Discovery, prediscovery and early follow-up

A timeline of the early observations:

- 2024-12-24 18:30: Reaches elongation >30°, V<21
- 2024-12-25 04:45: Perigee @ ~830 000 km, V~16
- 2024-12-25 07:19: ATLAS (W68) prediscovery single trail, ~200”/min
- 2024-12-26 10:08: Catalina (703) prediscovery tracklet
- 2024-12-27 05:43: ATLAS (W68) discovery
- 2024-12-27 09:21: Catalina (I52) follow-up
- 2024-12-27 10:07: ZTF (I41) archival detections, ~20”/min

These tracklets ensure sufficient astrometric data from the early part of the apparition.

A few critical issues:

- Trailing: most of these detection were significantly trailed, proper trail fitting astrometry was needed.
- Timing: given the fast sky-plane motion, the accuracy of timetags was investigated in detail (e.g. ATLAS).

Current apparition follow-up

After the initial tracklets, regular follow-up was obtained by many stations:

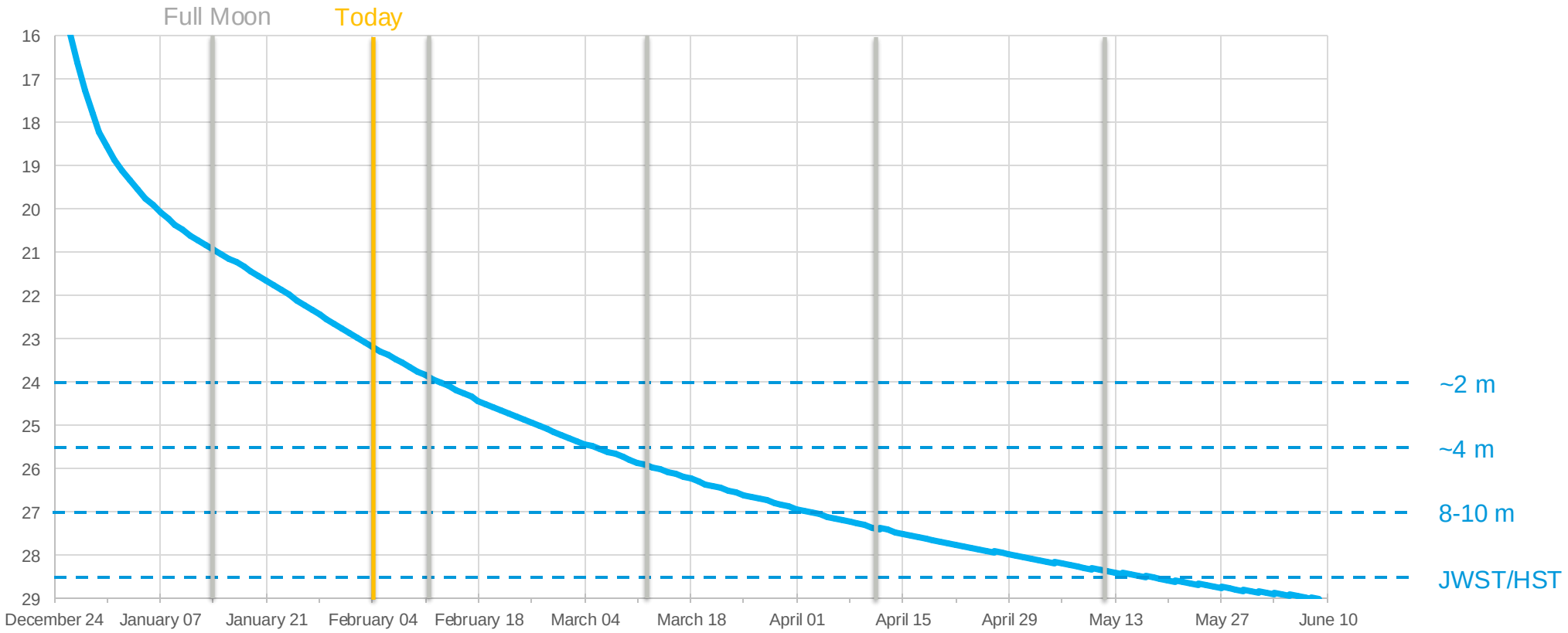
- Dedicated follow-up facilities: T12, H01, 291, 691, H21, J04, 095, …
- Incidental detections by US surveys: Pan-STARRS, Catalina, ATLAS
- Multiple independent stations

Additional photometric images obtained lightcurve and color determination are also extremely useful for astrometric purposes:

- 1.54 m Danish reflector (W74) in La Silla, Chile (P. Pravec, K. Hornoch et al.)
- 4.3 m Lowell Discovery Telescope (G37) in Arizona, USA (N. Moskovitz et al.)
- 8.2 m Very Large Telescope (309) in Paranal, Chile (O. Hainaut, M. Devogèle et al.)
- 1.52 m Loiano reflector (598) in Italy (A. Carbognani et al.)
- 2.56 m Nordic Optical Telescope (Z23) in La Palma, Spain (M. Granvik, G. Fedorets, Z. Gray et al.)

Thanks to these efforts, ~0.05”-0.10” level astrometry is being reported nearly daily.

Planned arc extension timeline



- Next lunation (February) will be the focus of 2-4 m class telescopes.
- The following one (March) will need 8-10 m class instruments.
- After that, only space facilities will be able to get astrometry.

Follow-up plans with 8-10 m facilities

The observed arc so far benefitted from multiple stations submitting independent astrometric data.

This will hopefully still be doable next lunation, but becomes harder in ~March.

There are currently just a few (fully-steerable) 8-10 m class telescopes worldwide:

- Gran Telescopio Canarias
- Keck telescopes (×2)
- Large Binocular Telescope (×2, comounted)
- Subaru telescope
- Very Large Telescopes (×4)
- Gemini telescopes (×2, different sites)

The planetary defence community should coordinate efforts to ensure astrometry is obtained from at least a few (≥ 3) of these facilities, ensuring control of station-dependent biases.

IAWN will set up a page to note ToO plans to access large-aperture telescopes, to avoid duplication.

Past observability and precovery efforts

The asteroid had a very favourable opposition in August-September 2016, V~20.7, ephemeris uncertainty ±2°.

Other fainter opportunities happened in August 2012 (V~23.0, ±1°) and September 2020 (V~23.5, ±10').

Surveys and missions checked their archives:

- Catalina inspected an excellent set of images from G96, including the VI counterimage. No candidates found.
- Pan-STARRS identified a few fields in 2012, 2016 and 2020. No candidates found, 2012 and 2020 are too shallow.
- P. Tanga checked possible detections by Gaia, but it was never within the FoV.
- J. Bauer checked the NEOWISE data.
- D. Woods checked the US SST telescope data.
- J. de Wit searched TESS and other exoplanet surveys.

Multiple people checked datasets currently indexed by the CADC SSOIS service. In particular:

- A set of images from the Blanco DECam imager in August 2016. No moving objects matching.
- A single DECam image includes the VI counterimage, no sources unmatched with static sky sources are visible on the LoV.
- Some frames from Subaru in August 2016, reportedly inspected by various people on MPML.

Negative precoveries

Many of these field have been carefully inspected and nothing was found: can we indirectly use this information?

- Exclude an impacting trajectory, if the counterimage of the VI is visible in an exposure.
- Exclude portions of the probability region, if other segments of the uncertainties are visible.

This information can be used, but only as a last resort measure and with a lot of care! Two main types of issues:

- Orbital dynamics: determining what each point of an image corresponds to, in orbital space.
  - Mapping the counterimage of the Earth and its uncertainty onto the plane of the sky is not trivial.
  - Non-gravitational effects may need to be included in the model.
- Observational constraints: excluding with confidence that the object is not actually visible.
  - Lightcurve and/or phase effects can make an object much fainter than expected.
  - Field stars or contamination may hide the object.
  - Chip gaps or other discontinuities can affect the completeness of the coverage.

As of 2021, a protocol is in place to validate and handle negative observations for planetary defence purposes.

https://minorplanetcenter.net/mpcops/documentation/negative-observations/