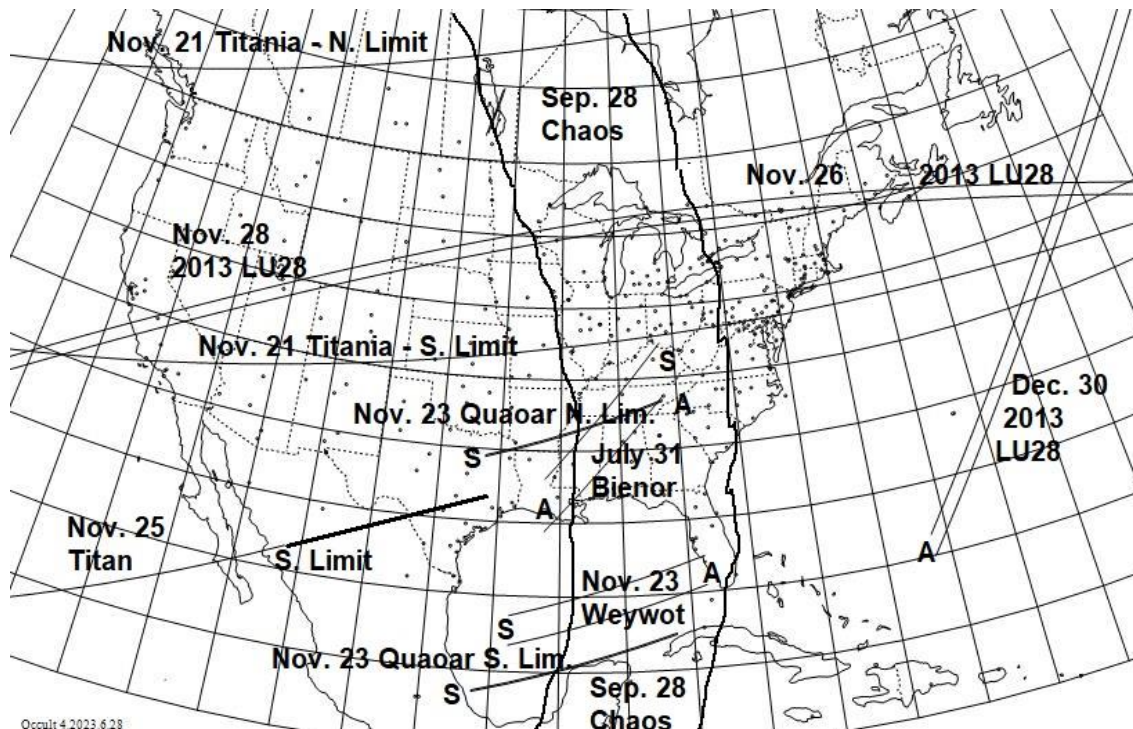# 2023 Occultations by Distant Solar System Objects

Of special interest are occultations by distant trans-Neptunian and Centaur objects, many of which have moons and some have rings. These distant objects move slowly, so occultations by them are rare, so fainter stars had to be considered, requiring larger telescopes to observe. The uncertainties of these paths is generally many path-widths, requiring special astrometric observations with large telescopes to predict their location well enough for observing campaigns, and these are accomplished usually only a few weeks before the event. You should find the event on the main IOTA prediction (Steve Preston's) Web site at **https://www.asteroidoccultation.com/** - the 1-σ lines are shown on the Occult-produced map shown there, and better on the interactive Google maps at either **http://www.poyntsource.com/New/Global.htm** or by Occult Watcher (OW; it also shows the 3-σ lines as fainter, outside the 1-σ lines). You can also assess the uncertainties by the event's rank given by Preston and/or OW. On OW's station list, you can also see the formal probability for an occultation at each station. The Lucky Star predictions (see below) often have smaller errors; OW gives their predictions precedence over IOTA's. Many of these events are too faint for most amateur telescopes, but an occultation of a 10th-magnitude star by the Centaur object (60558) Echeclus that occurred over northern Mexico on January 6th is included. Brighter stars are occulted by two outer-planet moons later in 2022.

A good example of a successful campaign for an occultation by a rather large Kuiper Belt Object, (84522) 2002 TC302, took place in November 2021, observed by several in the USA and Europe. It's remarkable that many amateur astronomers with relatively small telescopes could determine the size and shape of an object over 40 AU away, farther than the current distance to Pluto. An account of this event is at **https://occultations.org/publications/rasc/2022/2002TC302Results.pdf**, adopted from an article that was published in the January 2022 issue of *Stardust*, publication of the National Capital Astronomers. We hope to have some further distant-object successes in 2022, with the opportunities portrayed below.

The best occultations of stars by Distant Solar System Objects in North America during the rest of 2023

The best occultations of stars by Distant Solar System Objects in North America during the rest of 2023

Date		U.T.	Diam	Dur.	Star	Mag	Eln	Star	d	Path		Planet	Moon		R.A. (J2000)		Dec.		
m	d	h m	km	sec	mag	Drop	o				No	Name	Dist	ill	h m	s	o	'	"
Jul 31		9 25	188	5.5s	14.6	4.6	34	UCAC4 653-044855		LA-KY	54598	Bienor	164	97	6 42	17.421	40	26	37.59
Sep 28		7 11	364	63.5s	13.5	7.5	92	UCAC4 607-028826		FL-ON	19521	Chaos	103	98	6 9	56.940	31	21	23.25
Nov 21		5 18	1577	72.8s	11.8	2.2	172	TYC 1236-00841-1		NL-CA		Titania	72	59	3 12	17.324	17	32	27.04
Nov 23		0 25	139	4.9s	14.8	4.2	38	UCAC4 373-131780	s	FL-low		Weywot	87	78	18 29	5.730	-15	24	54.02
Nov 23		0 32	1095	37.9s	14.8	4.2	38	UCAC4 373-131780	s	TX-GA	50000	Quaoar	87	78	18 29	5.730	-15	24	54.02
Nov 25		3 55	5150	367s	14.4	0.01	88	UCAC4 386-150960		wNAm		Titan	64	94	22 12	47.559	-12	50	56.62
Nov 26		7 43	76	3.2s	14.7	3.5	112	UCAC4 695-050057		CA-NS	468861	2013 LU28	78	99	9 24	15.663	48	54	52.09
Dec 30		0 9	76	2.0s	15.8	2.3	141	UCAC4 703-049020		Berm	468861	2013 LU28	29	91	8 59	57.152	50	30	12.43

The map (at the bottom of the previous page), and the corresponding table above, are similar to those for main-belt and other types of occultations published in the *RASC Observer's Handbook for 2023*, showing the paths for occultations of some of the better distant-object occultations during the rest of 2023. The successive columns in the table list: (1) the date and central time of the event; (2) the diameter of the occulting body; (3) the duration of the central occultation; (4) the star's apparent visual magnitude; (5) the expected magnitude change from the combined brightness; (6) the elongation of the star from the Sun; (7) the catalogue and number of the occulted star, and a code indicating possible stellar duplicity; (8) the path location specified by the lands crossed by the eastern and western ends of the path shown on the map; (9) the number and name of the occulting body; (10) the elongation (Dist) of the star from the Moon in deg.; (11) the percent sunlit (ill) of the Moon; and (12) the star's right ascension and (6) declination. For the path location, the two-letter abbreviations for the US States and Canadian Provinces are given, with the order indicating the direction of motion of the shadow. "wNAm" is western North America (for the very wide path of an occultation by Saturn's moon Titan) and "Berm" is Bermuda. The times are for the center of the path; for any specific location in North America, the event time can be a few minutes earlier or later.

Details of most of these events will be given on the Paris Observatory's Lucky Star Project's web site at **https://lesia.obspm.fr/lucky-star/predictions.php** , while some will also be described at **https://www.boulder.swri.edu/~buie/recon/reconlist.html** , the prediction Website of the Research and Education Collaborative Occultation Network (RECON), the network of observatories in the western USA and Canada dedicated to observation of distant-object occultations. Bienor is a Centaur asteroid with a ring, while Chaos and Quaoar are Kuiper-belt objects. Our orbit for Chaos is wrong, with the path over the Atlantic Ocean; Lucky Star has used a previous occultation to generate a better path prediction that I have drawn sloppily on the map; the path is still rather uncertain, so observers with large-enough telescopes throughout North America are encouraged to try to record the occultation. Quaoar was recently found to have two rings well outside its Roche lobe, so brief occultations are possible well outside its path; however, they will be difficult to detect as the star is faint and the ring optical depths are low.
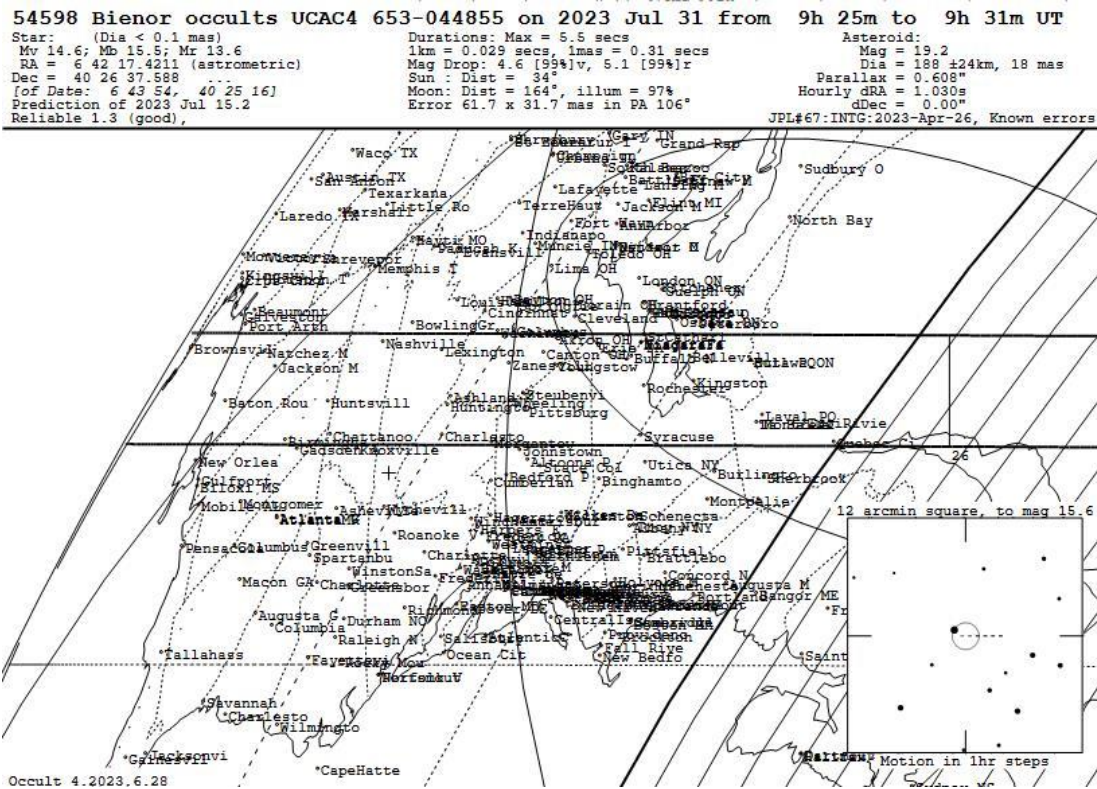
Weywot is a 140-km moon of the large TNO (trans-Neptunian object) (50000) Quaoar; the Lucky Star prediction should be pretty good since it is based on two previously-observed occultations.
Titan, the 8th-mag. largest moon of Saturn with a thick atmosphere, will occult a faint star on Nov. 25. The occultation will be visible from much of western and central North America, north of the southern limit shown on the map; the northern limit misses the Earth. The event will occur at low altitude in the Great Lakes region, as can be ascertained from the Occult map given below. Titan will be a few arc-minutes west of Saturn when the occultation occurs. Local circumstance predictions (U.T. of central occultation, and altitudes of the star and Sun) will be posted for hundreds of North American cities on this Web site before the November occultation.

Titania, also known as Uranus III, is 1577 km across, Uranus' largest moon. The northern limit of the Nov. 21st occultation is over southern Canada while the southern limit extends from New Jersey to southern California (see the map); the event will occur at high altitude across North America, but will also be visible around 5:14 UT in Iberia, low in the western sky. Titania will be about 30 arc-seconds east and a little south of Uranus during the occultation.

2013 LU28 is a Damoclid trans-Neptunian object (TNO) with a highly eccentric (0.95) retrograde (inclination 125°) orbit. It has a perihelion distance of 8.73 AU and an aphelion distance of 353 AU; it will reach perihelion around 2031. Unfortunately, the path uncertainty is much larger than the expected path width, so observers in a wide area are encouraged to try the event, as shown in the prediction maps for the event below. The object is faint (21st magnitude) so obtaining new astrometry to improve the path prediction will be difficult, but will likely be attempted; if an improved path becomes available, it will be announced on the IOTAoccultations list, and will be updated on the event's Lucky Star page and maybe here.
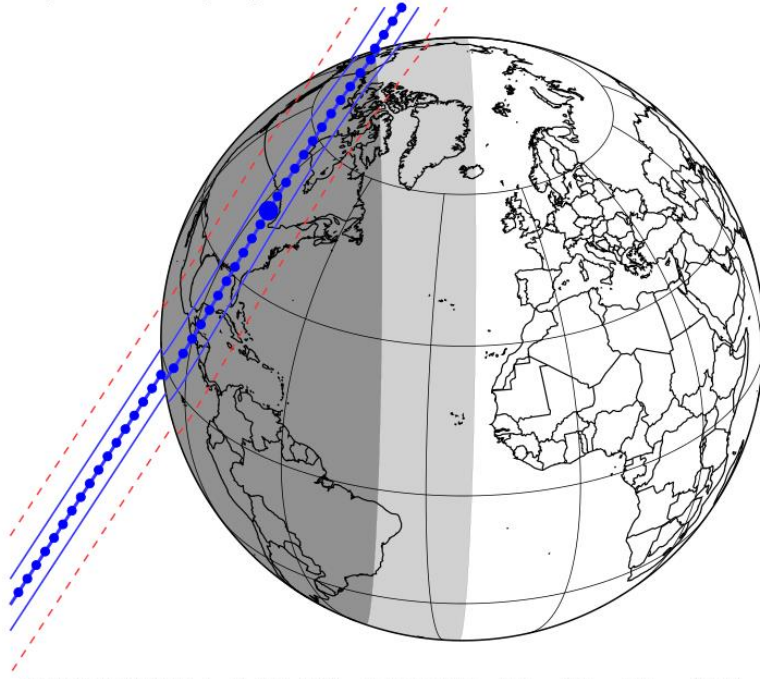
The worldwide Occult input data includes some other objects. On July 28, just after 6h UT, the large TNO (28978) Ixion will occult a 14.5-mag. star over southern Brazil, northern Argentina, and central Chile.

The Lucky Star world map for the September 28th occultation by Chaos is on the next page; further details, including a zoomable Aladin star chart and path Google map (click on it at your location to obtain local event times and circumstances) can be found at
https://lesia.obspm.fr/lucky-star/occ.php?p=124402 .

```
yyyy mm dd hh:mm:ss.s  RA_star_J2000  DE_star_J2000   C/A    P/A    vel   Delta   G*    RP*   H*
2023-09-28 07:14:48.1  06 09 56.9405  +31 21 23.245  0.165 303.39  5.73  41.0980  12.1  11.1  8.8
```

P7M03 Titania (III) occults TYC 1236-00841-1 on 2023 Nov 21 from 5h 13m to 5h 24m

```
Star:     (Dia < 0.1 mas)            Durations: Max = 72.8 secs              Asteroid:
  Mv 11.8; Mb 12.1; Mr 11.8          1km = 0.046 secs, 1mas = 0.62 secs         Mag = 13.8
  RA =  3 12 17.3241 (astrometric)   Mag Drop: 2.2 [87%]v, 1.9 [82%]r           Dia = 1577 ±1km, 117 mas
Dec =   17 32 27.039                 Sun : Dist = 172°                        Parallax = 0.472"
[of Date:  3 13 39,  17 37 55]       Moon: Dist =  72°, illum = 59%          Hourly dRA =-0.402s
Prediction of 2022 Jun 15.1          Error 20.0 x 20.0 mas in PA 0°                 dDec = -0.66"
Reliable 1.1 (good),                                                         DE440+JPL#ura111, Star+Assumed
```
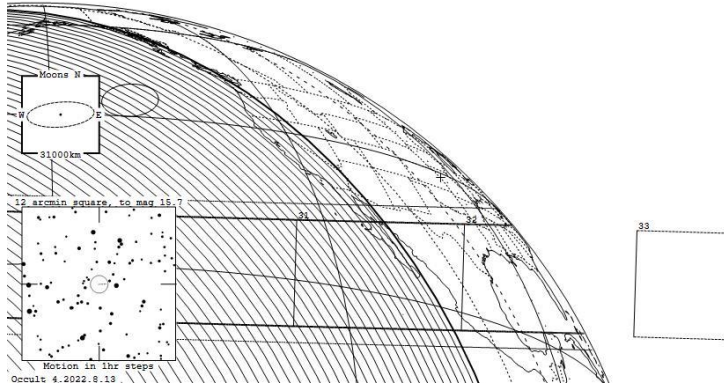

1° square, to mag 12.8

Motion in 6hr steps

Occult 4.2023.6.28

50000 Quaoar occults UCAC4 373-131780 on 2023 Nov 23 from 0h 26m to 0h 34m UT

```
Star:     (Dia < 0.1 mas)              Durations: Max = 37.9 secs              Asteroid:
  Mv 14.7; Mb 16.4; Mr 13.5            1km = 0.036 secs, 1mas = 1.1 secs         Mag = 18.9
  RA = 18 29  5.7300 (astrometric)     Mag Drop: 4.2 [99%]v, 5.0 [99%]r          Dia = 1096 ±7km, 35 mas
  Dec = -15 24 54.019                  Sun : Dist = 37°                          Parallax = 0.202"
  [of Date: 18 30 26, -15 24  0]       Moon: Dist =  87°, illum = 78%            Hourly dRA = 0.228s
  Prediction of 2022 Aug 14.8          Error 9.3 x 5.3 mas in PA 87°             dDec = -0.10"
  Reliable 0.9 (good),                                                          JPL#43:2022-Aug-09, Known errors
  ─────────────────────────────────────────────────────────────────────────────────────────────────
  1 moon. {Weywot} 81km at 13800km, Period 12.260days  Orbit@Miriade
```
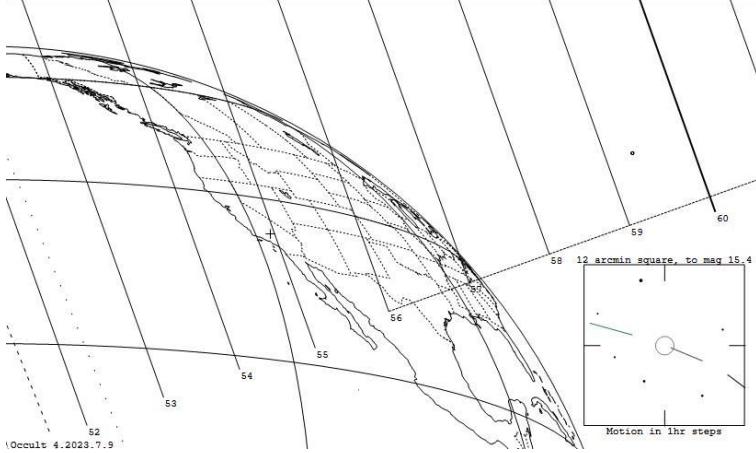


```
Moons  N
W           E
31000km
12 arcmin square, to mag 15.7
Motion in 1hr steps
Occult 4.2022.8.13
```

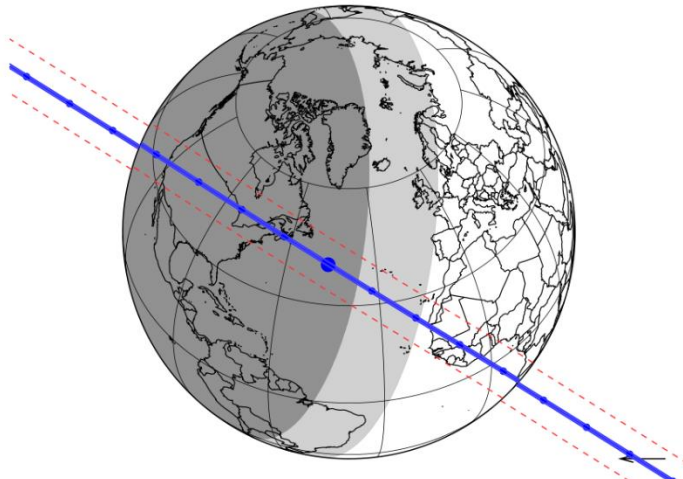## P6M06 Titan (VI) occults UCAC4 386-150960 on 2023 Nov 25 from 3h 41m to 3h 59m UT

```
Star:     (Dia < 0.1 mas)              Durations: Max = 367.2 secs             Asteroid:
  Mv 14.4; Mb 15.4; Mr 14.4            1km = 0.071 secs, 1mas = 0.50 secs        Mag = 8.6
  RA = 22 12 47.5593 (astrometric)     Mag Drop = 0.01 [ 1%]v                    Dia = 5150 ±0km, 730 mas
  Dec = -12 50 56.615                  Sun : Dist = 88°                          Parallax = 0.904"
  [of Date: 22 14  4, -12 43 56]       Moon: Dist =  63°, illum = 94%            Hourly dRA = 0.461s
  Prediction of 2022 Jun 15.1          Error 2.0 x 2.0 mas in PA 0°              dDec =  2.40"
  Reliable 1.1 (good),                                                          DE440+JPL#sat4411, Star+Assumed
```
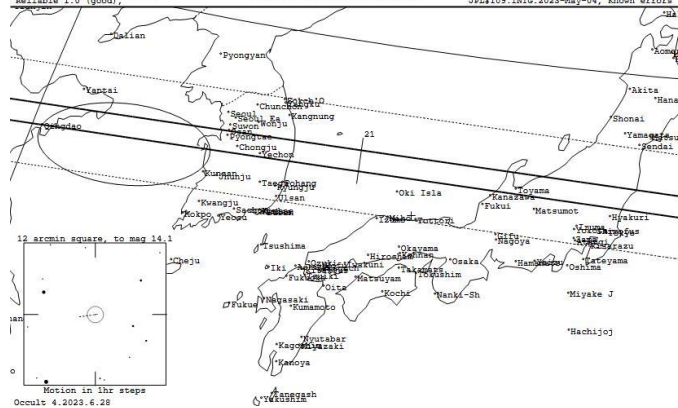


```
60
59
58   12 arcmin square, to mag 15.4
56
55
54
53
52
Occult 4.2023.7.9                                        Motion in 1hr steps
```

2013LU28, GaiaDR3+pmGaiaDR3, NIMAv6   Offset: 0.0mas 0.0mas

```
updated: 2023-03-27 by Lucky Star
```



```
    yyyy mm dd hh:mm:ss.s  RA_star_J2000  DE_star_J2000   C/A    P/A    vel    Delta    G*    RP*   H*
    2023-11-26 07:40:35.4  09 24 15.6631  +48 54 52.086   0.181 212.21 -23.87  8.4002  14.9  14.5  13.7
```
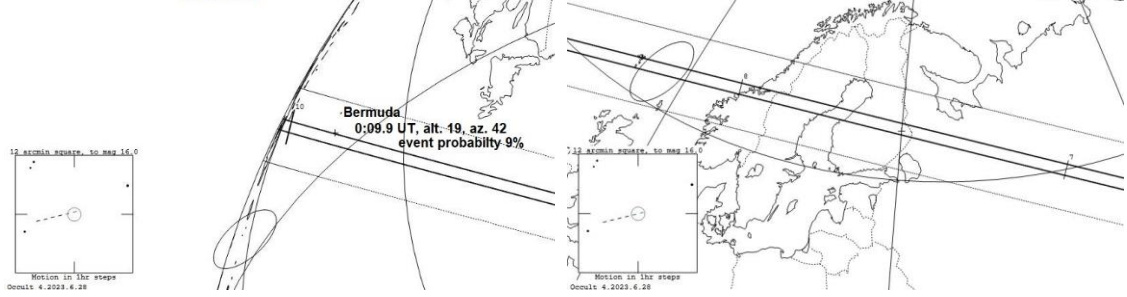
60558 Echeclus occults UCAC4 537-043188 on 2023 Dec 19 from 15h 14m to 15h 24m UT

468861 2013 LU28 occults UCAC4 703-049020 on 2023 Jul 30 from 0h 4m to 0h 10m U

waning Moon alt. 3, az. 66
at Bermuda

Bermuda
0;09.9 UT, alt. 19, az. 42
event probabilty 9%

468861 2013 LU28 occults UCAC4 703-049020 on 2023 Jul 30 from 0h 4m to 0h 10m U

Our orbital elements are all from the NASA JPL Horizons Web site at **https://ssd.jpl.nasa.gov/horizons.cgi** and the stellar data are from the Early third release (EDR3) of the European Space Agency's Gaia mission, as implemented with UCAC4, Tycho, and Hipparcos catalog identifiers with IOTA's free *Occult* software.

Zoomable Aladin star charts centered on the target, interactive Google maps and other details for most of these events, and other event details are given for most of these occultations at the Lucky Star prediction Web site at **https://lesia.obspm.fr/lucky-star/predictions.php .** It's worth checking these Web sites a week or two before an occultation that you might observe, since Lucky Star updates their predictions with the help of earlier occultation observations which can shift the paths substantially from what we show on the map,

The maps were produced with IOTA's free *Occult* software; see **http://www.lunar-occultations.com/iota/occult4.htm** . You can download and use this software and use it to compute your own local lists and information about these and many other occultations. Instructions are at **http://www.lunar-occultations.com/iota/2022iotapredictions.pdf** . This describes a prediction input file for planetary and asteroidal occultations called **All2002.xml**. You can use that file to generate local predictions, but you can replace it with the other files listed below to generate predictions for more occultations, mainly of fainter stars than shown on the maps, or for other parts of the world. But note that these generally don't have good error information; you should consult the Web sites given near the top of this document for better and current errors.

Nam23distoccsFinal.xml – This is the input for the 8 distant Solar System objects occultations for North America shown on the main map on the first page of this document (but ignore Chaos, use the Lucky Star site for that object).

2023worldDistantoccs.xml – This is the input for 102 occultations worldwide by selected Centaurs and Kuiper-Belt Objects of stars to mag. 16.

PlanetsPlusMainSatellites_2023.xml – This is the input for 200 occultations worldwide by major planets and their moons of stars to mag. 16 (but brighter limits for most objects), provided by Dave Herald.

For worldwide occultations by major and all types of minor planets (mainly main-belt) worldwide for the whole year, fairly comprehensive only to about mag. 12.5, use the **All2023.xml** file noted above, but even more occultations can be found with Occult Watcher (it is limited to the next two months), free software for finding observable occultations at your location or region obtainable at **http://www.occultwatcher.net/** .

David and Joan Dunham, dunham@starpower.net, 2023 July 21