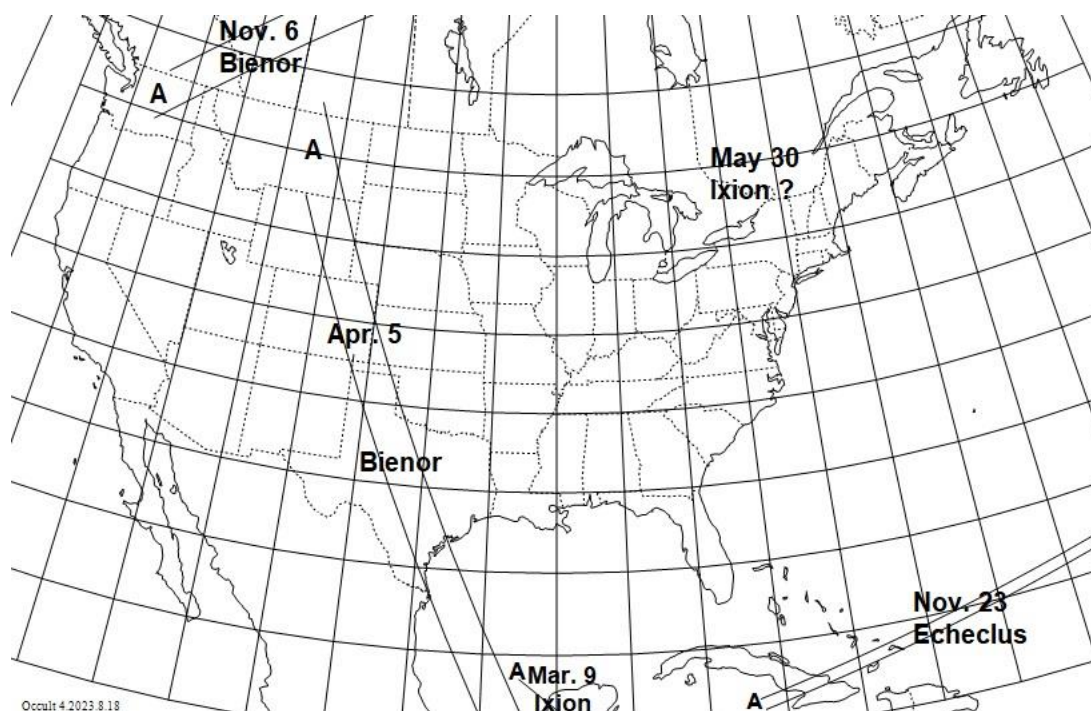


## 2024 Occultations by Distant Solar System Objects

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- $\sigma$  lines are shown on the Occult-produced map shown there, and better on the interactive Google maps on Occult Watcher cloud. You can also assess the uncertainties by the event's rank given by Preston and/or Occult Watcher (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 with integrating cameras in good conditions, some can be reached, especially with the larger instruments, and occasionally, a bright star is occulted by one. Be sure to also visit our 2024 occultations-by-distant-objects Web page associated with this document at <https://occultations.org/publications/rasc/2024/nam24distantoccs.htm> for additional links and information, especially with links to get the worldwide Occult input files of TNO and Centaur occultations described near the end of this document.

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 2024, with some opportunities portrayed below.

### The best 2024 occultations of stars by Distant Solar System Objects in North America



## 2024 OCCULTATIONS BY DISTANT OBJECTS

Date	UT	Occulting Body	Star	Mag.	RA (2000)			Dec			Dur. s	Path	
					h	m	s	°	'	"			ΔMag.
Mar. 9	09:11	28978 Ixion	UCAC4 294-188147	15.6	18	25	42.0	-31	12	43	3.9	48.6	Mex
Apr. 5	03:08	54598 Bienor	UCAC4 653-044261	12.9	06	36	41.8	+40	30	38	6.3	11.7	MT-TX
May30	05:35	28978 Ixion	UCAC4 293-190793	15.2	18	23	43.7	-31	35	23	4.2	32.4	neUSA?
Nov. 6	04:29	54598 Bienor	UCAC4 644-043294	12.8	07	41	41.8	+38	38	00	6.3	27.0	SK-WA
Nov.23	04:11	60558 Echeclus	UCAC4 531-045449	14.5	08	13	19.7	+16	07	04	6.2	6.8	BS-Cuba

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 2024*, showing the paths for occultations of some of the better distant-object occultations during 2024. The successive columns in the table list: (1) the date and central time of the event; (2) the number and name of the occulting body; (3) the star's catalog and number; (4) the star's apparent visual magnitude; (5) the star's J2000 right ascension and (6) declination; (7) the expected magnitude change from the combined brightness; (8) the duration of the central occultation; and (9) the path location specified by the lands crossed by the eastern and western ends of the path shown on the map. 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. BS is the Bahamas. 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.

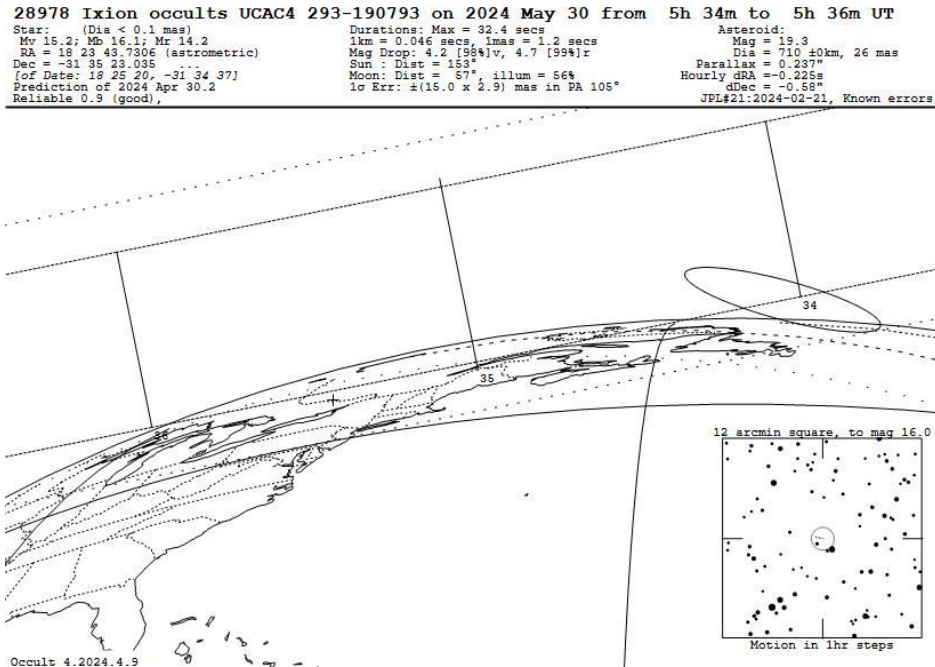
**(28978) Ixion** is a large (710-km) trans-Neptunian object (TNO).

**(54598) Bienor** is a 188-km Centaur; the best information about it is in Fernández-Valenuela et al.'s 2017 MNRAS paper, "Physical properties of centaur (54598) Bienor from photometry", that speculates that Bienor may have one or more rings, based on photometric evidence and the detection of water ice in its spectrum. The authors argue that observation of future occultations by the object should have high priority to test their ring(s) hypothesis. A few occultations have been observed since their paper was published. None of those showed evidence for rings, but for each of them, the stars were too faint relative to the size of the telescopes used, to reliably detect ring events.

**(60558) Echeclus** is a 59-km Centaur that has had outbursts and other cometary activity.

We apologize for being too late for posting this, missing the first two events. The faint March 9<sup>th</sup> event was unlikely to be observed anyway, occurring in Yucatan (at low altitude) and areas farther southeast with no known observatories capable of recording the occultation. Worse is missing the good April 5<sup>th</sup> Bienor occultation in the central USA, but that was only 3 days before the total solar eclipse that distracted many, including us; it's path crossed thousands of eclipse chasers who had arrived early in the San Antonio and Austin Texas hill country. As far as I know, none of them knew of the occultation, although it was published on p. 251 of the *2024 RASC Observer's Handbook*. The occultation was recorded by John Moore from Tulsa, OK, near the central line. He had an occultation nearly as long as the predicted central duration, showing that the prediction for the event was good, but unfortunately, he was apparently the only observer of the event.

The Lucky Star world map for the May 30th occultation by Ixion can be found at <https://lesia.obspm.fr/lucky-star/occ.php?p=130223> . Below is the path according to the JPL Horizons orbit with the corresponding OW cloud link being <https://cloud occultwatcher.net/event/1245-28978-260437-646016-U190793/Horizons;GaiaEDR3> , but Lucky Star shows the path will be about 280 km farther north, off the Earth's surface with similar errors.



**May 30, Ixion:** The altitude above the horizon will be too low for this faint star in its path over Canada (the predicted southern limit extends from P.E.I. to Lake Ontario and northern lower Michigan), but the path uncertainty means the occultation might be seen from Pennsylvania and possibly farther south, where the altitude should be high enough. I know at least 2 planned to try the event before it occurred, but I believe conditions were not good enough for them to observe the faint star, and I think both of them cancelled, as currently there is no record of anyone signed up for the event on its OW cloud page.

**Nov. 6, Bienor:** At 4:15 UT, the path crosses Morocco with high altitude above the horizon; a possible ring of Bienor might occult the star in the Canary Islands and/or western Iberia.

**Nov. 23, Echeclus:** At 4:03 UT, the path is over the Canary Islands with high altitude.

There are some other North American events, but we do not show them because the 1-sigma error of the path predictions for them are dozens of their path-widths, usually wider than the whole "lower 48" USA, so the chances for an occultation by any observer are extremely low; the next ones not shown above are:

Aug. 8, 13.2-mag. star, 8km (37117) Narcissus, OK-TX Panhandles, low altitude with some twilight

Aug. 25, 13.7-mag. star, 33km (332685) 2009 HH36, s. British Columbia

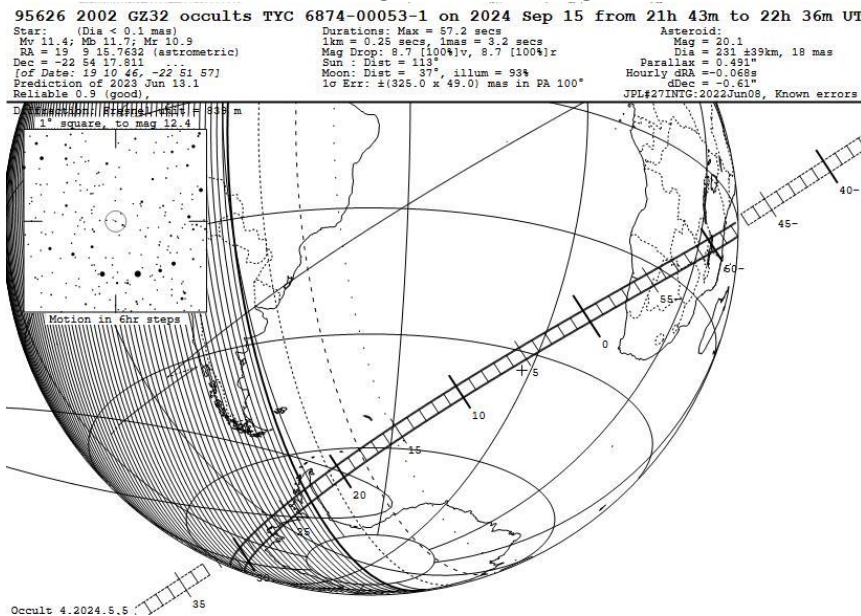
Oct. 18, 13.7-mag. star, 24km 2008 HY21, s.e. USA (un-numbered object)

Nov. 23, 14.3-mag. star, 77km (248835) 2006 SX368, n.w. USA

On June 2, an occultation of a 13.2-mag. star in Sagitta by the 126-km TNO (523700) 2014 GM54 occurred somewhere across or near North America. In mid April, the event had been added to OW cloud through the NALowMag feed, and a number of observers signed up to try it, but several other potential observers weren't notified until 2h before the event; some of them jumped in to try it. There were a few miss

observations, but no positives, and several “clouded out or no observation” reports. An account of the event is at <https://occultations.org/publications/rasc/2024/20240602-523700occForWeb.pdf> and prediction maps, etc. for the event are on the Web page for this .pdf given on the middle of p. 1 above. As described in the event document, we need to do a better job of notifying observers of these events with a week or more warning. The Lucky Star events are flagged by Occult Watcher and OW Cloud, but the June 2<sup>nd</sup> event wasn’t picked up by Lucky Star. If you find a TNO or Centaur event on OW or OW Cloud that has not been mentioned previously in IOTAoccultations or Planoccult, please send a message about the event to one of those lists including the event’s OW cloud link.

Besides these events in N. America, Steve Preston (we are using his predictions for 2024 from his 2024 prediction Web site at <https://asteroidoccultation.com/2024/>) calculated predictions for 91 Centaur and TNO occultations worldwide for 2024. Of these, the brightest occurred on Feb. 21 involving a 10.2-mag. star by the 78km TNO (248835) 2006 SX368, from Kamchatka to n. India, but the error of the path was larger than the Earth. The future brightest event (mag. 11.4) is shown in the Occult map below:



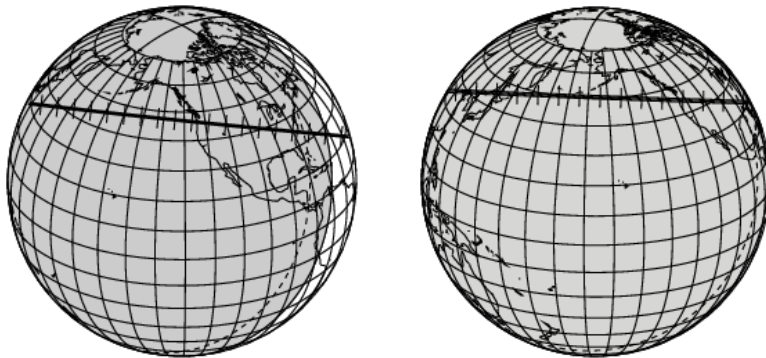
Namibia has a chance.

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 this Web site 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 Lucky Star site has predictions for many more occultations by distant objects, and their predictions, using astrometry and updated orbits available only to them, are usually better than ours. Thanks to Felipe Braga Ribas in Brazil, the past occultation observation details collected by Lucky Star are available at <https://occultations.ct.utfr.edu.br/results/> but many results there are preliminary. It would be very useful if a volunteer could check their results with IOTA’s database of asteroidal occultation observations, and add observations there that are not currently in IOTA’s records; then the observations

would be picked up by JPL to significantly improve their orbits that in turn would be used by Occult Watcher to generate better paths for these objects that we would use. Observers submit their observations to the Lucky Star Occultation Portal at <https://occultation.tug.tubitak.gov.tr/>.

Another large effort to predict and observe occultations by Centaurs and TNO's is the **Research and Education Collaborative Occultation Network (RECON)** organized by Marc Buie and John Keller at the Southwest Research Institute in Boulder; see <http://tnorecon.net/> . They conduct campaigns from about 50 observatories at colleges and high schools spread from north to south across the western USA, with collaborations with a few additional observatories in southern British Columbia and Baja California. Like Lucky Star, they collect their own astrometric observations and issue three levels of predictions for the next two years that you can find on their campaigns page at <http://tnorecon.net/observation-campaigns/> including a global candidate list. Their RECON TNO Event List includes 7 occultations during the rest of 2024 visible primarily from the western USA. Two are relatively bright, involving a 14.1-mag. star on Dec. 01 around 10:38 UT and a 13.4-mag. star on Dec. 17 around 11:43 UT; the others involve fainter stars ranging from mag. 15.4 to 16.2 – see the RECON Web page for details, including w. USA path maps, finder charts, and a list of predicted circumstances at all of the RECON stations. As usual, these paths have large error bars, so observers throughout N. America have some chance for a valuable “hit”. If you see a Centaur or TNO event on Occult Watcher, please try to observe it, as they are among the most valuable occultations, but usually they will be missed in OW as observers filter out the less-probable events by setting a low “rank”. It would be better to highlight these events more in OW, especially when they are Lucky Star events; that can't be used as the sole discriminant since most Lucky Star events are of the more common Trojan asteroids. IOTA stresses the importance of the distant objects with the “Beyond Jupiter” series that highlights one of the distant objects near the end of each issue of *Journal For Occultation Astronomy*.



**Left:** 2024 Dec. 1 occ of 14.1mag. star by (15875) 1996 TP66; **Right,** Dec. 17 of 13.7mag. star (123509) 2000 WK183.

Our N. American path 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/2024iotapredictions.pdf> . This describes a prediction input file for planetary and asteroidal occultations called **All2024.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 OW or the Web sites given near the top of this document for better and current errors.

**nam24distantoccsFinal.xml** – This is the input for the 5 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).

**TNO-2024-raw.xml** – This is the input for 91 occultations worldwide by selected Centaurs and Kuiper-Belt Objects of stars to mag. 16, by Steve Preston.

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 **All2024.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](mailto:dunham@starpower.net), 2024 May 24; updated June 5