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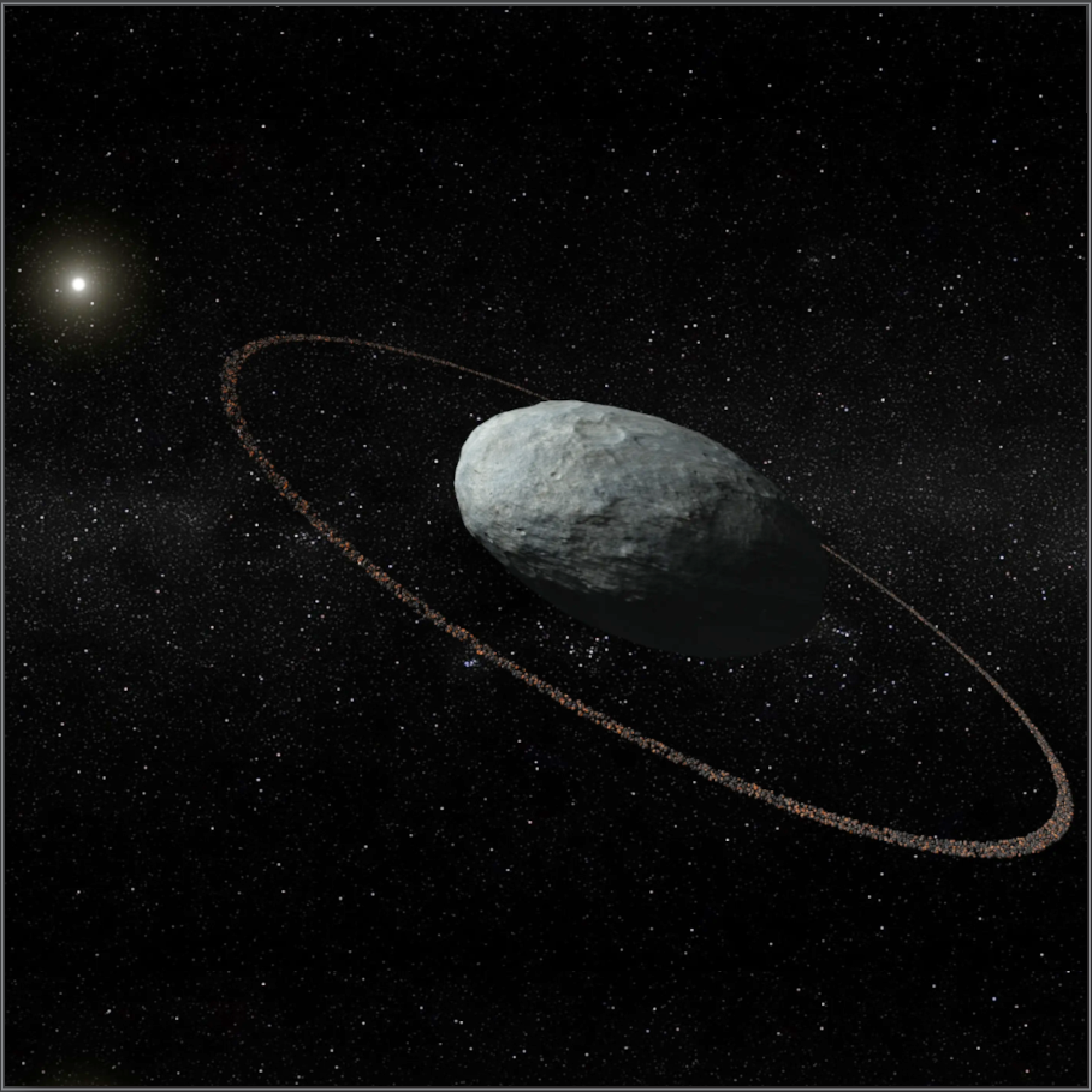

Occultation by (136108) Haumea, 2026 May 4

Dear reader,

A heated debate is currently taking place within the astronomical community: Smart telescopes – a curse or a blessing? Whilst some celebrate the simplification of the process, others are concerned about the loss of astronomical expertise.

The Unistellar Group has demonstrated that these devices can generate scientific results for selected occultation events. Due to the high price, there have not yet been many observers.

Now, simpler devices are entering the market and the first observational results are being presented. It is therefore very pleasing that one of our most active contributors, Christian Weber, has undertaken an analysis of the Seestar S50. In our news section, you will find a short note entitled 'Occultation Observations with Smart Telescope Seestar S50 - A First Test Report '. It contains a link to a detailed evaluation.

Let us wait and see whether this turns out to be a curse in the form of unanalysable and poor-quality observations, or a blessing in the form of an increase in data. The world remains exciting and thrilling.

Konrad Guhl
IOTA/ES, President

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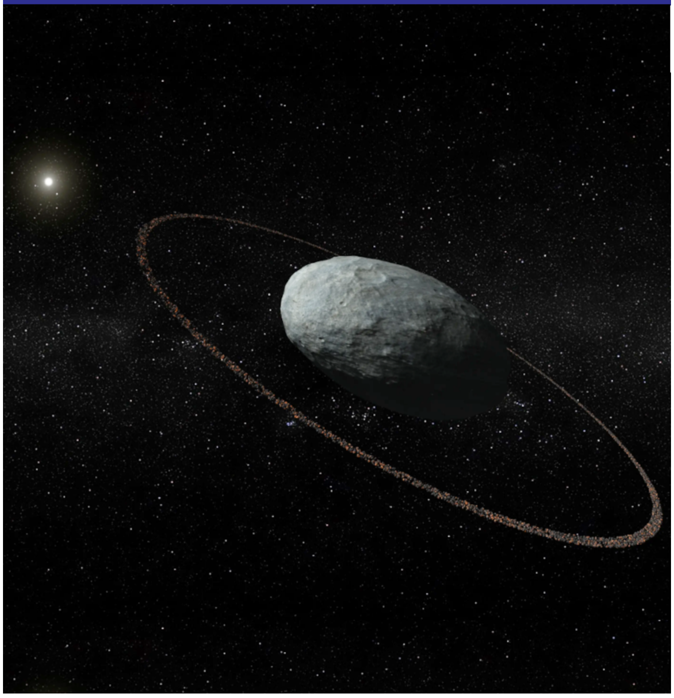
In this Issue:

COVER



The cover image shows an artist's impression of (136108) Haumea. The ring was discovered during a stellar occultation on 2017 January 21. The main body and the ring are shown to scale. The ring is located 2,287 kilometres from the centre of the ellipsoidal main body. A good opportunity to study the trans-Neptunian object and its ring will arise on 2026 May 4.
(Image: IAA-CSIC/UHU)

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Journal for Occultation Astronomy

CALL FOR OBSERVATIONS:

Stellar Occultation by (136108) Haumea on 2026 May 4

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ABSTRACT: On 2026 May 4, the dwarf planet (136108) Haumea will occult a relatively bright (Gaia G = 14.7) star, producing one of the most favourable stellar occultation events by a trans-Neptunian object in the coming decade. The event is observable across large parts of Europe, Africa, and adjacent regions, with particularly strong prospects for coordinated campaigns in Europe and southern Africa (Namibia, South Africa). Recent high-angular-resolution observations reveal that the target star is a close binary (~0.12 arcs separation, Δm ≈ 3.1), implying that two distinct occultations will occur. This provides a unique opportunity to probe both Haumea's main body and its ring system, as well as to refine its 3D shape, density, and possible hydrostatic equilibrium state. We encourage both professional and amateur astronomers to participate in a coordinated observing campaign.

Introduction and Scientific Motivation

(136108) Haumea is one of the most unusual bodies in the Solar System: a rapidly rotating, highly elongated dwarf planet with a ring system and two satellites. Stellar occultations remain the most powerful ground-based method to study such distant objects, providing kilometre-scale constraints on size, shape, and environment.

The 2017 occultation [1] revealed a larger-than-expected size and a lower bulk density (~2000 kg m^{-3}), raising important questions about (136108) Haumea's internal structure and whether it is in hydrostatic equilibrium. However, that result relied on a limited number of chords and assumptions about its triaxial shape. Additional high-quality occultations are therefore essential to:

- Constrain (136108) Haumea's 3D shape and density
- Test hydrostatic equilibrium vs. non-equilibrium configurations
- Probe topography and limb irregularities
- Study the ring system (opacity, width, particle size distribution)
- Search for additional rings or faint satellites

The upcoming 2026 May 4 event [2] is particularly valuable because the projected shadow width is estimated to be ~2224 ± 30 km, significantly larger than conservative assumptions, greatly increasing the probability of multi-chord detections.

Event Overview

- Date: 2026 May 4

- Time (UT): ~20:12 – 20:22
  ((136108) Haumea's shadow on the Earth)

- Gaia DR3 ID: 1185968739624622848 = UCAC4 524-056397

- ICRS coordinates (at occ. epoch):
  RA = 14 40 58.5, DE = +14 40 26

- Star brightness: Gaia G = 14.7 mag, RP = 14.2 mag

- (136108) Haumea Magnitude: V = 17.2 mag

- Maximum duration: ~66 s

- Shadow width: ~2200 km

- Regions: Europe, North Africa, Middle East, with extended visibility toward southern Africa (due to fainter companion of the primary target star, see next section).
  See Figures 1+2.

This is one of the brightest and most accessible (136108) Haumea occultations identified through 2030.

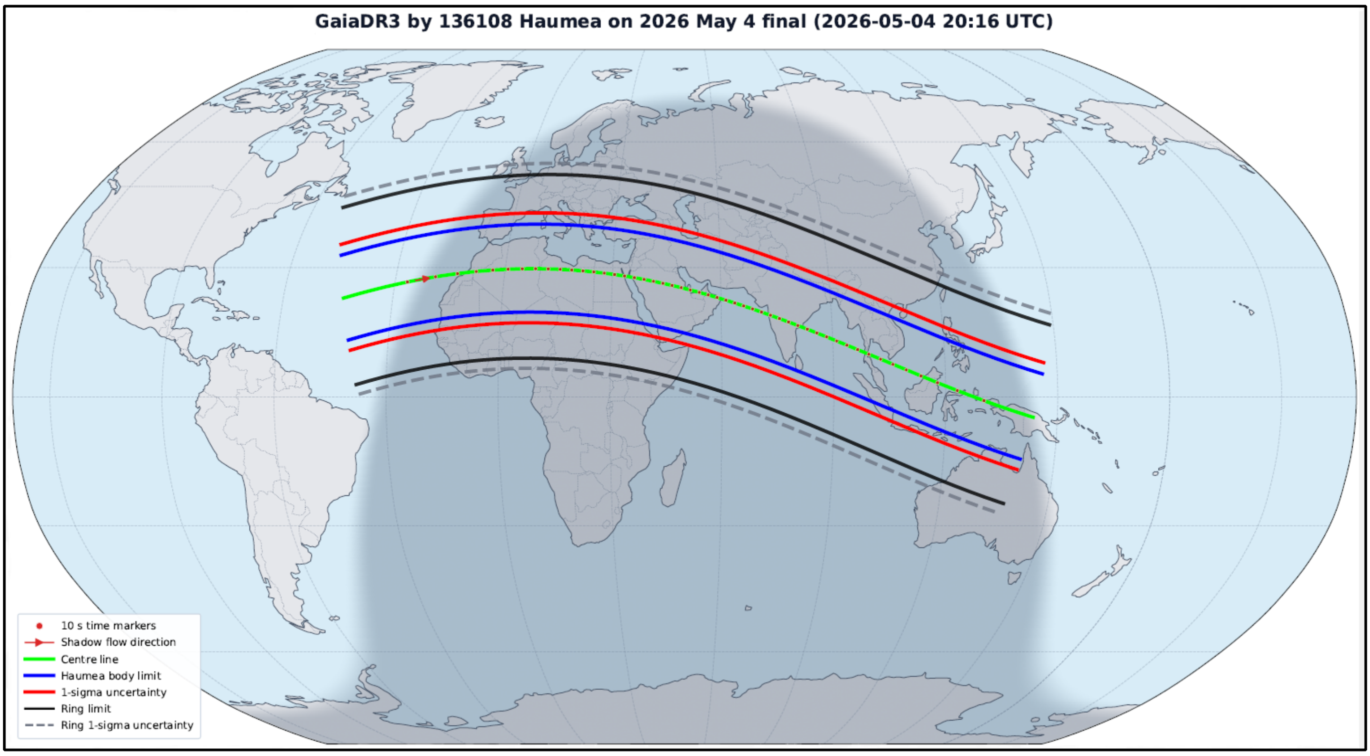
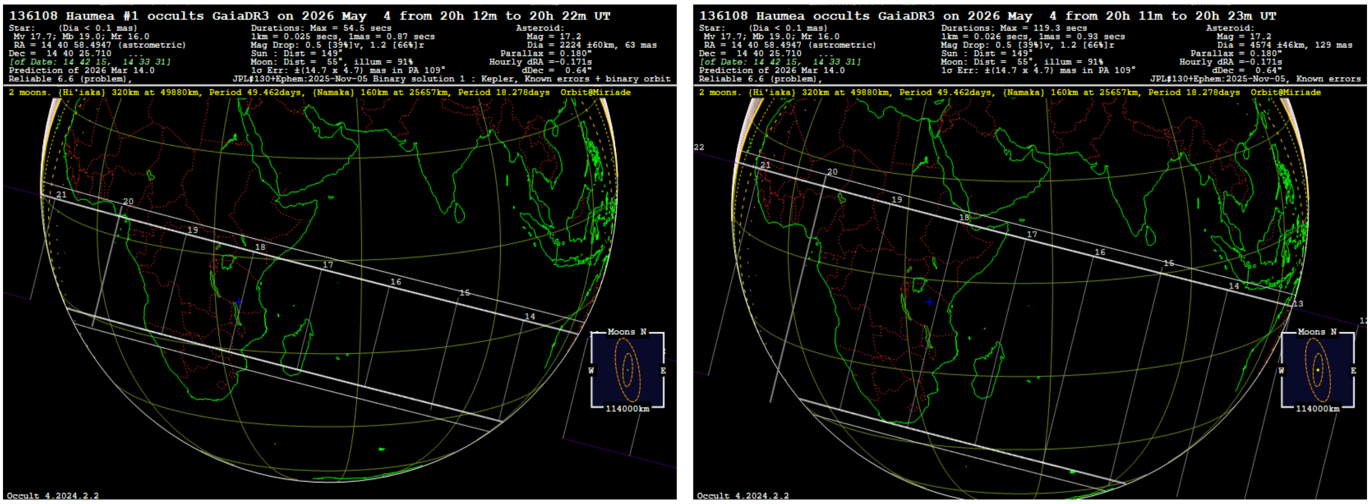


Figure 1. Predicted geometry of the 2026 May 4 event (target star primary component) showing the broader ring-occultation shadow region relative to the main-body shadow. A zoomable version of the map is available at:
https://opop.obspm.fr/media/data/chords/156331/Haumea_4th_May_2026_occultation_map_IAA-CSIC.html



```
136108 Haumea #1 occults GaiaDR3 on 2026 May  4 from 20h 12m to 20h 22m UT
Star:     (Dia < 0.1 mas)              Durations: Max = 54.5 secs                   Asteroid:
 Mv 17.7; Mb 19.0; Mr 16.0             1km = 0.025 secs, 1mas = 0.87 secs             Mag = 17.2
 RA = 14 40 58.4947 (astrometric)      Mag Drop: 0.5 [39%]v, 1.2 [66%]r               Dia = 2224 ±60km, 63 mas
Dec =  14 40 25.710   ...              Sun : Dist = 149°                          Parallax = 0.180"
[of Date: 14 42 15,  14 33 31]         Moon: Dist =  55°, illum = 91%           Hourly dRA =-0.171s
Prediction of 2026 Mar 14.0            1σ Err: ±(14.7 x 4.7) mas in PA 109°           dDec =  0.64"
Reliable 6.6 (problem),             JPL#130+Ephem:2025-Nov-05 Binary solution 1 : Kepler, Known errors + binary orbit
2 moons. {Hi'iaka} 320km at 49880km, Period 49.462days, {Namaka} 160km at 25657km, Period 18.278days  Orbit@Miriade
```

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136108 Haumea occults GaiaDR3 on 2026 May  4 from 20h 11m to 20h 23m UT
Star:     (Dia < 0.1 mas)              Durations: Max = 119.3 secs                  Asteroid:
 Mv 17.7; Mb 19.0; Mr 16.0             1km = 0.026 secs, 1mas = 0.93 secs             Mag = 17.2
 RA = 14 40 58.4947 (astrometric)      Mag Drop: 0.5 [39%]v, 1.2 [66%]r               Dia = 4574 ±46km, 129 mas
Dec =  14 40 25.710   ...              Sun : Dist = 149°                          Parallax = 0.180"
[of Date: 14 42 15,  14 33 31]         Moon: Dist =  55°, illum = 91%           Hourly dRA =-0.171s
Prediction of 2026 Mar 14.0            1σ Err: ±(14.7 x 4.7) mas in PA 109°           dDec =  0.64"
Reliable 6.6 (problem),                                       JPL#130+Ephem:2025-Nov-05, Known errors
2 moons. {Hi'iaka} 320km at 49880km, Period 49.462days, {Namaka} 160km at 25657km, Period 18.278days  Orbit@Miriade
```

Figure 2. Occultation path to be expected for the ≈3.1 mag fainter companion of the primary target star in case the northern speckle solution [2] is correct thus shifting the shadow path to southern Africa. The left panel shows the ground track for the (136108) Haumea main body, the right panel for the rings. Created with Occult 4.2024.2.2 [3].

Binary Nature of the Target Star

A key result from our preparation for this event [2] is that the occulted star is not a single object, but a close binary revealed by speckle interferometry:

- Separation: ~0.12 arcsec
- Magnitude difference: Δm ≈ 3.1

This has two critical implications:

Two Distinct Occultations

Both components will be occulted by (136108) Haumea, producing two separate events with slightly offset shadow paths (~8 mas shift on sky).

- The primary star → main occultation (bright star, large mag drop)
- The secondary star → fainter occultation, small mag drop, shifted geographically.

Due to the 180 degree ambiguity in speckle orientation, the secondary event may occur either:

- Over northern Europe, or
- Over southern Africa (Namibia, South Africa)

As it seems that the northern solution of the companion is a little bit more likely, this makes southern Africa a critical observing region for the secondary event (Figure 2).

Expected Magnitude Drop of the Companion

The magnitude difference Δm ≈ 3.1 implies a magnitude drop of: Δm ≈ 0.06 mag. To detect such a small drop a higher SNR as for the primary star occultation is needed (SNR ≈ 20 or higher).

Ring Occultation and Extended Science

(136108) Haumea's ring system significantly enlarges the observable region:

- The ring occultation path is much wider than the main-body shadow
- Detectable as brief, shallow dips before/after main event
- Strong wavelength dependence → probe particle size distribution

Multi-site observations can:

- Constrain ring width, opacity, and structure
- Detect azimuthal variations or clumps
- Search for additional narrow rings or arcs

Observational Strategy

Recommended Equipment

Target	Telescope	Cadence	Notes
Primary occultation	≥ 0.2 m	~ 1–10 Hz	Easily detectable
Secondary occultation	≥ 0.3–0.5 m	~ 1–10 Hz	≈0.06 mag drop
Ring events	≥ 0.4 m	>= 10 Hz	Short, shallow features

Conclusion

The 2026 May 4 occultation by (136108) Haumea represents a rare and exceptional opportunity:

- Relatively bright target → accessible to many observers
- Wide shadow path → high probability of success
- Binary target star → two independent occultations
- Haumea ring system → extended science return

Coordinated observations across Europe and southern Africa will be particularly powerful.

We strongly encourage the community to prepare observing campaigns and contribute to this event, which has the potential to significantly advance our understanding of one of the most intriguing objects in the trans-Neptunian region. Observers are encouraged to register their participation and report observations through the Occultation Portal [4].

References

[1] Ortiz, J. L., et al. The size, shape, density and ring of the dwarf planet Haumea from a stellar occultation, 2017, Nature, 550, 219 https://doi.org/10.48550/arXiv.2006.03113

[2] Ortiz, J. L., et al. Predictions of Stellar Occultations by Haumea and the Event of 4 May 2026, https://arxiv.org/pdf/2603.15049

[3] Herald, D., Occult V4, https://occultations.org/sw/occult/occult4.htm

[4] Occultation Portal, https://opop.obspm.fr/create_report/2518/

The 2024 Oct 7 Stellar Occultation by the Trans-Neptunian Object (225088) Gonggong: Report of a Non-Observation

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ABSTRACT: We report on a coordinated international observing campaign targeting a predicted stellar occultation by the trans-Neptunian object (225088) Gonggong on 2024 October 7. Despite extensive preparation, multiple astrometric refinements, and generally favourable observing conditions across a large geographic range, no unambiguous occultation was detected at any participating station. We summarise the scientific motivation, prediction updates, observational strategy, and results, and discuss plausible reasons for the negative outcome. This study highlights the continued challenges of predicting occultations by distant trans-Neptunian objects and underscores the scientific value of well-documented non-detections.

Introduction

Centaurs and trans-Neptunian objects play a fundamental role in constraining the formation and dynamical evolution of the outer Solar System [1, 2, 3 and references therein]. These bodies preserve relatively unaltered material from the early Solar System and thus retain physical and chemical signatures of planet formation processes. Accurate measurements of size, albedo, density, and shape are essential inputs for evolutionary models.

Unlike radiometric methods, which infer size and albedo from thermal models and rely on far-infrared observations from space-based facilities such as the *Herschel Space Observatory* within the TNOs are Cool key programme [4], stellar occultations provide direct geometric constraints. Since the end of the Herschel mission, and apart from observations with the *James Webb Space Telescope* [5, 6] or sub-millimetre facilities such as *Atacama Large Millimeter/Submillimeter Array* [7], occultations remain the most effective technique for characterising distant trans-Neptunian objects [8]. In addition, stellar occultations provide astrometric constraints at the sub-milliarcsecond level, leading to improved orbital solutions and more accurate future predictions.

Trans-Neptunian Object (225088) Gonggong

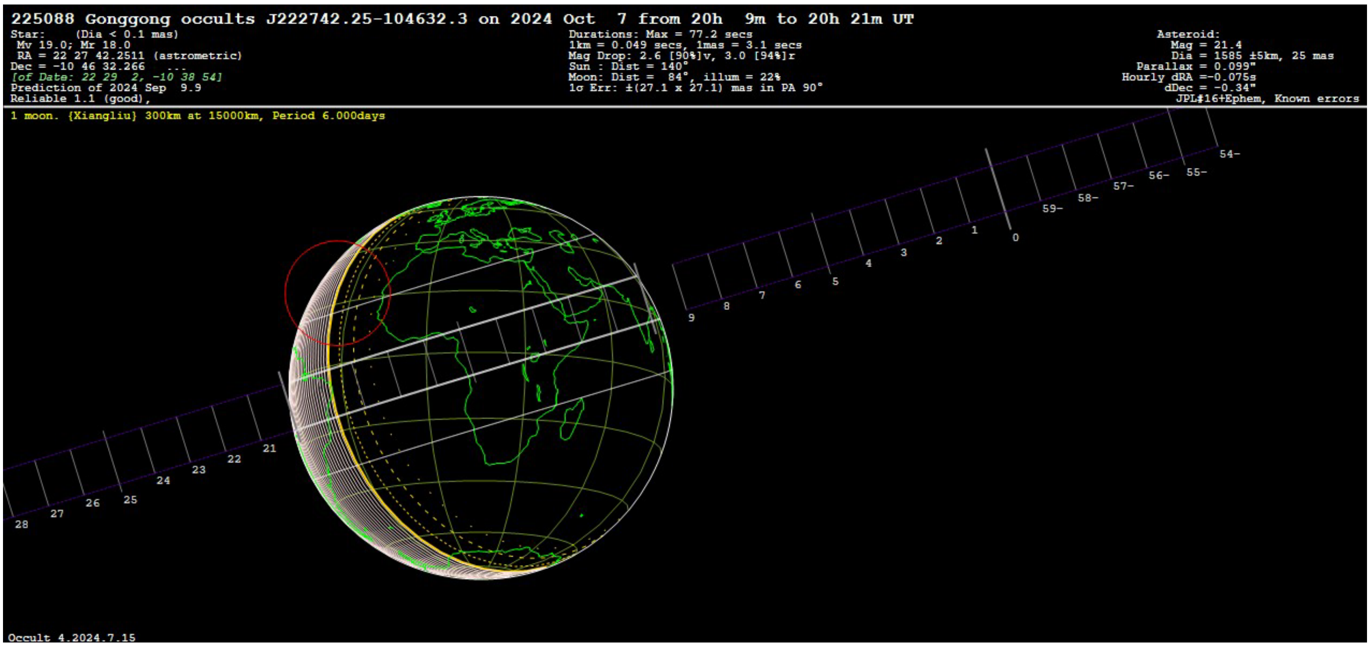
(225088) Gonggong is among the largest known objects beyond Neptune. Discovered in 2007 by M. E. Schwamb, M. E. Brown, and D. L. Rabinowitz and initially designated 2007 OR_{10} [9], it follows a highly eccentric and inclined orbit with a semimajor axis of approximately 67 au, an eccentricity of 0.50, and an inclination of 31°. Its heliocentric distance ranges from about 33 au at perihelion to 101 au at aphelion, with an orbital period of roughly 550 years.

Infrared observations with the Herschel Space Observatory and the Kepler Space Telescope (K2) indicated an effective diameter of approximately 1535 +75 -225 km and a geometric albedo of about 0.09 [10]. These values were later revised to 1230 ± 50 km and an albedo of 0.14 following the 2017 discovery of a satellite in Hubble Space Telescope year 2010 images [11, 12]. Earlier radiometric estimates spanned a wide range but were significantly refined by these measurements. The discovery of the satellite in 2016/2017, provisionally named Xiangliu, also enabled estimates of the system mass and mean density. Given its size, (225088) Gonggong is considered a strong dwarf-planet candidate.

Near-infrared spectra of (225088) Gonggong exhibit a pronounced red spectral slope along with broad absorption bands at ~1.5 and ~2.0 µm characteristic of water ice, and earlier low-signal indications of methane were suggested based on its colour and spectral shape, although more recent observations do not confirm strong CH_4 absorption features. These spectral properties point to an ice-rich surface modified by irradiation and complex organics, as seen across large trans-Neptunian objects [13].

Occultation Predictions and Astrometric Updates

Initial predictions of a potential occultation of a G ≈ 19 mag star by (225088) Gonggong on 2024 October 7 were generated at the Instituto de Astrofísica de Andalucía (IAA) in early September 2024, based on the JPL Horizons #16 orbital solution (Figure 1). The preliminary shadow path included parts of Africa and India, but with substantial uncertainty due to ephemeris errors and the large geocentric distance.



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225088 Gonggong occults J222742.25-104632.3 on 2024 Oct  7 from 20h  9m to 20h 21m UT
Star:     (Dia < 0.1 mas)                 Durations: Max = 77.2 secs                          Asteroid:
 Mv 19.0; Mr 18.0                         1km = 0.049 secs, 1mas = 3.1 secs                     Mag = 21.4
 RA = 22 27 42.2511 (astrometric)         Mag Drop: 2.6 [90%]v, 3.0 [94%]r                      Dia = 1585 ±5km, 25 mas
Dec = -10 46 32.266   ...                 Sun : Dist = 140°                                  Parallax = 0.099"
[of Date: 22 29  2, -10 38 54]            Moon: Dist =  84°, illum = 22%                  Hourly dRA =-0.075s
Prediction of 2024 Sep  9.9               1σ Err: ±(27.1 x 27.1) mas in PA 90°                   dDec = -0.34"
Reliable 1.1 (good),                                                                        JPL#16+Ephem, Known errors
1 moon. {Xiangliu} 300km at 15000km, Period 6.000days

Occult 4.2024.7.15
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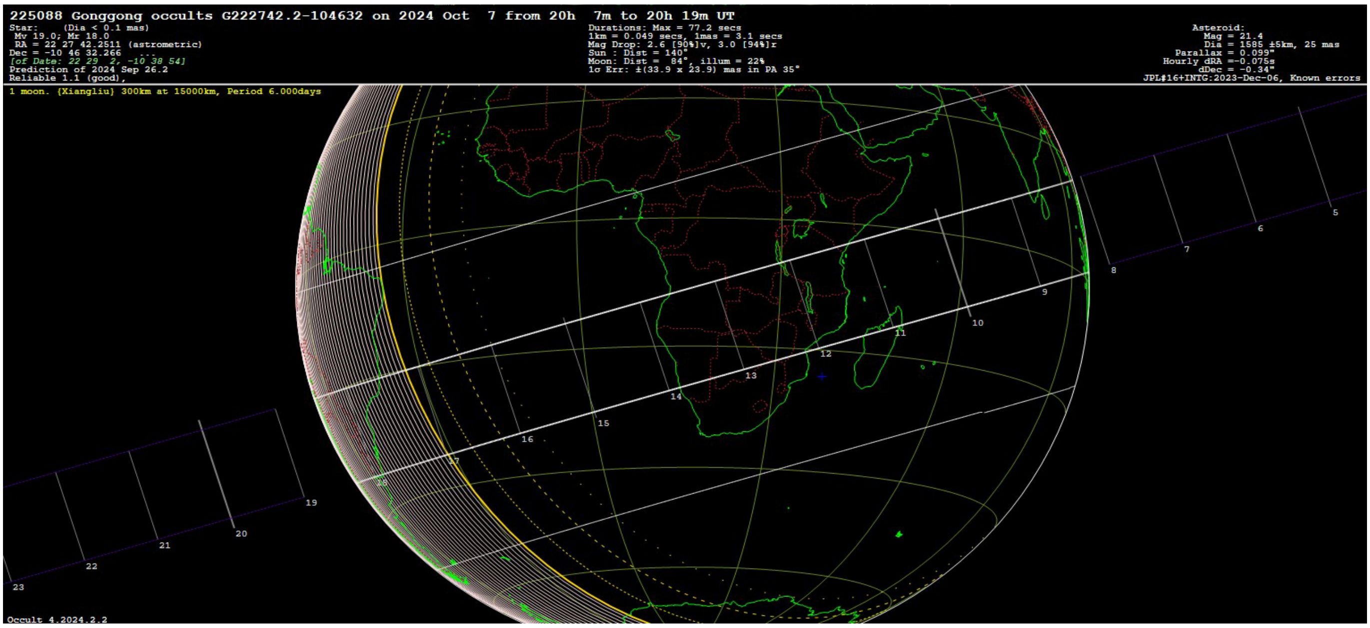
Figure 1. Initial occultation prediction for (225088) Gonggong based on the JPL Horizons solution #16. The red circle indicates the 1σ prediction uncertainty dominated by ephemeris errors at the large geocentric distance. (Occult 4.2024.7.15)

Follow-up astrometric observations by the IAA with the 2-m *Liverpool Telescope* on La Palma revealed a systematic offset relative to the nominal ephemeris, shifting the predicted occultation zone southward and placing Namibia within the central path (Figure 2). Additional observations with the *Liverpool Telescope* and the 1.5-m telescope at the *Sierra Nevada Observatory* (OSN) in Spain suggested a further modest southward shift, potentially including sites in South Africa (Figure 3). Residual scatter among the astrometric measurements indicated remaining uncertainties at the 10–30 mas level, corresponding to several hundred kilometres on Earth



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225088 Gonggong occults G222742.2-104632 on 2024 Oct  7 from 20h  7m to 20h 19m UT
Star:     (Dia < 0.1 mas)                 Durations: Max = 77.2 secs                          Asteroid:
 Mv 19.0; Mr 18.0                         1km = 0.049 secs, 1mas = 3.1 secs                     Mag = 21.4
 RA = 22 27 42.2511 (astrometric)         Mag Drop: 2.6 [90%]v, 3.0 [94%]r                      Dia = 1585 ±5km, 25 mas
Dec = -10 46 32.266   ...                 Sun : Dist = 140°                                  Parallax = 0.099"
[of Date: 22 29  2, -10 38 54]            Moon: Dist =  84°, illum = 22%                  Hourly dRA =-0.075s
Prediction of 2024 Sep 26.2               1σ Err: ±(33.9 x 23.9) mas in PA 35°                   dDec = -0.34"
Reliable 1.1 (good),                                                              JPL#16+INTG:2023-Dec-06, Known errors
1 moon. {Xiangliu} 300km at 15000km, Period 6.000days

Occult 4.2024.2.2
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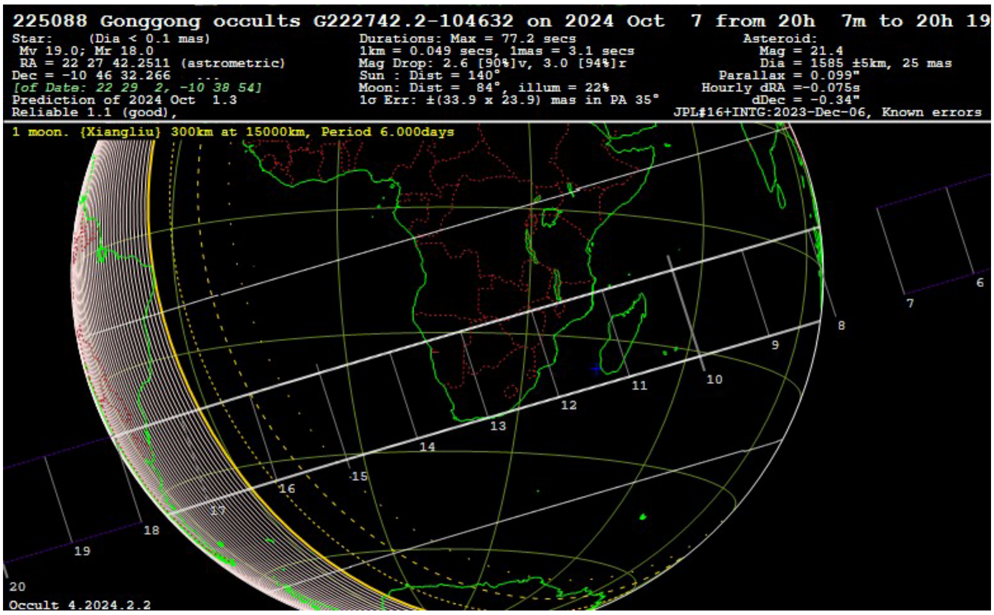
Figure 2. Updated occultation path after astrometric refinement using Liverpool Telescope observations, showing the southward shift of the predicted shadow path toward Namibia. (Occult V4.2024.2.2)



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225088 Gonggong occults G222742.2-104632 on 2024 Oct  7 from 20h  7m to 20h 19
Star:    (Dia < 0.1 mas)             Durations: Max = 77.2 secs               Asteroid:
 Mv 19.0; Mr 18.0                    1km = 0.049 secs, 1mas = 3.1 secs          Mag = 21.4
 RA = 22 27 42.2511 (astrometric)    Mag Drop: 2.6 [90%]v, 3.0 [94%]r           Dia = 1585 ±5km, 25 mas
Dec = -10 46 32.266   ...            Sun : Dist = 140°                       Parallax = 0.099"
[of Date: 22 29  2, -10 38 54]       Moon: Dist =  84°, illum = 22%         Hourly dRA =-0.075s
Prediction of 2024 Oct  1.3          1σ Err: ±(33.9 x 23.9) mas in PA 35°       dDec = -0.34"
Reliable 1.1 (good),                                                  JPL#16+INTG:2023-Dec-06, Known errors
1 moon. {Xiangliu} 300km at 15000km, Period 6.000days
```

Figure 3. Final occultation prediction after additional astrometric updates from IAA observations. Namibia, South Africa, Madagascar, and La Réunion lie within the predicted uncertainty corridor.
(Occult V4.2024.2.2)

Observational Campaign

Based on the refined predictions, observers and observatories across southern Africa, La Réunion, the Middle East, and Europe (for a potential satellite detection) were alerted. At the *International Amateur Observatory* (IAS), coordinated observations were planned using both the 50-cm AK3 telescope and the 80-cm CJ telescope in a hybrid on-site and remote configuration. The predicted mid-time for the occultation in Namibia was around 20:13–20:14 UT, with a timing uncertainty of several minutes.

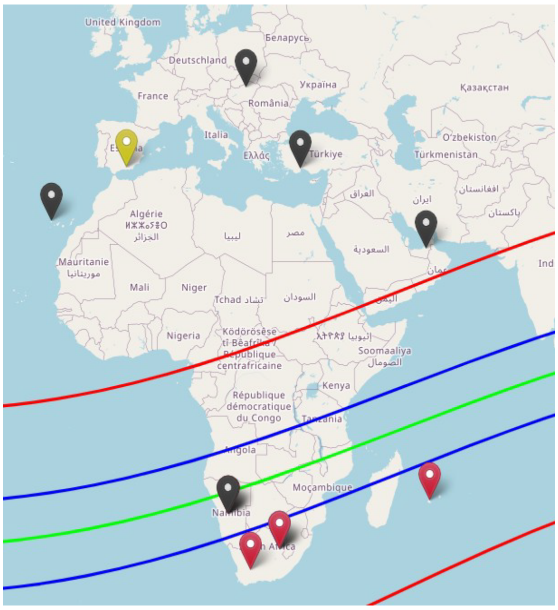


Figure 4. Map of participating observing stations. The predicted shadow centreline is shown in green, with northern and southern limits in blue. Red lines indicate the 1σ uncertainty bounds. Red and black markers: negative observations (no occultation); yellow markers: no observation due to bad weather or technical problems.

In total, approximately a dozen observatories participated, with telescope apertures ranging from 36 cm to 2 m (Figure 4, Table 1). Most sites experienced suitable weather conditions (Figure 5). Exposure times ranged from a few seconds to over 20 seconds, depending on telescope aperture and instrumentation, reflecting the faintness of the target star.

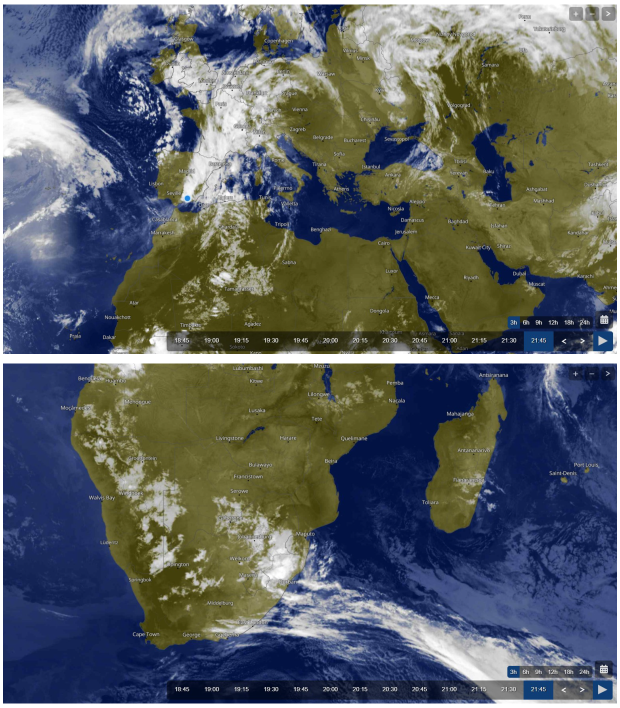


Figure 5. Weather conditions over Europe (top) and southern Africa (bottom) shortly before the predicted occultation time. (Source: Meteoblue)

Observatory	Location	Aperture	Exposure	Weather and Result	Observer(s)
Al Khatim Observatory	Abu Dhabi (UAE)	36 cm	30 s	Clear, no occultation	Mohammad Odeh
BOOTES-6	Boyden (RSA)	60 cm	7 s	Clear, no occultation	E. J. Fernandez García I. Pérez-García
Boyden Obs.	Boyden (RSA)	150 cm	25 s	Clear, no occultation	H. J. van Heerden
IAS	Hakos (NAM)	51 cm	15 s	Clear, no occultation	K.-L. Bath, M. Mushardt, T. Steinbach, M. Kretlow, G. Hoffarth, M. Junius, L. Demetz
IAS	Hakos (NAM)	80 cm	15 s	Clear, no occultation	D. Husar, K.-L. Bath, M. Mushardt, T. Steinbach, M. Kretlow, G. Hoffarth, M. Junius, L. Demetz
Liverpool Telescope	La Palma (ES)	200 cm	1 s	Clear, no occultation	N. Morales, R. Duffard
OSN	Sierra Nevada (ES)	150 cm	-/-	Clouds, no observation	P. Santos-Sanz, N. Morales
Oryx Obs.	Goellschau (NAM)	36 cm	24.2 s	Partly cloudy, no occultation	C. R. Foster
Piszkéstető	Mátraszentimre (HU)	100 cm	5 s	Partly cloudy, no occultation	R. Szakáts, A. Pal, C. Kiss, N. Takacs
Sainte-Marie	La Réunion (FR)	40 cm	20 s	Partly cloudy, no occultation	B. Mondon
Schiaparelli Southern Observatory	Hakos (NAM)	36 cm	20 s	Clear, no occultation	L. Buzzi, G. Galli
Sutherland-LCO Aqawan A #1	Sutherland (RSA)	100 cm	20 s	Clear, no occultation	T. Santana
Türkiye National Observatories	Bakırtepe (TR)	100 cm	13 s	Clear, no occultation	O. Erece, S. Eryilmaz

Table 1. Participating observatories.

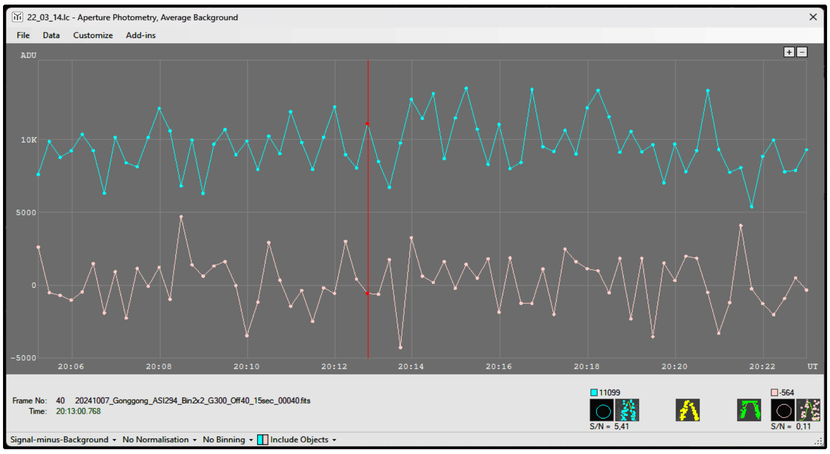
Results

No participating station reported a statistically significant stellar disappearance consistent with an occultation by (225088) Gonggong. Representative light curves from several sites show no flux drops exceeding the noise level at or near the predicted times (Figures 6 - 9). Given the faintness of the star (low SNR) and the long exposure times required at some sites, it cannot be completely excluded that a very short or shallow event escaped detection at an individual station. However, the absence of a positive detection across multiple well-placed sites strongly suggests that the occultation did not occur within the predicted region.

Discussion

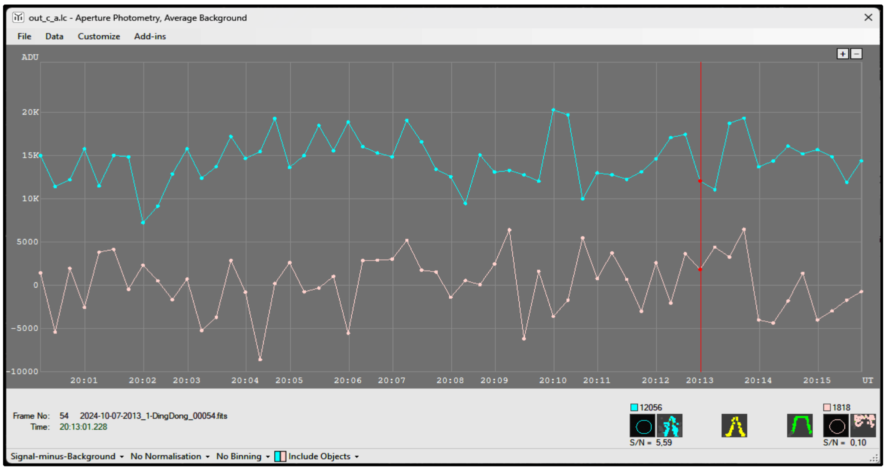
The most likely explanation for the negative result is a remaining ephemeris error that displaced the true shadow path outside the region covered by observers. Gaps in geographical coverage between southern Africa and the Middle East, as well as farther north between Europe and the Arabian Peninsula, leave open the possibility that the occultation track passed through unmonitored regions. A further southward displacement beyond South Africa cannot be excluded.

Systematic effects may also contribute. In particular, unresolved satellites can shift the photocentre measured in astrometric obser-



Frame No: 40 20241007_Gonggong_ASI294_Bin2x2_G300_Off40_15sec_00040.fits
Time: 20:13:00.768

Figure 6. Light curve from the 50-cm AK3 telescope at Hakos. The upper curve corresponds to the target star, the lower curve to a comparison star. No statistically significant flux drop is detected. The vertical red line marks the predicted mid-time of the occultation.



Frame No: 54 2024-10-07-2013_1-DingDong_00054.fits
Time: 20:13:01.228

Figure 7. Light curve (blue) obtained with the 80-cm CJ telescope at Hakos, showing no detectable occultation event.

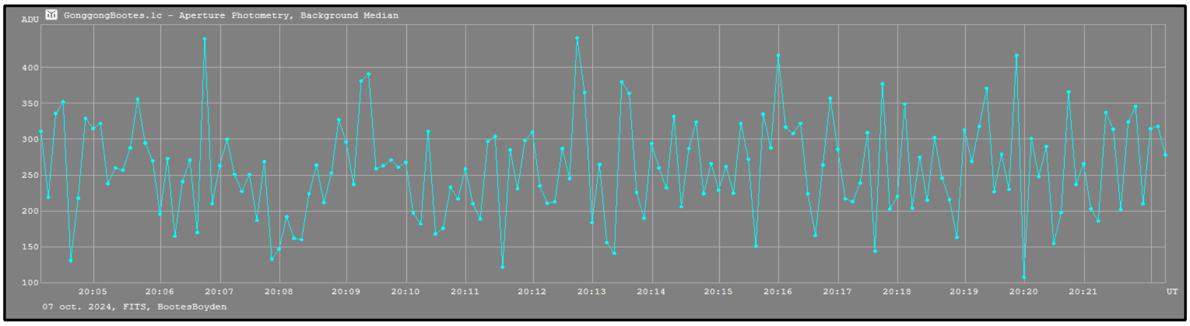


Figure 8. Light curve recorded by the BOOTES-6 telescope at Boyden Observatory, South Africa.

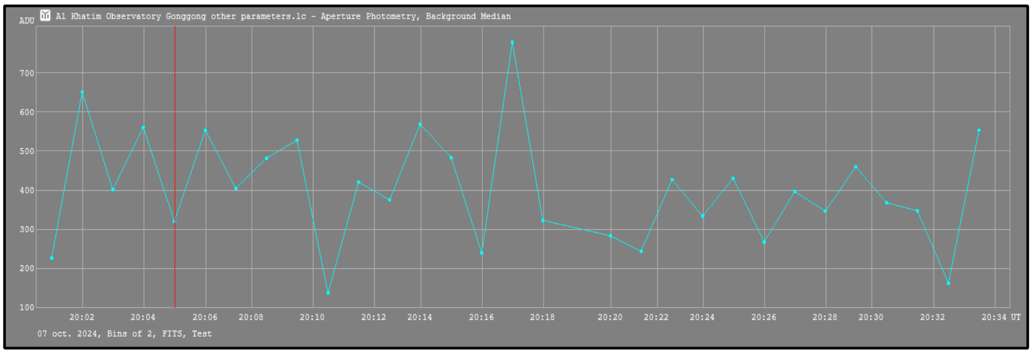


Figure 9. Light curve recorded at Al Khatim Observatory, United Arab Emirates.

vations relative to the primary body or system barycentre. A combined positional error of only 10 mas for the star and TNO corresponds to a displacement of approximately 650 km at Earth. Such limitations illustrate why occultation predictions for distant TNOs remain challenging, despite significant advances over the past 15 years.

Conclusions

Although no occultation by (225088) Gonggong was detected during the 2024 October 7 campaign, the effort demonstrates the collaborative and valuable contribution to ongoing occultation research. Carefully documented non-detections provide important constraints on ephemeris uncertainties and inform future prediction strategies. Continued coordinated campaigns, combining high-precision astrometry with widespread pro-am observing participation, remain essential for advancing the physical characterisation of distant trans-Neptunian objects.

Future Prospects

This raises the question: when will be the next opportunity to observe a stellar occultation by (225088) Gonggong for the first time? Unfortunately, some patience will be required. On the CORA (Collaborative Occultation Resources and Archive) website [14], predictions for TNO and Centaur occultations are available. For (225088) Gonggong, only two events (worldwide) are listed through 2029 December 31 for stars brighter than 18 G-mag (Table 2).

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Date	T0 (UT)	Star Mag	ΔMag	Max Duration	Moon	URL
2028-04-21	10:37:46	15.15	6.36	75.6 s	18° (11%)	1
2028-08-03	20:48:24	16.75	4.71	59.4 s	41° (98%)	2

Table 2. Future occultation opportunities for (225088) Gonggong (G < 18).

1: https://smallbodies.org/cora/occultations/acac3920-4098-11f0-4ed7-ceb7fde7adc2/

2: https://smallbodies.org/cora/occultations/acfdb480-4098-11f0-4ed7-13cbfde79f45/

A New Tool for Evaluating the Fresnel Diffraction Integral

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ABSTRACT: In 2022, Max Cubillos and Edwin Jimenez published a new method for evaluating the 2D Fresnel diffraction integral. Their algorithm, referred to here as the Sinc method, is the new tool highlighted in this article. This article compares the Sinc method to the Trester method (Seymour Trester, 1999) which is frequently applied to modelling diffraction effects in stellar occultations. It is shown that when applied to the same problem, the two methods produce identical results. Several examples illustrate why the Sinc method can handle a broader range of observational situations than the Trester method. A link at the end of the article gives a url to a GitHub repository containing the Jupyter(Python) notebooks used in preparing this article.

Introduction

The 2D Fresnel diffraction integral accurately describes diffraction effects seen at an observation plane when an object in a distant source plane is illuminated by a plane wave. It is assumed that the observation plane is extremely distant compared to the size of the object(s). These conditions are well satisfied when stellar occultations by asteroids or other objects occur.

Figure 1 shows an example of a stellar occultation configuration involving a central object with a companion satellite. The object pair is 40 au distant from Earth (the observation plane) and the star is modelled as a point source.

The leftmost plot shows what the ground shadow would be if there was no diffraction involved.

The middle plot shows the intensity distribution when viewed with a single wavelength of light (400 nm).

The rightmost plot shows what an observer viewing that star through a telescope would record as star intensity versus time as the ground shadow swept past the telescope due to asteroid motion. In this case, the observer was exactly on the centreline of the shadow, so the record shows the shadow of both objects. Diffraction spikes and effects like the u-shaped bottom of the smaller object are readily apparent.

Trester Method — High Level View

The Trester method [1] solves the Fresnel integral problem by making a critical change of variables, followed by the multiplication of each point in the N×N discrete source plane by a quadratic phase factor that is a simple function of the coordinates of that point. The Discrete Fast Fourier Transform (DFFT) is then applied to that modified source plane to obtain the propagated e-field at the observation plane (which is the same size as the source plane). The final step is to calculate the observation plane intensity distribution by computing the absolute value of the e-field at each point.

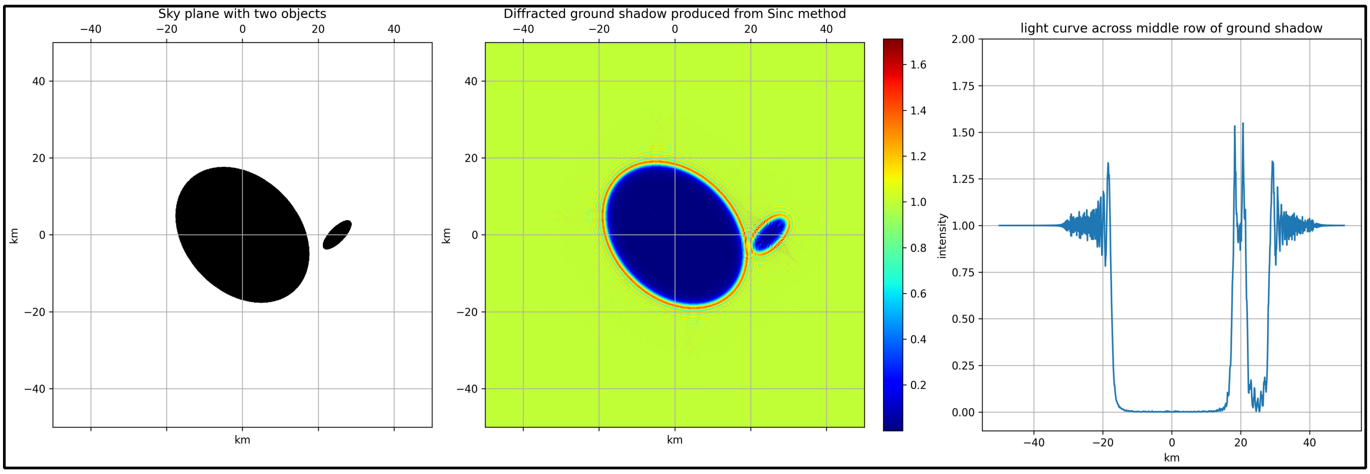

Figure 1. A stellar occultation with clear diffraction effects.

The *Python* code to perform those calculations is easy to read and very short, about a dozen lines, and is given in totality in **Trester-diffraction-module.ipynb** [2].

The change of variables used in Trester's solution has the major consequence that the field of view (FOV) is locked to the number of points (N) in the source plane for any given observational situation where, of course, the distance and wavelength are fixed. That relationship is:

$$\mathbf{N = \frac{(FOV_{km} * FOV_{km})}{wavelength_{km} * distance_{km}}}$$

That same constraint also fixes the resolution (distance between sampling points) in the source and observation planes to:

$$\mathbf{resolution_{km} = \frac{FOV_{km}}{N}}$$

In short, in the Trester method, the only way to change the FOV is by the choice of N. That inflexibility limits the range of stellar occultation observations that can use this method to investigate diffraction effects.

For example, to view the diffraction effects around Pluto (about 2300 km in diameter) when it is 40 au from Earth, and a FOV of 3000 km is needed to give a little room around the Pluto image, then N will have to be about 3,000,000. The computer memory required to handle such a case is prohibitive because we need N×N×16 bytes for the matrices — and computing a 3,000,000 × 3,000,000 DFFT is not feasible.

The Trester FOV constraints can even be problematic for common objects in the main asteroid belt. For example, a 100 km diameter asteroid at 3.0 au imaged at a light wavelength of 500 nm has the following Trester parameters for a source plane matrix size of 65536 × 65536.

- N = 65536 gives a FOV of 121.3 km at a resolution of 0.00185 km per pixel

To apply the Trester method to this size input matrix would require about 12 minutes of calculation time on my computer to evaluate the needed DFFT, if I had the needed 70 GB of memory (I don't) to hold the matrix. Note that the resulting FOV is still barely sufficient to hold the asteroid shape and the resulting resolution (185 cm per pixel) is much finer than is needed to adequately sample the diffraction fringes.

Sinc Method — High Level View

The solution to the Fresnel diffraction integral found by Cubillos and Jimenez [3] is simple in form:

$$\mathbf{e^{-ikz}\, W * S * W^T = G}$$

They teach how to calculate the N×N **W** matrix such that the above string of matrix multiplications (dot products of rows times columns) around the N×N source plane matrix **S** results in **G** (the ground plane e-field). The ground plane intensity image is then simply abs(**G**). (**W**^{T} means the transpose of **W**)

Because we only need the ground plane intensity distribution, the global phase factor $\mathbf{e^{-ikz}}$ need not be calculated/included and the **W** matrix is symmetric (**W**^{T} = **W**) so, for our application, the computation becomes:

$$\mathbf{GroundPlaneIntensity = abs(W * S * W)}$$

The matrix elements in **W** are straightforward to calculate even though they involve the Fresnel integral functions S(x) and C(x), but the needed values can be quickly calculated with polynomial evaluations.

The code needed for the above computations is provided in **Sinc-diffraction-module.ipynb** [2].

Sinc Method Optimisations

Two optimisations are available with the Sinc method formulated as above.

The first optimisation is based on the observation that not only is the **W** matrix symmetric, but the values on any given diagonal are also equal. This means that the top row of the **W** matrix can be used to generate all other rows of **W** by a simple rotation operation — so we only need to compute a single row of **W** to know all the values throughout the matrix.

The second, and most significant optimisation, is designed to conserve memory when light curves with many thousands of points are needed and producing a full diffraction image is impractical. We note that:

$$\mathbf{rowFromW * S = rowNew}$$

where the * operator is still a matrix multiplication, but we perform it by computing columns of **S** on an on-demand basis. That means we can calculate the e-field of a single row at the observation plane by the chain of computations:

$$\mathbf{(rowFromW * S = rowNew) * W = rowInG}$$

where the second matrix multiplication utilises columns of **W** computed on demand. Finally, to get the desired light curve intensities, we calculate the absolute value of the e-field. When this optimisation is used, we can skip the full image computation — which sometimes can take an exorbitant amount of time and memory to produce — and content ourselves with a single light curve row. We don't get a pretty image to look at, but for analysing

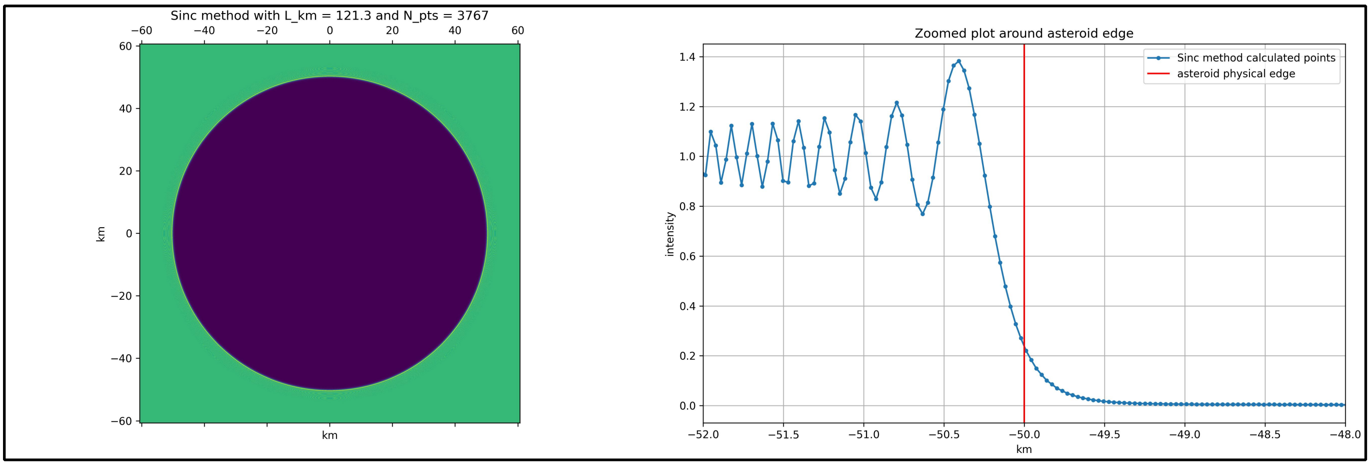

Figure 2. A 100 km main belt object (3.0 au distant) simulated with the Sinc method.

occultation light curves, one only needs to deal with a single row at a time anyway.

Note: as opposed to the Trester method, we have freedom to pick the FOV that is needed to contain a given object, and we have control over the output resolution by choosing an appropriate **N**. Because our interest is usually in diffraction effects and those effects are on the order of the Fresnel length of the observation, I use

$$\mathbf{N} = \frac{\mathbf{FOV}}{\frac{\mathbf{fresnelLength}}{\mathbf{10}}}$$

as a rule-of-thumb in choosing a good starting value for **N**. Applying this rule normally results in well-characterised diffraction effects. Figure 2 shows the Sinc method result obtained when this process is applied to the 100 km diameter main belt object (at 3.0 au with a fresnelLength of 0.335 km @ 500 nm wavelength) that was intractable with the Trester method, but using the rule-of-thumb equation, needs only 3767 points. The parameters of the two methods are:

Method	FOV (km)	N	km per pixel
Trester	121.3	65535	0.335/181
Sinc	121.3	3767	0.335/10.5

Sinc Method — Validation Tests

Test 1 - Infinite Knife Edge

There is a well-known analytic solution for diffraction by an infinite knife edge. In Figure 3, the Sinc solution is shown with the analytic solution overlaid. The agreement is excellent.

Test 2 - Poisson Spot: Compare Sinc Method and Trester Method Results

In this test, we apply both methods to the same problem, that of computing the Poisson spot produced by an object that is only a few Fresnel lengths in radius and compare the results.

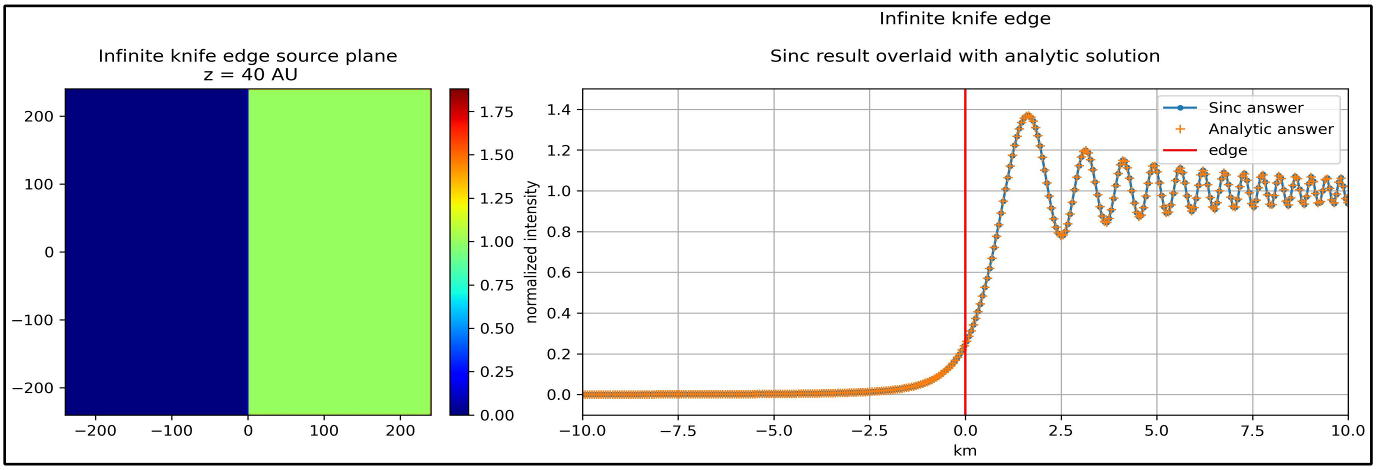

Figure 3. Infinite knife edge test of Sinc method.

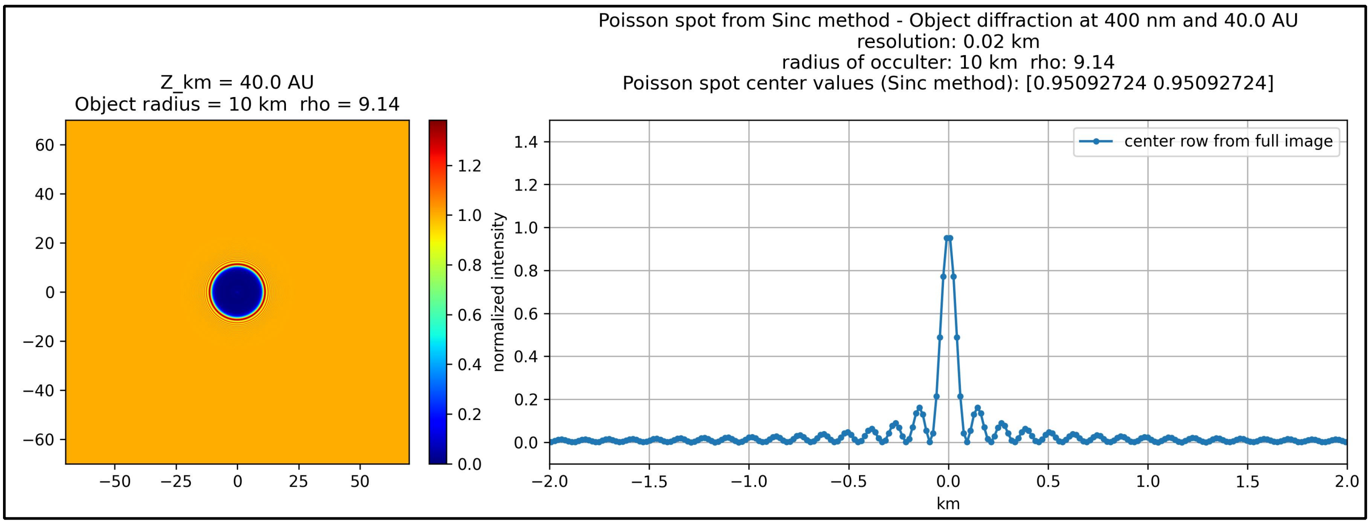

Figure 4. Poisson spot test – Sinc method – report 2 center values.

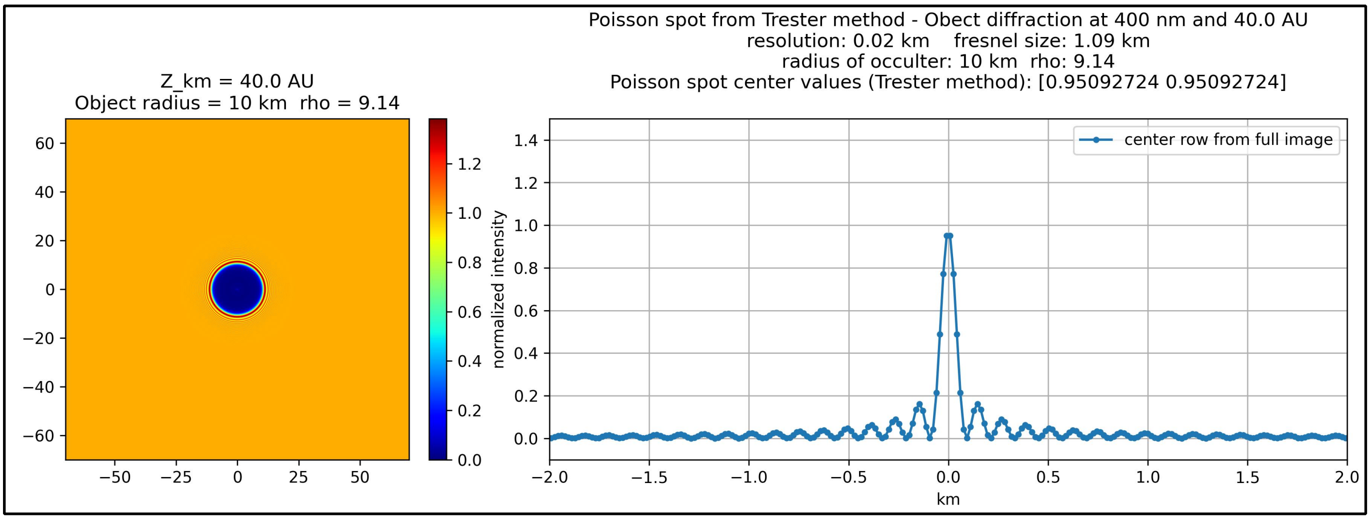

Figure 5. Poisson spot test – Trester method – report 2 center values.

Figure 4 shows the Sinc method result and Figure 5 shows the Trester method result. The visual comparison is convincing, but the quantitative comparison of the two points at the peak of the Poisson spot is even more convincing. All 4 points have an intensity value of 0.95092724. Considering the very different way that those values were calculated, the agreement to 8 decimal places is amazing.

Test 3 - Show Sinc Single Row Calculation Matches Single Row from Full Image

The single row optimisation that is available for the Sinc method is shown (visually) to match the same row extracted from a full image matrix in Figure 6. In addition, every corresponding point in the two rows was compared using the 'nearly equal' function provided in Numpy. The result of that test was that, within floating point precision, the two rows contain identical values.

Summary

This article presents a high-level description of the commonly used Trester method of simulating Fresnel diffraction and compares it with a new method, the Sinc method, of accomplishing the same task. The advantages of the Sinc method over the Trester method are shown by examples. Several tests are presented to validate the use of this new method for stellar occultation analysis. A link to a GitHub repository containing *Python* code for both methods plus code used in generating figures for this article is provided [3].

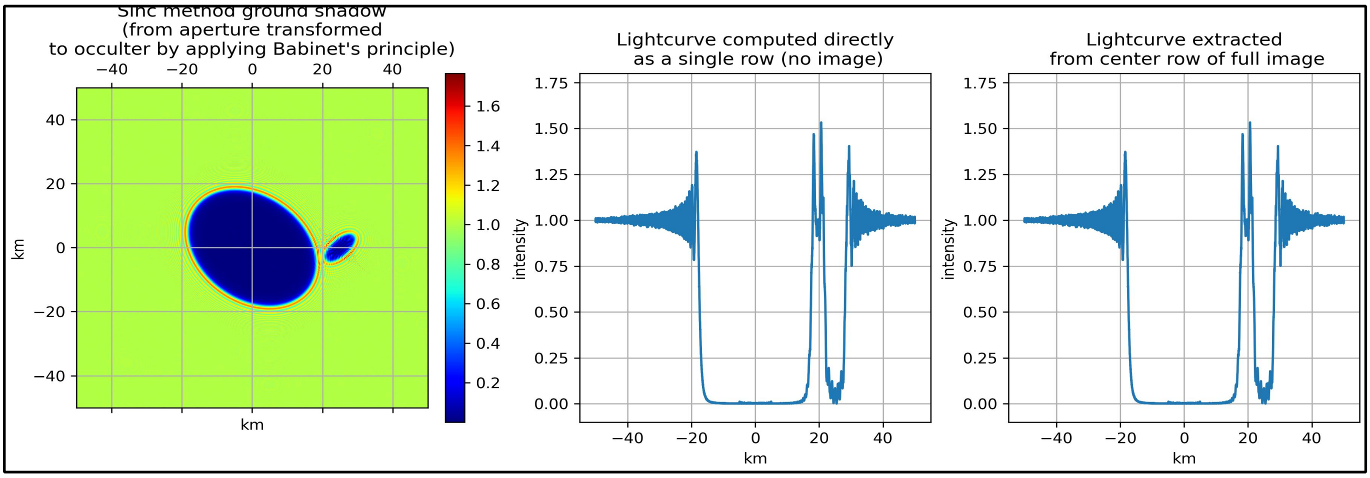

Figure 6. Single row computation versus row extracted from full image.

Acknowledgements

This project benefited from the encouragement and advice of Dr. Eliot F. Young of Southwest Research Institute (SwRI).

Thanks to Teddy Meissner for publishing [4] where he discusses the Sinc method. It provided the starting point for my own Sinc method explorations. While the code in these notebooks differs significantly from Meissner's code, he provided a working example that saved me a lot of time.

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Improvement in VAMOR Process to VAMOR+

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ABSTRACT: In 2023, the authors presented the VAMOR (Validation of Asteroid Models by Occultation Results) method, in which the contact times of stellar occultations by minor planets are added to existing 3D models. The VAMOR process was created with an easy step to process the points from the fundamental plane to the asteroid. This step was a compromise to reduce the workload and streamline the process. Deeper analyses show this assumption is suitable only for spherical bodies. Many of the asteroids and their respective models are elongated, irregularly shaped and sometimes with non-convex zones. Therefore, the VAMOR method was improved to VAMOR+. The results of both methods are presented using the models of the asteroids (22) Kalliope and (24) Themis.

Introduction

Determining the shape and size of minor planets has been an important area of solar system research for many years. However, direct investigation by space probes or high-resolution imaging using adaptive optics (AO) is only possible for a few objects. For the majority of asteroids, the objects' rotation light curves are analysed to determine their shape, and the results from stellar occultations are used to determine their size. The idea behind VAMOR is to use computer-aided design (CAD) software to apply the observation data from the stellar occultations to a 3D model of the celestial body.

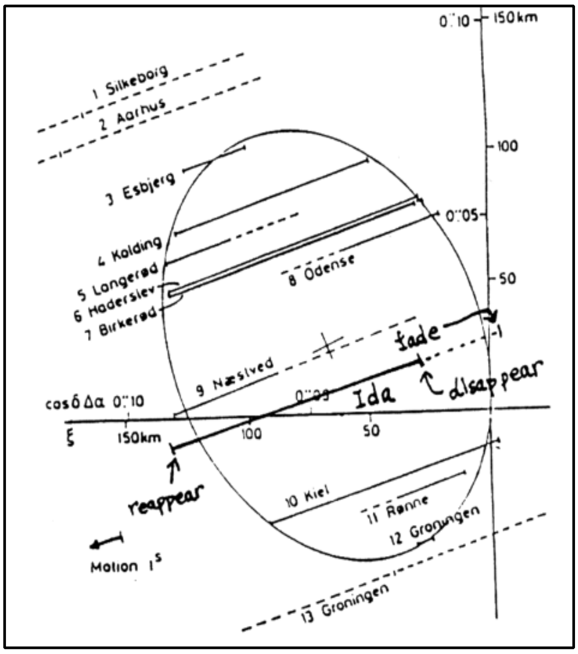

Figure 1. Reduction of the occultation by (106) Dione from 1983 Jan 19 on the fundamental plane.
(L.K. Kristensen)

Using 3D Models for Observation Reduction in the Past

After data review of occultation observations, the results are presented in the fundamental plane. This allows multiple observations obtained by several, spatially-separated observers to be brought together. The times of disappearance and reappearance (hereinafter referred to as data points) represented graphically in this way can be connected with a circle or an ellipse to find the projected silhouette of the occulting asteroid. Such a graphical solution was the first way to find the shape and dimensions of asteroids by occultation observation. Figure 1 shows an early example from 1984 [1].

Today, this graphical solution is possible with the software tool *Occult* [2]. Figure 2 shows such a result as a preliminary data reduction with the best fit ellipse.

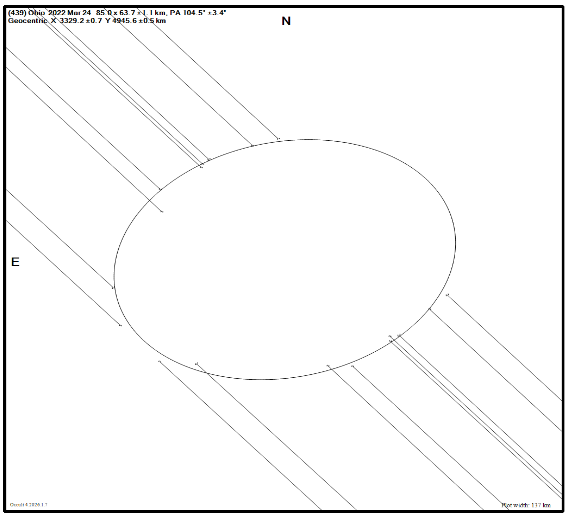

Figure 2. Chords of observations with ellipse in the fundamental plane, from Occult.

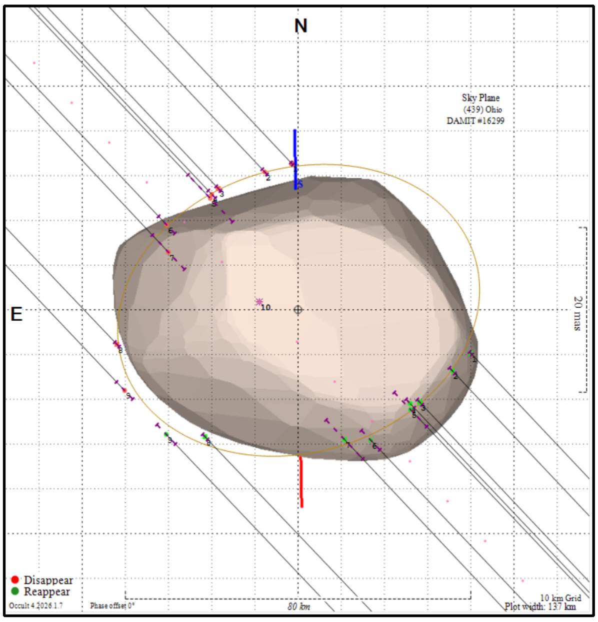

Figure 3. View of the fundamental plane with the fit to the shape model.

At the beginning of our century Kaasalainen and Torppa [3] introduced the light curve inversion method to find asteroid shape models. This was the basis for the Database of Asteroid Models from Inversion Techniques (DAMIT) [4]. Today, DAMIT contains more than 16,000 models for at least 10,000 asteroids (for many asteroids, there is more than one model). The typical model is not scaled in size. If a 3D model, generated from light curves, exists for the observed body, it can be projected onto the fundamental plane. The correct view to the asteroid results from orientation of the asteroid in space, and the rotation and position of the Earth. Figure 3 shows such a fit of the data points to the shape model.

The Original VAMOR Process

As described in [5], VAMOR uses professional 3D CAD software for positioning the observation times of disappearance and reappearance (data points) on 3D models of asteroids. Therefore, the 2-dimensional results in the fundamental plane are one plane in the 3D space and can be connected with the correctly-positioned 3D model (Figure 4).

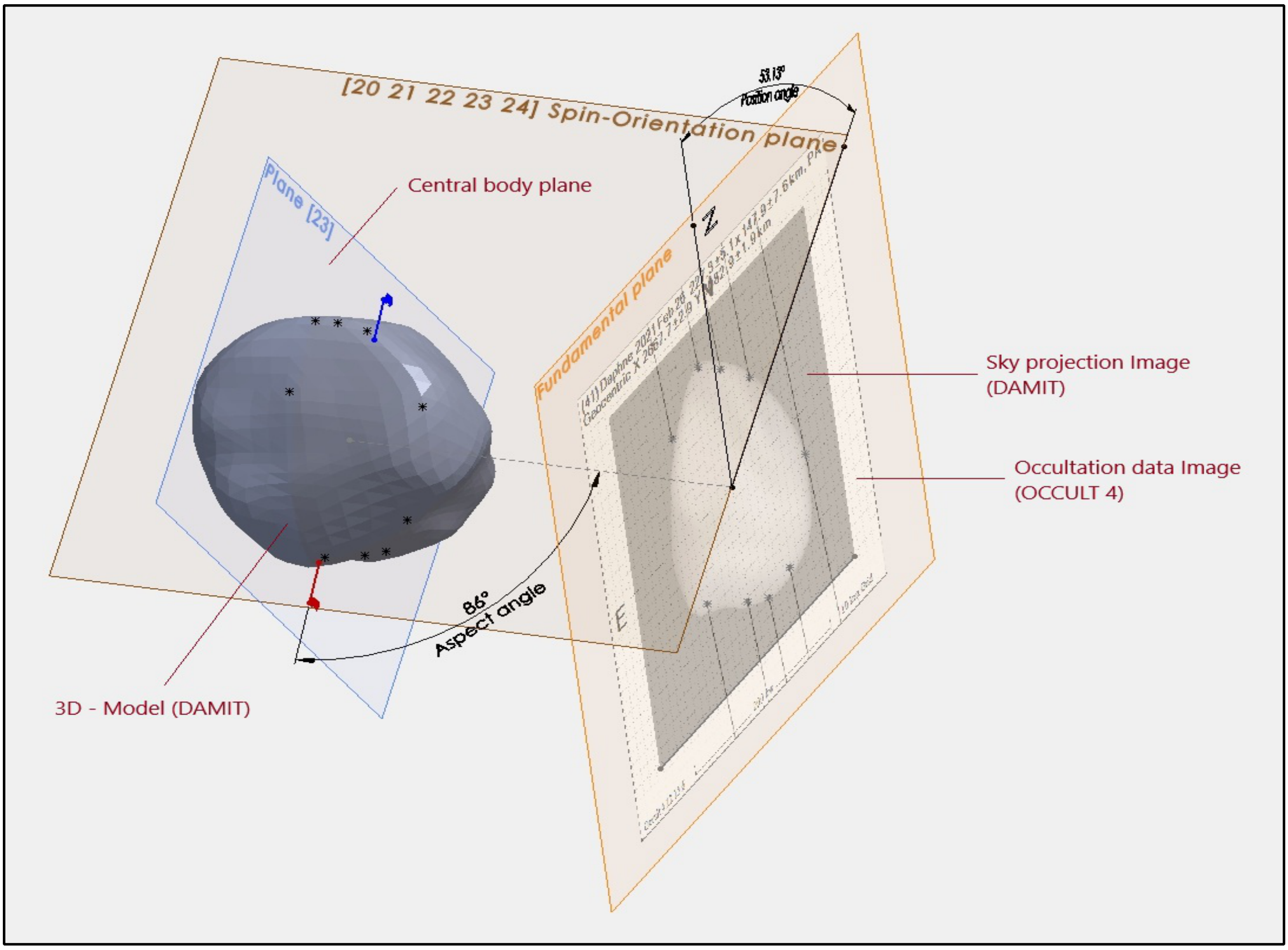

Figure 4. Relationships between fundamental plane (labelled yellow) and model in space.

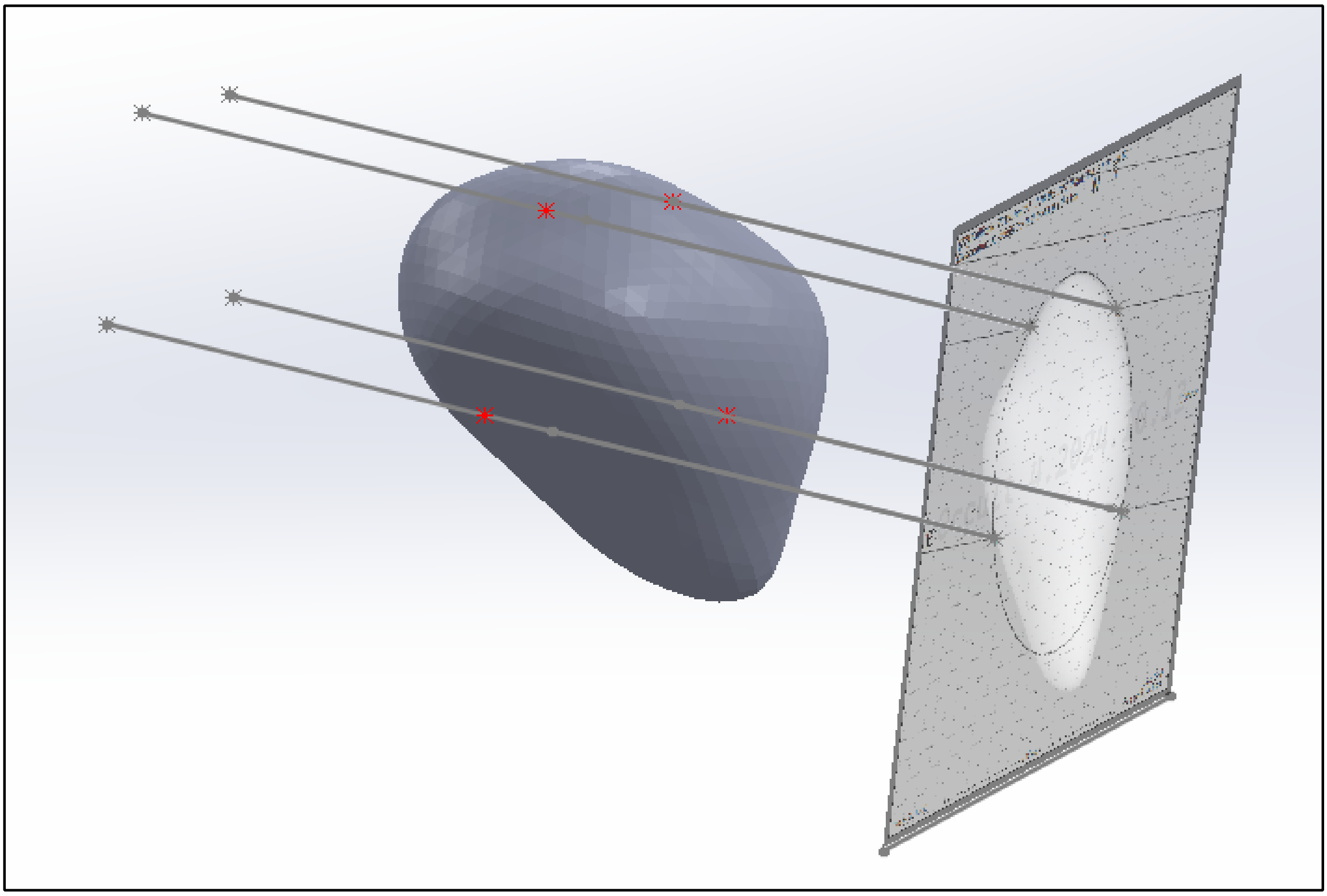

Figure 5. "Auxiliary beams" for data point transformation to find the smallest distance between data point and body.

The transfer of data points was done by transfer to a parallel plane from the fundamental plane. This new plane is positioned in the centre of the body (3D model). This step was a compromise to reduce the workload and streamline the process. Analyses show this assumption is suitable for spherical bodies only. For the more elongated, irregular-shaped bodies or those with non-convex zones such a data point transfer could not show the true shape of the body because of the projection.

Improvement to VAMOR+ and Test on the Model of (22) Kalliope

The projection of the shape model in the fundamental plane comes from a 3D model. This projection is the maximum cross-section along the perpendicular in the direction observer-body (silhouette). The projection depends on shape, rotation phase and inclination of the rotation axis. So, the ray from the observer may hit the body on uncalculated points or (depending on its size) miss it. Only for a near spherical body are the contact points positioned in a plane. For VAMOR+, rays are projected from each data point perpendicular to the fundamental plane to the 3D model. The transferred data points are positioned on the ray and movable along the ray to find the smallest distance between point and surface (body) (Figure 5).

This allows the data point to be positioned on the body where the event was most likely measured. The data points are not positioned on the centre plane any more but can be freely positioned up to the closest distance to the model. To test the method, we selected (22) Kalliope as an elongated asteroid with a well-known 3D model. This 3D model is based on light curve analyses, AO-imaging, mutual occultation and transit events of (22) Kalliope and its satellite Linus [6].

The 3D program allows the distance to the surface of the model to be determined for each data point. The average of all distances is shown in Table 1.

	Datapoints	Average Distance	RMS
VAMOR	128	4.19 km	5.55
VAMOR+	128	2.89 km	4.10

Table 1. Average distance on DAMIT model 16282 of (22) Kalliope.

The model of the minor planet is of high quality (quality flag 4 in DAMIT). This means that the significantly smaller deviation of the values from the body is an indication of the improvement from VAMOR to VAMOR+.

Comparison of Methods for Spherical Objects

We tested both methods on an object with a more spherical shape. The selected asteroid is (24) Themis. The DAMIT model 5916 also has a quality flag of 4 and the 8 multi-chord occultation observations give 76 data points. Table 2 shows the results of both methods.

With both methods the scaling of 100% gives the lowest average distance of data points from the surface. The RMS value for the 100% scaling is the same for both methods. The exact 3D-model is fitted a little bit better by VAMOR+, but the VAMOR result would also be acceptable because it is in any case within all possible tolerances.

The greatest inaccuracy is the exact timing of the occultations. On average, a time tolerance of 100 ms means a resolution of approximately one kilometre on the asteroid.

Conclusions

With the new data point transfer method in VAMOR+ it is possible to more accurately match observation results to the 3D-model surface. So, further investigation like symmetric and asymmetric scaling or correction on the model shape are possible. For nearly spherical objects, the less labour-intensive VAMOR method can be used. A future task is to investigate at what level of deviation from the spherical shape does VAMOR+ have to be applied.

Scaling of Diameter	99%	100%	101%
VAMOR av.dist./RMS	3.25 km/3.84	3.16 km/3.87	3.28 km/4.17
VAMOR+ av.dist./RMS	3.16 km/3.77	3.14 km/3.87	3.30 km/4.23

Table 2. Average distance on DAMIT model 5916 of (24) Themis.

Event	Date	Time	Chords	Observer	Country
2	2006-11-07	19:48:00	6	M. Kashiwagura, S. Uchiyama, A. Yaeza, H. Sato, H. Tomioka, H. Okita, M. Sato	JP
4	2011-11-22	02:42:00	4	B. Brinkmann, O. Klös, J. Mueller, M. Parl	DE
5	2016-11-08	03:40:00	4	G. Baruffetti, D. Vizzoni,	IT
				J. Polák, M. Rottenborn, S. Smid, R. Neuvirt, K. Halíř	CZ
6	2016-12-24	22:04:00	10	H. Kavi, S. Kamat/M. Gavali, P. Bhagat/N. Ghol, M. Tembe/M. Gundecha, M. Petanka/K. Jogdel, S. Deshpande/H. Kulkar, M. Inandar/T. Nirokh, P. Maley/S. Gurjar, P. Nanivedekar/Ningole, S. Kulkarni, V. Shende/S. Nondode, D. Khaimar/ V. Anjali	IN
8	2019-02-16	16:14:00	2	J. Broughton	AU
9	2019-06-27	10:44:00	2	J. Broughton	AU
14	2021-09-09	18:46:00	2	M. Ida, H. Watanabe	JP
15	2021-12-14	09:24:00	3	D. Oesper, M. Loose, A. Olsen, J. Randolph	US
16	2022-03-02	02:33:00	9	J. Barton, T. Blank, N. Carlson, D. Dunham, J. Dunham, K. McKeown, P. Stuart, T. George, D. Kenyon, R. Jones, C. McPartlin	US
17	2022-04-15	21:08:00	11	A. Leroy	FR
				R. Boninsegna	BE
				S. Kidd, W. Stewart, T. Haymes, P. Tickner, P. Birtwhistle, D. Ward	UK
				S. Sposetti, A. Ossola	CH
				P. Fini/G. Betti	IT
18	2022-04-22	10:53:00	5	H. Tomioka, A. Hashimoto, H. Watanabe, A. Asahi	JP
20	2023-03-19	13:19:00	2	J. Broughton, G. McKay, W. Hanna	US
21	2023-04-20	11:47:00	11	K. Kitazaki, Hiroyuki Watanabe, H. Yamamura, A. Asahi, M. Ida, Hayato Watanabe, Y. Ikari, H. Kishimoto, H. Kasebe, M. Yamashita, M. Mizutani, G. Hashimoto	JP

Appendix A. Observers of the multi-chord events which were used for the investigation of (22) Kalliope.

Event	Date	Time UT	Chords	Observer	Country
5	2015-04-30	08:20:00	3	T. George, E. Iverson, R. Wasson, P. Maley	US
6	2015-09-24	12:07:00	2	J. Broughton	AU
8	2016-07-31	02:13:00	4	R. Neuvirt, K. Halíř, T. Janík	CZ
				E. Frappa	FR
9	2021-04-09	18:03:00	6	A. Asahi, M. ida, Y. Ikari, K. Isobe, T. Terada, G. Hashimoto	JP
13	2021-08-01	14:44:00	2	H. Yamamura, Y. Ikari	JP
14	2021-10-07	03:56:00	3	J. Barton, D. Eisfeld, E. Iverson	US
15	2024-02-14	02:13:00	4	P. Maley, R. Harvey, R. McConnell, L. Dorsey	US
16	2024-02-28	10:21:00	15	K. Kitazaki, Hiroyuki Watanabe, M. Ishida, M. Ida, Y. Ikari, H. Yamamura, M. Takimoto, M. Ovada, G. Hashimoto, H. Yoshihara, K. Isobe, M. Uno, H. Watanabe, T. Horikawa	JP

Appendix B. Observers of the multi-chord events which were used for the investigation of (24) Themis.

References

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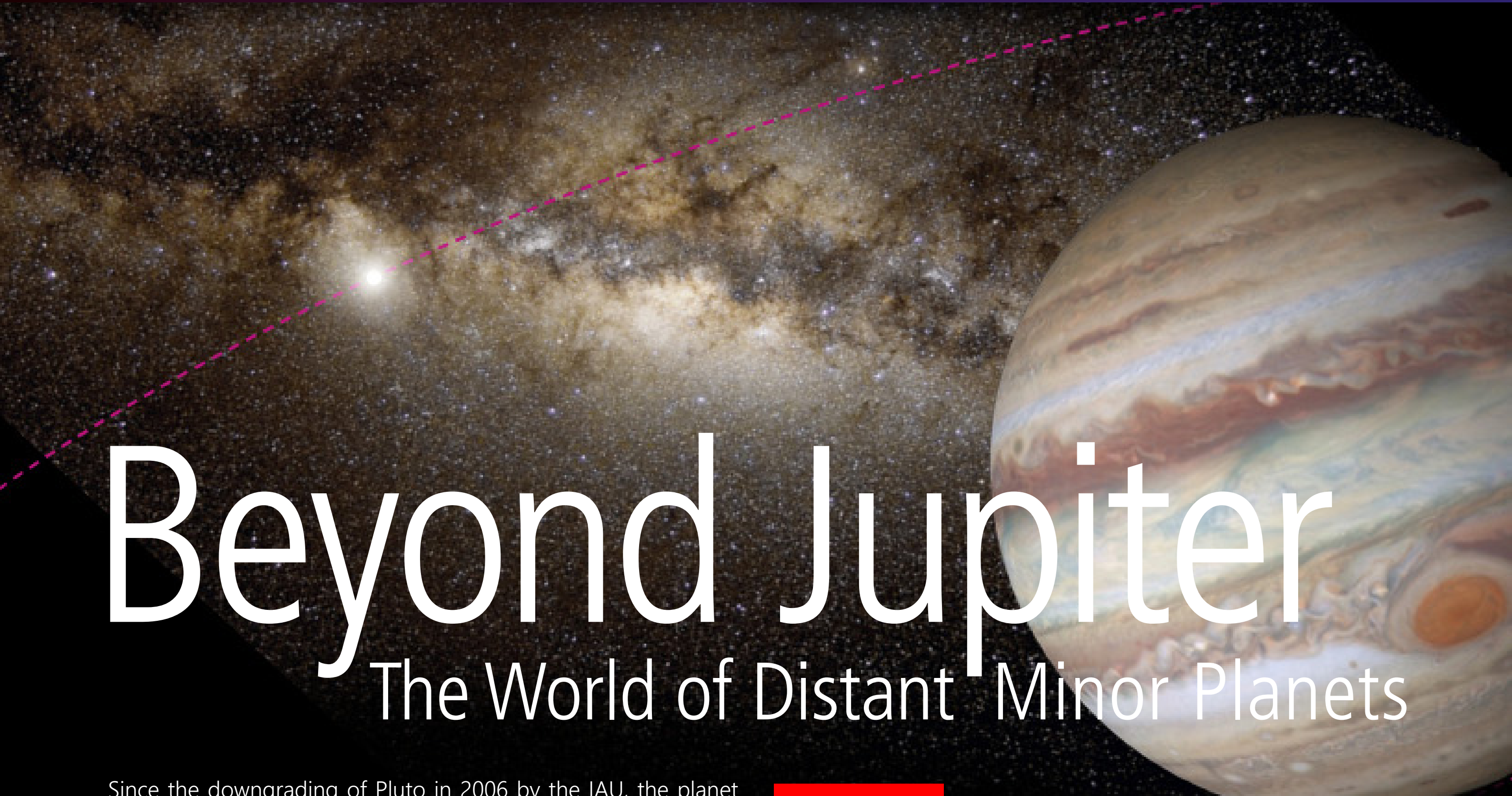

Beyond Jupiter

The World of Distant Minor Planets

Since the downgrading of Pluto in 2006 by the IAU, the planet Neptune marks the end of the zone of planets. Beyond Neptune, the world of icy large and small bodies, with and without an atmosphere (called Trans-Neptunian Objects or TNOs) starts. This zone between Jupiter and Neptune is also host to mysterious objects, namely the Centaurs and the Neptune Trojans. All of these groups are summarised as "distant minor planets". Occultation observers investigate these members of our solar system, without ever using a spacecraft. The sheer number of these minor planets is huge. As of 2026 March 24, the *Minor Planet Center* listed 2044 Centaurs and 3816 TNOs.

In the coming years, JOA wants to portray a member of this world in every issue; needless to say not all of them will get an article here. The table shows you where to find the objects presented in former JOA issues. (KG)

No.	Name	Author	Link to Issue
944	Hidalgo	Oliver Klös	JOA 1 2019
2060	Chiron	Mike Kretlow	JOA 2 2020
5145	Pholus	Konrad Guhl	JOA 2 2016
5335	Damocles	Oliver Klös	JOA 2 2023
7066	Nessus	Konrad Guhl	JOA 1 2024
8405	Asbolus	Oliver Klös	JOA 3 2016
10370	Hylonome	Konrad Guhl	JOA 3 2021
10199	Chariklo	Mike Kretlow	JOA 1 2017
15760	Albion	Nikolai Wünsche	JOA 4 2019
15810	Awran	Konrad Guhl	JOA 4 2021
20000	Varuna	Andre Knöfel	JOA 2 2017
28728	Ixion	Nikolai Wünsche	JOA 2 2018
31824	Elatus	Konrad Guhl	JOA 2 2025
32532	Thereus	Konrad Guhl	JOA 1 2023
38628	Huya	Christian Weber	JOA 2 2021
47171	Lempo	Oliver Klös	JOA 4 2020
49036	Pelion	Joachim Siegert	JOA 4 2025
50000	Quaoar	Mike Kretlow	JOA 1 2020
53311	Deucalion	Konrad Guhl	JOA 2 2024
54598	Bienor	Konrad Guhl	JOA 3 2018
55576	Amycus	Konrad Guhl	JOA 1 2021

In this Issue:

(225088) Gonggong

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Görlitz · Germany · mike@kretlow.de

ABSTRACT: (225088) Gonggong (provisional designation 2007 OR_{10}) is one of the largest known trans-Neptunian objects and a strong dwarf-planet candidate. With an effective diameter close to 1230 km, a highly eccentric and inclined orbit, an unusually slow rotation, and a distinctly red surface, (225088) Gonggong represents a notable example among the more massive bodies of the scattered disk. The discovery of its satellite Xiangliu provides critical constraints on its mass and bulk density. This article reviews the discovery, orbital properties, physical characteristics, satellite system, and the current status of stellar occultation observations.

No.	Name	Author	Link to Issue
58534	Logos & Zoe	Konrad Guhl	JOA 4 2023
60558	Echeclus	Oliver Klös	JOA 4 2017
65489	Ceto and Phorcys	Konrad Guhl	JOA 1 2025
90377	Sedna	Mike Kretlow	JOA 3 2020
90482	Orcus	Konrad Guhl	JOA 3 2017
120347	Salacia	Andrea Guhl	JOA 4 2016
121725	Aphidas	Konrad Guhl	JOA 1 2026
134340	Pluto	Andre Knöfel	JOA 2 2019
136108	Haumea	Mike Kretlow	JOA 3 2019
136199	Eris	Andre Knöfel	JOA 1 2018
136472	Makemake	Christoph Bittner	JOA 4 2018
174567	Varda	Christian Weber	JOA 2 2022
208996	2003 AZ_8	Sven Andersson	JOA 3 2022
229762	G!kúnǁ'hòmdímà	Konrad Guhl	JOA 3 2025
341520	Mors-Somnus	Konrad Guhl	JOA 4 2022
471143	Dziewanna	Wojciech Burzyński	JOA 3 2024
486958	Arrokoth	Julia Perła	JOA 3 2023
-	2004 XR_{190}	Carles Schnabel	JOA 1 2022
541132	Leleākūhonua	Konrad Guhl	JOA 4 2024

The Discovery

(225088) Gonggong was discovered on 2007 July 17 by M. E. Schwamb, M. E. Brown, and D. L. Rabinowitz during a wide-field survey for distant Solar System bodies conducted with the 1.2-m *Samuel Oschin Telescope* at *Palomar Observatory* [1]. Following its initial identification, (225088) Gonggong was found on pre-discovery images dating back to 1985, extending its observational arc by more than two decades.

The Name

The object's naming followed a public vote organised by the discovery team, offering three mythological candidates. Gonggong was selected and formally approved by the International Astronomical Union on 2020 February 5. In Chinese mythology, Gonggong is a Chinese water god with red hair and a serpent-like tail. He is known for creating chaos, causing flooding, and tilting the Earth; he is often depicted with the head of a human and the body of a snake. Gonggong is often attended by his minister, Xiangliu, a nine-headed poisonous snake monster for whom the satellite is named. The name reflects both the object's reddish appearance and its remote, dynamically excited orbit in the outer Solar System.

The Orbit and the Dynamical Classification

(225088) Gonggong follows a highly eccentric and inclined orbit, placing it among the dynamically excited populations beyond Neptune (Figure 1). Its approximate orbital elements at current epoch are a semi-major axis of about 67 au, an eccentricity of about 0.50, an inclination of about 31 degrees, a perihelion distance near 33 au, and an aphelion distance close to 101 au. The resulting orbital period is roughly 550 years.

These parameters classify (225088) Gonggong as a scattered-disk object (SDO) [2],[3]. Its perihelion lies just beyond Neptune's orbit, but the object is sufficiently detached to avoid strong present-day scattering. Numerical integrations suggest that (225088) Gonggong may reside near a weak or transient 10:3 mean-motion resonance with Neptune. Objects in this region were likely scattered outward during the epoch of planetary migration [4], leading to long-term chaotic evolution. The large inclination of (225088) Gonggong's orbit supports a history of strong dynamical excitation rather than formation in situ.

With an absolute magnitude of about H = 1.8 mag, (225088) Gonggong is one of the brightest and largest known scattered-disk objects, comparable in scale to (136472) Makemake and (136108) Haumea, although dynamically distinct from the classical Kuiper Belt population. Given its size, (225088) Gonggong is considered a strong dwarf-planet candidate.

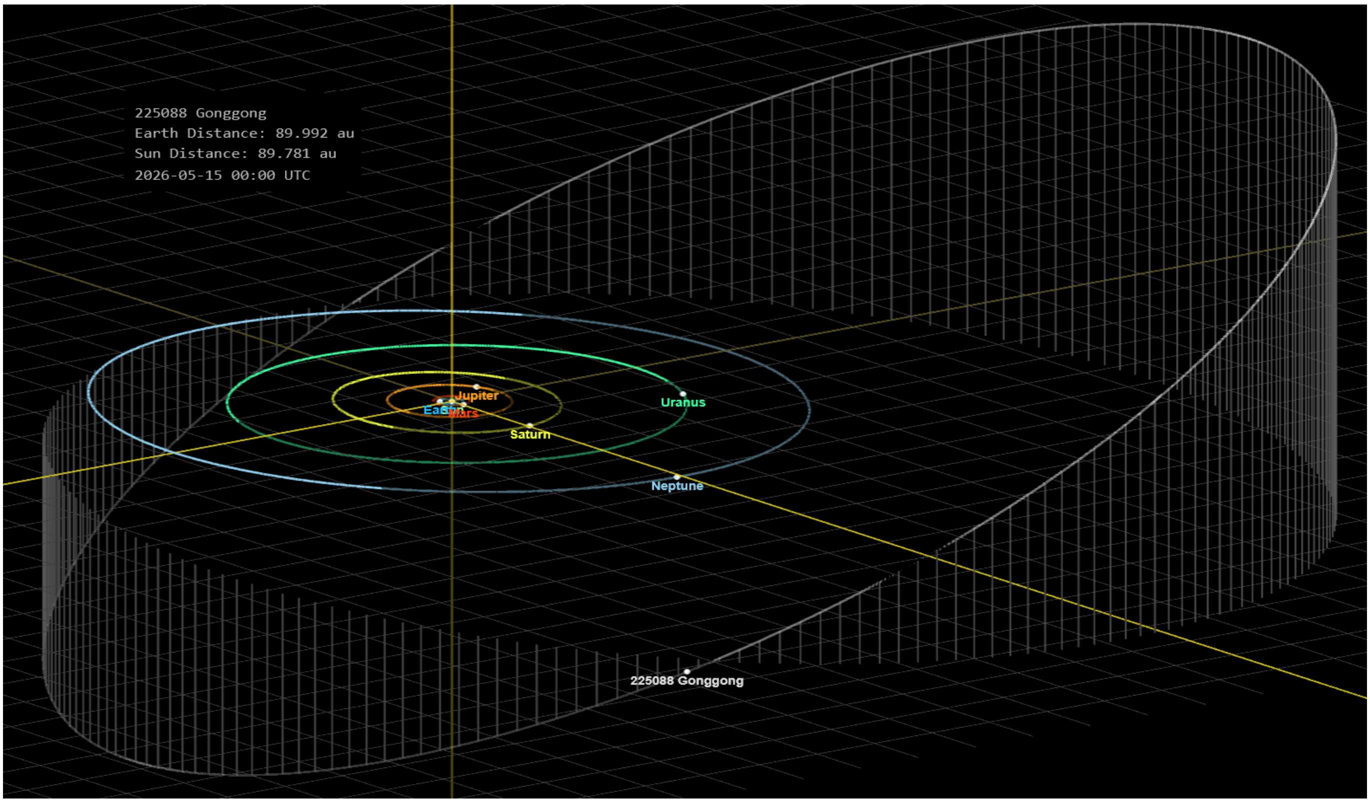


Figure 1. Orbit of (225088) Gonggong as shown in the JPL Small-Body Database orbit viewer for the date 2026 May 15. The grid indicates the ecliptic plane. (Source: https://ssd.jpl.nasa.gov/tools/sbdb_lookup.html#/?sstr=gonggong&view=VOSPD)

The Physical Characteristics

Infrared observations obtained with the *Herschel Space Observatory*, together with data from the *Kepler K2* mission, initially suggested an effective diameter of approximately 1535 km, with uncertainties of +75 and -225 km, and a geometric albedo near 0.09 [5]. Following the discovery of a satellite in *Hubble Space Telescope* year 2010 images (Figure 2), these estimates were revised to a diameter of 1230 ± 50 km and a higher albedo of about 0.14 [6]. Earlier radiometric determinations covered a broad range of values, but the availability of satellite-based constraints significantly improved the reliability of the later results.

Light-curve observations indicate a slow rotation, with a preferred double-peaked period of approximately 44.8 hours [5], while a single-peaked solution with a period of about 22.4 hours cannot be entirely ruled out; in either case, the rotation is unusually slow for a trans-Neptunian object of this size.

Early photometric observations showed (225088) Gonggong to possess a very red spectral slope, among the reddest known for large trans-Neptunian objects. Near-infrared spectra of (225088) Gonggong exhibit broad absorption bands at ~1.5 and ~2.0 µm that are characteristic of water ice on the surface, along with a very red spectral slope commonly interpreted as the presence of complex organic material produced by irradiation of surface ices. Some observations have suggested a weak absorption feature near ~2.27 µm that has been attributed to methanol or its irradiation products, although this identification remains tentative due to limited signal-to-noise in the available data [7].

Based on its large size and mass, and the likely presence of surface and/or subsurface ices, (225088) Gonggong could in principle sustain a very tenuous, transient atmosphere during epochs when it is closer to perihelion, although no such atmosphere has been detected to date; from Earth, any such atmosphere would most plausibly be detectable only through stellar occultation observations.

Moons and Rings

(225088) Gonggong has one known satellite. The discovery of its natural moon, Xiangliu, named after the nine-headed serpent who served Gonggong in Chinese mythology, was announced in 2016/2017 following a reanalysis of archived *Hubble Space Telescope* images acquired in 2010 [8]. Xiangliu orbits (225088) Gonggong with a semi-major axis of approximately 24,000 km, an eccentricity of about 0.3, and an estimated orbital period of roughly 25 days. These orbital parameters imply a total system mass of approximately 1.75×10^{21} kg. Assuming an effective diameter of 1230 ± 50 km for (225088) Gonggong, the corresponding bulk density of about 1.75 g cm^{-3} appears more plausible for an object of this size than densities below ~1 g cm^{-3} implied by earlier diameter estimates near 1535 km [6].

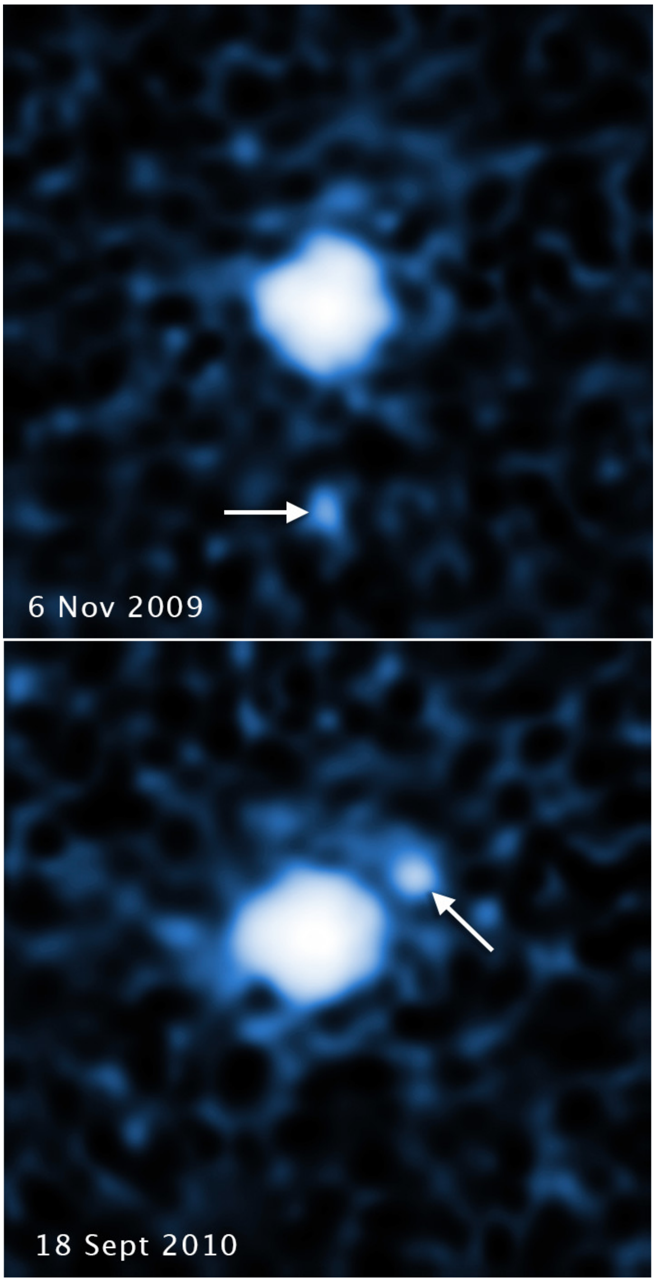
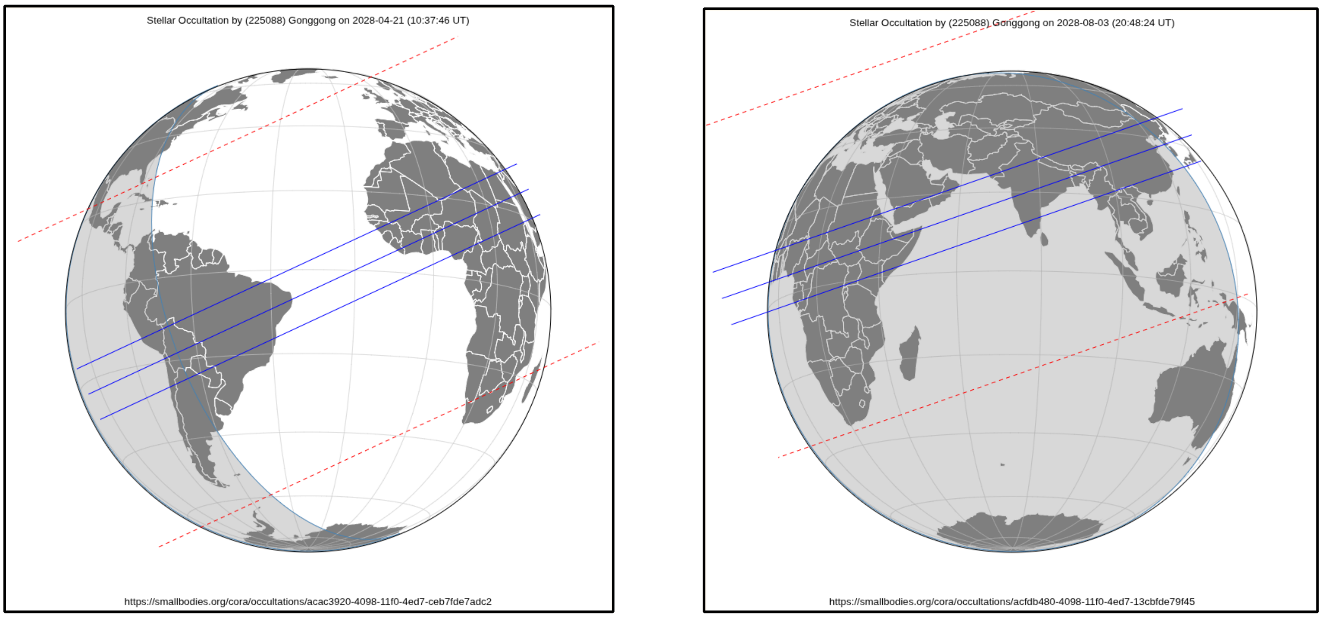


Figure 2. These two images, taken a year apart, reveal a moon orbiting the trans-Neptunian object 2007 OR$_{10}$. Each image, taken by the NASA/ESA Hubble Space Telescope's Wide Field Camera 3, shows the companion in a different orbital position around its parent body. Credit: NASA, ESA, C. Kiss (Konkoly Observatory), and J. Stansberry (STScI)

Based on dynamical considerations, the authors further conclude that the satellite is relatively small, with a diameter below 100 km, and likely possesses a comparatively high geometric albedo ($p_V > 0.2$).

No ring system is yet known, but to discover a potential ring (system) from Earth, this would only be possible during the observation of a stellar occultation.



Figures 3, 4. Occultations by (225088) *Gonggong on 2028-04-21 (left) and 2028-08-03 (right) as predicted by CORA. For the predictions, a larger diameter of about 1470 km was still assumed, rather than the currently favoured value of approximately 1230 km for the primary, as discussed in the text.*

Stellar Occultations

To date, no stellar occultation by (225088) Gonggong has been successfully observed. The most recent dedicated campaign took place on 2024 October 7, as described in a separate JOA article in this issue, but did not yield a positive detection. Future efforts to observe a stellar occultation by (225088) Gonggong are highly valuable, as even a single multi-chord event could provide decisive constraints on its size, shape, possible atmosphere, and the presence of rings. On the CORA (Collaborative Occultation Resources and Archive) website [9], predictions for TNO and Centaur occultations are available. For (225088) Gonggong, only two events (worldwide) are listed through 2029 December 31, for stars brighter than 18 G-mag (Table 1).

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[2] Lykawka, P. S., & Mukai, T. (2007). Icarus, 189, 213.

[3] Volk, K., & Malhotra, R. (2012). Icarus, 221, 106.

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[6] [8] Kiss, C. et al. (2019). The mass and density of the dwarf planet (225088) 2007 OR10. Icarus, vol. 334, 3–10.

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[8] Kiss, C., et al. (2017). ApJL, 838, L1.

[9] Kretlow, M., Collaborative Occultation Resources and Archive (CORA) https://smallbodies.org/cora

Date	T0 (UT)	Star Mag	ΔMag	Max Duration	Moon	URL	Figure
2028-04-21	10:37:46	15.15	6.36	75.6 s	18° (11%)	1	3
2028-08-03	20:48:24	16.75	4.71	59.4 s	41° (98%)	2	4

Table 1. Future occultation opportunities for (225088) Gonggong (stars brighter than 18 G-mag). T0 is the time of geocentric closest approach (c/a). The column 'Moon' indicates the elongation of the Moon to the star and the percent sunlit in ().

1: https://smallbodies.org/cora/occultations/acac3920-4098-11f0-4ed7-ceb7fde7adc2/

2: https://smallbodies.org/cora/occultations/acfdb480-4098-11f0-4ed7-13cbfde79f45/

News

Latest Discoveries of Binary Asteroids by Occultation Observations

The Central Bureau for Astronomical Telegrams has announced four further discoveries of satellites of asteroids, made following the analysis of stellar occultation observations. The discoveries are presented in the order in which they were announced..

On 2025 July 12, Josef Käser and Jonas Schenker observed an occultation by asteroid (108968) 2001 PE$_{40}$ using a 45-cm telescope from Switzerland. They recorded an occultation duration of 1.10 s for the main body and 0.21 s for the satellite. Martin Gutekunst in Germany was able to confirm the satellite during the same event with an observation of 1.14 s and only 0.09 s, respectively. The discovery by the three observers was announced with CBET 5589.

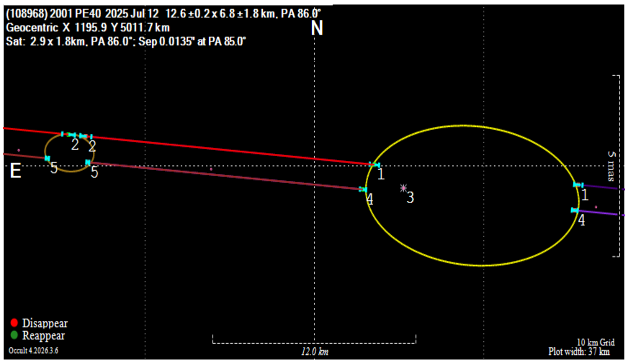


Figure 1. Profile of (108968) 2001 PE$_{40}$ and its satellite. Chords 1 and 2 were recorded by Martin Gutekunst while Josef Käser and Jonas Schenker measured chords 4 and 5.

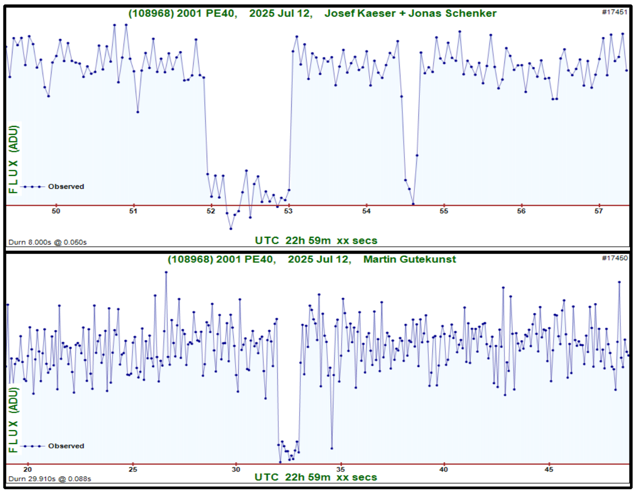


Figure 2. The lightcurves of the discovery of the satellite of (108968) 2001 PE$_{40}$. Note the single data point drop by the satellite in Martin Gutekunst's lightcurve.

Hristo Pavlov, Peter Nosworthy, and Dave Gault, Trans-Tasman Occultation Alliance (TTOA), recorded an occultation by asteroid (60186) Las Cruces on 2025 June 26. Whilst Dave Gault recorded a miss, Peter Nosworthy measured a positive chord for the main body with a duration of 1.60 s. Hristo Pavlov recorded only a short occultation of 0.24 s by the satellite in three frames. The discovery was announced with CBET 5629.

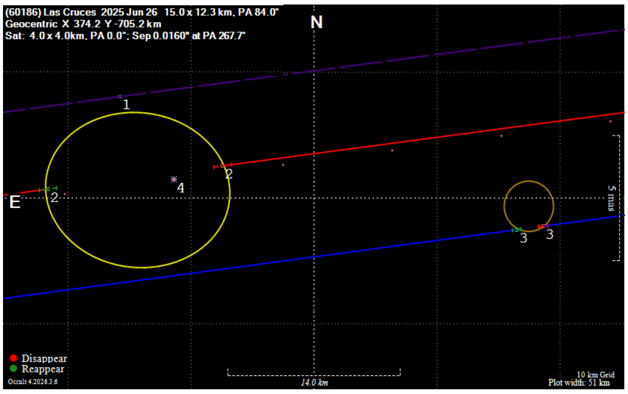


Figure 3. Profile of (60186) La Cruces and its satellite. Chord 4 represents the predicted centre line.

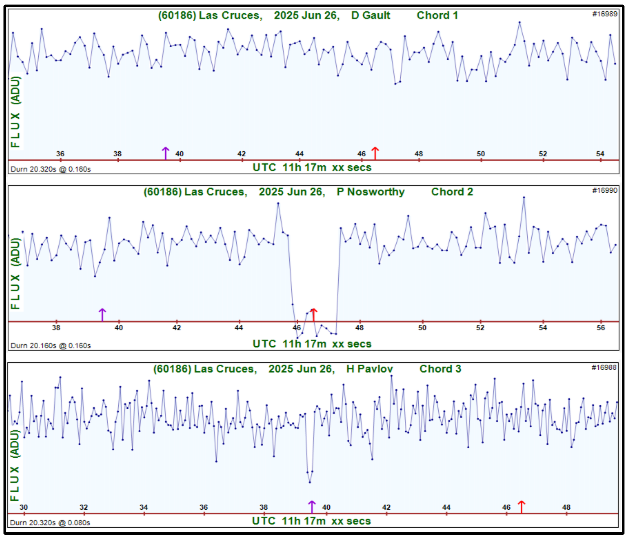


Figure 4. The lightcurve at the top shows Dave Gault's negative observation. Peter Nosworthy's measurement shows the occultation by the main body of (60186) La Cruces (chord 2). The curve at the bottom presents the 3-frame-occultation by the satellite recorded by Hristo Pavlov (chord 3). The bright red arrows mark the event time for the main body.

News

On 2024 April 25, George Viscome observed an occultation by asteroid (7563) 1988 BC. He was able to measure two consecutive occultation events with durations of 2.48 s and 0.25 s, respectively. The time interval between the two events was 3.49 s. The single-observation-discovery was published in CBET 5654.

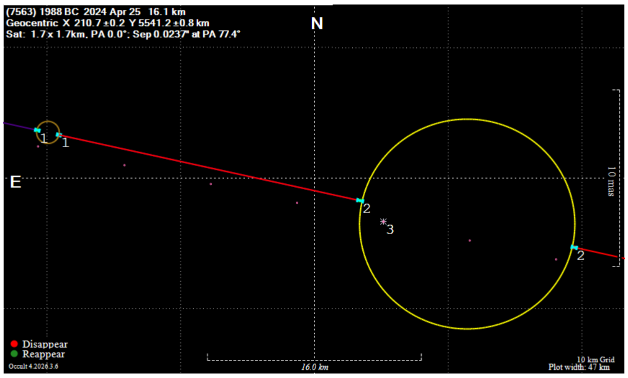


Figure 5. Profile of George Viscome's measurement of the stellar occultation by asteroid (7563) 1988 BC (chord 2) and its satellite (chord 1). The predicted centre line of the event is shown as chord 3.

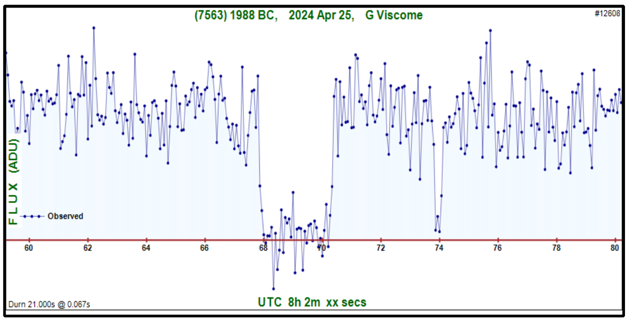


Figure 6. The lightcurves of the discovery of the satellite of (7563) 1988 BC. Four data points around 74 s on the x-axis clearly show the occultation by the satellite.

Another single-observation-discovery was made by Simon Kidd on 2025 December 03. Two events, each less than one second, were recorded during an occultation by asteroid (50142) 2000 AY$_{129}$. The first event lasted only 0.13 s and was followed 0.29 s later by a second occultation with a duration of 0.53 s. The discovery of the satellite was announced in CBET 5656.

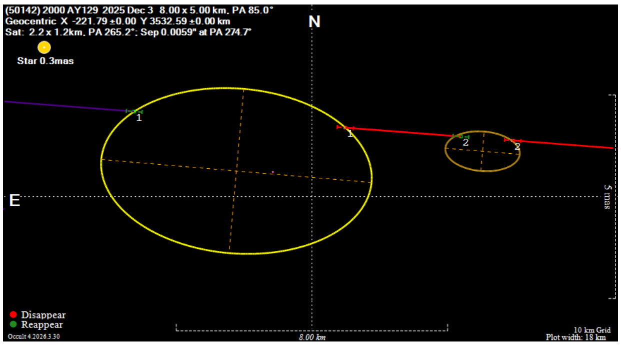


Figure 7. Profile of (50142) 2000 AY$_{129}$ and its satellite.

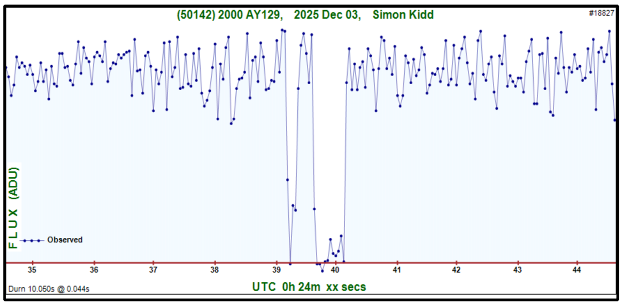


Figure 8. The lightcurve of the discovery of the satellite of asteroid (50142) 2000 AY$_{129}$ on 2025 Dec 03. The two events are separated by only six data points.

All plots are from *Occult V4*.

Access to the 50 most recent CBETs is available here:

http://www.cbat.eps.harvard.edu/cbet/RecentCBETs.html

(O. Klös)

News

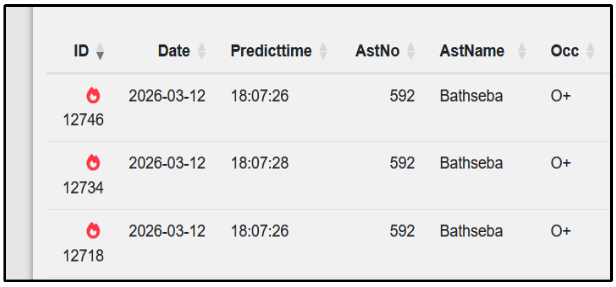
New Function in the Stellar Occultation Data Input System (SODIS)

The SODIS team at IOTA/ES has introduced a new feature on the SODIS portal: observers and reviewers can flag a positive observation as a 'Hot Case' (HC).

A 'HC' refers to an unusual light curve, an unexpectedly low drop, multiple occultations or similar occurrences. After clicking the HC button on the SODIS page of the report, a newly created "Hot Case Task Force (HCTF)", comprising experienced reviewers will analyse the light curve in more detail. The new features for the SODIS users were presented in a Zoom meeting.

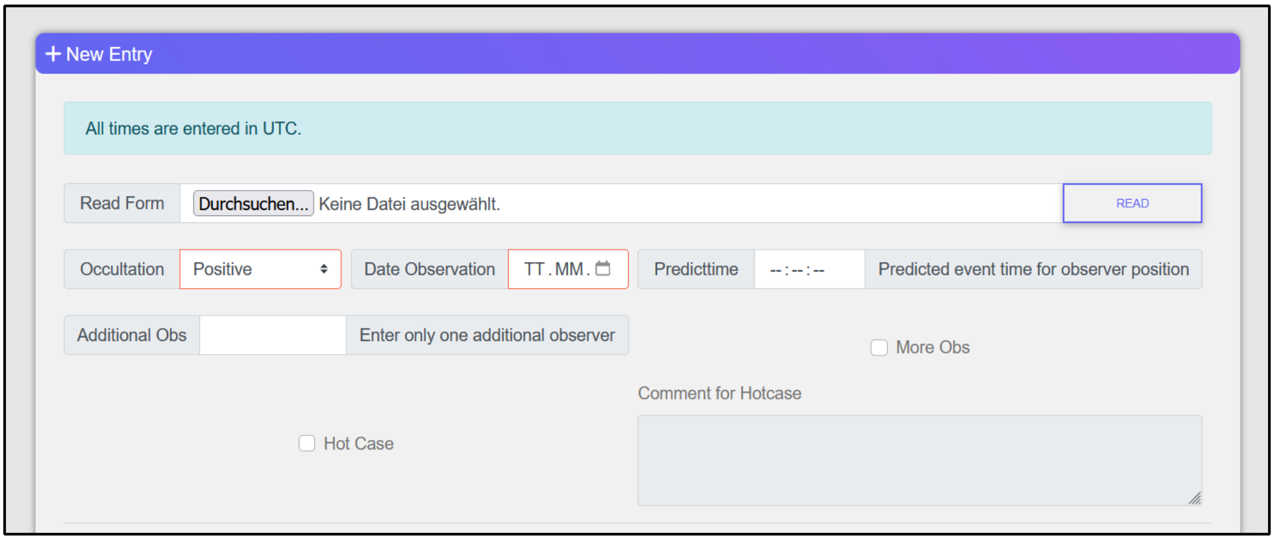
The HCTF currently has eight members and is led by Christian Weber. To date, 30 cases have been investigated; the results will be reported in future journals.

(C. Weber, K. Guhl)



ID	Date	Predicttime	AstNo	AstName	Occ
🔥 12746	2026-03-12	18:07:26	592	Bathseba	O+
🔥 12734	2026-03-12	18:07:28	592	Bathseba	O+
🔥 12718	2026-03-12	18:07:26	592	Bathseba	O+

Figure 2. A marker in the ID column flags an entry on the main page of the SODIS portal if an observation was marked as a 'Hot Case'. An observation only becomes a 'Hot Case' once it has been recognised by HCTF, which assigns it the 'Hot Case' status.



+ New Entry

All times are entered in UTC.

Read Form | Durchsuchen... Keine Datei ausgewählt. | READ

Occultation: Positive

Date Observation: TT.MM.

Predicttime: --:--:-- | Predicted event time for observer position

Additional Obs: | Enter only one additional observer

☐ More Obs

Comment for Hotcase

☐ Hot Case

Figure 1. An observer can mark an observation as a potential 'Hot Case' in the report form using the 'Hot Case' button. Additional information explaining why this observation should be analysed by the Task Force should be provided in the 'Comment for Hotcase' field. This entry can be made in a new report or by editing a report already in the database, and can be made by the observer or the reviewer of the event. Once the HCTF has accepted the event as a 'Hot Case', the observation is flagged (see Figure 2).

News

Occultation Observations with Smart Telescope Seestar S50
A First Test Report

Christian Weber (IOTA/ES) has published his test report on occultation work using a ZWO Seestar S50. He investigated whether and how this smart telescope can be used to measure stellar occultations. In his 18-page document, he tested the Seestar S50 under several aspects, for example :

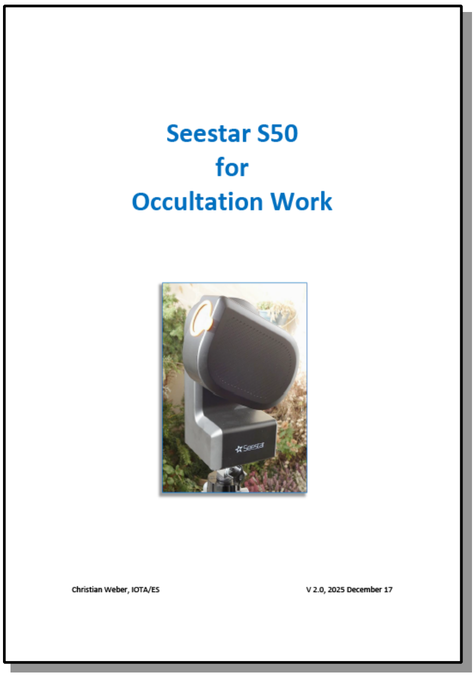
- The S50's achievable limiting magnitude
- Recordable occultation events with the S50
- Timing measurements

A NEXTA (New EXposure Timing Analyser) was used to analyse the accuracy of the timing measurements. In addition, tests with simulated occultations were recorded and the results were compared with the timing measurements of a QHY-174M-GPS.

The document is available here:

https://www.iota-es.de/seestar_report.pdf

(O. Klös)

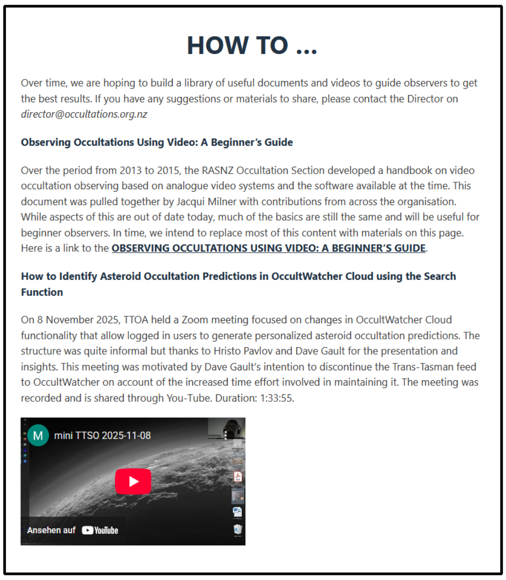


Seestar S50
for
Occultation Work

Christian Weber, IOTA/ES

V 2.0, 2025 December 17

A New Webpage for the Trans-Tasman Occultation Alliance



HOW TO ...

Over time, we are hoping to build a library of useful documents and videos to guide observers to get the best results. If you have any suggestions or materials to share, please contact the Director on *director@occultations.org.nz*

Observing Occultations Using Video: A Beginner's Guide

Over the period from 2013 to 2015, the RASNZ Occultation Section developed a handbook on video occultation observing based on analogue video systems and the software available at the time. This document was pulled together by Jacqui Milner with contributions from across the organisation. While aspects of this are out of date today, much of the basics are still the same and will be useful for beginner observers. In time, we intend to replace most of this content with materials on this page. Here is a link to the **OBSERVING OCCULTATIONS USING VIDEO: A BEGINNER'S GUIDE**.

How to Identify Asteroid Occultation Predictions in OccultWatcher Cloud using the Search Function

On 8 November 2025, TTOA held a Zoom meeting focused on changes in OccultWatcher Cloud functionality that allow logged in users to generate personalized asteroid occultation predictions. The structure was quite informal but thanks to Hristo Pavlov and Dave Gault for the presentation and insights. This meeting was motivated by Dave Gault's intention to discontinue the Trans-Tasman feed to OccultWatcher on account of the increased time effort involved in maintaining it. The meeting was recorded and is shared through You-Tube. Duration: 1:33:55.

The Trans-Tasman Occultation Alliance (TTOA), observing section for occultation phenomena of the Royal Astronomical Society of New Zealand (RASNZ), has a new webpage:

https://occultations.org.nz/website_d9bc6b2c/

The previous webapge was created in 1998 by Graham Blow and maintained by Steve Kerr, Director of the TTOA, to keep it up to date. Thanks to *Occult Watcher* the distribution of predictions is no longer a main focus. The emphasis is now on results, guides (see example on the left) and information about meetings. Observers can share their experiences on a blog.

The old webpage remains available.

(O. Klös)

News

TTSO20 - 20th Trans-Tasman Symposium on Occultations

TTSO20 will take place on 2026 April 06 (Australian Eastern Standard Time) in Tamworth, New South Wales, Australia, in conjunction with the National Australian Convention of Amateur Astronomers (NACAA XXXII):

https://occultations.org.nz/website_d9bc6b2c/meetings/

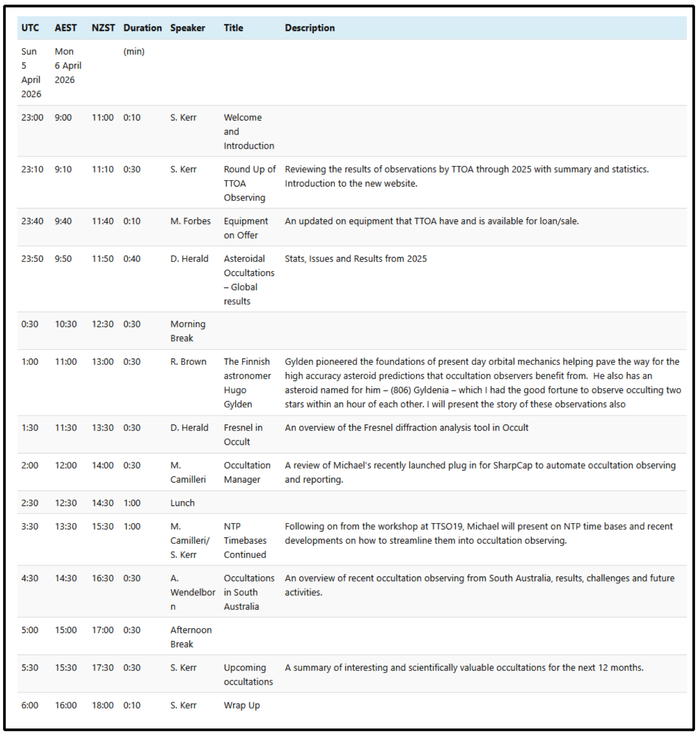
Registration for in-person attendance is still open and can be completed via the NACAA website:

https://www.nacaa.org.au/2026/register

As has been the practice for some years, the programme will be webcast via Zoom with some speakers presenting remotely. If you wish to participate via Zoom, please send us an e-mail requesting registration:

director@occultations.org.nz

We will save your e-mail address and send you the access details for the event. We confirm all e-mail enquiries, but please be patient as it may take a few days for us to reply. Please note that participation in TTSO20 via Zoom is free of charge. We will record all sessions and make them available on YouTube in the coming months.



UTC	AEST	NZST	Duration	Speaker	Title	Description
Sun 5 April 2026	Mon 6 April 2026		(min)			
23:00	9:00	11:00	0:10	S. Kerr	Welcome and Introduction	
23:10	9:10	11:10	0:30	S. Kerr	Round Up of TTOA Observing	Reviewing the results of observations by TTOA through 2025 with summary and statistics. Introduction to the new website.
23:40	9:40	11:40	0:10	M. Forbes	Equipment on Offer	An updated on equipment that TTOA have and is available for loan/sale.
23:50	9:50	11:50	0:40	D. Herald	Asteroidal Occultations – Global results	Stats, Issues and Results from 2025
0:30	10:30	12:30	0:30	Morning Break		
1:00	11:00	13:00	0:30	R. Brown	The Finnish astronomer Hugo Gylden	Gylden pioneered the foundations of present day orbital mechanics helping pave the way for the high accuracy asteroid predictions that occultation observers benefit from. He also has an asteroid named for him – (806) Gyldenia – which I had the good fortune to observe occulting two stars within an hour of each other. I will present the story of these observations also
1:30	11:30	13:30	0:30	D. Herald	Fresnel in Occult	An overview of the Fresnel diffraction analysis tool in Occult
2:00	12:00	14:00	0:30	M. Camilleri	Occultation Manager	A review of Michael's recently launched plug in for SharpCap to automate occultation observing and reporting.
2:30	12:30	14:30	1:00	Lunch		
3:30	13:30	15:30	1:00	M. Camilleri/ S. Kerr	NTP Timebases Continued	Following on from the workshop at TTSO19, Michael will present on NTP time bases and recent developments on how to streamline them into occultation observing.
4:30	14:30	16:30	0:30	A. Wendelborn	Occultations in South Australia	An overview of recent occultation observing from South Australia, results, challenges and future activities.
5:00	15:00	17:00	0:30	Afternoon Break		
5:30	15:30	17:30	0:30	S. Kerr	Upcoming occultations	A summary of interesting and scientifically valuable occultations for the next 12 months.
6:00	16:00	18:00	0:10	S. Kerr	Wrap Up	

Preliminary programme of TTSO20. Screenshot of 2026 March 22. Changes are possible. Please refer to the TTSO20 webapge for the latest schedule.

(S. Kerr)

Newsletters from Laboratoire Temps Espace (LTE)

The Laboratoire Temps Espace in Paris (formerly Institut de Mécanique Céleste et de Calcul des Éphémérides, IMCCE) publishes news about occultations among other astronomical topics:

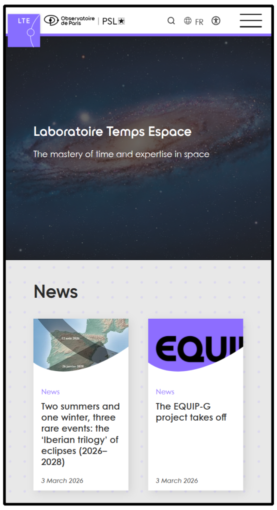
https://lte.observatoiredeparis.psl.eu/?lang=en

Additionally, you can subscribe to the IMCCE Newsletter or read it in the online archive:

https://www.imcce.fr/lettre-information/

The IMCCE Newsletter is in French. Use the translation tool of your browser to translate it into your preferred language.

(O. Klös)



Laboratoire Temps Espace

The mastery of time and expertise in space

News

News

Two summers and one winter, three rare events: the 'Iberian trilogy' of eclipses (2026–2028)

3 March 2026

News

The EQUIP-G project takes off

3 March 2026

Following successful conferences in Germany and Poland, the European Symposium on Occultation Projects (ESOP) will be held in France.

This time, we are pleased to welcome symposium participants to Toulouse, a vibrant city located in the southwest of the country. Toulouse is easily accessible via the A61 highway, fast trains from Paris and Barcelona, and by air through Toulouse-Blagnac International Airport.

Toulouse is home to the renowned *Observatoire Midi-Pyrénées* (OMP), a leading research centre focused on minor bodies of the solar system, which will host the ESOP meeting (Figure 2). The conference venue will be a spacious auditorium at the OMP, conveniently located near the city centre. The meeting is coorganised by the Adagio Association in partnership with SAF (French Society of Astronomy).

Before the two-day conference begins, an optional (but exceptional) excursion to the *Pic du Midi Observatory* (2876 m) is planned (Figure 4). After the first day of the conference, we invite participants to visit the *Belesta Observatory* (Figure 3) and enjoy a famous Southwest menu featuring “cassoulet”.

Figure 1. From top to bottom and left to right: Saint-Pierre Bridge in Toulouse, Ariane 5 (Cité de l'Espace), Saint-Sernin Basilica in Toulouse, Place du Capitole in Toulouse, Airbus A380, Musée des Augustins in Toulouse.(Credit: Compilation by Milou34 — (CC-BY-3.0) by Gremi357 (CC-BY-SA-4.0) by Mike Peel (CC-BY-SA-3.0) by PMRMaeyaert (CC-BY-SA-3.0) by Benh LIEU SONG (CC-BY-SA-3.0) by w:de:User:Benutzer:Xeper (CC-BY-SA-3.0) by Didier Descouens, (CC BY-SA 3.0), https://commons.wikimedia.org/w/index.php?curid=38150216)

Figure 3. Belesta Observatory in Lauragais (Image: ESOP 45 LOC)

Details and registration here:

https://esop45.iota-es.de

Figure 2. Observatoire Midi-Pyrénées (OMP), site of the conference. (Image: Sebastien Chastanet, OMP, (CC-BY-SA-4.0), https://commons.wikimedia.org/wiki/File:Entr%C3%A9e_de_l%27OMP.jpg

Figure 4. Pic du Midi Observatory (Image: ESOP 45 LOC)

As is traditional for ESOP, after the conference, additional excursions will be offered both in the historic city centre and its surroundings, showcasing beautiful landscapes, gardens, and museums. This 45th edition will also provide the opportunity to discover the great site of the City of Carcassonne (Figure 5), visit the Aeroscopia and Cité de l'espace Museums, and explore Airbus industry facilities.

On behalf of the Organising Committee, we invite the entire community interested in occultation phenomena to join the 45th ESOP symposium. We will be delighted to welcome you in Toulouse in person, but online participation via Zoom will also be available.

Pascal André
LOC ESOP 45

Figure 5. Aerial panorama of Cité de Carcassonne.
(Image by Chensiyuan, CC-BY-SA-4.0), https://commons.wikimedia.org/wiki/File:1_carcassonne_aerial_2016.jpg

Journal for
Occultation Astronomy

IOTA's Mission

The International Occultation Timing Association, Inc was established to encourage and facilitate the observation of occultations and eclipses It provides predictions for grazing occultations of stars by the Moon and predictions for occultations of stars by asteroids and planets, information on observing equipment and techniques, and reports to the members of observations made.

The Journal for Occultation Astronomy (JOA) is published on behalf of IOTA, IOTA/ES and RASNZ and for the worldwide occultation astronomy community.

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IOTA maintains the following web sites for your information and rapid notification of events:

www.occultations.org
www.iota-es.de
www.occultations.org.nz

These sites contain information about the organisation known as IOTA and provide information about joining.

The main page of occultations.org provides links to IOTA's major technical sites, as well as to the major IOTA sections, including those in Europe, East Asia, Middle East, Australia/New Zealand, and South America.

The technical sites hold definitions and information about all issues of occultation methods. It contains also results for all different phenomena. Occultations by the Moon, by planets, asteroids and TNOs are presented. Solar eclipses as a special kind of occultation can be found there as well results of other timely phenomena such as mutual events of satellites and lunar meteor impact flashes.

IOTA and IOTA/ES have an on-line archive of all issues of Occultation Newsletter, IOTA'S predecessor to JOA.

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