (2.56 m)
LCOGT (1 m)

Italy

Asiago (1.8 m, 1 m)

Israel

Wise (0.71 m)

Qatar

Qatar Univ. (0.3 m)

Kenya

OPTiK (0.4 m)

Namibia

Drebach South (0.4 m)
Springbok (0.36 m)

Réunion

Les Makes (0.6 m)

Chile

ALMA
VLT (8.2 m x 4)
Magellan (6.5 m)
SOAR (4.1 m)
La Silla (1.54 m)
LCOGT (1 m)
Swope (1 m)
ATLAS (0.5 m)

Argentina

Jorge Sahade (2.15 m)
EABA Bosque Alegre (1.5 m)

South Africa

LCOGT (1 m)
SAAO (1 m)
ATLAS (0.5 m)
SMARTnet (0.5 m)
Watcher (0.4 m)

Australia

LCOGT (1 m)

Antarctica

ASTEP (0.4 m)

New Zealand

Mt. John (1.8 m)



HST



JWST

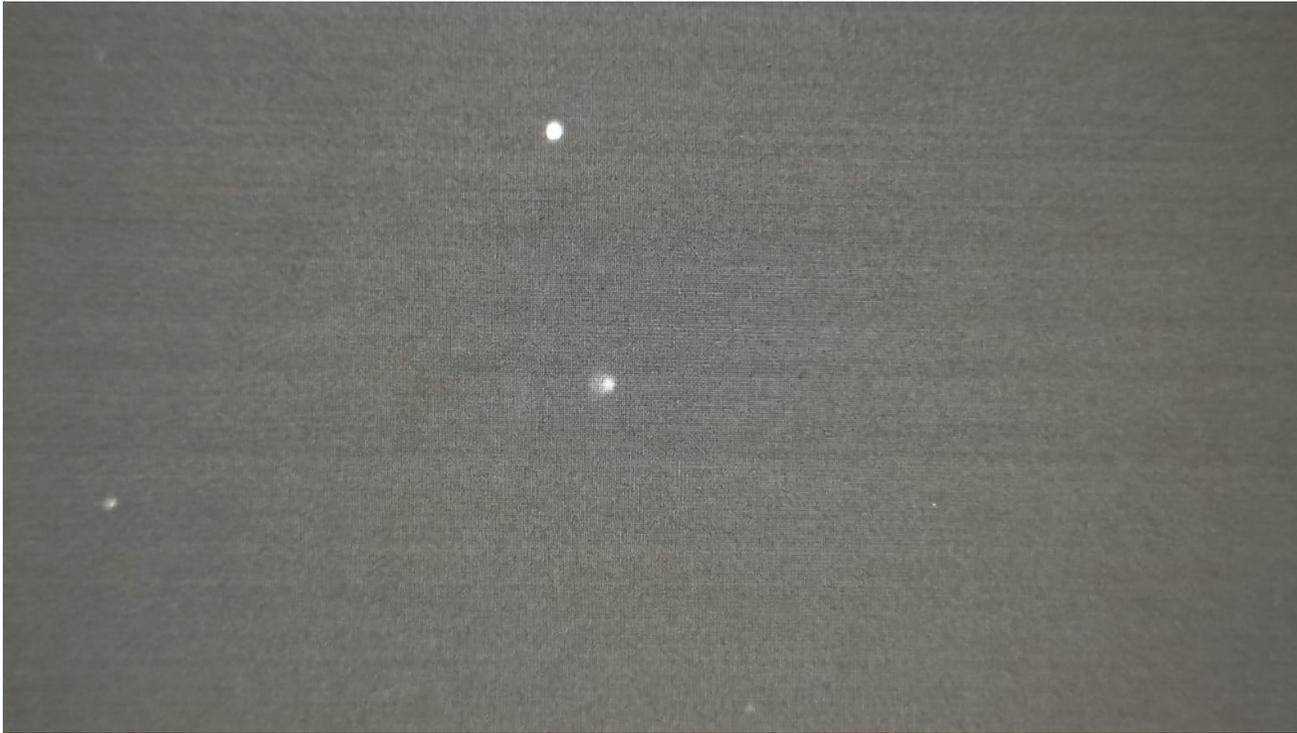


Lucy

DART – Double Asteroid Redirection Test

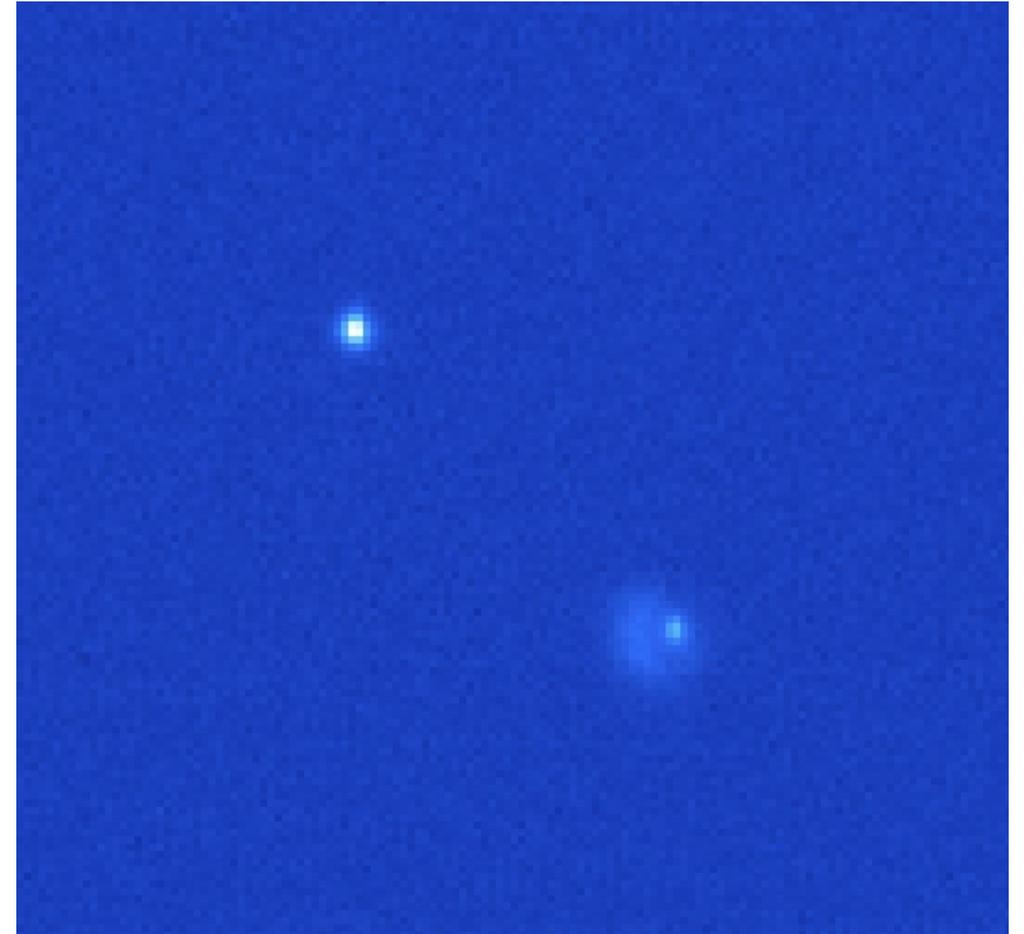
Kenya, posted to Slack 4 minutes after the impact

Credit: Murabana, Owen, Tilson (Travelling Telescope),
Snodgrass (U. Edinburgh)



South Africa, posted to slack 6 minutes after impact

Erasmus (South African Astronomical Observatory)
and Sickafoose (Planetary Science Institute)

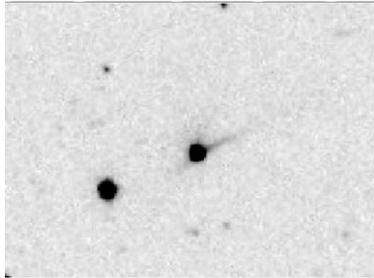




ATLAS South Africa (University of Hawai'i/NASA PDCO)

Telescopic observations from around the world

Africa
(South Africa)



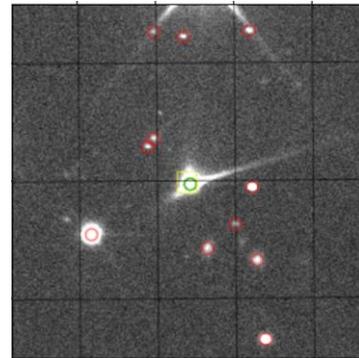
ATLAS project,
HQ at U.
Hawai'i.

North America
(United States)



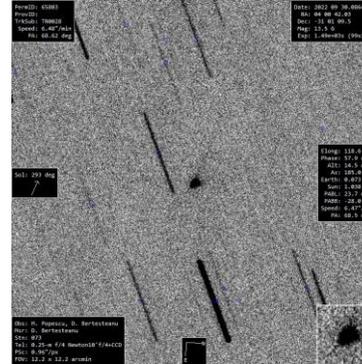
Bill and Eileen Ryan:
Magdalena Ridge Obs.
NM Tech

South America
(Chile)



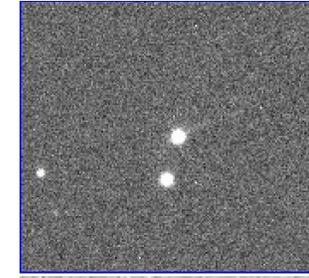
T. Lister, J.
Chatelain, E.
Gomez /
Las Cumbres
Observatory

Europe
(Romania)



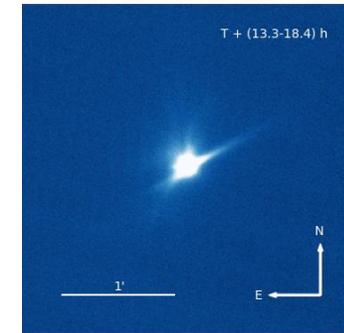
Popescu:
Astronomical
Institute of the
Romanian
Academy

Asia
(Israel)



Ofek/Polishook,
Weizmann
Institute of
Science.

Oceania
(New Zealand)



R. Ridden-
Harper/M. T.
Bannister/N. Tan/T.
Brown/P. Tristram,
U. Canterbury

Antarctica
(Concordia)

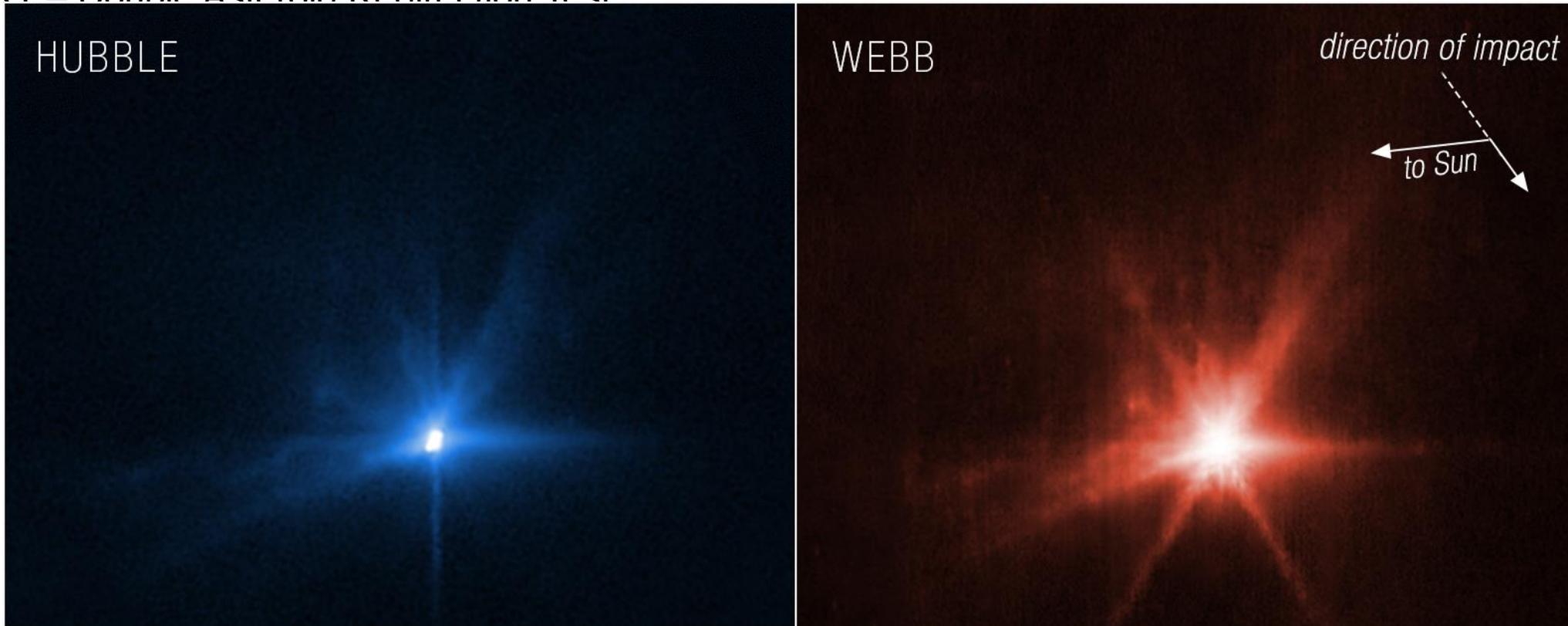


Abe/Guillot:
Antarctic
Search for
Transiting
ExoPlanets
Project

And this is just a snapshot! There is so much more than this and telescopes continue to provide new data daily.



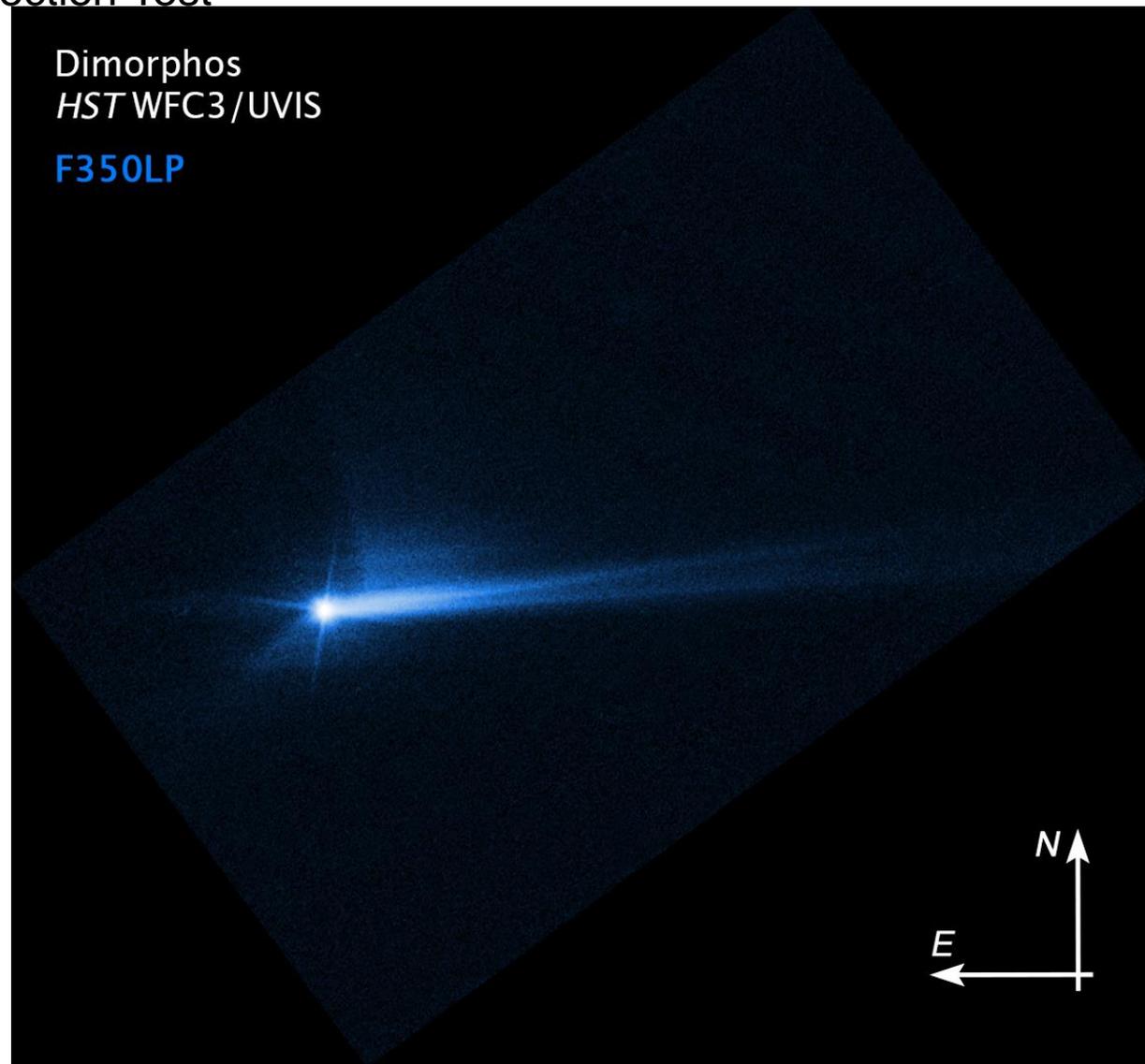
DART – Double Asteroid Redirection Test



Webb, Hubble Capture Detailed Views of DART Impact

These images, Hubble on the left and Webb on the right, show observations of the Didymos-Dimorphos system several hours after NASA's Double Asteroid Redirection Test (DART) intentionally impacted the moonlet asteroid.

Credit: Science: NASA, ESA, CSA, Jian-Yang Li (PSI), Cristina Thomas (Northern Arizona University), Ian Wong (NASA-GSFC); image processing: Joseph DePasquale (STScI), Alyssa Pagan (STScI)



Hubble Captures Detail in Debris Trail

This imagery from NASA's Hubble Space Telescope from Oct. 8, 2022, shows the debris blasted from the surface of Dimorphos 285 hours after the asteroid was intentionally impacted by NASA's DART spacecraft on Sept. 26. The shape of that tail has changed over time. Scientists are continuing to study this material and how it moves in space, in order to better understand the asteroid. **Credits: NASA/ESA/STScI/Hubble**

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~~T=28 seconds~~
~~EXP=0.001~~
~~PHA=57.276~~
~~DIST=812.882~~

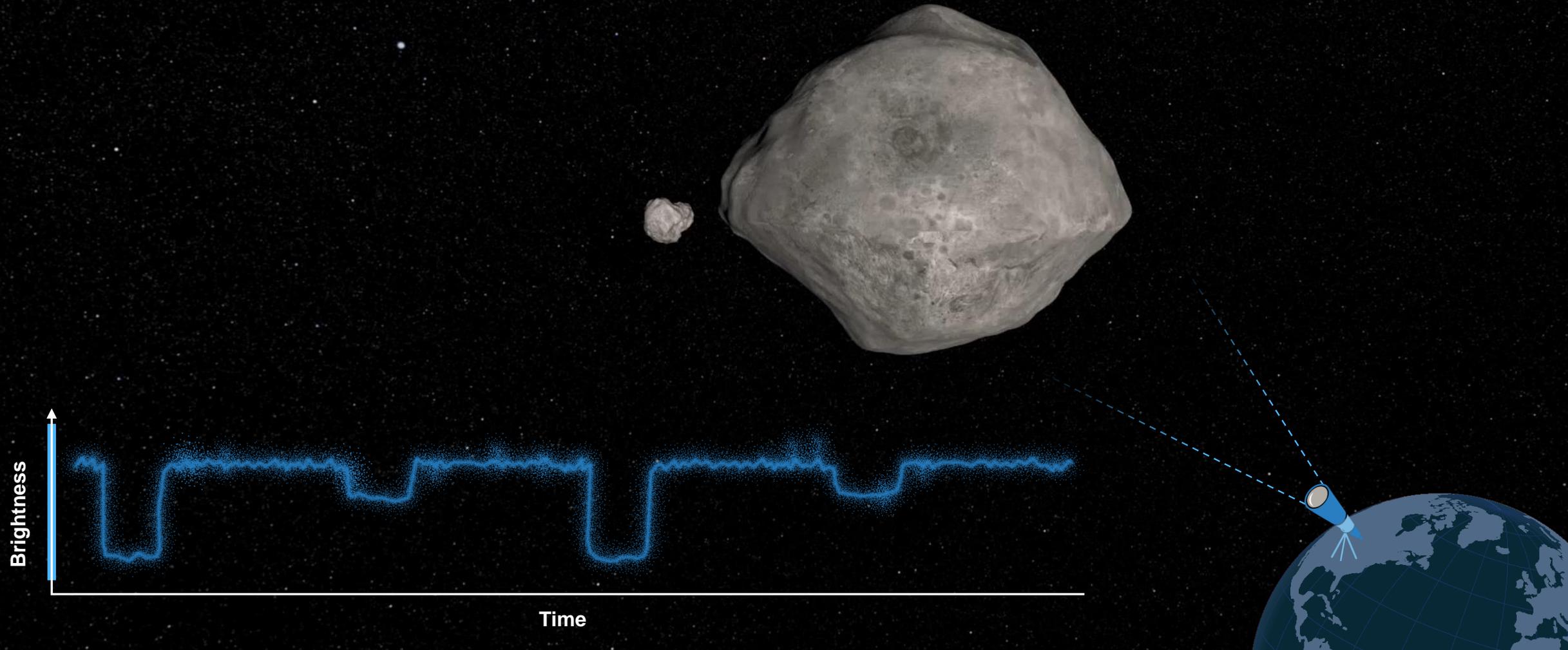
LICIACube LUKE Images
not debayerized yet

Exp time < 0.007s

Image roll, sunward angle, and DART angle
still being investigated

Credit: Pedro Hasselmann
INAF-Osservatorio Astronomico di Roma

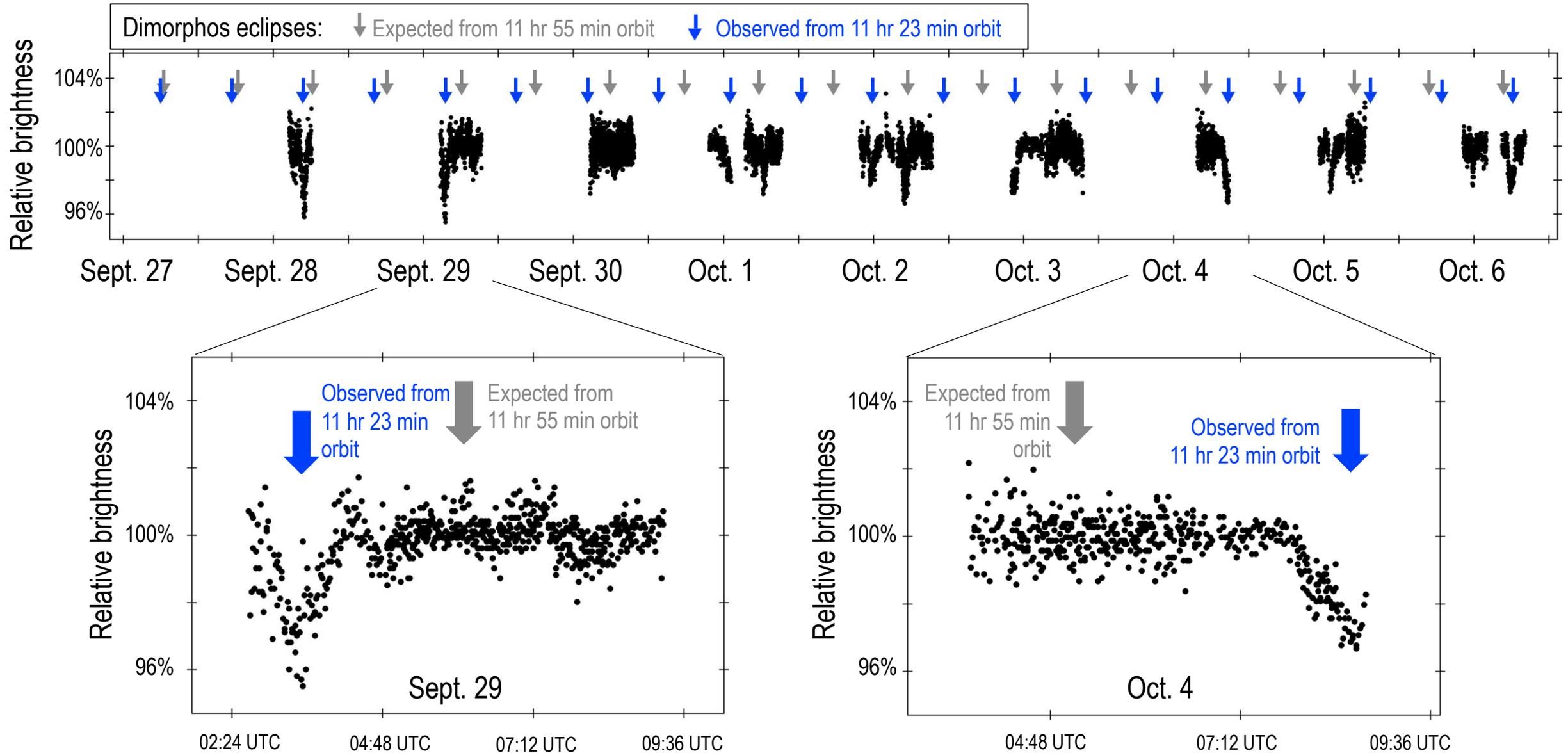
Measuring result of the impact from Earth: new orbit for Dimorphos



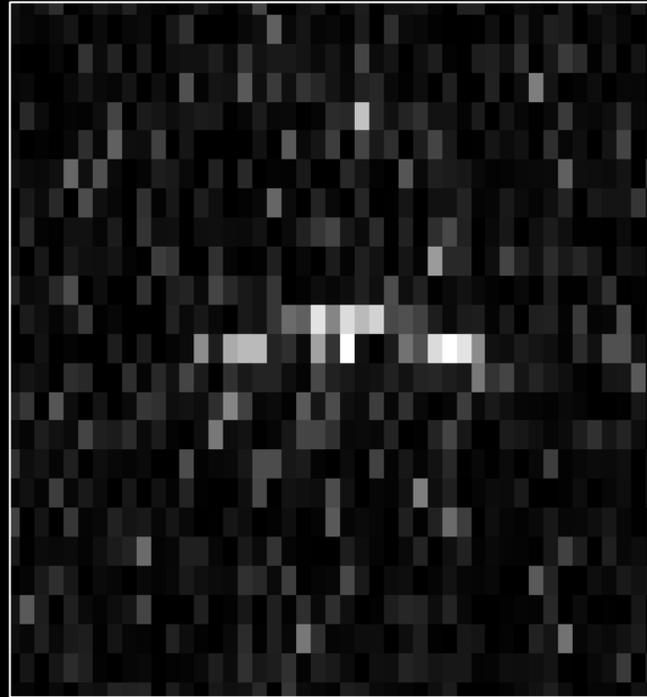
Observations after DART impact show orbit change

- Prior to DART's impact, it took Dimorphos 11 hours and 55 minutes to orbit its larger parent asteroid, Didymos.
- Since DART's intentional collision with Dimorphos on Sept. 26, astronomers have been using telescopes on Earth to measure how much that time has changed.
- Now, the investigation team has confirmed the spacecraft's impact altered Dimorphos' orbit around Didymos by **32 minutes**, shortening the 11 hour and 55-minute orbit to 11 hours and 23 minutes.
- This measurement has a margin of uncertainty of approximately plus or minus 2 minutes

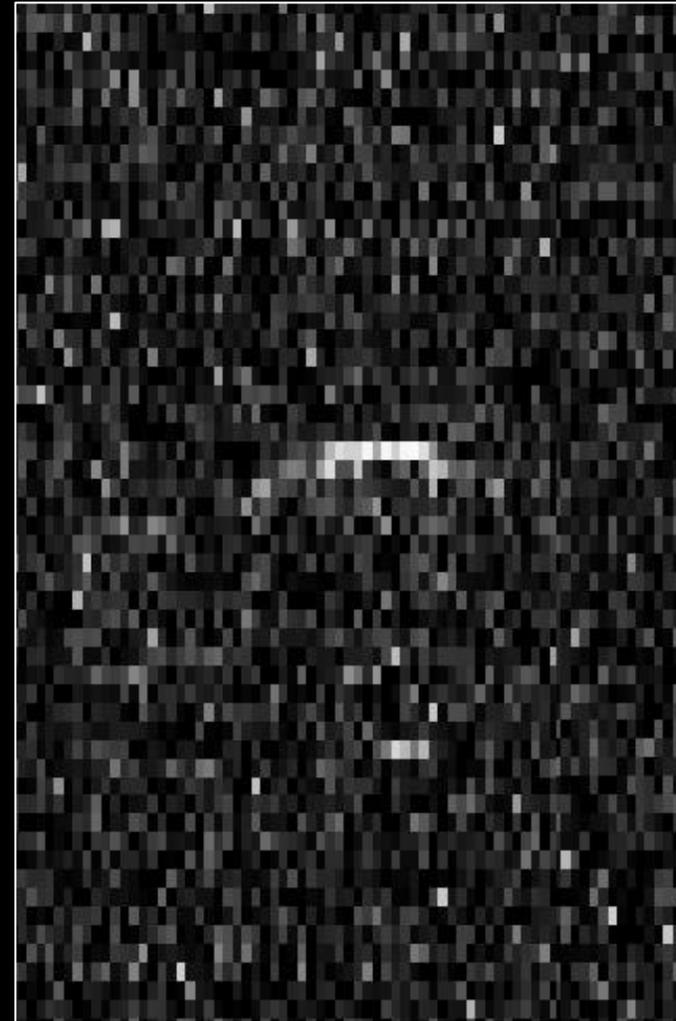
Observations after DART impact show orbit change



Radar images detect Didymos and Dimorphos and show orbit change

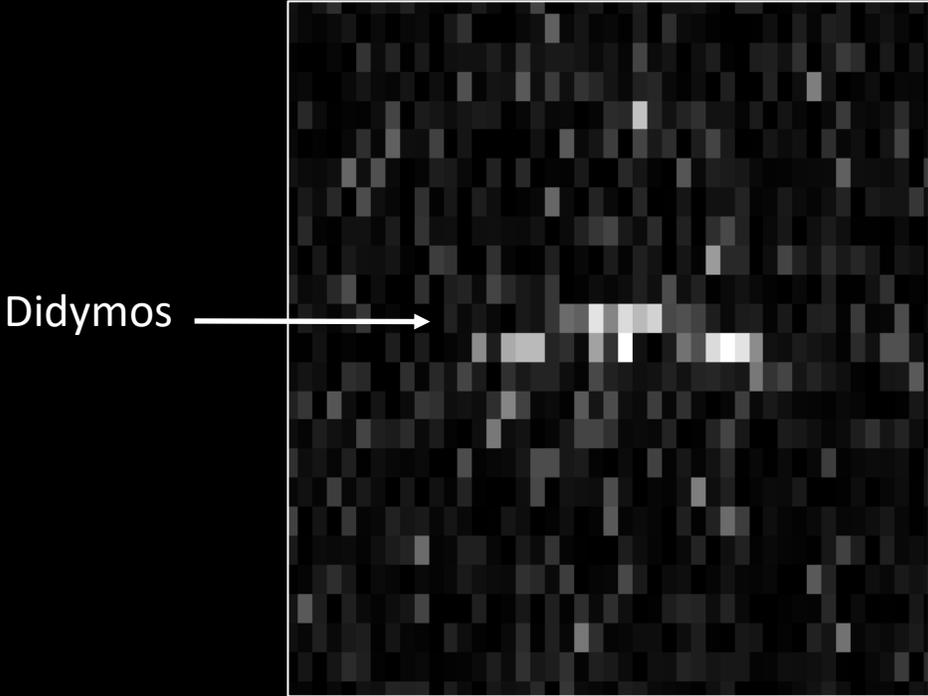


2022 Oct 04 11:55:39 UTC

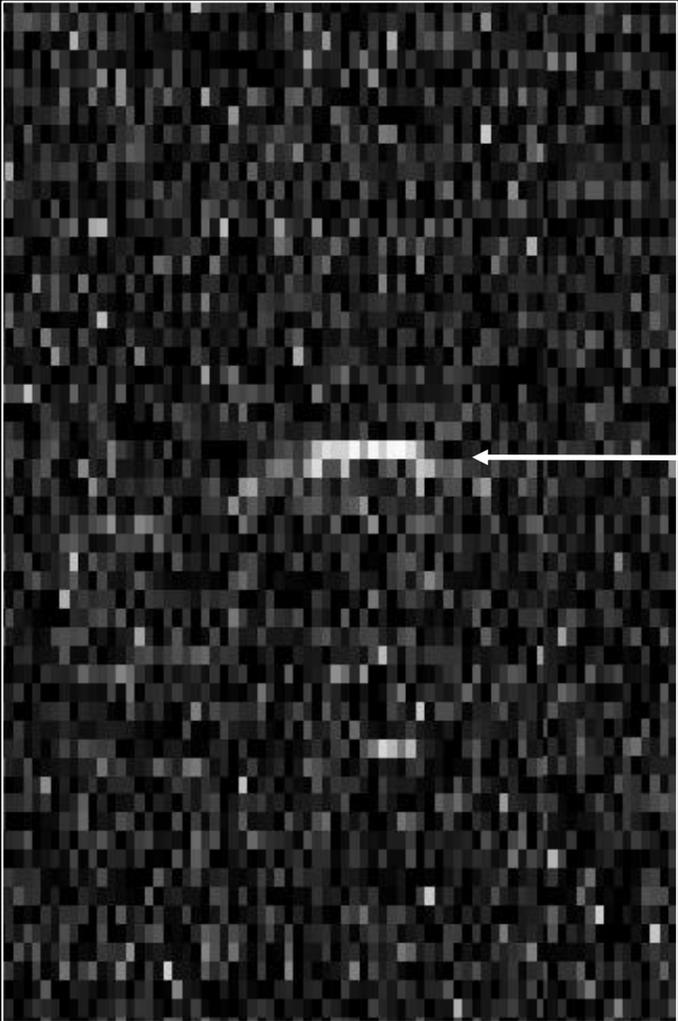


2022 Oct 09 10:56:47 UTC

Radar images detect Didymos and Dimorphos and show orbit change

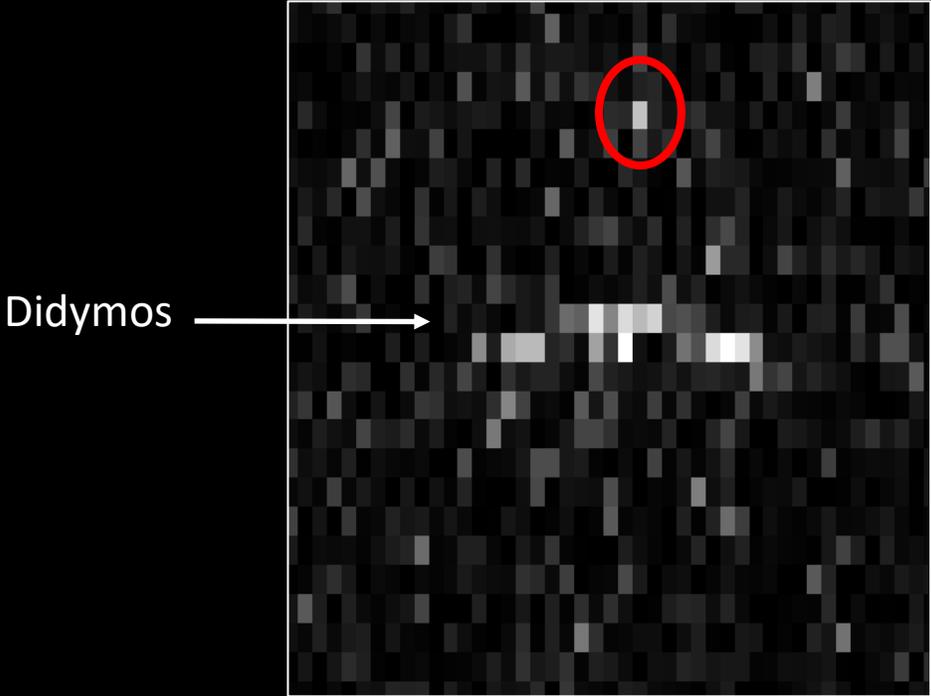


2022 Oct 04 11:55:39 UTC

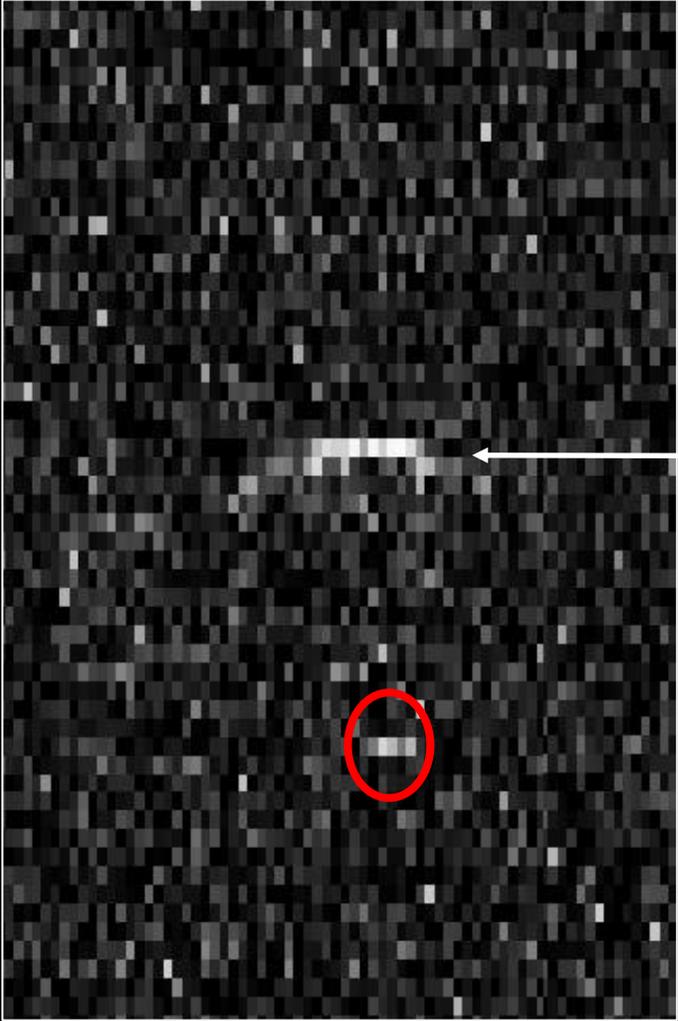


2022 Oct 09 10:56:47 UTC

Radar images detect Didymos and Dimorphos and show orbit change



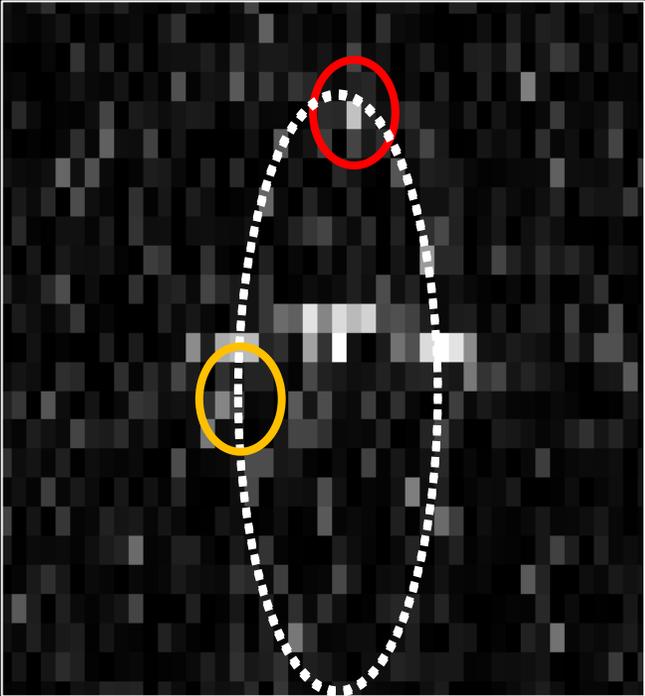
2022 Oct 04 11:55:39 UTC



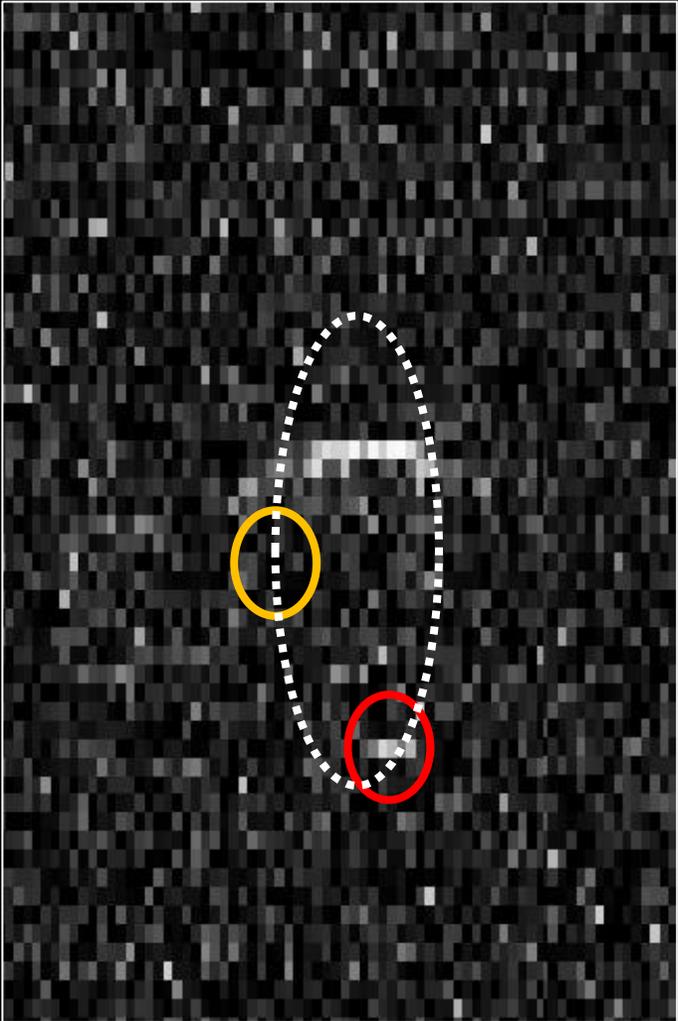
○ Observed
Dimorphos

2022 Oct 09 10:56:47 UTC

Radar images detect Didymos and Dimorphos and show orbit change



2022 Oct 04 11:55:39 UTC



2022 Oct 09 10:56:47 UTC

- Observed Dimorphos
- Expected Dimorphos from 11 hr 55 min orbit
- Dimorphos orbit

