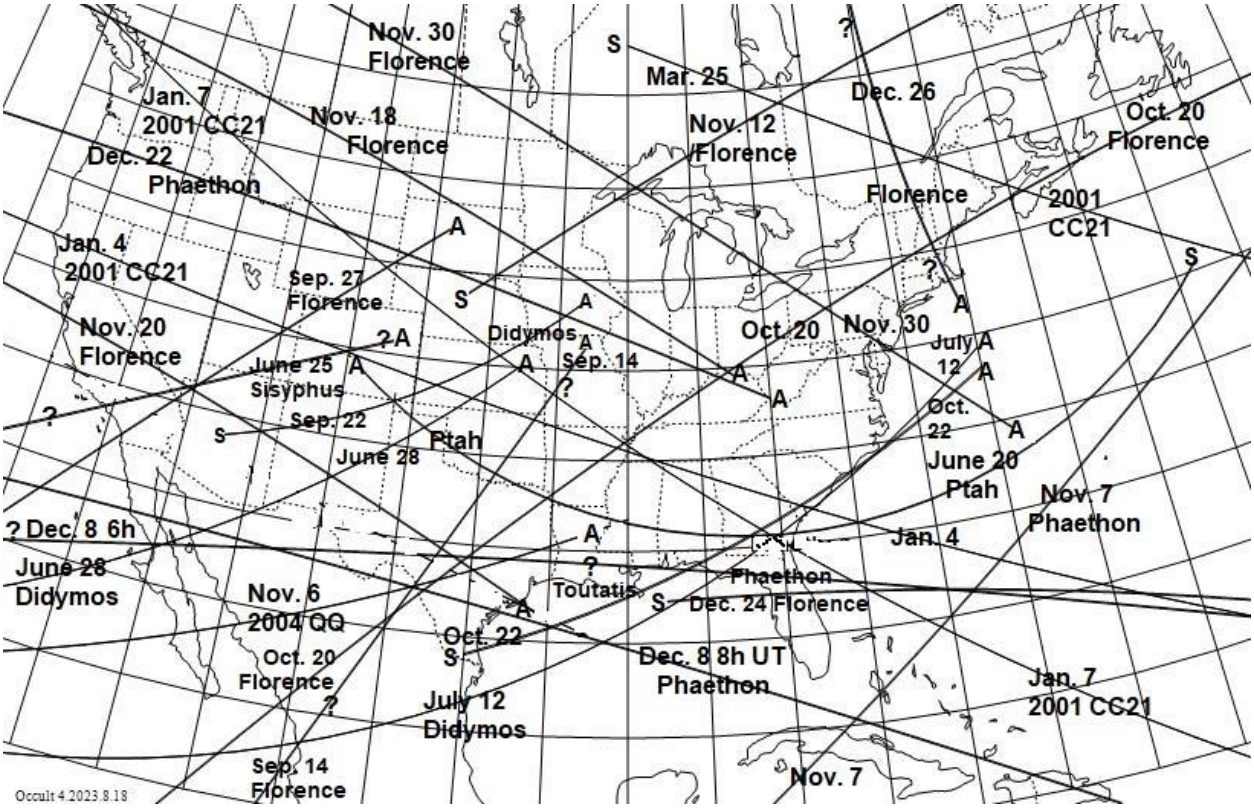
2024 Occultations by Near-Earth Asteroids

More information can be found on IOTA's page for 2024 North American Near-Earth Asteroid (NEA) occultations at **https://occultations.org/publications/rasc/2024/nam24NEAoccs.htm** . Also there for some occultations, when appropriate, are finder charts, maps, links to other resources, cloud cover forecast maps, and Google Earth files with parallel fence lines for detailed coordinated site selection. Interactive (zoomable) maps that show event U.T. and circumstances when clicking on a specific location, Aladin zoomable photographic star charts, and different path statistics can be found on the OW cloud page for an event available with Occult Watcher (OW) for events generally less than two months in the future. When using OW for these events, you need to set the size and rank limits to small values to get the events to show up. For example, for the (98943) 2001 CC21 campaigns, the object is only 600m in diameter and with current 1-sigma errors of about 8 path-widths, the rank of the events are around 9, so a size limit of 0 km and rank limit of 6 are recommended in your OW configuration. For a specific event, you might select a site (from the General tab) near the path you want with a small (such as 100 km) distance, to add that event to your OW list, without cluttering OW with dozens of inappropriate events, which would likely happen if you selected a large-enough distance with your home location.

Occultations by Near-Earth Asteroids (NEAs) is an exciting new endeavor that contributes to planetary defense by refining the orbits of these small but possibly dangerous objects. IOTA's first success with NEA events was with (3200) Phaethon in 2019, but more spectacularly with (99942) Apophis in 2021, and finally with Didymos in 2022; much information about the occultations, their value, and how they helped retire the threat of Apophis, is given in papers presented at (see especially IOTA's presentation at the top of the page) given at the 2023 Asteroids, Comets, and Meteors Conference that you can obtain at **https://occultations.org/publications/rasc/2023/ACM2023.htm** . There are several opportunities in 2024 shown on the map and table below, similar to those described for bright main-belt occultations given on another Web page. Since NEA occultations are so short, their expected durations are given to 0.01s; in the table, Since the paths for NEA events are all very narrow, one must travel to them with mobile equipment to observe them, rather like grazing occultations of stars by the Moon. And like lunar grazes, it is necessary to adjust the location for elevation above sea level. John Irwin in the UK has supplied special Google Earth files that take elevation into account, and IOTA's free Occult program can now also generate them. Unfortunately, no observations of occultations by either Didymos or Dimorphos were obtained before the successful DART impact on 2022 Sept. 26, but shortly after that, Goldstone radar and radiometric tracking data of DART resulted in a good-enough improvement of Didymos' orbit that the first ever occultation by Didymos was recorded by Roger Venable on 2023 Oct. 15, and several more were observed in the following months. We have a few opportunities with Didymos in 2024, see below, but first, in early January, there are chances to observe an occultation by the elusive NEA (98943) 2001 CC21, a flyby target of the Japanese Hayabusa-2 extended mission; see below for more discussion of its value, and the need for campaigns to try to record an occultation by the object early this year.

On the top of the next page is the map of 2024 NEA occultations that's on p. 247 of the *Observer's Handbook 2024* of the Royal Astronomical Society of Canada, and the corresponding table of information about each of the plotted occultations. The 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.

The best occultations of stars by NEA's in North America during 2024



Date	UT	Occulting Body		Star	Mag.	RA (2000) h m s	Dec ° ′ ″	Dur. ΔMag.	Dur. s	Path
Jan. 4	05:41	98943	2001 CC21	TYC 2390-00255-1	9.5	05 15 29.2	+31 48 03	7.8	0.10	SC-CA
Jan. 7	08:10	98943	2001 CC21	UCAC4 611-017927	12.0	05 04 44.1	+32 08 28	5.5	0.11	GA-BC
Mar.25	01:40	98943	2001 CC21	UCAC4 624-022444	11.8	05 23 23.1	+34 45 05	7.8	0.12	ON-NS
Jun. 20	05:35	5011	Ptah	TYC 7404-05785-1	11.4	18 12 46.2	–36 42 50	8.0	0.11	GA-CO
Jun. 25	07:05	1866	Sisyphus	TYC 4974-00442-1	11.6	13 55 19.0	–06 38 53	3.8	0.46	CO-CA
Jun. 28	09:35	65803	Didymos	UCAC4 317-188802	11.9	18 27 38.6	–26 44 55	6.7	0.10	KS-Baja
Jul. 12	06:23	65803	Didymos	TYC 6850-02664-1	11.2	18 00 23.3	–27 49 45	7.6	0.10	NC-Mex
Sep.14	02:23	3122	Florence	UCAC4 302-124834	9.5	17 17 39.8	–29 47 06	5.0	0.31	Mex-MO
Sep.22	02:32	65803	Didymos	TYC 6853-03502-1	11.8	17 58 46.2	–29 12 59	8.0	0.09	AZ-IA
Sep.27	03:58	3122	Florence	UCAC4 371-110913	11.4	17 55 51.5	–15 52 36	3.2	0.29	CA-SD
Oct. 20	01:55	3122	Florence	UCAC4 498-103066	10.7	19 00 48.7	+09 27 37	3.9	0.29	Mex-NS
Oct. 22	00:57	4179	Toutatis	UCAC4 335-187231	12.1	18 46 28.9	–23 09 11	6.3	0.15	TX-NC
Nov. 6	02:24	175114	2004 QQ	UCAC4 378-144292	12.0	18 58 39.6	–14 27 21	6.1	0.05	Baja-LA
Nov. 7	01:38	3200	Phaethon	UCAC4 648-021940	10.0	04 47 05.9	+39 35 40	7.1	0.30	BS-Cuba
Nov.12	00:27	3122	Florence	TYC 2671-00075-1	11.4	20 09 35.9	+30 17 58	3.4	0.31	NE-QC
Nov.18	05:18	3122	Florence	TYC 2693-01730-1	10.7	20 30 58.7	+34 49 38	4.1	0.30	BC-OH
Nov.20	05:20	3122	Florence	TYC 2698-01552-1	11.3	20 38 16.6	+36 11 19	3.6	0.30	CA-TX
Nov.30	04:26	3122	Florence	UCAC4 662-094547	8.2	21 18 09.1	+42 13 21	6.7	0.29	AB-NJ
Dec. 8	06:59	3200	Phaethon	TYC 2334-00124-1	11.1	02 57 48.0	+34 04 52	5.3	0.22	FL-Baja
Dec. 8	08:14	3200	Phaethon	TYC 2334-00386-1	12.6	02 57 36.5	+34 03 38	3.7	0.22	DO-Baja
Dec.22	08:11	3200	Phaethon	TYC 1764-00040-1	9.4	02 13 34.6	+27 56 40	7.2	0.25	WV-OR
Dec.24	23:47	3122	Florence	TYC 3648-01960-1	9.3	23 26 05.7	+51 28 60	6.0	0.25	FL
Dec.26	06:54	3122	Florence	TYC 3649-00666-1	10.2	23 33 40.3	+51 42 34	5.1	0.25	QC-MA

Like for lunar grazes, it is necessary to adjust the location for elevation above sea level. John Irwin in the UK has helped IOTA with this by supplying special Google Earth files that take elevation into account. His were important for also showing the paths of Dimorphos events, but for other NEA's, thanks to Dave Herald's updates, we can now generate those files with Occult4. Information about using them is on our North American NEA occultations Web page for 2024 with link at the top of the first page.

The successive columns in the table list: (1) the date and time of the event for a location near the center of the path on the map; (2) the number and name of the occulting body; (3) the catalogue and number of the occulted star; (4) the star's apparent visual magnitude; (5) the star's right ascension and (6) declination; (7) the expected magnitude change from the combined brightness; (8) the predicted maximum duration of the occultation in seconds; and, (9) the path location specified by the lands crossed by the eastern and western ends of the path shown on the map. The two-letter abbreviations for the US States and Canadian Provinces are given, with the order indicating the direction of motion of the shadow. "Baja" is Baja California, either Norte or Sur, while "Mex" denotes the rest of Mexico. "DO" is used for the Dominican Republic. Note that for any specific location in North America, the event time can be a few minutes earlier or later. As noted above for Didymos, when a NEA occultation is first observed, it generally must be done by a large team of observers to cover the relatively large uncertainty zone. But after one occultation is observed, that data can refine the orbit to allow more accurate prediction of future events that can then be covered by only a few observers.

Some information about the occulting NEAs portrayed above is given below:

(1866) Sisyphus: Observations of occultations by this large NEA are valuable since Sisyphus is out of radar range for at least the next 20 years. Due to the important Didymos campaigns, IOTA did not conduct a large effort to observe a reasonable Sisyphus event on 2022 Nov. 26 as originally planned, but Steve Messner travelled to the predicted path and recorded the occultation, allowing a good orbit update.

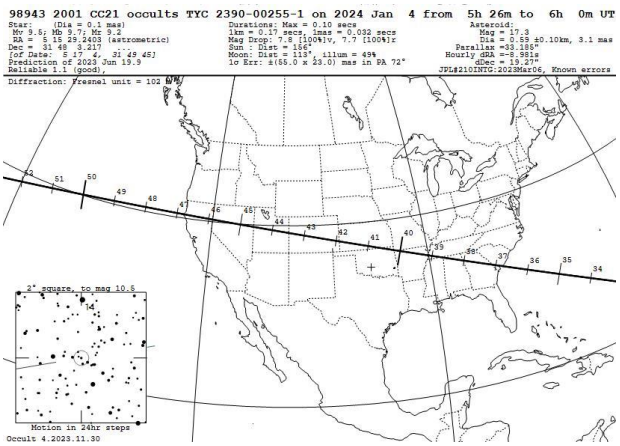
(3122) Florence: 2017 radar observations found two Florence moons, one about 200m across and about 5 km away, while the other is a little more than 300m across and about 10 km away. There are some good occultations by Florence late in the year.

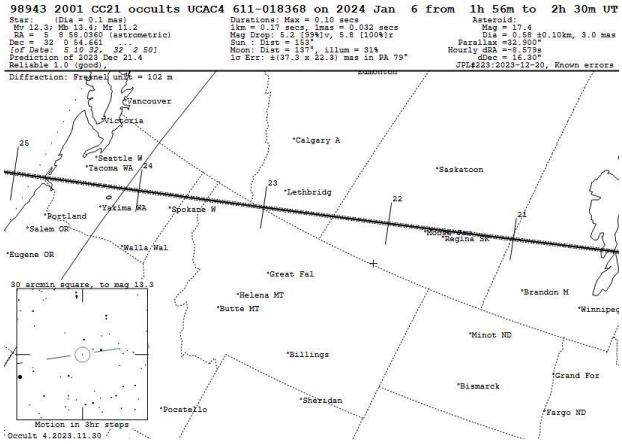
(3200) Phaethon: The paths should be quite accurate, with the orbit well-determined from the 2019, 2020, and 2022 occultations. But more observations are desired, to check for variations in Phaethon's non-gravitational forces caused by mass shedding (Geminid meteoroids) from its extreme thermal environment. A significant shift was found by a large expedition in Japan for an event in 2022 October, possibly due to shedding of a sizeable object during its 2022 May perihelion passage (see our paper for PDC 2023 linked to from the IOTA NEA occultations page for details), so we plan significant efforts for the Phaethon events. Phaethon is JAXA's DESTINY+ mission target.

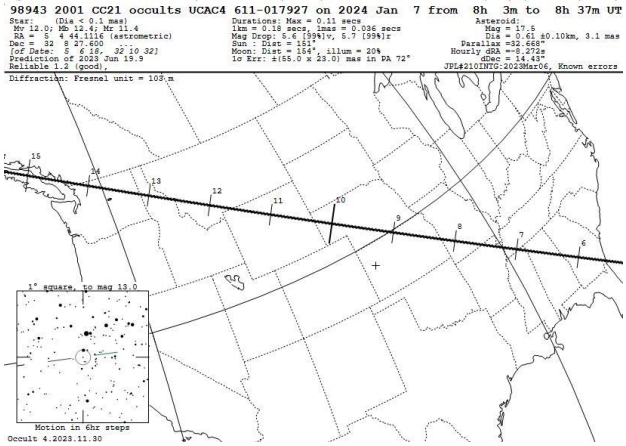
(65803) Didymos: The occultations by Didymos had the highest priority since NASA's DART mission planned to impact Dimorphos, Didymos' 160m moon that is 1.2 km away, on September 26, 2022. Once a first occultation was observed, the following ones were predicted more accurately; then, especially valuable were observations of occultations by Dimorphos as well as by Didymos, to help measure the effect of the DART impact. The 6.6-km/sec impact changed the orbital period of Dimorphos around Didymos by many minutes. More about the Didymos efforts are given in a Sky and Telescope article by Damya Souami at **https://skyandtelescope.org/astronomy-news/how-citizen-scientists-are-monitoring-the-dart-impact/** .

(98943) 2001 CC21: This estimated 600m NEA is a flyby target of the Hayabusa2 extended mission (the flyby will occur in July 2026) that hopes to rendezvous with the 30m Apollo-orbit NEA 1998 KY26 in 2031. The Japanese space agency JAXA is interested in characterizing 2001 CC21 that is currently occulting many stars. Six large expeditions were mounted in Japan in 2023; 2 were clouded out and the others had 10 and 12 stations that all had no occultation, except one in early March secured one positive chord. However, it

did not help because the 10th-mag. star had a high Gaia RUWE so its Gaia position had larger-than-expected errors. The orbit updated with the 2023 March 5th occultation caused subsequent efforts to all fail, so the occultation observation was down-weighted for the current JPL orbit. Below are 3 Occult maps for early January events (the one on Jan. 6 is too faint for our map and table on p. 2); more will be given later, as updates to the NEA occultations Web page, which includes links to Google Earth files with parallel fence lines for the 3 early Jan. occultations.







Other NEA's in our list, including **(4179) Toutatis, (5011) Ptah, and (175114) 2004 QQ**, are important because there is a chance for a collision with Earth during the next 1000 years. These are 3 from a longer list of 20 of the most threatening NEA's 1 km or larger whose current orbit uncertainties are large enough that an impact with Earth is possible (but with low probability) during the period from 100 to 1000 years from now. This list of the most hazardous NEAs can be found at **https://occultations.org/publications/rasc/2023/2312PHAsNext1000years.pdf.**

– – – – –

Fresnel Diffraction Effects for NEA Occultations

IOTA's page for North American NEA occultations includes a section, "Limiting Distance when Fresnel Diffraction Smearing is Significant", relying heavily on a presentation about NEA occultation light curves given by Roger Venable at the 2022 IOTA meeting. These give formulae for the Fresnel Length, FL, that depends on the object's distance and the wavelength of light. A factor "rho" is found by dividing the object's radius by FL; previous studies show that Fresnel diffraction smearing becomes a significant problem, especially for low S/N events, when rho is $\leq$0.88. This happens at the following distances for:
Dimorphos (radius r = 80m), 0.18 AU; **Apophis** (r = 169m), 0.82 AU; **2001 CC21** (r = 300m), 2.59 AU; and
Didymos (r = 400m), 4.60 AU. Beyond these distances, the object becomes "diffracted out", unless the star is bright enough to provide a high S/N. Didymos and 2001 CC21 only have significant diffraction problems when they are farthest from Earth and near the aphelia of their orbits.

The Asteroid Collaborative Research via Occultation Systematic Survey **(ACROSS)** project home page is at **https://lagrange.oca.eu/fr/home-across** , and predictions are at **https://lagrange.oca.eu/fr/prediction** . The effort is funded by the European Space Agency (ESA) and is focused on Didymos and other Hera mission NEA possibilities.

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. The information for doing this is at **http://www.lunar-occultations.com/iota/2024iotapredictions.pdf** . This describes a prediction input file for planetary and asteroidal files called **All2024.xml**; this year, it includes many of the better NEA events. You can use that file to generate local predictions, but you can replace it with the other files listed at **https://occultations.org/publications/rasc/2024/nam24NEAoccs.htm** to generate predictions for more occultations, of fainter stars than shown on the maps, or for other parts of the world. There are fewer Occult input files there this year since Steve Preston now includes quite comprehensive Occult input files for 2024 NEA occultations, including the ones we consider most important, on his Web site at **https://www.asteroidoccultation.com/** .

This document will seldom be updated; more frequent updates with more timely information will be made at **https://occultations.org/publications/rasc/2024/nam24NEAoccs.htm** . Later in the year, some past-event files will be removed that may result in broken links.

David and Joan Dunham, dunham@starpower.net, 2023 Jan. 3.