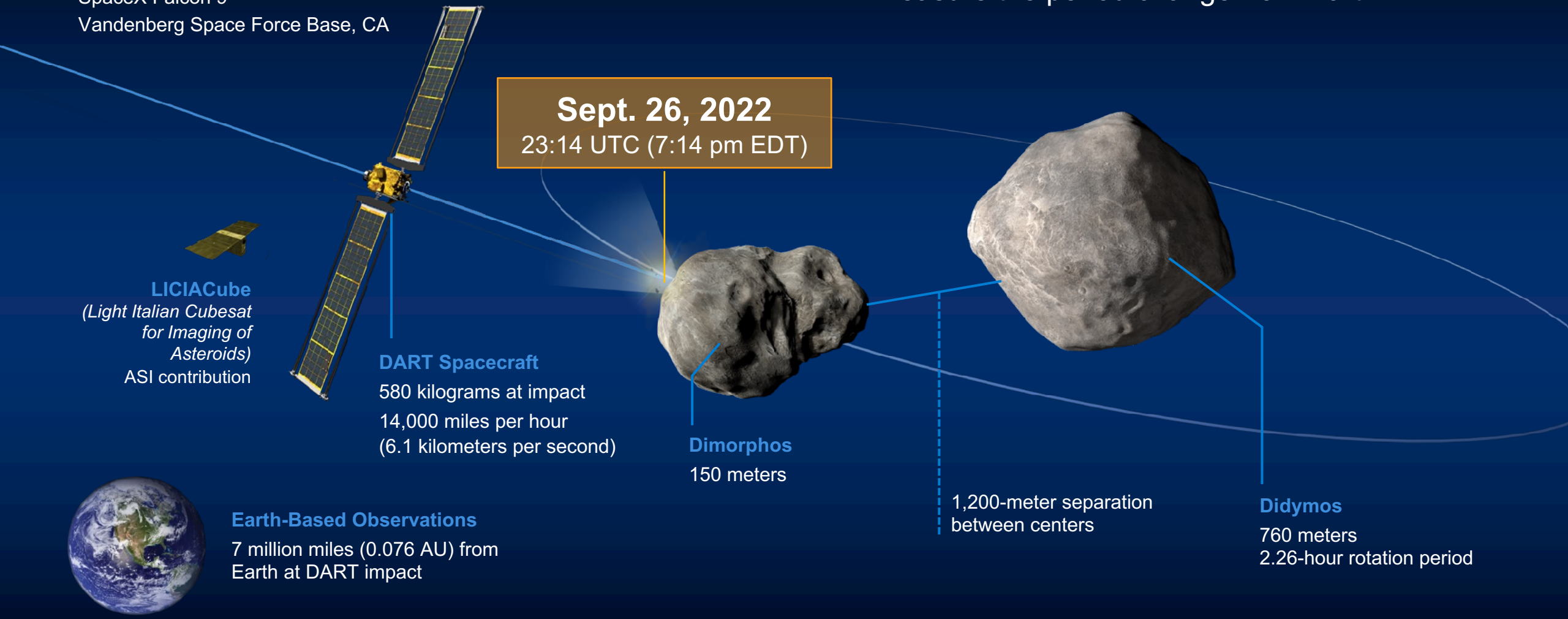
Didymos and Dimorphos before, during, and after the DART impact

Andrew S. Rivkin
and the
Double Asteroid Redirection Test Investigation Team

Launch

Nov. 24, 2021
SpaceX Falcon 9
Vandenberg Space Force Base, CA

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



Sept. 26, 2022
23:14 UTC (7:14 pm EDT)

LICIACube
(Light Italian Cubesat for Imaging of Asteroids)
ASI contribution

DART Spacecraft
580 kilograms at impact
14,000 miles per hour
(6.1 kilometers per second)

Dimorphos
150 meters

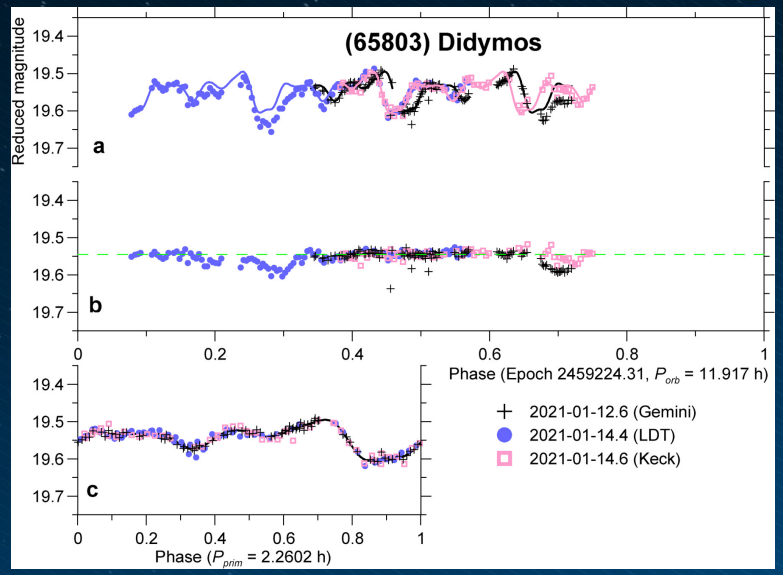
1,200-meter separation between centers

Didymos
760 meters
2.26-hour rotation period

Earth-Based Observations
7 million miles (0.076 AU) from Earth at DART impact

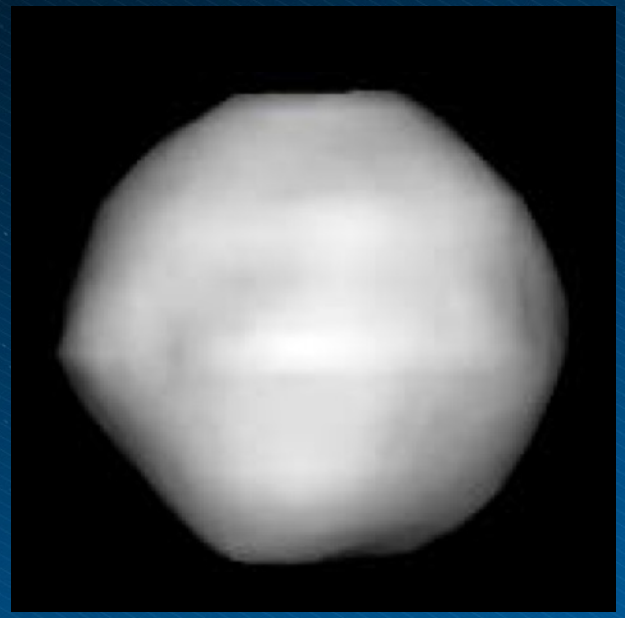
Pre-arrival Knowledge about Didymos

Lightcurves



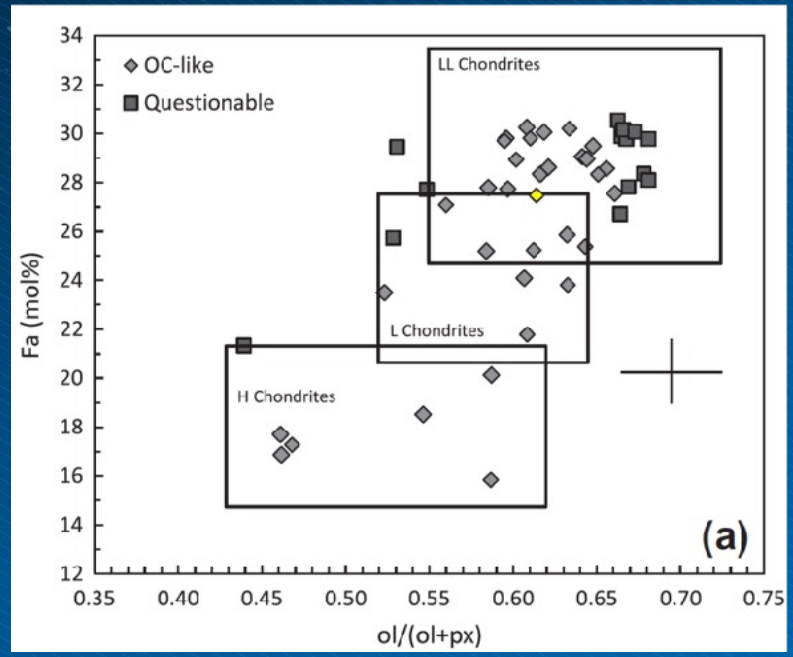
Example pre-impact lightcurve of Didymos showing components due to Didymos' rotation, mutual events, and the total lightcurve (Pravec et al. 2022).

Radar Shape Model



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

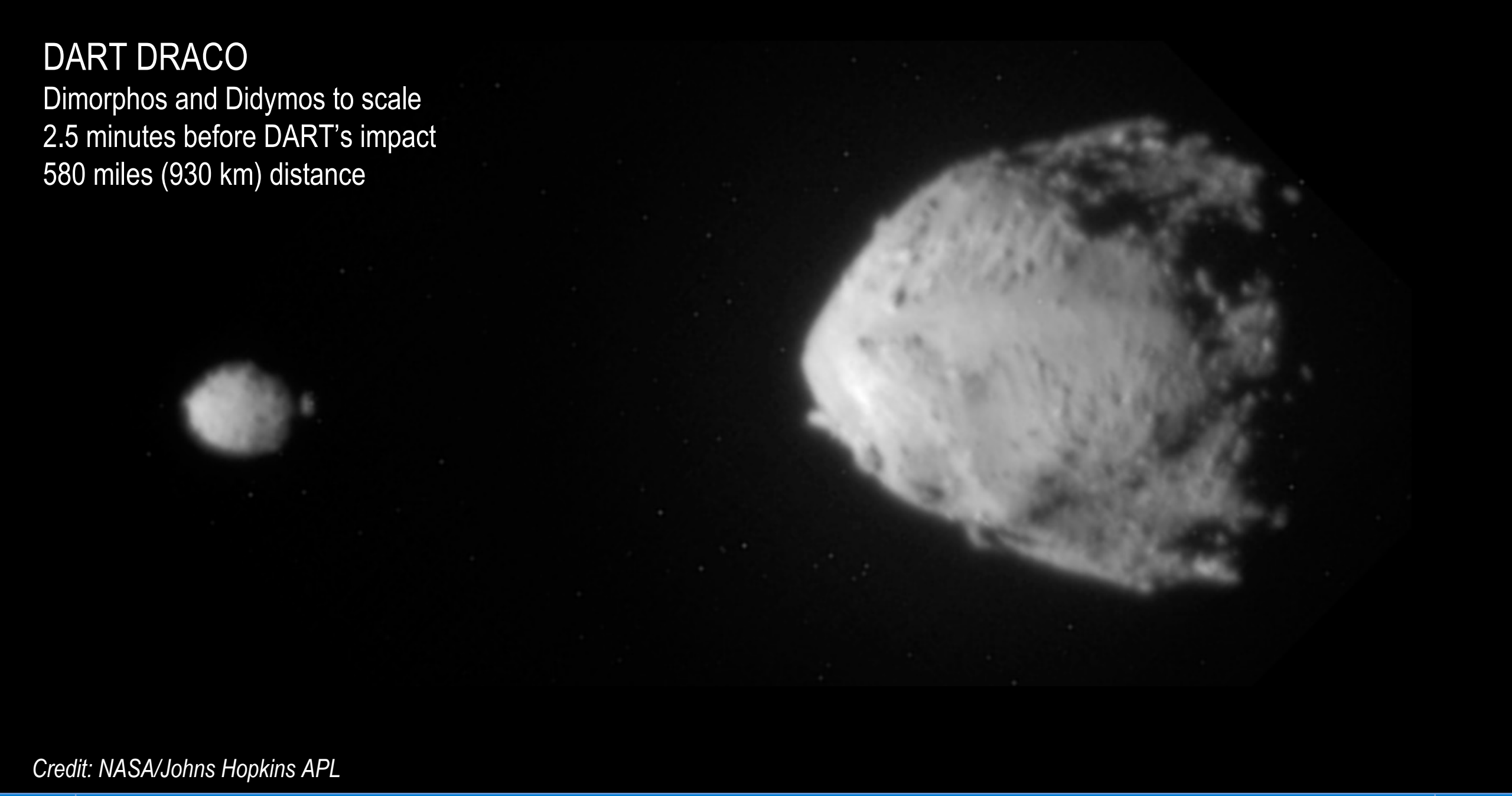
Composition



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.

DART DRACO

Dimorphos and Didymos to scale
2.5 minutes before DART's impact
580 miles (930 km) distance



Credit: NASA/Johns Hopkins APL

DART DRACO

Dimorphos

11 seconds before DART's impact

42 miles (68 km) distance

Credit: NASA/Johns Hopkins APL

IAU Theme:
Percussion Musical Instruments

DART DRACO

Dimorphos

2 seconds before DART's impact

7 miles (12 km) distance

Image is ~100 feet (31 m) across

Credit: NASA/Johns Hopkins APL

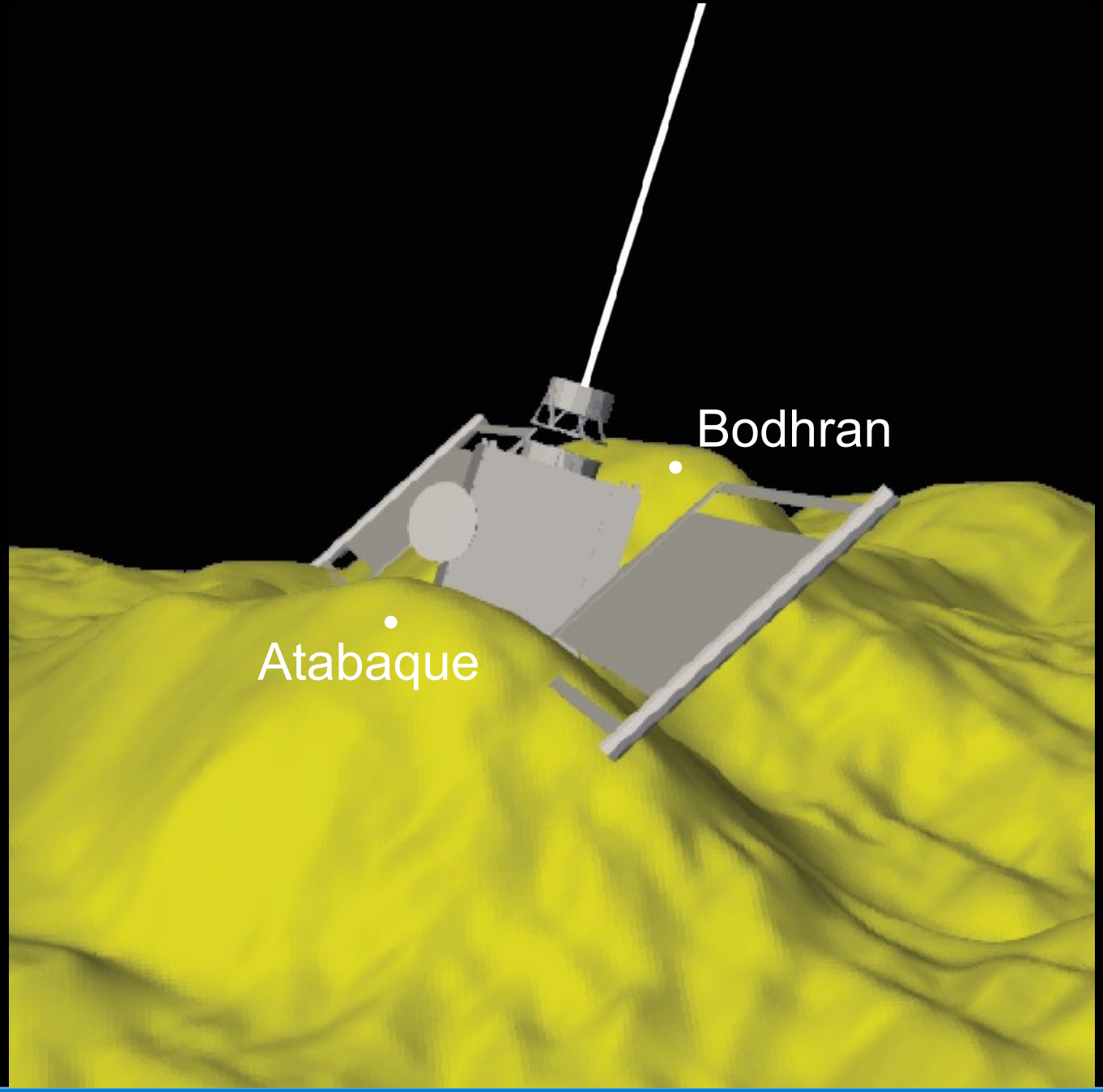
DART's Impact Site

Within 25 m of the center of figure of Dimorphos

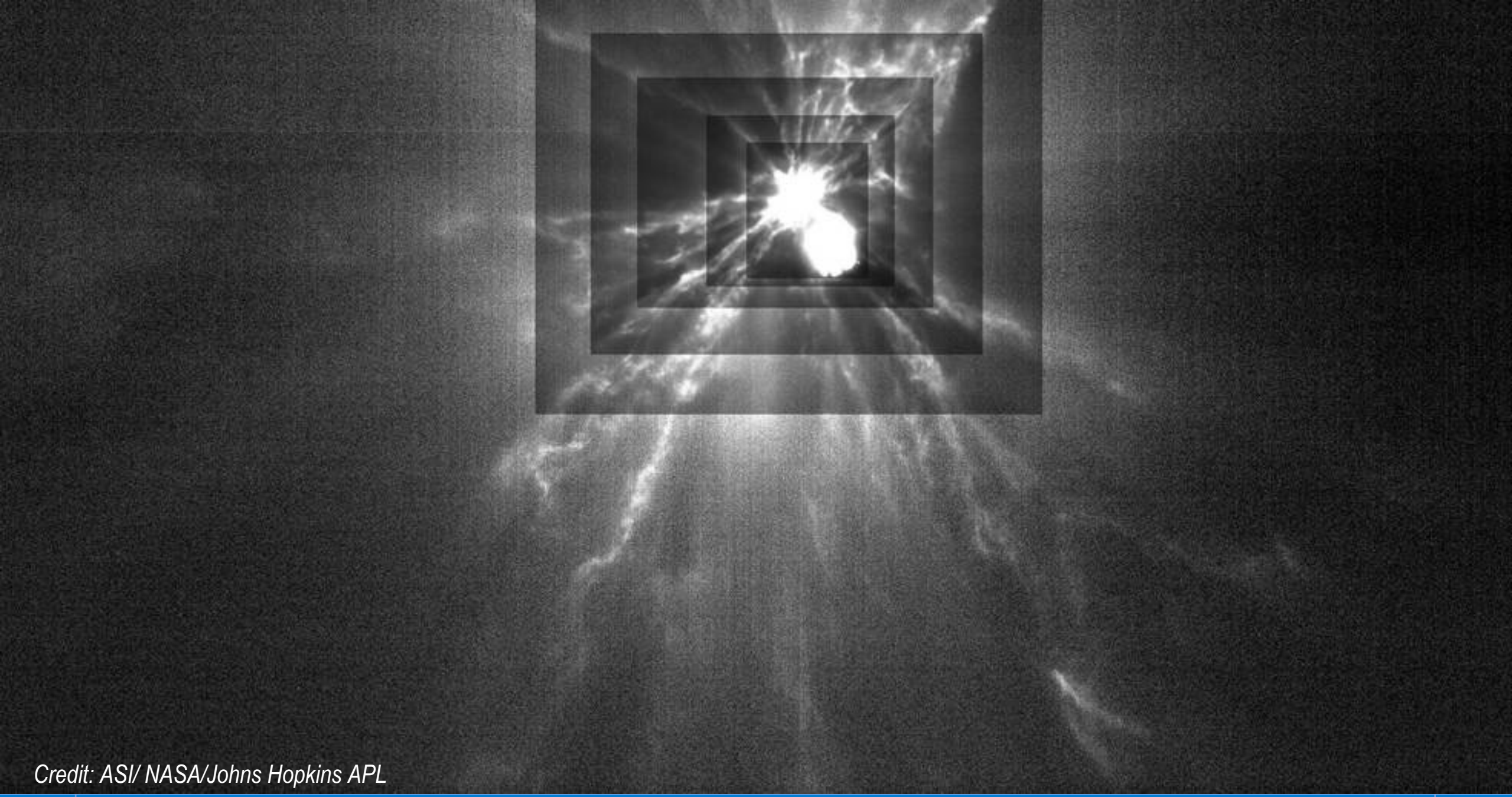
Atabaque Saxum – 6.5-m long, ~2.2-m height above surface

Bodhran Saxum – 6.1-m long, ~1.6-m height above surface

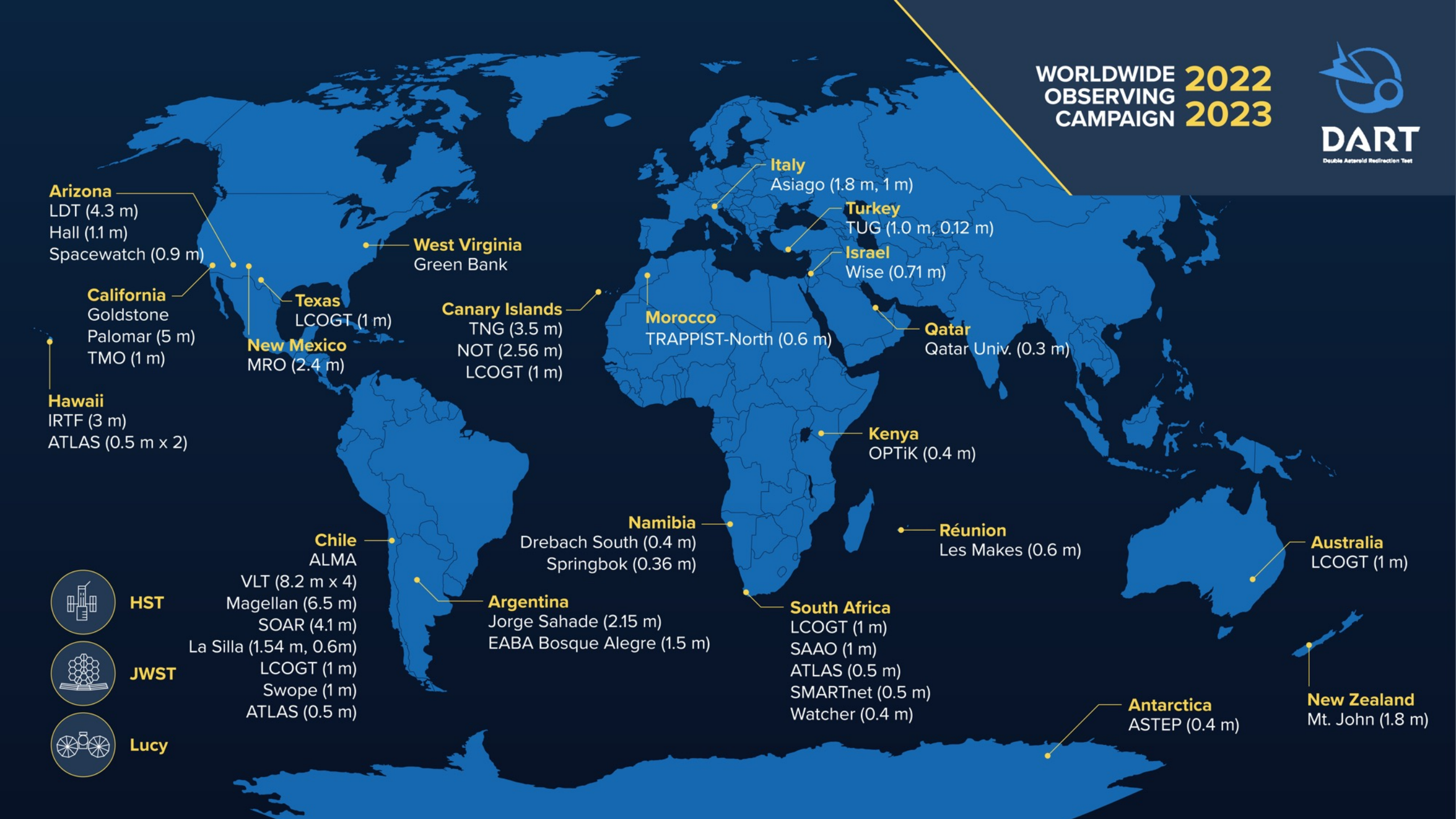
DART's solar array first contacted Atabaque Saxum, followed by the other solar array grazing Bodhran Saxum, followed by the spacecraft bus (with ~88% of the spacecraft mass) impacting the surface.



Daly, Ernst, Barnouin et al. (2023)



Credit: ASI/ NASA/Johns Hopkins APL


WORLDWIDE OBSERVING CAMPAIGN 2022 2023
DART
Double Asteroid Redirection Test
Arizona
LDT (4.3 m)
Hall (1.1 m)
Spacewatch (0.9 m)
California
Goldstone
Palomar (5 m)
TMO (1 m)
Hawaii
IRTF (3 m)
ATLAS (0.5 m x 2)
Texas
LCOGT (1 m)
New Mexico
MRO (2.4 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)
Turkey
TUG (1.0 m, 0.12 m)
Israel
Wise (0.71 m)
Morocco
TRAPPIST-North (0.6 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)
Australia
LCOGT (1 m)
Chile
ALMA
VLT (8.2 m x 4)
Magellan (6.5 m)
SOAR (4.1 m)
La Silla (1.54 m, 0.6m)
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)
Antarctica
ASTEP (0.4 m)
New Zealand
Mt. John (1.8 m)
HST
JWST
Lucy

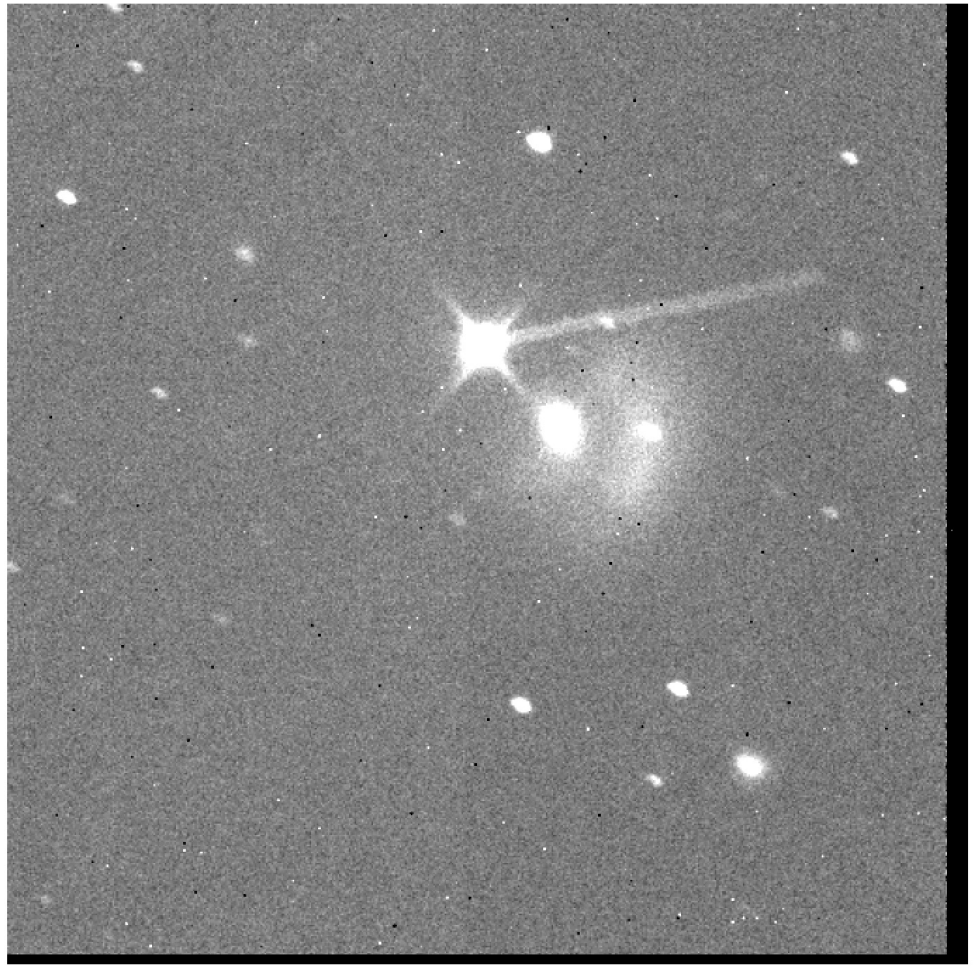
September 26
23:26 UTC
(12 min. post-impact)

23:29 UTC
(15 min. post-impact)

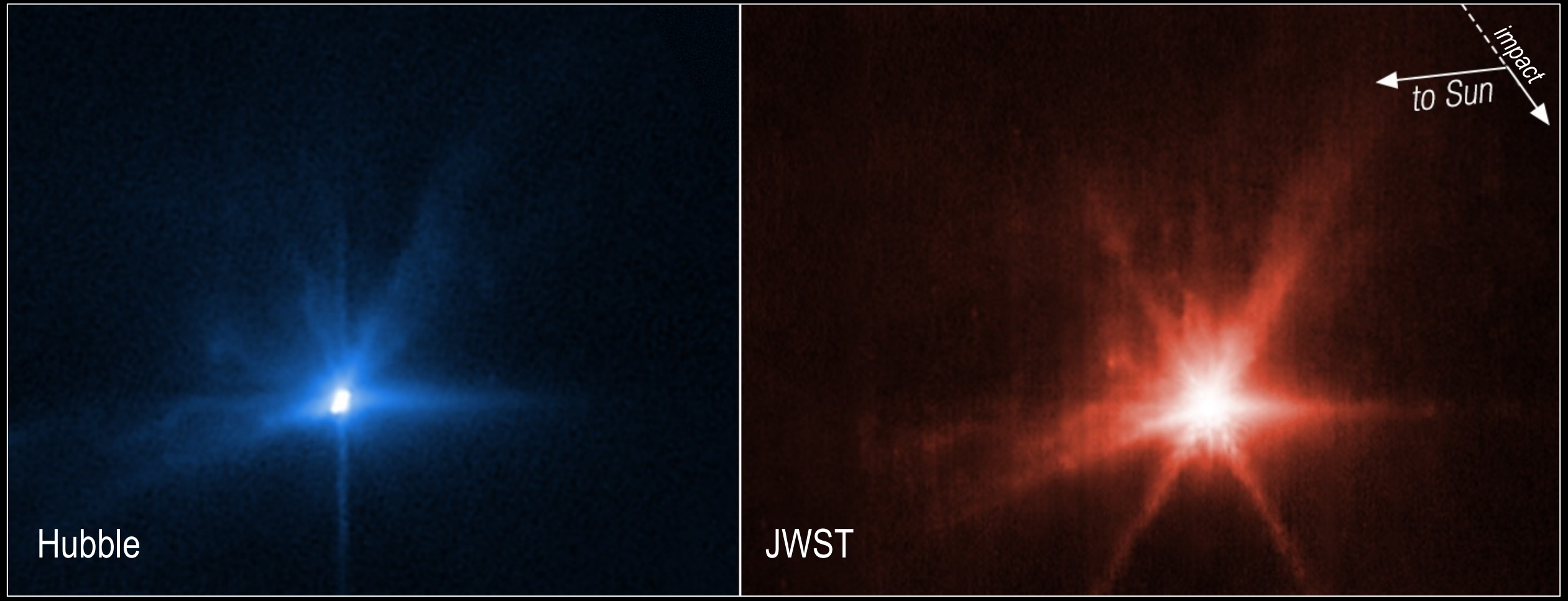
Credit: Tim Lister, Joseph Chatelain, Rachel Street, Edward Gomez, Joseph Farah / Las Cumbres Observatory.

LCOGT 1 meter Telescope at SAAO South Africa

UT Date: 09/26/2022 11:31:11 PM (26 of 50)



September 27, 2022
~5 hours post-impact



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)

September 26—25 October, 2022

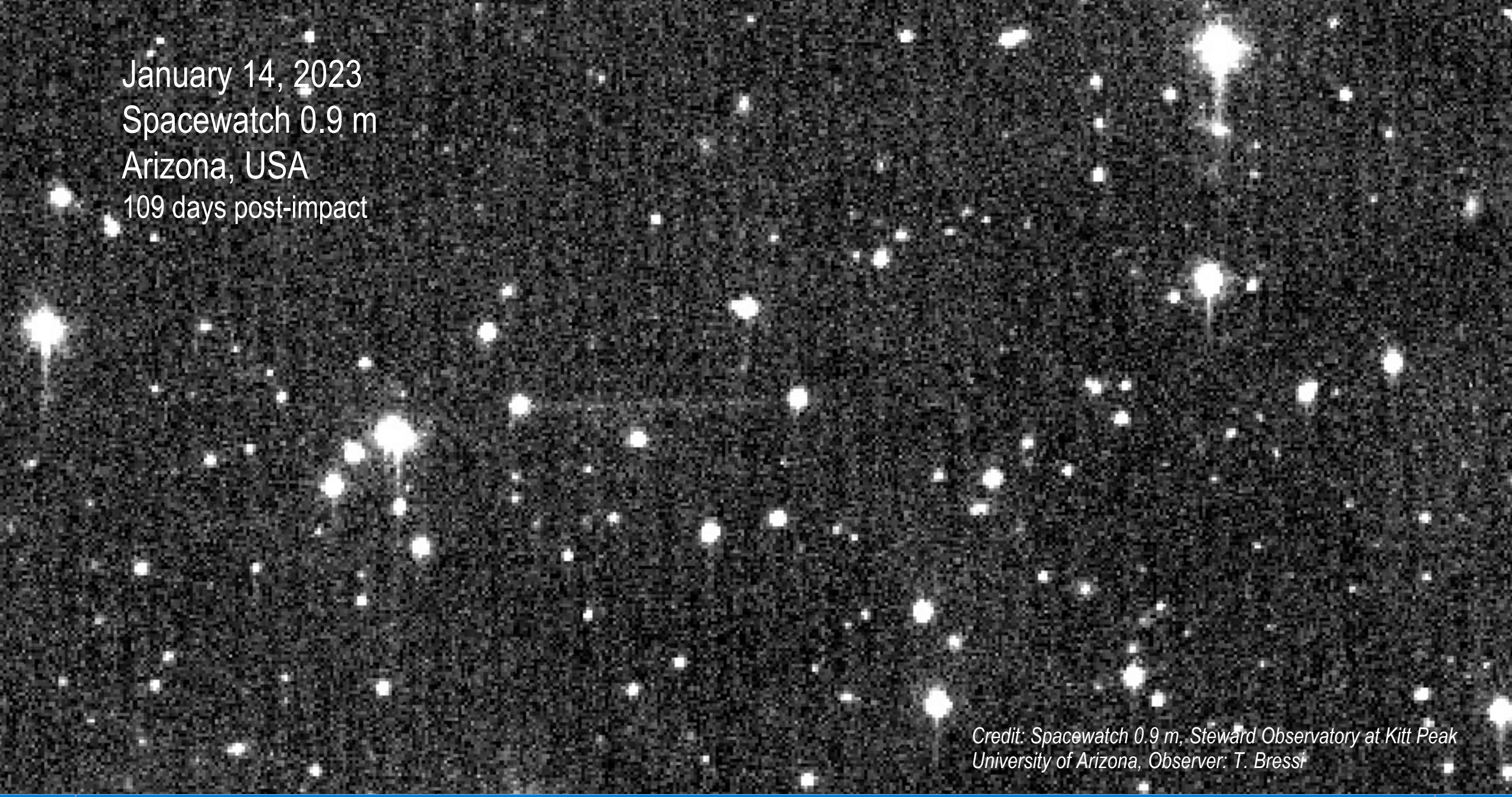
~16 hours pre-impact to ~1 month post-impact

Evolution of ejecta cloud morphology and tail formation and evolution as seen from Chile's VLT.

Credit: *ESO/Opitom et al.*

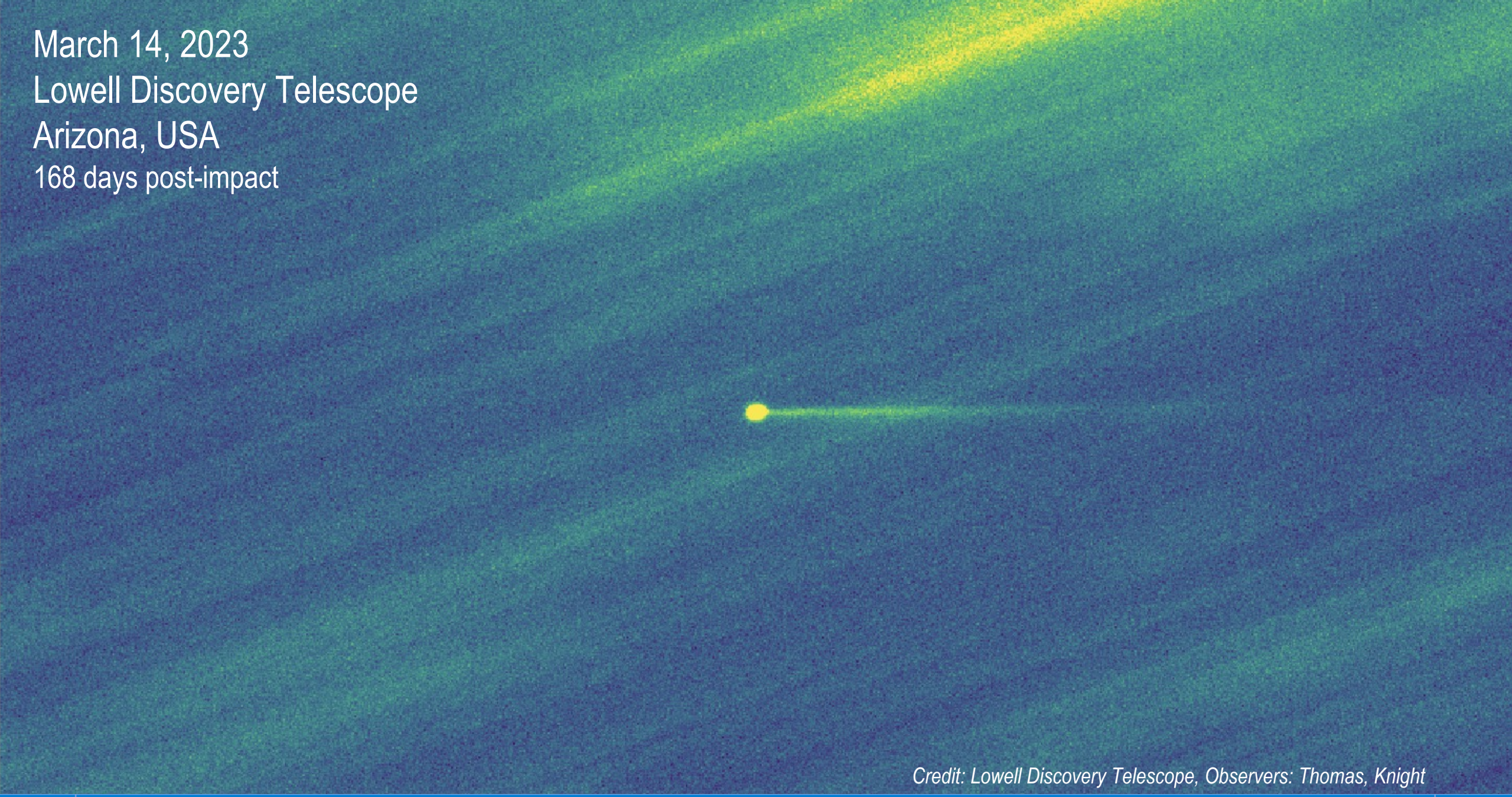

November 18, 2022
Lowell Discovery Telescope
Arizona, USA
52 days post-impact
Credit: Thomas, Knight, Moskovitz


December 25, 2022
Magdalena Ridge Observatory
New Mexico, USA
89 days post-impact
Credit: MRO/ NM Tech



Credit: Spacewatch 0.9 m, Steward Observatory at Kitt Peak University of Arizona, Observer: T. Bressi

March 14, 2023
Lowell Discovery Telescope
Arizona, USA
168 days post-impact



Credit: Lowell Discovery Telescope, Observers: Thomas, Knight

Dimorphos By Comparison

Dimorphos itself is roughly as big as this building

≅

The debris tail stretches at least as far as the blue arc

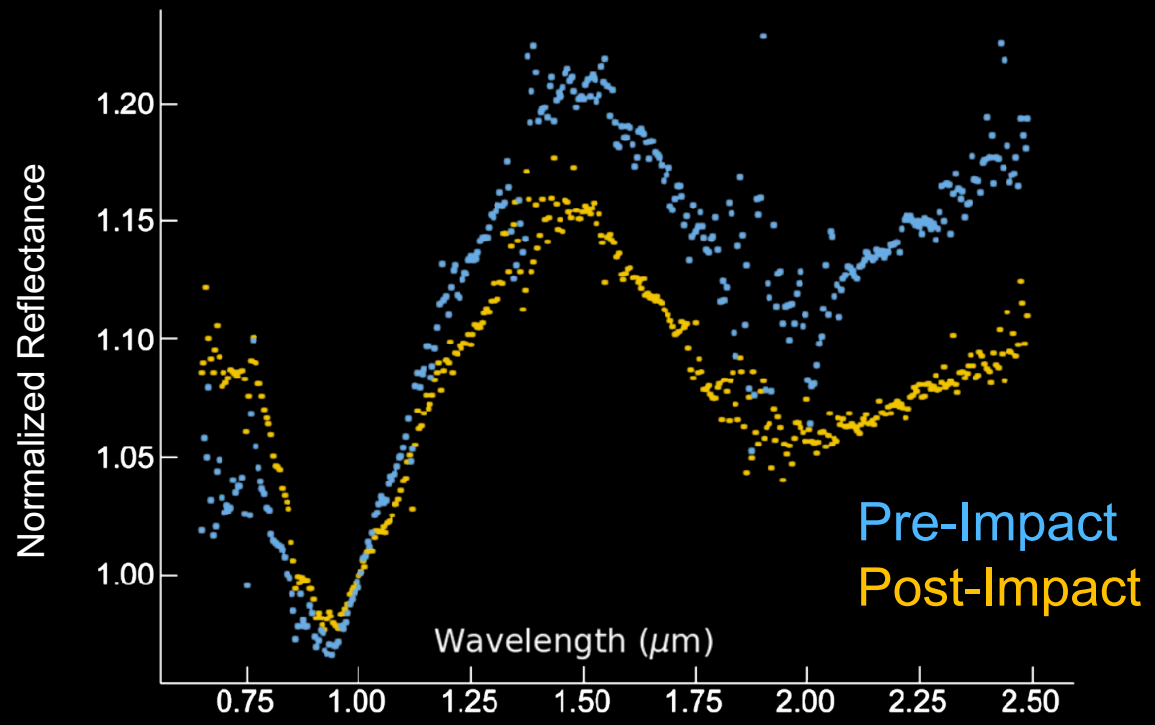
≅

And has at least as much material to fill at least 6 rail cars (and perhaps as much as 60!)

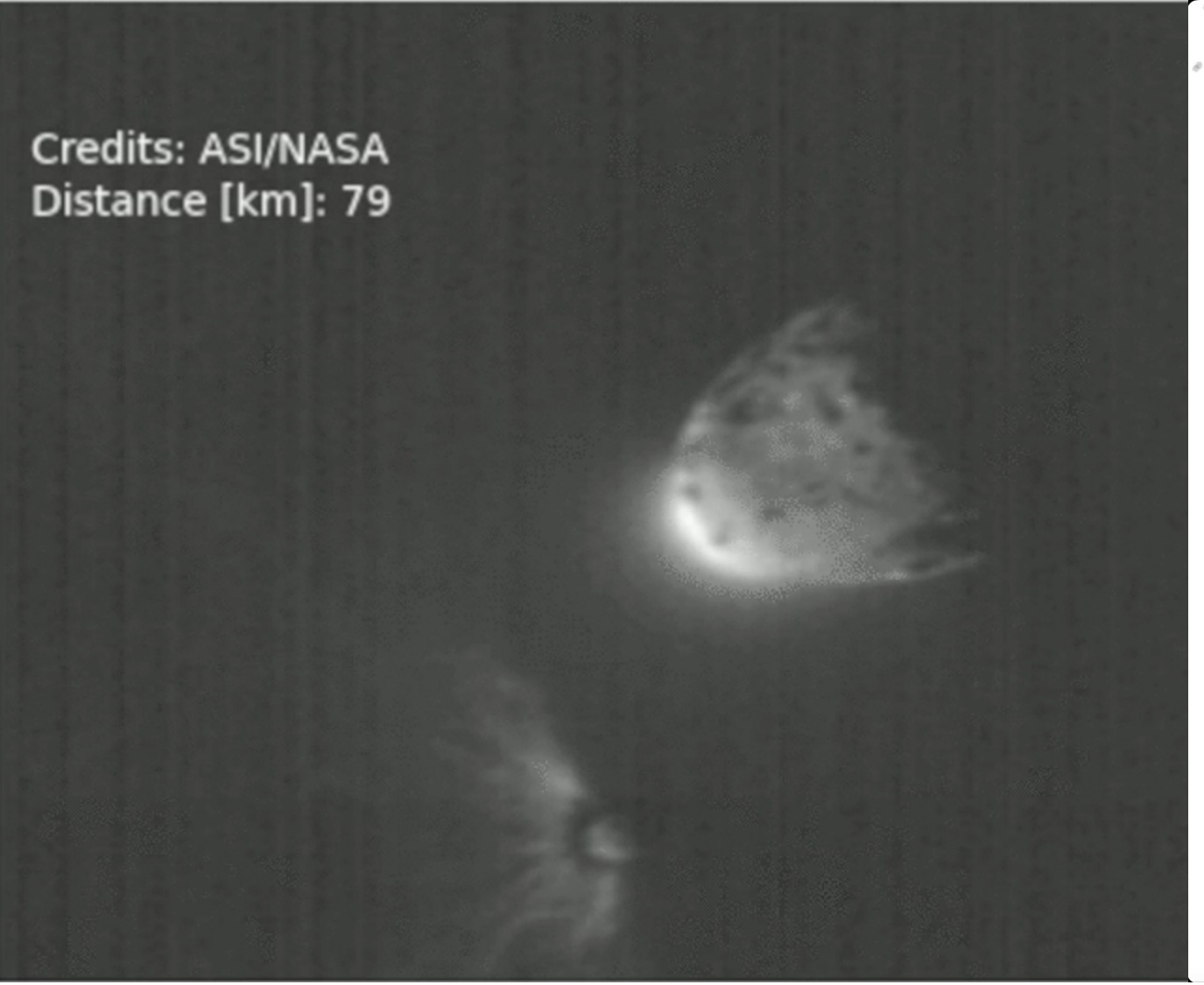
≅

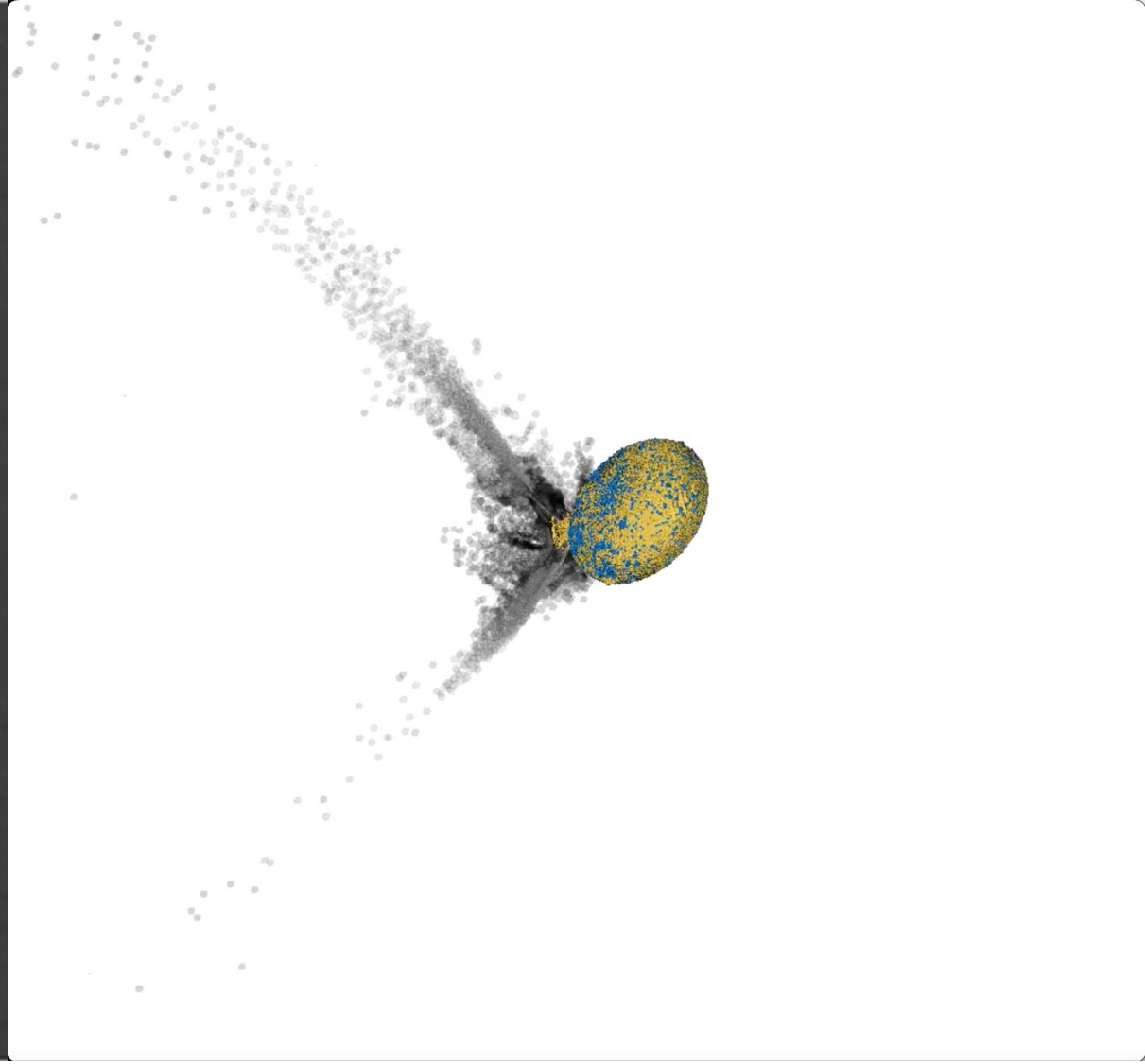
Characterization Measurements during Impact Epoch

- Spectra of system by Polishook et al. show similar spectra when Didymos dominates spectrum and when Dimorphos dominates
  - Similar results from other datasets
- JWST spectra in 3-μm region show no evidence of hydrated minerals, can place upper bound on OH created by solar wind
- Spectropolarimetry from VLT by Bagnulo et al. (2023) showed a change in absolute amount of polarization at impact, but similar trends pre- and post-impact
- Mid-infrared measurements of system from VLT and JWST show thermal inertias ~300-500 (SI units), similar to what is seen for other Didymos-sized objects.



Credit: NASA Infrared Telescope Facility/Weizmann Institute of Science/ Massachusetts Institute of Technology

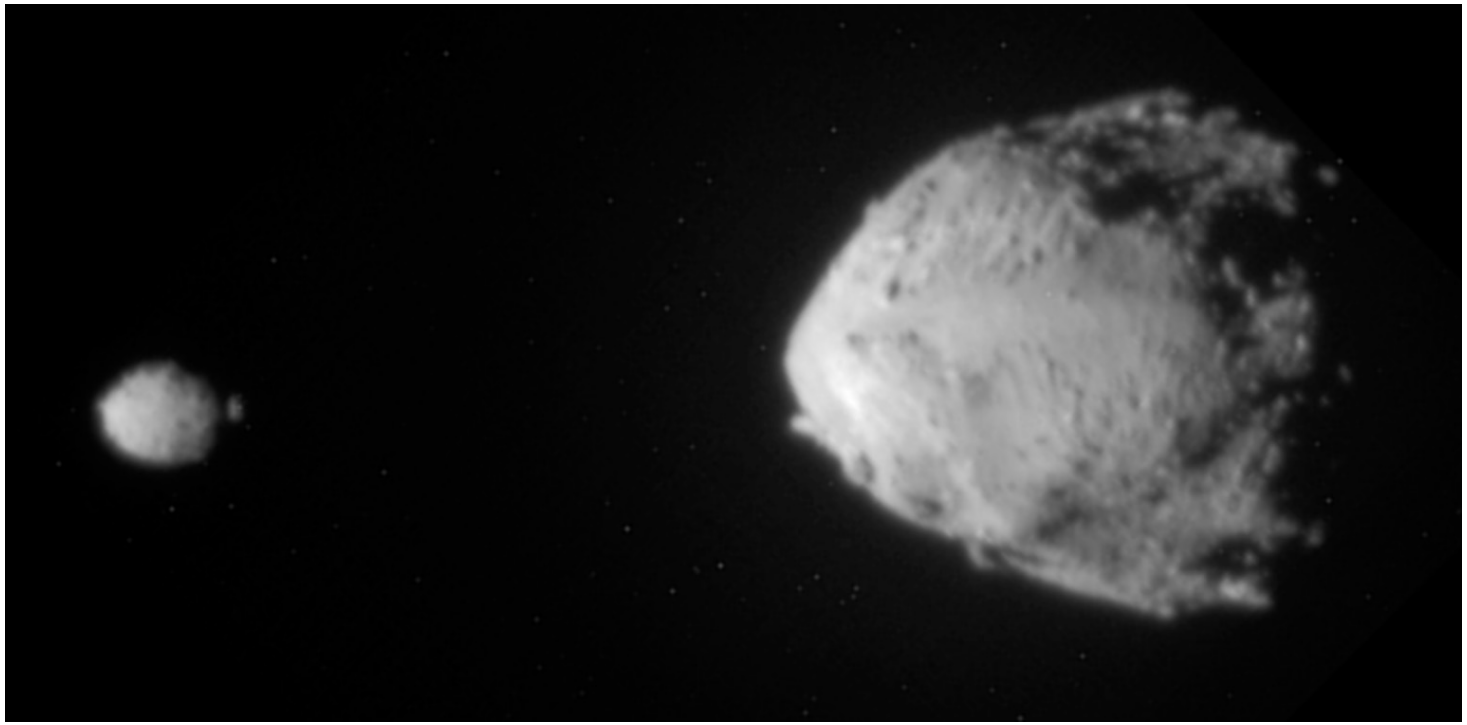




Credit: This work was supported by the DART mission, NASA Contract No. 80MSFC20D0004. Portions of this work were performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344. LLNL-VIDEO-845965

Summary: A Smashing Success

- Pre-arrival measurements of Didymos by the DART team were borne out:
  - Precision of ~0.01 s on Dimorphos' orbit period enabled interception
  - Size ratio measured within ~5%
  - Size of Dimorphos estimated within ~10%
  - Composition of Dimorphos consistent
- Ejecta from DART impact much more than *minimum* expected case, but within range considered pre-impact
- First papers published, more to come. DART-supported datasets will be archived in PDS.
- Looking forward to Hera and future projects using DART data!



See these presentations for more detail!

- Wednesday: Session 4a
  - Didymos and Dimorphos surface and ejecta reflectance properties through DART and LICIACube imaging: Hassellmann
  - The Color Analysis Of Dimorphos Plume Produced By Dart Impact Using Liciacube-luke Data: Results On Physical Properties And Composition To Better Constrain Planetary Defence Efficency: Poggiali
  - Energy Dissipation in Didymos Prior to Hera's Arrival: Meyer
- Wednesday: Session 5
  - 3D Characterization of the Ejecta Produced by the DART Impact: Farnham
  - The effects of macro vs. microporosity in kinetic impactor missions: Owen
  - Modeling the DART Impact: Effects of Surface Morphology and Rubble Pile Structure on Deflection Observables: Rainey
  - Deflecting rubble-pile asteroids: Lessons learned from the DART impact on Dimorphos: Raducan
  - Momentum Enhancement of Rubble Pile Simulants At 5 km/s: Walker
  - Simulating the DART impact: Effects of spacecraft and boulder geometry on ejecta: Kumamoto
  - Spacecraft Geometry Effects for the DART Mission: Graninger
- Plus posters (which weren't on the program when I submitted this presentation)!