Coordinating the 2024 Didymos occultation campaigns in Australia

Efforts lead by the France-Greece ACROSS collaboration

to support the Hera ( ) (ESA) mission

Call for observers/ collaborators

This is a call for observers mainly addressed to the membership of the Astronomical Society of Australia. The best of 2024 Didymos occultation events will be observable from the Southern hemisphere, mainly across Australia, hence this call for observers across the country.

> **Each observer, each institution is considered as a collaborator and is therefore a co-author to the scientific paper** (unless they object to it).
>
> *In return, we ask that you communicate your results to us (as mentioned in Section 7) and not post them on social media (in order to preserve the integrity of the science).*

While these observations might seem challenging at first glance, the feasibility of the observation is guaranteed as we recorded in collaboration with our partners (IOTA, IOTA-ES, and JOIN), 20 successful occultations between Oct. 2022 and March 2023 (papers in preparation).

This is a first version of this document, which might contain typos or mistaken hyperlinks, therefore as we get closer to the events we recommend you check our ACROSS website and Occult Watcher Cloud (OWC, ACROSS -feed) for most recent updates.

Furthermore, we might update the instructions as we receive questions from the interested observers.

Our partners *(across the globe)*
- IOTA: International Occultation Timing Association
- IOTA-ES: International Occultation Timing Association - European Section
- JOIN: Japan Occultation Information Network (now part of IOTA-East Asia)
- TTOA: Trans-Tasman Occultation Alliance (which is much smaller in membership and includes observers from Australia and New Zealand).
- the Unistellar network.

Contents

1 Background

The Hera (ESA) mission will be launched in October 2024. It is part of the AIDA[1] (first planetary defence programme) and will visit the Didymos-Dimorphos (binary near-Earth asteroid system) to study the aftermath of the impact imparted by the DART[2] (NASA) kinetic impactor.

ACROSS (Asteroid Collaborative Research via Occultation Systematic Survey) is a project (PIs: Paolo Tanga - Nice, France -, and Kleomenis Tsiganis - Thessaloniki, Greece -) that was initially (2021-2022) funded by ESA to validate the concept of using stellar occultations by sub-km sized Near Earth Asteroids (NEAs hereafter) in the framework of planetary defence.

The main objective of ACROSS is to support the Hera (ESA) mission by improving the astrometry of the Didymos-Dimorphos system and by measuring the size of the system. Furthermore, the high-accuracy occultation-derived astrometry from stellar occultation will allow us along with other parameters that will be measured with Hera to better constrain the new heliocentric orbit of the system, and better constrain the momentum transfer resulting from the DART impact. This will help the planetary defence community draw all conclusions from the first planetary defence programme.

Stellar occultations – The sudden disappearance of a star, as a Solar System objects passes in front of it, brings a wealth of information on this occulting object objects. By measuring the ingress (disappearance) and egress (reappearance) of the star, we measure the size, the shape (apparent limb), but also its astrometry. ACROSS exploits the immense accuracy of *Gaia* (ESA) stellar catalogues, to predict occultations by challenging small targets (mainly sub-km sized NEAs).

ACROSS supports the DART (NASA) and Hera (ESA) missions, by targeting in particular occultations by the asteroid Didymos. In order for these to succeed a good coverage in terms of observers is required; the support of the amateur community and the organisation and coordination of specific campaign are at the core of ACROSS.

Specific challenges to occultations by NEAs – Occultations by NEAs are much more challenging than occultations by other Solar System:
(i) the objects are much smaller, and therefore the occultation's duration is much shorter,
(ii) NEAs move faster in the plane of the sky, therefore the crossing of the galactic plane (denser stellar population) which is associated with a large number of occultation opportunities lasts only a few weeks.
(iii) moreover, the narrow projected shadow (consequence of the object's small size) is highly sensitive to the topography on Earth. Therefore, **we must carefully coordinate the positioning of the observers across the shadow's path**.

While challenging these observations are feasible, see this Sky & Telescope paper.

REMARK: The first events are the following: 2024-05-05 event (e) in Table 2 and 2024-05-31 event (a) in Table 1. These events are crucial to pinning down Didymos' orbit, after months without occultations and without any classical astrometry. This will prepare the "best" events. Furthermore, no other classical astrometric observations are possible before the "occultation season" as Didymos is crossing crowded stellar fields!

The 2024-08-13 event, (c) in Table 1, stands out as unique[a] event, as it the longest event in expected duration (0.74 s) and with the brightest occulted star (6.7 G mag).

[a] In 2022-2023 the 20 successfully observed occultations were (0.15 s to 0.34 s) in maximum expected duration, and involved stars that were between 13.54 and 9.07 in G magnitudes *(paper in preparation)*.

[1] Asteroid Impact Deflection Assessment
[2] Double Asteroid Redirection Test

While this document summarises the best Didymos 2024 events observable from Australia, updates on each event will be posted as on our ACROSS website and on the Occult Watcher Cloud (OWC, ACROSS -feed), as we get closer to the events and improve the accuracy of the prediction.

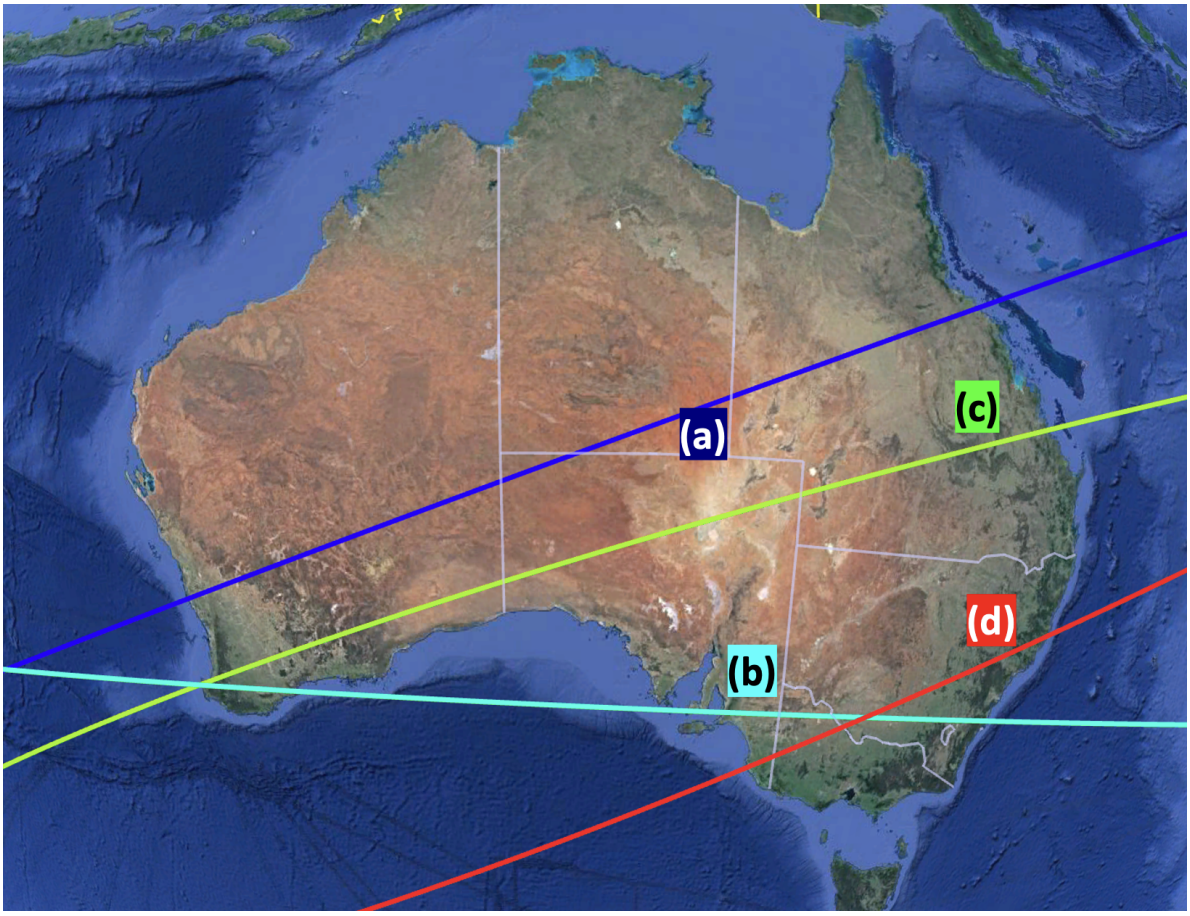
2 The very best events

Events in this category, for which we could have a possible occultation by both components, will also be highlighted, on our website and on OWC, as we approach the event's date and links to interactive sky charts will also be given.

Table 1: **The four very best events:** the table gives basic information about the events: epoch, the star's G magnitudes, the maximum expected duration and expected mag. drop, the geographic regions crossed, and finally a hyperlink to the FoV centred around the occulted star. The label used in the sky chart column for a given event is the same as on the map (Fig. 1).

Epoch (UT)	Stars' G mag.	max. duration	max. drop	geographic region	interactive sky chart (lab.)
2024-05-31 T15:22	11.8	0.21 s	6.43	**QLD**, NT, SA, WA	(a)
2024-08-10 T09:37	11.0	0.40 s	5.87	**NSW**, **VIC**, SA	(b)
2024-08-13 T13:02	6.7	0.74 s	9.47	**QLD**, SA, WA	(c)
2024-08-26 T13:38	11.4	0.29 s	6.03	**NSW**, **VIC**, SA	(d)

Figure 1: Map showing the projected path for the best observable events given in Table 1.

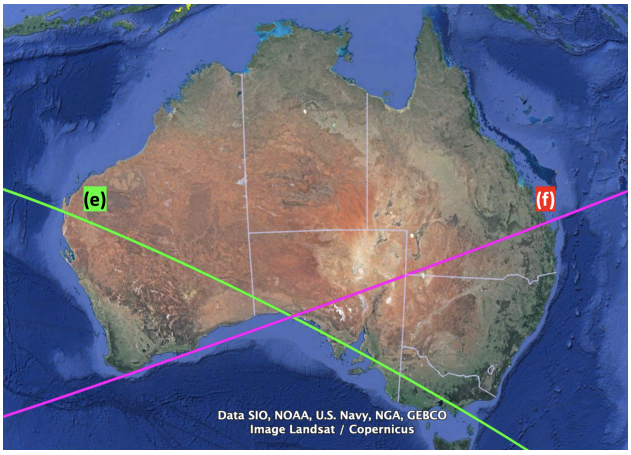


3 Events for the most experienced observers and for practice

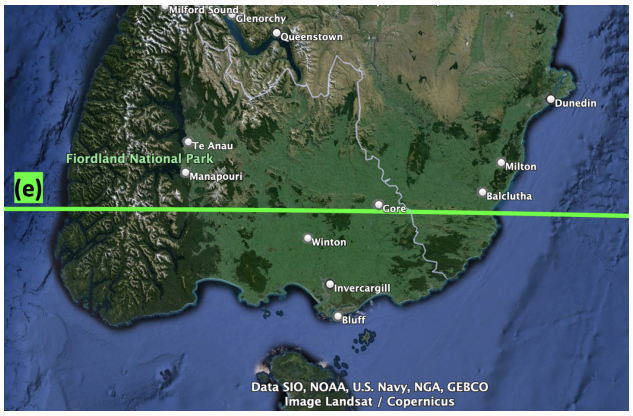
Table 2: **Events for the most experienced observers and/or for good practice:** the table gives basic information about the events: epoch, the star's G magnitudes, the maximum expected duration and expected mag. drop, the geographic regions crossed, and finally a hyperlink to the FoV centred around the occulted star. The label used in the sky chart column for a given event is the same as on the map Fig. 2.

Epoch (UT)	Stars' G mag.	max. duration	max. drop	geographic region	interactive sky chart (lab.)
2024-05-05 T15:25	10.9	0.17 s	8.62	(**VIC**, SA, WA), & (**NZ**)	(e)
2024-06-05 T16:26	12.0	0.16 s	6.35	**QLD**, SA	(f)

Figure 2: Map showing the projected path for the best observable events given in Table 2.



(a) Two events in Australia



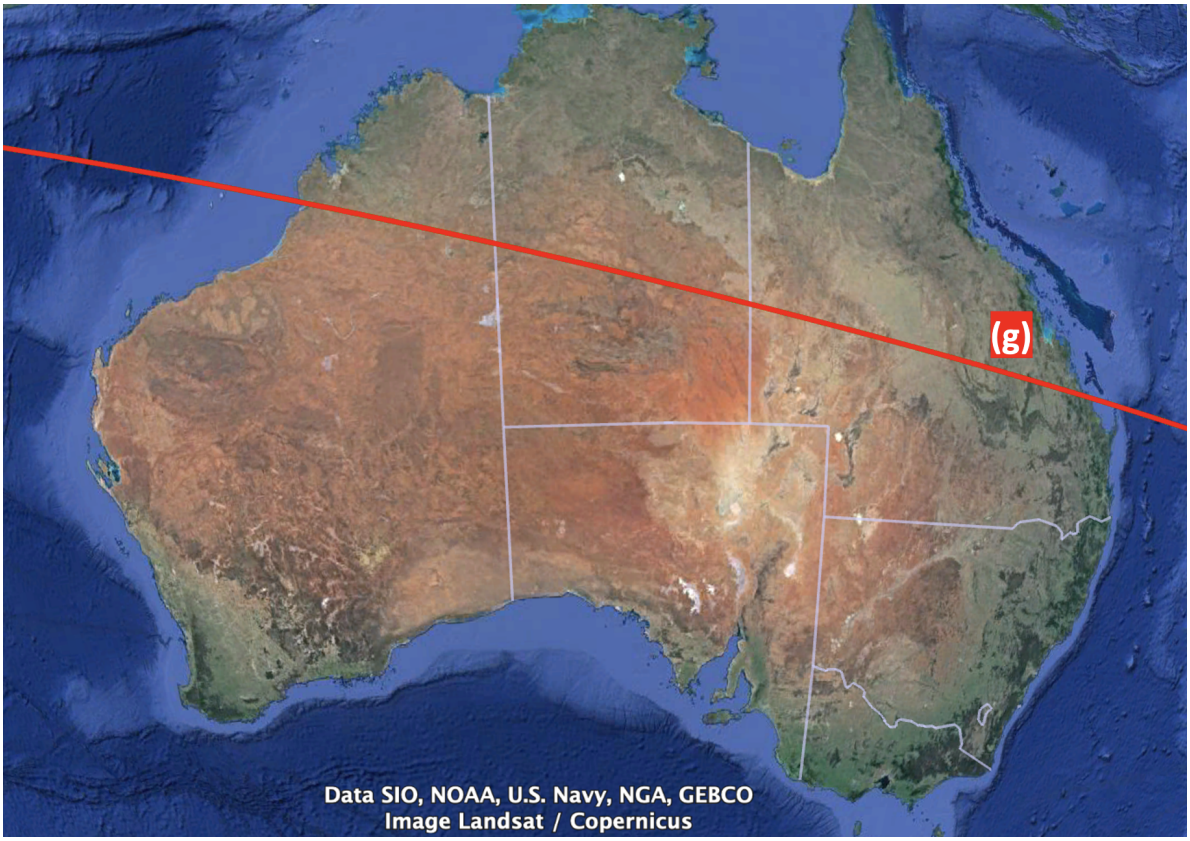
(b) One event in Southern New Zealand.

4 Events for those looking for challenges

Table 3: **much more challenging event:**

Epoch (UT)	Stars' G mag.	max. duration	max. drop	geographic region	interactive sky chart (lab.)
2024-07-12	10.4	0.09 s	7.47	**QLD**, NT, WA	(g)

Figure 3: Map showing the projected path for the challenging event given in Table 3.



5 Gear requirements

You will need mobile telescopes, if you are off the path by 500m, and you are not mobile ...

• **Timing requirements:** GPS timing accuracy is by-far the most reliable, as the timing uncertainty cannot be larger than (or equivalent the exposure) time.

→ The 1a solution: use of cameras with integrated GPS antennas is by far the best option.

→ The 1b solution: time-boxes if you can (external GPS antenna, practice, practice, practice),

→ The second best is NTP synchronisation of your computer clock,

→ an alternative solution to be explored depending in your equipment is the use of a chronoflash.

• **Telescope's aperture:** for the brightest events, small aperture scopes can be used (here again depending on your instrumental setup).

• **Frame acquisition rate:** depending on the event, we would suggest at least 33Hz, however tests must be made (see. Section 6).

6 Other recommendations

Practice on the field, practice on the field, practice on the field ...

→ Identify the FoV: while the field of view seems dense, exposing a couple of seconds will be enough (depending on your instrumental setup) for you to confirm that you are on the field.

→ Test your equipment and understand its limitations on sky

→ Charge your batteries, and do not let your laptop and other devices run for hours before the event

→ Do not get too comfortable in your practice, always expect a challenge (just like in Tennis, where you would play every single serve as if it were the last one).

→ Test your equipment to find the most optimal exposure time, an SNR of ∼5 on the occulted star is enough.

→ if you are seeing "sharply" the star (especially for the very bright ones), then you are definitely "over-exposing"

→ Test your own equipment, only you can determine the most optimal setting for your telescope, camera ...

→ Identify the USB-3 port on your laptop, and always use it to plug the camera. Here again, only tests will reveal to you possible buffering issues that will result in the loss of frames.

→ Do not use any optical filter.

7 The campaigns

7.1 Coordination and deployment for the campaigns

• When it comes to occultations by very small objects, coordinating the deployment on the ground is very important. Indeed depending on the number of registered observers per event, we will assigne observing chords to observing (accounting for the local topographical constraints). The goal is to ensure the most optimal coverage and to have nearly equidistant "chords" in the plane of the sky. This work is done within a few days of the events, once we have locked the last orbital solution, and once we know the number of observers on the ground.
In order to get organised and better coordinate the events, we ask observers to complete the following **online form**, so that we can contact you as we are approaching the event.

7.2 Collecting the data

• The data (original recordings) and observational reports must be sent within a week (at most from the event), so that we can update predictions for the future events.
To collect the data efficiently, and to keep records of everyone's contribution, we urge each observer to submit their data and complete the report on our Occultation Portal.

Looking forward to collaborating you with you.

The ACROSS team