DART time of impact observations and long-term photometry of Didymos from the LCOGT Network

Tim Lister[1] (tlister@lco.global), Joseph Chatelain[1], Rachel Street[1], Edward Gomez[2] and Helen Usher[3]

[1]*Las Cumbres Observatory (LCO), Goleta, CA, USA,* [2]*LCO, School of Physics & Astronomy, Cardiff University, UK*

[3] *School of Physical Sciences, The Open University, Milton Keynes, UK*

The impact of NASA's Double Asteroid Redirection Test (DART) spacecraft into Dimorphos, the secondary of the binary asteroid 65803 Didymos, occurred on 2022 Sep. 26 23:14 UTC during the night for LCO's South Africa site. We used three of LCO's 1-meter telescopes and the fast readout guider cameras to obtain quasi-simultaneous multicolor data covering the time of DART's impact and for several hours after. The images and photometry from the time of impact allow study of the initial impact and resulting effects.

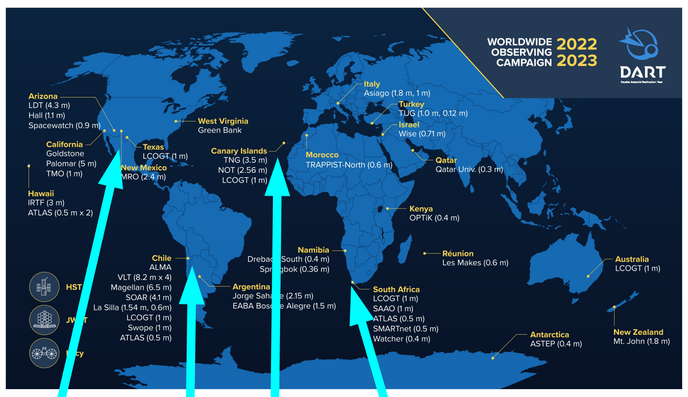
The DART mission and the LCOGT Network

The Double Asteroid Redirection Test (DART) mission [1] is a NASA planetary defense and technology demonstration mission that demonstrated the feasibility of kinetic impactor deflection missions. The spacecraft deliberately impacted Dimorphos, the secondary component of the Near Earth Object (NEO) binary system (65803) Didymos [2]. This resulted in a change in the binary orbital period of -33.0 ± 1.0 mins [3] that was measured by a number of ground-based telescopes including those of Las Cumbres Observatory (LCOGT). This enabled the measurement of the momentum enhancement factor, beta[4], and the first experimental test of a kinetic impactor as a technique for mitigating potential hazardous asteroids.

LCOGT has a worldwide network of robotic telescopes deployed and operating:

- 2m FTN & FTS with low-resolution (*R*~400, 320 – 1000 nm) FLOYDS spectrographs. FTN has MuSCAT3 4 channel imager; MuSCAT4 coming to FTS in 2024.
- Twelve 1m telescopes with 26'x26' FOV Sinistro CCD with 21 filters and 5.8'x5.8' FOV FLI imagers (**see right**).
- Ten 0.4-m telescopes with CCD imagers.

The worldwide network is ideal for both long-term monitoring and observations from a specific place and time (**see right**).



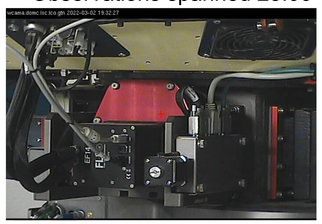
Map of DART observing facilities
Ejecta, lightcurve and long-term monitoring observations took place with the 1-m's in Chile and South Africa in 2022 Sep-Oct before shifting to the Texas and Tenerife sites in 2022 Nov-2023 Jan. as Didymos moved north.

LCOGT 1m telescopes at SAAO (South Africa)

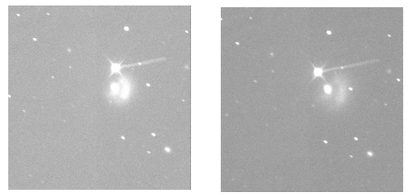
Observations and Analysis

Time of Impact Observations with FLI Instruments

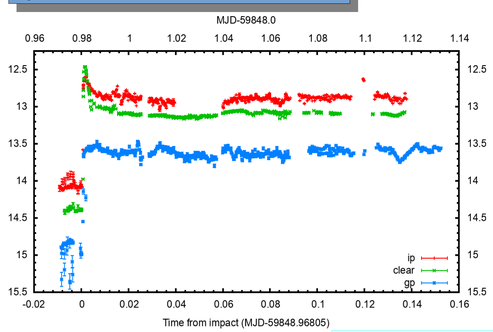
- Impact predicted for 2022-09-26 23:14 UTC during the night at LCO's site at South African Astronomical Observatory (SAAO) at Sutherland, South Africa
- Considerable uncertainty (~10 mags) in pre-impact predictions of ejecta brightening following impact of DART spacecraft.
- Performed quasi-simultaneous imaging in SDSS g', i', and clear filters using the 3 LCO 1m telescopes (single filter per telescope) at SAAO using cadence of 2x2s, 2x10s & 2x30s exposures (with ~1s deadtime).
- Observations spanned 23:00 → 03:00 (end of night).



A FLI instrument on the side port of one of the LCO 1m telescopes. The FLI imagers, are normally used as autoguiders with the Sinistro imagers (see right), can also be operated as fast frame rate cameras.

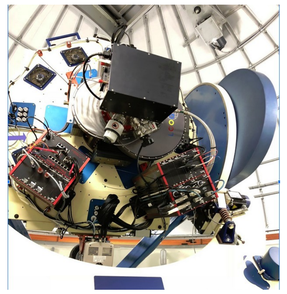


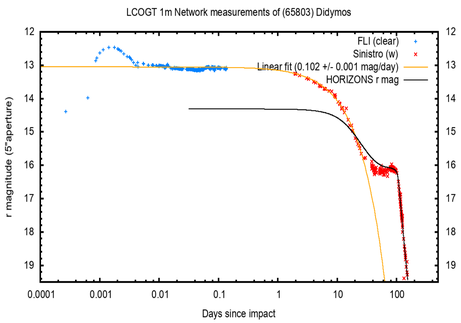
FLI clear observations of the expanding fast-moving ejecta cloud following the DART spacecraft impact into Dimorphos. Frames taken at 12 and 15 minutes post-impact.



Three color lightcurves (SDSS g' (blue points) & i' (red points) along with a 400-1200nm bandpass clear filter (green points)) of Didymos from the LCO 1m+FLI instruments at SAAO during the DART impact. Cameras. There is considerable chromaticity in the ejecta with the red (i') and clear filter showing a large brightening (~2 mags) and then a rapid decay while the bluest (g') data showed only a steady ~1.5mag increase in brightness.

Long-term monitoring with LCOGT Network





- Long-term monitoring and lightcurve observations of Didymos for period determination and ejecta monitoring conducted using the LCOGT 1m telescopes & Sinistro instrument (above left).
- Observations scheduled using NEOexchange [5], our Target and Observation Manager (TOM) system for scheduling, reducing and analyzing small body observations.
- Daily observations of 4 to 7 75 – 240s exposures (depending on Didymos's brightness and on-sky motion) in PanSTARRS *w* were scheduled at LCO's Chile and South Africa sites (2022 Sep. and Oct.) and then at Texas and Tenerife (2022 Nov – 2023 Feb.) - **150 days total.**
- Supplemented by additional obs. from LCO's educational time through partnership with Comet Chasers project (see Usher et al. this meeting).
- Consistently calibrated against Gaia-DR2 with photometry in 11 apertures (1"...10" radius) – 5" aperture photometry plotted above right (X axis is time since impact on log scale).

Conclusions and Future Work

- Time of impact observations from LCOGT's 1m telescopes + FLI instruments at SAAO and other observatories shows fast-moving (~2km/s) ejecta produced by impact (to be published in [6])
- Multi-color LCOGT observations confirm a color dependence on the size of brightening and decay timescale of the initial fast-moving ejecta
- Analysis of the first 30 days of ejecta observations [7] shows a consistent -0.1mag/day decline with a "pause" in the decline (also seen by other observatories) at t+8 days which could correspond to tail development seen by Li et al. (2023) in the HST data.
- Evidence ejecta cleared and mag. returned to prediction at t+80 days.

References

1) Rivkin A. S. et al. (2021) Planetary Science Journal, 2, 173 – 197.
2) Daly, R.T., et al. (2023) Nature, https://doi.org/10.1038/s41586-023-05810-5
3) Thomas, C. A. et. al. (2023) Nature, https://doi.org/10.1038/s41586-023-05805-2
4) Cheng, A.F., (2023) Nature, https://doi.org/10.1038/s41586-023-05878-z
5) Lister T. A. et al. (2021) Icarus, 364, 114387
6) Fitzsimmons, A. F. et al. (2023) in preparation.
7) Kareta, T. et al. (2023) in preparation.

This work is supported by the DART mission, NASA Contract No. 80MSFC20D0004. Johns Hopkins Applied Physics Lab manages the DART mission for NASA's Planetary Defense Coordination Office as a project of the agency's Planetary Missions Program Office.