Deliverable

H2020 COMPET-05-2015 project "Small Bodies: Near And Far (SBNAF)"

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WP5 Ground based observations
Objectives: The main objective of WP5 is to execute observations from ground-based telescopes with the goal to acquire more data on the SBNAF targets. One of the scheduled observations is the occultation of a star by a Main Belt Asteroid (MBA), a Centaur or a Trans-Neptunian Object (TNO). For this particular stellar occultation technique the main tasks are: i) to predict the stellar occultation, ii) to coordinate the observations, and iii) to produce results on physical parameters of the MBAs, Centaurs and TNOs (i.e. sizes, shapes, albedos, densities, etc).

Description of deliverable D5.3
The potential occultation candidates for 2018 are presented. This deliverable follows deliverables D5.1 and D5.2, and is related to milestones MS5 "Occultation predictions with 10 mas accuracy", and MS12 "25 successful TNO occultation measurements". In this document, we first give a short state of the art of the stellar occultation technique (Section 1), then we discuss about the expected goal to reach ~10 mas accuracy in the prediction of stellar occultations by TNOs (Section 2). After that we give a list of stellar occultations observed within the SBNAF project (Section 3), and finally we provide our stellar occultation predictions for the year 2018 (Section 4).

Contents

1 Very brief state of the art of the stellar occultation technique

Stellar occultations by solar system bodies (planets, MBAs, TNOs, Centaurs, etc) are phenomena that give plenty of information (Sicardy et al. 2006) on the bodies that cause the occultations, and sometimes on the stars that are occulted (see Figure 1).

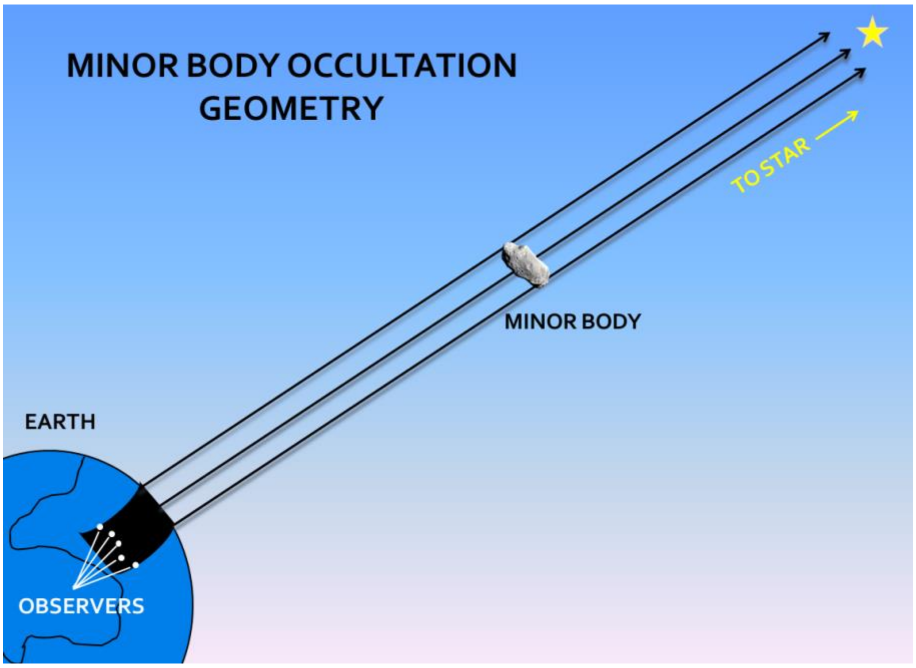


Figure 1.- Scheme of a stellar occultation by a Solar System minor body. Figure from Santos-Sanz et al. (2016).

During the last year 2017 and thanks to the GAIA data release 1 (GAIA-DR1) the field of the stellar occultations has experienced a true revolution. The coordinates and magnitudes of millions of stars with unprecedented precision were published in the GAIA-DR1. This star catalogue is extremely useful for refining the prediction of stellar occultations produced by asteroids and in particular by Trans-Neptunian Objects (TNOs) and Centaurs. The GAIA star catalogue does not provide positions and magnitudes of solar system bodies but provides the positions of the to-be occulted stars with unprecedented precision. In this first release, the astrometric precision of the position of a star (as function of the magnitude) is 0.5 milli-arcsecond (mas) for a 6-magnitude star, 1.1 mas for a 9 magnitude star, 3 mas for a 12 magnitude star, and 7 mas for a 15 magnitude star. These precisions will be overcome by the next GAIA data release (GAIA-DR2) which also will include stellar proper motions and astrometry for a pre-selected list of more than 10,000 Main Belt Asteroids (MBAs). The GAIA data release 2 (https://www.cosmos.esa.int/web/gaia/release) is expected for April 2018.

In a typical occultation of a star by a Solar System body, the error in the determination of the shadow path on the surface of the Earth is determined by the error in the star position and the error in the orbit (ephemeris) of the solar system body. With the GAIA catalogue, the error in the star position is decreased to less than 10 mas, in most of the cases. For a typical MBA, 1 mas corresponds to 2 kilometers in error in the shadow path on the surface of the Earth. In the case of a typical TNO, 1 mas corresponds to 30 km in error in the shadow path. Uncertainty in a typical asteroid orbit is around 150 mas and around 450 mas for a typical TNO orbit.

In short, the predictions of the occultation of bright stars (magnitudes lower than 14) by a MBA, Centaur or TNO is improved with the use of GAIA DR1 (and will be even more improved and extended to fainter stars during 2018 thanks to GAIA DR2) and now the shadow path can be determined with a few kilometers of error on the surface of the Earth for MBAs and few hundreds of kilometers for TNOs and Centaurs. The main source of error is now the error in the determination of the orbit, which is larger for the more distant objects. To solve this source of error we need more accurate astrometry for the MBAs and especially for the TNOs and the Centaurs. A positive occultation observation is one of the ways to diminish this error, as for that moment the MBA/Centaur/TNO is at the exact position of the occulted star. This astrometric improvement is not automatically taken into account in the orbit determinations. Here we suggest to include this improvement in the orbits refinements, at least for the most relevant targets.

2 Stellar occultation by TNOs: the 10 mas accuracy goal in the predictions

Stellar occultations produced by TNOs are quite different to stellar occultations produced by MBAs, and often require specific methods to observe them. There are a number of differences:

- TNOs are very exotic and rare objects compared to MBAs. Only around 2,000 such bodies are catalogued, whereas more than 746,000 MBAs are catalogued. Stellar occultations by all the known MBAs are very frequent whereas stellar occultations by TNOs are rare events.

- In most cases, the predictions of occultations caused by the TNOs involve much fainter stars than typical predictions for MBAs. So usually, more powerful telescopes are needed to study occultations by TNOs than occultations by MBAs.

- Uncertainties in the orbits of the TNOs are far larger than for MBAs, so their absolute positions on the sky are known with far less accuracy than their angular diameters, so predicting reliable occultations by TNOs is far more challenging than predicting regular asteroidal occultations.

- Stellar occultations by TNOs usually last much longer than MBAs occultations. This is because the sky motion of TNOs is far slower than for asteroids. Occultations by TNOs typical last a few tens of seconds whereas occultations by MBAs typically last around a few seconds.

- The scientific output of occultations by TNOs is currently much larger than for most MBAs occultations. This is because little is known about TNOs and the more information we gather, the better. Besides, TNOs are thought to be relics of the solar system formation and preserve material from that stage with fewer alterations than the material in regular MBAs.

- Even though many people call TNOs and Centaurs "asteroids", they are far more like comets than like asteroids. The TNOs do not develop coma and tail simply because they are far from the sun, in contrast to comets, which get close to the sun. From the observational point of view, through a telescope, TNOs are just moving star-like objects, and since asteroids also are moving star-like objects, they are very similar so sometimes people refer to TNOs as asteroids.

The improvement on the accuracy of stellar occultation predictions afforded by GAIA is especially relevant for TNOs and Centaurs. One clear example of the power of the GAIA new star positions is the 19 July 2016 stellar occultation by Pluto. The initial predictions -based on ground measurements of the star- put the shadow path centrality sweeping over mid-Europe (see Fig. 2-a), but with uncertainties as large as 50 mas, equivalent to about 1500 km when projected onto Earth's surface. This situation, which was common to many occultation events involving TNOs/Centaurs before the GAIA data release, makes the task of choosing the telescopes that will look at the event much more difficult, with the risk of missing some relevant observations, as the expected central flash due to Pluto's atmosphere. It is important to note that Pluto subtends a mere 100 mas diameter on the sky while being one of the largest TNOs.

The updated star position by GAIA DR1 drastically improved that accuracy, down to a few mas level (~5-7 mas), corresponding to ~120-170 km on the Earth's surface. The GAIA DR1 star position combined with an improved Pluto orbital solution based on the radio tracking of the New Horizons spacecraft reached an accuracy of about 100 km. This placed the centrality of the event over the Middle East and northern Africa, and triggered alerts in Israel, Morocco and the Canary islands (Fig. 2-b).

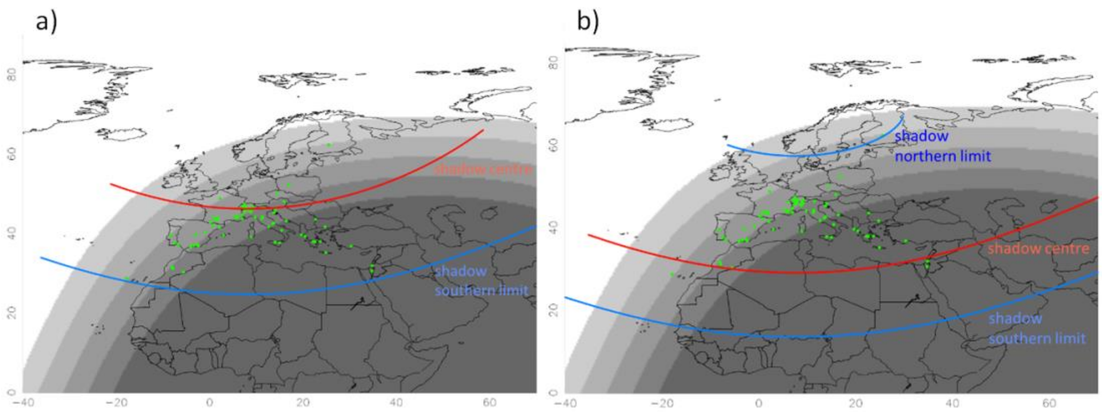


Figure 2.- (a) Initial prediction of the 19 July 2016 stellar occultation by Pluto. (b) The same prediction refined using GAIA DR1 star position and New Horizons ephemeris for Pluto.

We can compare this 19 July 2016 occultation by Pluto, with an accuracy on the prediction ~5-7 mas thanks to the use of GAIA DR1 and New Horizons ephemeris for Pluto, with some other positive stellar occultations by TNOs recorded up to date. Some of the most relevant occultations by TNOs (excluding Pluto) recorded **before the GAIA data release 1** are:

i) The 6th November 2010 stellar occultation by the dwarf planet (and TNO) Eris (Sicardy et al. 2011, Nature). The prediction of this occultation was done using UCAC4 star catalogue and the relative astrometry of Eris and the occulted star that was updated just few days prior to the occultation. The accuracy on the prediction respect to the real Eris shadow path was about ~14 mas (~970 km when projected onto Earth's surface).

ii) The 23rd April 2011 stellar occultation by the dwarf planet (and TNO) Makemake (Ortiz et al. 2012, Nature). As for the Eris' case, the prediction of this stellar occultation was done by means of UCAC4 catalogue and it was refined using relative astrometry of the star and Makemake itself a few days prior to the occultation. The accuracy reached by the prediction respect to the final Makemake shadow path was about ~10 mas (~370 km when projected onto Earth's surface).

And some of the most relevant stellar occultation by TNOs recorded **after GAIA DR1 are**:

i) The 21st January 2017 occultation by the dwarf planet (and TNO) Haumea (Ortiz, Santos-Sanz et al. 2017, Nature). In this case the prediction was done using GAIA DR1 and it was refined using relative astrometry of the star and Haumea itself a few days prior to the occultation. The "wobble" of the photocenter of the Haumea's system due to the presence of the Haumea's largest satellite (Hi'iaka) was also taken into account to refine the final prediction. The accuracy reached by the best prediction respect to the final shadow path of Haumea was about ~11 mas (~400 km when projected onto Earth's surface).

ii) The 17th July 2017 occultation by the TNO 2014 MU_{69} (Buie et al. 2017, in preparation). This small TNO is the target of the New Horizons mission next flyby expected for 1st January 2019. The prediction of this stellar occultation was done using a pre-release version of GAIA DR2 star positions and the astrometry of 2014 MU_{69} obtained from Hubble Space Telescope observations taken just a few weeks prior to the occultation. The accuracy obtained by the preferred prediction respect to the real shadow path of 2014 MU_{69} was about ~0.5 mas! (15 km projected onto Earth's surface!).

One of the milestones of the SBNAF project related with stellar occultations by TNOs is to obtain an accuracy of ~10 mas in the predictions of occultations by these bodies (for TNOs with sizes larger than ~300 km). As already stated in the examples above, this accuracy can be currently reached for the largest TNOs.

Thanks to the GAIA data release 2, expected for April 2018, and to the next GAIA data releases, we are more and more close to reach this goal for most of the TNOs larger than 300 km.

Reaching the ~10 mas accuracy in the predictions we are now ready to predict a stellar occultation by a TNO from a space telescope, like the James Webb Space telescope (launch expected in spring 2019). In the context of our SBNAF project, we have obtained Guaranteed Time Observations –GTO– within the Heidi Hammel Solar System GTO (http://www.stsci.edu/cgi-bin/get-jwst-gto-time#Heidi Hammel) to observe 2 stellar occultations by TNOs/Centaurs in Target of Opportunity (ToO) mode during JWST observing Cycle1 and Cycle2. If we succeed in predicting and observing one of these occultations from the JWST the scientific relevance for the TNOs science will be a real breakthrough.

3 Stellar occultations observed within the SBNAF project

We have built a detailed list with all the stellar occultations in the context of SBNAF in which we have been involved. These stellar occultations, observed within the SBNAF project, are included in our password protected target web page and can be accessed from the following link:

http://asteroidstnos.iaa.es/content/results

This **'Results on stellar occultations'** list contains basic information about the stellar occultation predictions, observations, and about the results in case of positive occultations. These data are useful, not only for the physical information that the occultation provides for each object, but also because this information is an important input for WP3 'Lightcurve inversion technique'.

This stellar occultations list is daily or weekly updated with the news on stellar occultations by MBAs, TNOs and Centaurs related with SBNAF. In the next page there are a few snapshots of the web page with positive (in green) or negative (in red) results on stellar occultations by MBAs, TNOs and Centaurs. For some of the positive occultations snapshots with the basic information linked to the occultation are also shown in the next pages.

Last but not least, from SBNAF we manage the so-called 'Gaia-GOSA' service to alert, activate and coordinate possible observers of Gaia perturbers MBAs (see http://www.gaiagosa.eu/). All the Gaia MBAs measurements are coordinated from the Gaia-GOSA service. Stellar occultations by Gaia perturbers are also announced and coordinated from this service.

Results on stellar occultations

MBAs

3 Juno (Negative, 24 May 2017)

8 Fides (Positive?, 11 Mar 2017)

16 Psyche (Negative, 26 Apr 2016)

18 Melpomene (Positive, 19 Nov 2017)

19 Fortuna (Positive, 12 Sep 2017)

21 Lutetia (Historical occultations)

21 Lutetia (Positive, 13 Aug 2016)

21 Lutetia (Positive, 24 Sep 2016)

21 Lutetia (Positive, 10 Feb 2017)

44 Nysa (Positive, 19 Sep 2017)

173 Ino (Positive, 8 Oct 2017)

227 Philosophia (Positive, 16 Aug 2016)

372 Palma (Positive, 10 Sep 2017)

501 Urhixidur (Positive, 13 May 2017)

596 Scheila (Positive, 21 Jan 2016)

654 Zelinda (Positive, 30 Jul 2017)

721 Tabora (Negative, 27 July 2017)

TNOs

19521 Chaos (Negative, 24 Nov 2016, TBC)

50000 Quaoar (Negative, 7 Jul 2016)

(84922) 2003 VS2 (Negative, 17 Nov 2016)

(119951) 2002 KX14 (Negative, 16 Apr 2016)

134340 Pluto (Positive, 14 Jul 2016)

134340 Pluto (Positive, 19 Jul 2016)

136108 Haumea (Negative, 27 Apr 2016)

136108 Haumea (Positive, 21 Jan 2017)

(145453) 2005 RR43 (Negative, 8 Dec 2016)

(202421) 2005 UQ513 (Negative, 1 Nov 2016)

(444030) 2004 NT33 (Positive, 16 Nov 2017)

(469506) 2003 FF128 (Negative, 13 June 2017)

(470599) 2008 OG19 (Negative, 9 Sep 2016)

(482824) 2013 XC26 (Negative, 26 Nov 2017)

(486958) 2014 MU69 (Negative, 3 June 2017)

(486958) 2014 MU69 (Positive, 17 Jul 2017)

Centaurs

10199 Chariklo (Negative, 28 Mar 2016)

10199 Chariklo (Negative, 18 May 2016)

10199 Chariklo (Negative, 7 Jul 2016)

10199 Chariklo (Positive, 25 Jul 2016)

10199 Chariklo (Positive, 26 Jul 2016, TBC)

10199 Chariklo (Positive, 8 Feb 2017)

10199 Chariklo (Positive, 23 Jul 2017)

32532 Thereus (Negative, 11 Jan 2016)

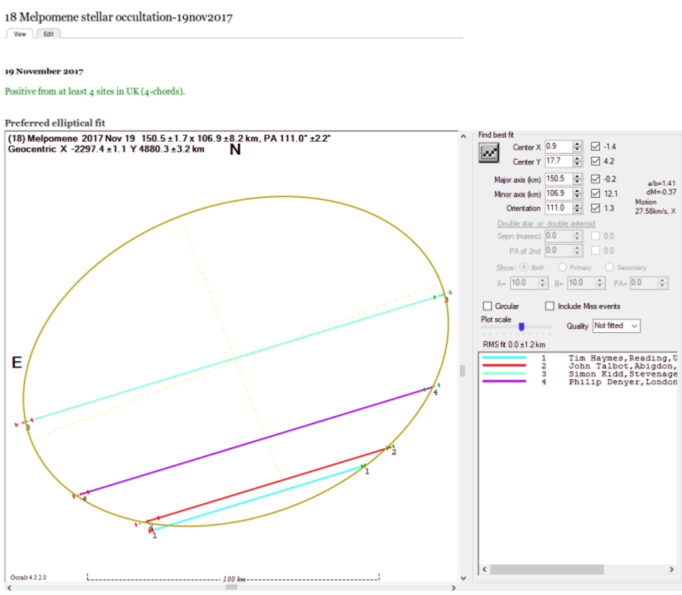
54598 Bienor (Negative, 13 Feb 2017)

54598 Bienor (Negative, 18 Oct 2017)

60558 Echeclus (Negative, 11 Sep 2016)

(95626) 2002 GZ32 (Negative, 9 May 2016)

(95626) 2002 GZ32 (Positive, 20 May 2017)



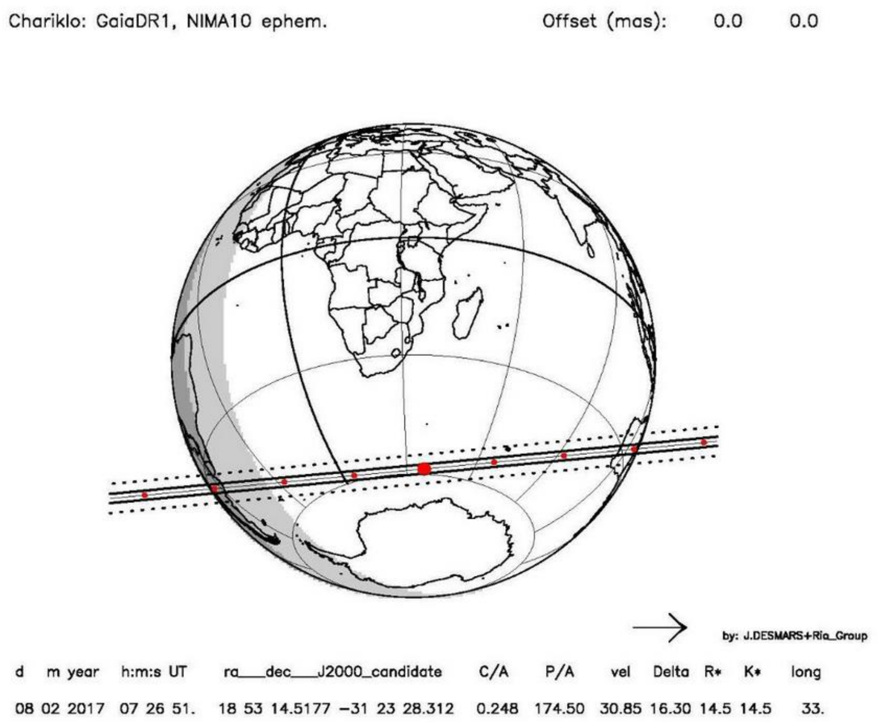
Chariklo stellar occultation-8feb2017

View | Edit

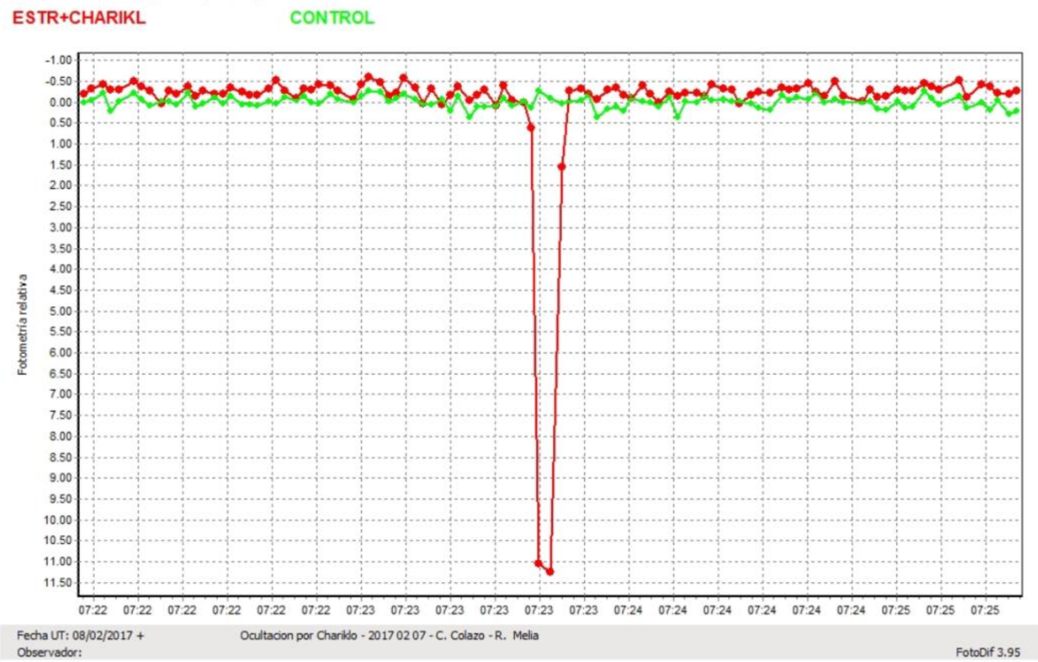
8 February 2017

Positive from Bosque Alegre, Observatorio Astronómico de Córdoba (Argentina).

Prediction map



Lightcurve from Bosque Alegre (Argentina)



654 Zelinda stellar occultations

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30 July 2017

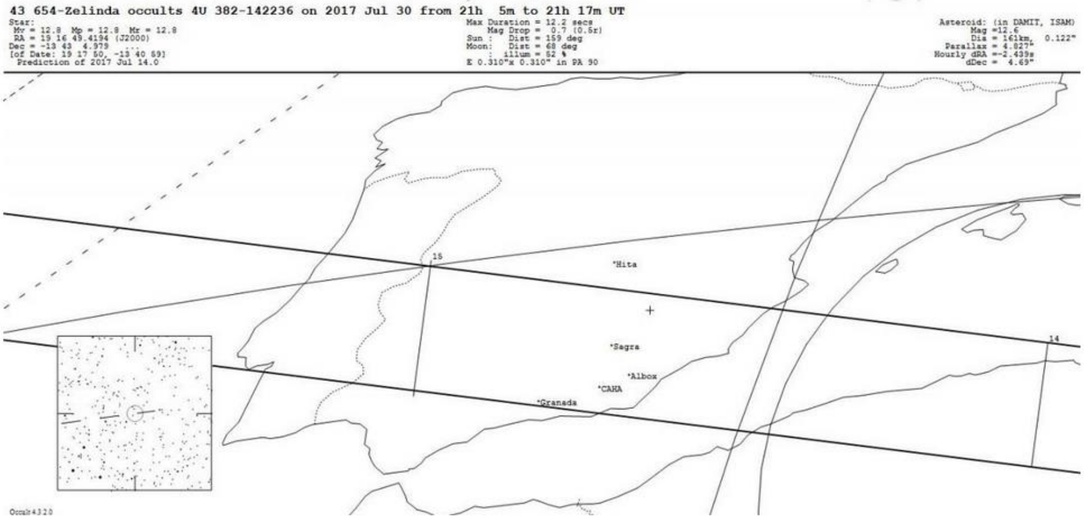
Positive occultation with 2-chords from Spain.

We contacted observatories in Spain and finally it was observed from 5 sites. Sadly, from two of the sites the telescope was pointing to an incorrect star field, and we missed the occultation from these sites. Detailed observatories:

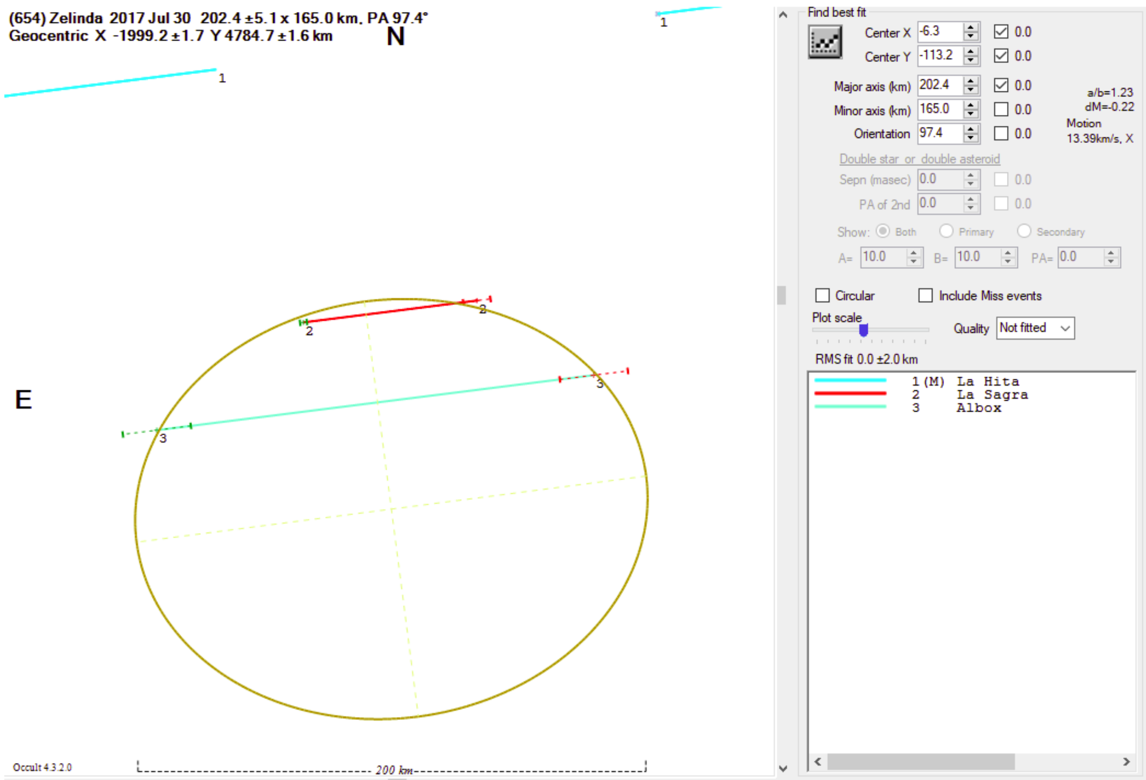
- **La Hita Observatory (Toledo, Spain):** NEGATIVE.
- **La Murta Observatory (Murcia, Spain):** Missed due to incorrect FOV.
- **La Sagra Observatory (Granada, Spain):** POSITIVE from 2 telescopes.
- **Albox Observatory (Almería, Spain):** POSITIVE
- **Calar Alto Observatory M14 telescope (Almeria, Spain):** Missed due to incorrect FOV.

Finally we obtained 3-positives observations (2 from La Sagra and 1 from Albox) and 2-chords: one from La Sagra and the other from Albox.

Prediction



Preferred elliptical fit



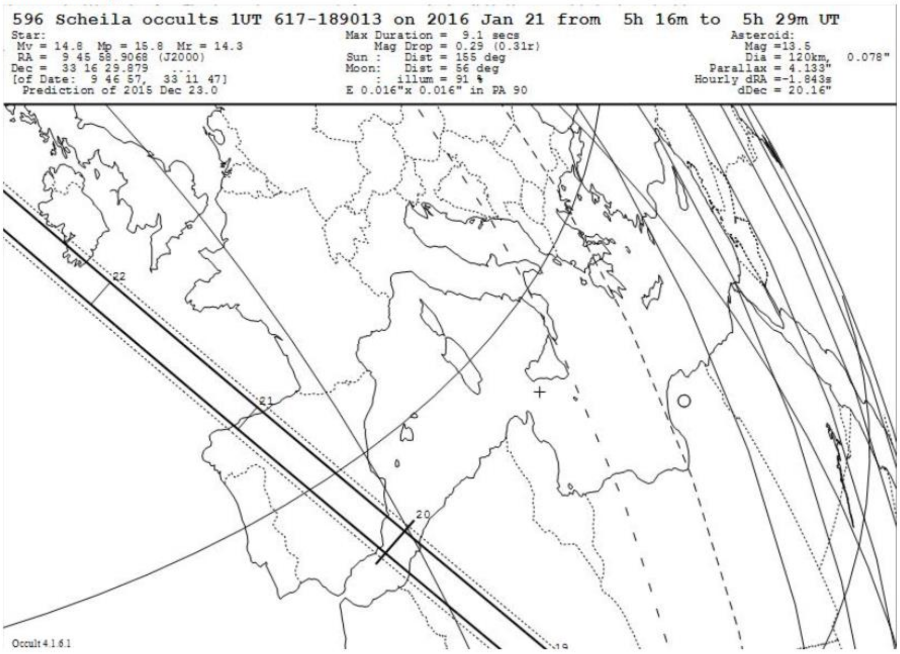
596 Scheila stellar occultations

View | Edit

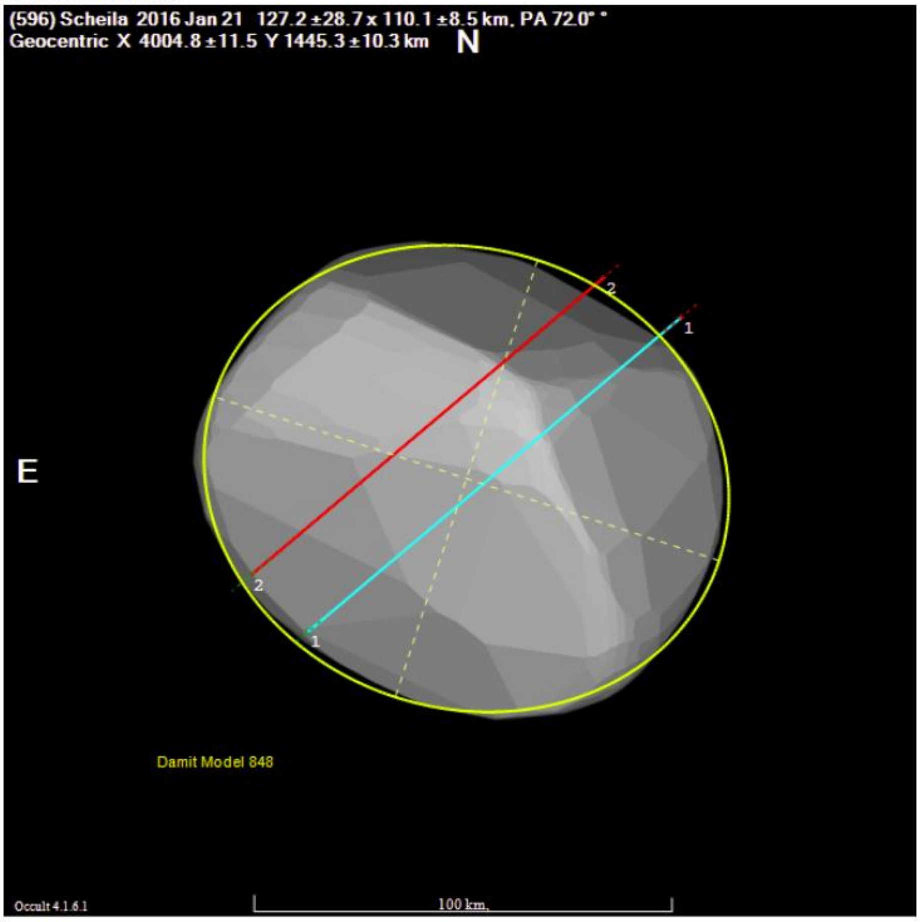
21 January 2016

Positive from Albox Observatory (Almeria, Spain) and La Hita Observatory (Toledo, Spain).

Prediction map



Preferred fit ellipse



4 Stellar occultation predictions for 2018

Accurate predictions are the main bottleneck for a successful campaign to observe an occultation produced by a MBA, Centaur or TNO. We use the GAIA catalogue (GAIA DR1) and the free software Occult to identify the occultations by MBAs, Centaurs and TNOs during the year 2018.

4.1 Occultations by MBAs predicted for 2018

We have identified occultations by MBAs interesting for the SBNAF project using the GAIA catalogue. Occultation predictions of stars brighter than mag 14 favourable to Europe, South America, North America, Australia/New Zealand and Japan have been obtained for the next list of MBAs:

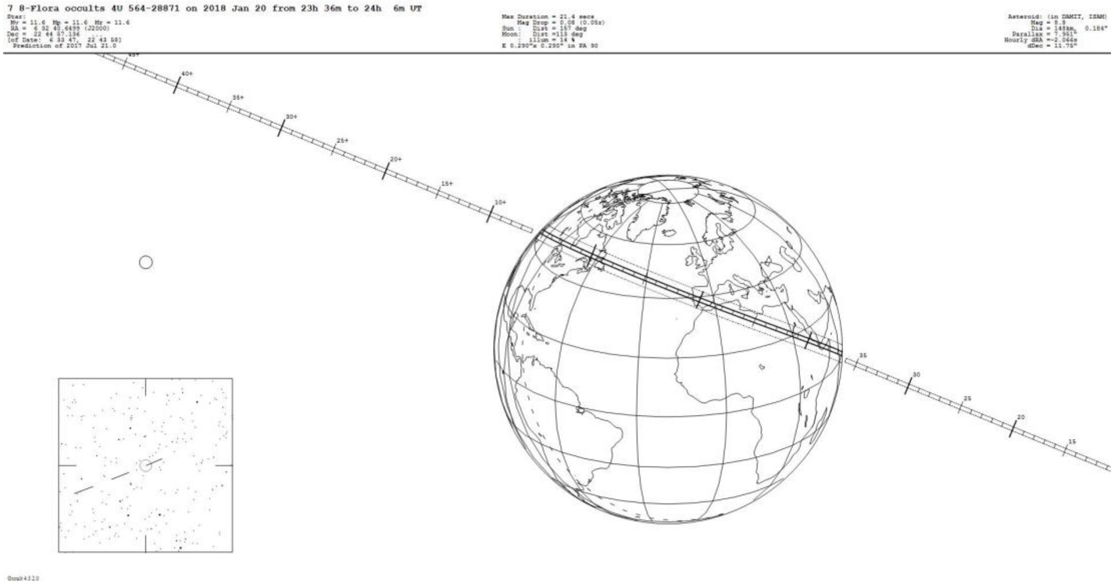
1 Ceres	20 Massalia	93 Minerva	423 Diotima
2 Pallas	21 Lutetia	113 Amalthea	441 Bathilde
3 Juno	27 Euterpe	114 Kassandra	511 Davida
4 Vesta	29 Amphitrite	145 Adeona	636 Erika
6 Hebe	37 Fides	162 Laurentia	654 Zelinda
7 Iris	40 Harmonia	173 Ino	704 Intermania
8 Flora	47 Aglaja	175 Andromache	721 Tabora
9 Metis	52 Europa	206 Hersilia	911 Agamemnon
10 Hygiea	54 Alexandra	297 Caecilia	951 Gaspra
13 Egeria	60 Echo	308 Polyxo	1427 Ruvuma
14 Irene	64 Angelina	360 Carlova	1626 Sadeya
16 Psyche	65 Cybele	372 Palma	2867 Steins
18 Melpomene	68 Leto	381 Myrrha	2951 Perepadin
19 Fortuna	88 Thisbe	402 Chloe	

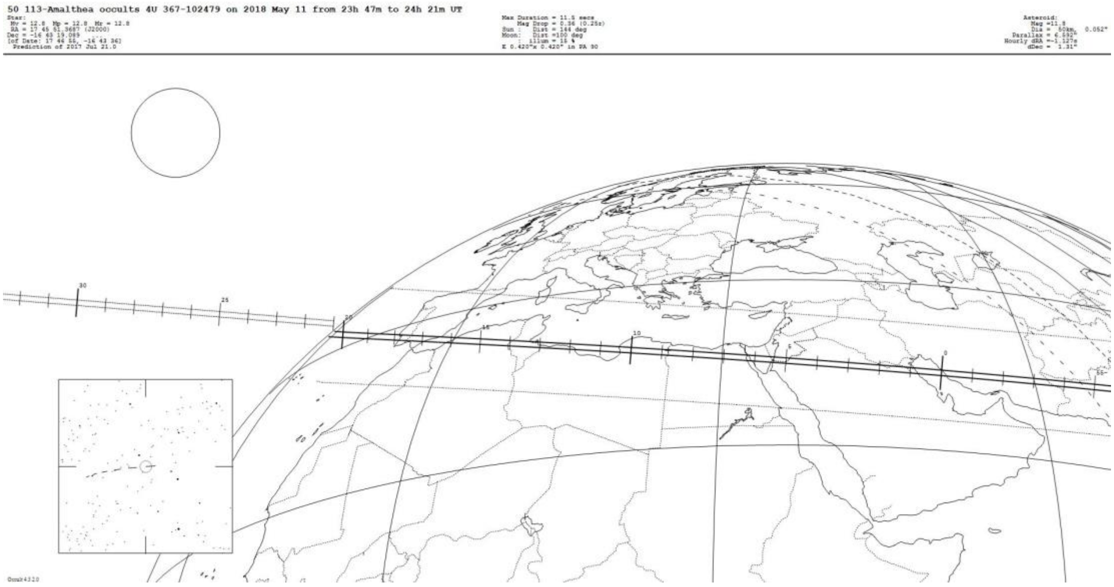
The selected Earth regions are those with a dense network of telescopes and observers with which we have collaborated in the past. The obtained predictions have been inspected one by one in order to remove predictions with shadows paths above the ocean, during daytime, or with the occulted star at low elevation. The number of final occultations by MBAs predicted for 2018 for each region is: Europe (30), South America (171), North America (68), Australia/New Zealand (94), and Japan (22). The whole prediction maps can be downloaded from:

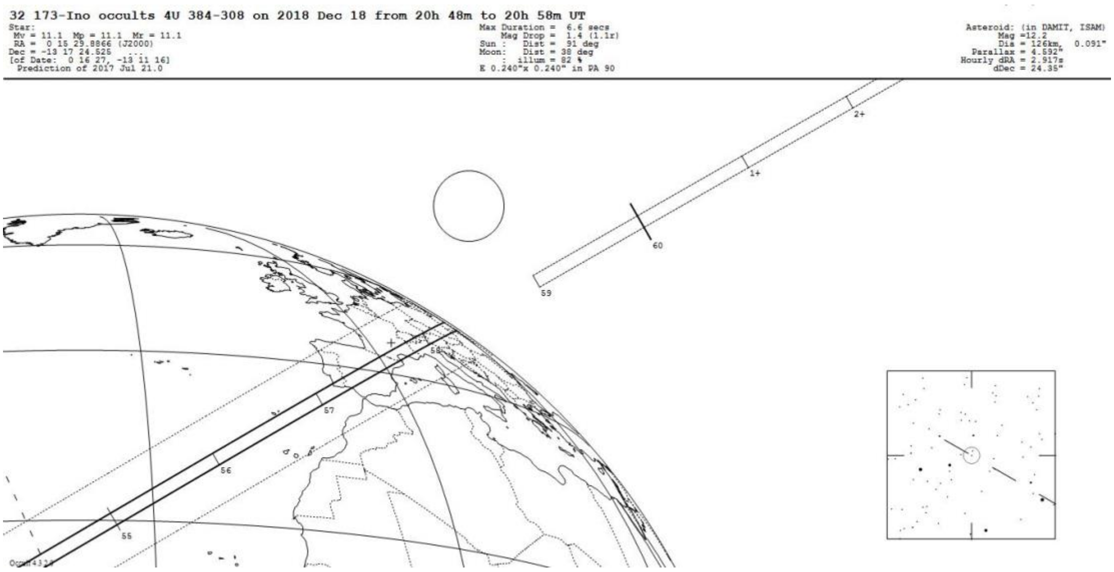
https://cloud.iaa.csic.es/public.php?service=files&t=b1b8bee24bbe80b77ec9142737bec7c1

Apart of the MBAs included in the last table, we also have done predictions of stellar occultations by some relevant Jupiter Trojans, in particular for the NASA Lucy space mission targets. Below are included a few examples of stellar occultation prediction maps for 2018 for each of the selected regions: Europe, South America, North America, Australia/New Zealand and Japan.

Europe


7 8-Flora occults 4U 564-28871 on 2018 Jan 20 from 23h 36m to 24h 6m UT
Star:
Mv = 11.6 Mp = 11.6 Mr = 11.6
RA = 6 32 40.6499 (J2000)
Dec = 22 44 57.136
[of Date: 6 33 47, 22 43 58]
Prediction of 2017 Jul 21.0
Max Duration = 21.4 secs
Mag Drop = 0.08 (0.06r)
Sun : Dist = 157 deg
Moon: Dist =118 deg
: illum = 14 %
E 0.290"x 0.290" in PA 90
Asteroid: (in DAMIT, ISAM)
Mag = 8.8
Dia = 148km, 0.184"
Parallax = 7.961"
Hourly dRA =-2.066s
dDec = 11.75"
Occult4320


50 113-Amalthea occults 4U 367-102479 on 2018 May 11 from 23h 47m to 24h 21m UT
Star:
Mv = 12.8 Mp = 12.8 Mr = 12.8
RA = 17 45 51.3687 (J2000)
Dec = -16 43 19.089
[of Date: 17 46 56, -16 43 36]
Prediction of 2017 Jul 21.0
Max Duration = 11.5 secs
Mag Drop = 0.36 (0.25r)
Sun : Dist = 144 deg
Moon: Dist =100 deg
: illum = 15 %
E 0.420"x 0.420" in PA 90
Asteroid:
Mag =11.8
Dia = 50km, 0.052"
Parallax = 6.692"
Hourly dRA =-1.127s
dDec = 1.31"
Occult4320


32 173-Ino occults 4U 384-308 on 2018 Dec 18 from 20h 48m to 20h 58m UT
Star:
Mv = 11.1 Mp = 11.1 Mr = 11.1
RA = 0 15 29.8866 (J2000)
Dec = -13 17 24.525 ...
[of Date: 0 16 27, -13 11 16]
Prediction of 2017 Jul 21.0
Max Duration = 6.6 secs
Mag Drop = 1.4 (1.1r)
Sun : Dist = 91 deg
Moon: Dist = 38 deg
: illum = 82 %
E 0.240"x 0.240" in PA 90
Asteroid: (in DAMIT, ISAM)
Mag =12.2
Dia = 126km, 0.091"
Parallax = 4.592"
Hourly dRA = 2.917s
dDec = 24.35"

South America

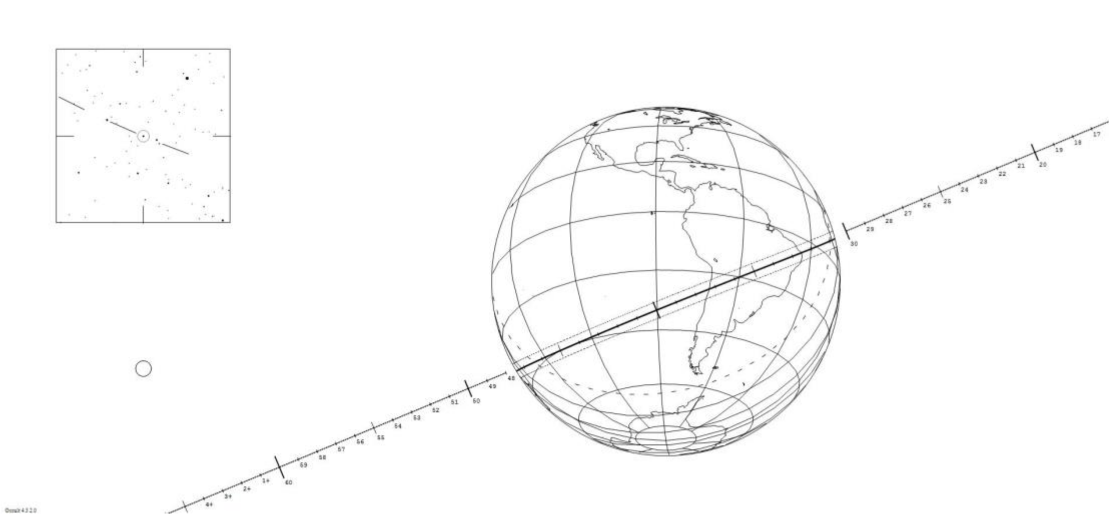
48 1626-Sadeya occults 4U 332-58011 on 2018 Feb 5 from 6h 31m to 6h 48m UT

Star:
Mv = 7.6 Mp = 7.6 Mr = 7.6
RA = 9 53 14.3900 (J2000)
Dec = -23 40 59.779 ...
[of Date: 9 54 5, -23 46 12]
Prediction of 2017 Jul 21.0

Max Duration = 1.2 secs
Mag Drop = 6.7 (6.3r)
Sun : Dist = 139 deg
Moon: Dist = 53 deg
: illum = 73 %
E 0.310"x 0.310" in PA 90

Asteroid: (in DAMIT, ISAM)
Mag =14.3
Dia = 16km, 0.016"
Parallax = 6.930"
Hourly dRA =-3.279s
dDec =-18.74"

Double star

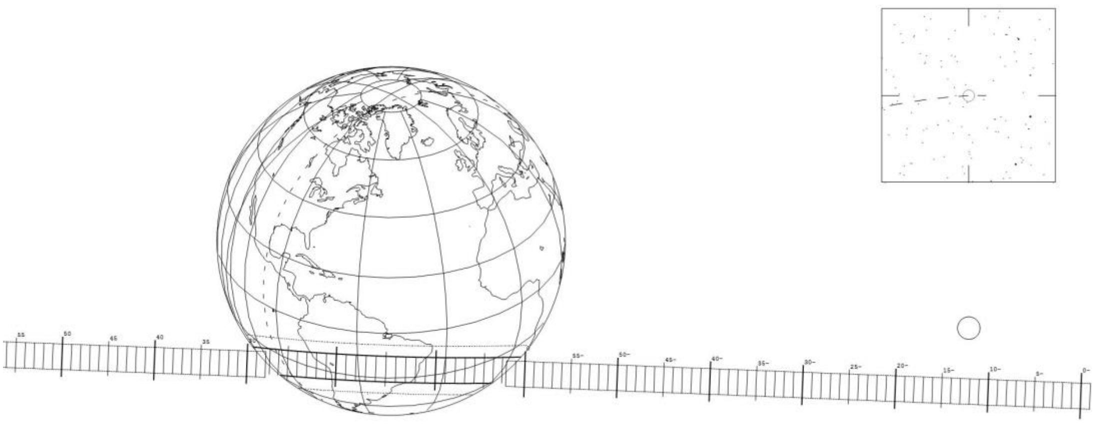


1 1-Ceres occults 4U 611-44000 on 2018 Mar 4 from 1h 0m to 1h 30m UT

Star:
Mv = 13.2 Mp = 13.2 Mr = 13.2
RA = 8 46 5.9893 (J2000)
Dec = 32 6 17.401 ...
[of Date: 8 47 14, 32 2 12]
Prediction of 2017 Jul 21.0

Max Duration =166.2 secs
Mag Drop = 0.01 (0.00r)
Sun : Dist = 140 deg
Moon: Dist = 64 deg
: illum = 95 %
E 0.330"x 0.330" in PA 90

Asteroid:
Mag = 7.4
Dia = 939km, 0.762"
Parallax = 5.107"
Hourly dRA =-1.279s
dDec = 0.61"

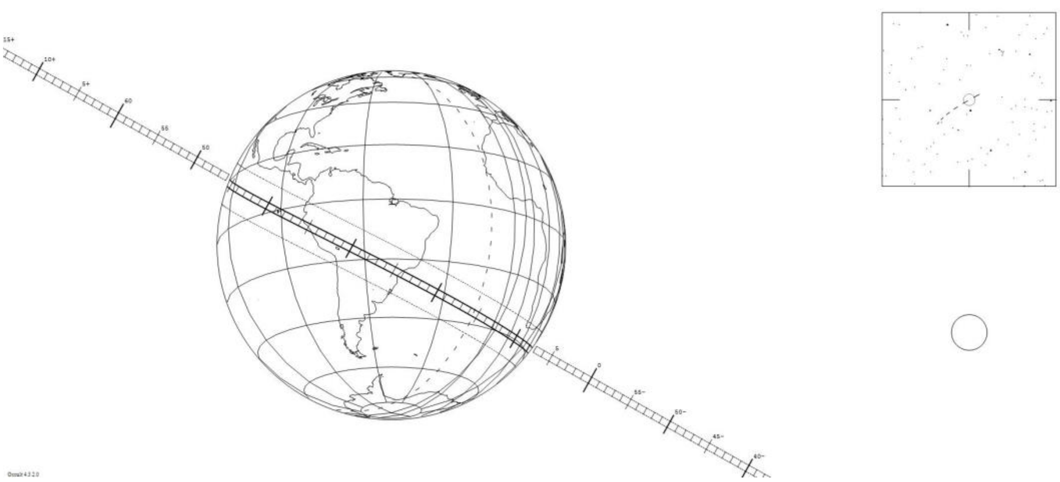


12 16-Psyche occults 4U 374-71728 on 2018 Mar 31 from 6h 7m to 6h 46m UT

Star:
Mv = 11.3 Mp = 11.3 Mr = 11.3
RA = 15 36 57.8870 (J2000)
Dec = -15 23 27.084 ...
[of Date: 15 38 0, -15 26 57]
Prediction of 2017 Jul 21.0

Max Duration = 46.0 secs
Mag Drop = 0.7 (0.5r)
Sun : Dist = 135 deg
Moon: Dist = 48 deg
: illum =100 %
E 0.360"x 0.360" in PA 90

Asteroid: (in DAMIT, ISAM)
Mag =11.2
Dia = 253km, 0.140"
Parallax = 3.526"
Hourly dRA =-0.663s
dDec = 5.35"



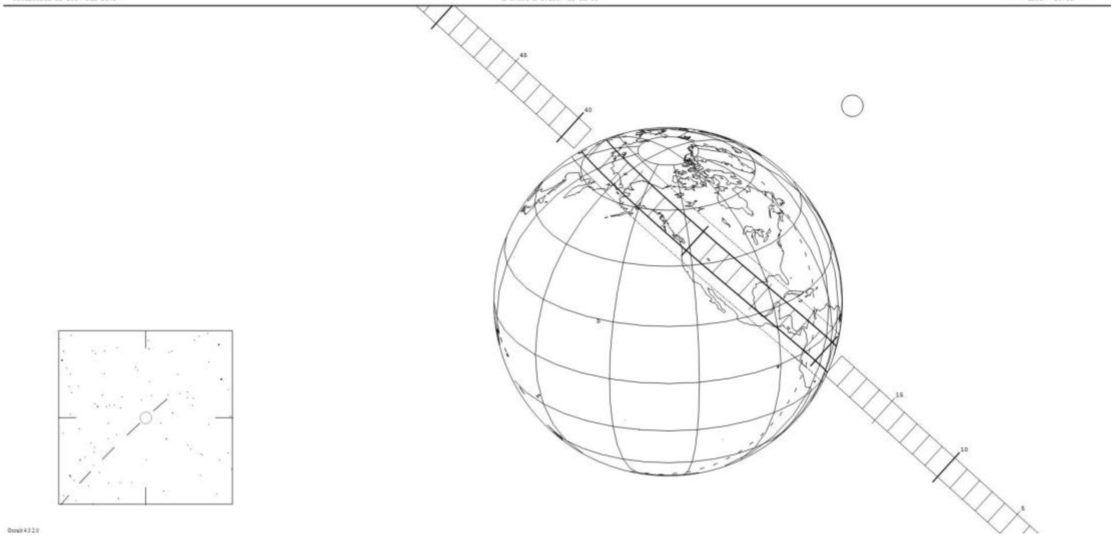
North America

1 1-Ceres occults 4U 591-47113 on 2018 Jan 15 from 10h 18m to 10h 39m UT

Star:
Mv = 12.6 Mp = 12.6 Mr = 12.4
RA = 9 25 39.7850 (J2000)
Dec = 28 8 39.684
[of Date: 9 26 44, 27 58 48]
Prediction of 2017 Jul 21.0

Max Duration = 91.1 secs
Mag Drop = 0.01 (0.00r)
Sun : Dist = 157 deg
Moon: Dist =140 deg
: illum = 3 %
E 0.330"x 0.330" in PA 90

Asteroid:
Mag = 7.1
Dia = 939km, 0.788"
Parallax = 5.352"
Hourly dRA =-1.747s
dDec = 20.90"



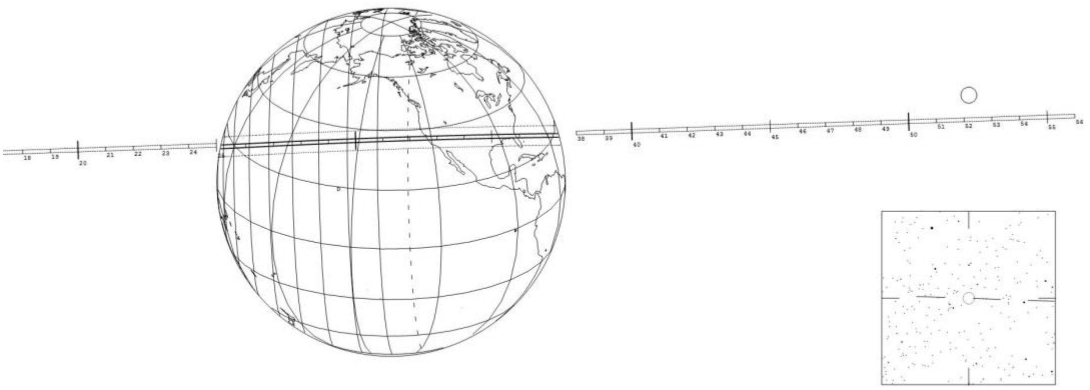
Occult4320

15 20-Massalia occults 4U 563-20884 on 2018 Mar 14 from 3h 25m to 3h 37m UT

Star:
Mv = 12.7 Mp = 12.7 Mr = 12.7
RA = 5 49 59.7874 (J2000)
Dec = 22 34 35.366
[of Date: 5 51 5, 22 34 44]
Prediction of 2017 Jul 21.0

Max Duration = 8.0 secs
Mag Drop = 0.12 (0.08r)
Sun : Dist = 94 deg
Moon: Dist =133 deg
: illum = 11 %
E 0.230"x 0.230" in PA 90

Asteroid: (in DAMIT, ISAM)
Mag =10.4
Dia = 136km, 0.108"
Parallax = 5.043"
Hourly dRA = 3.472s
dDec = 1.64"



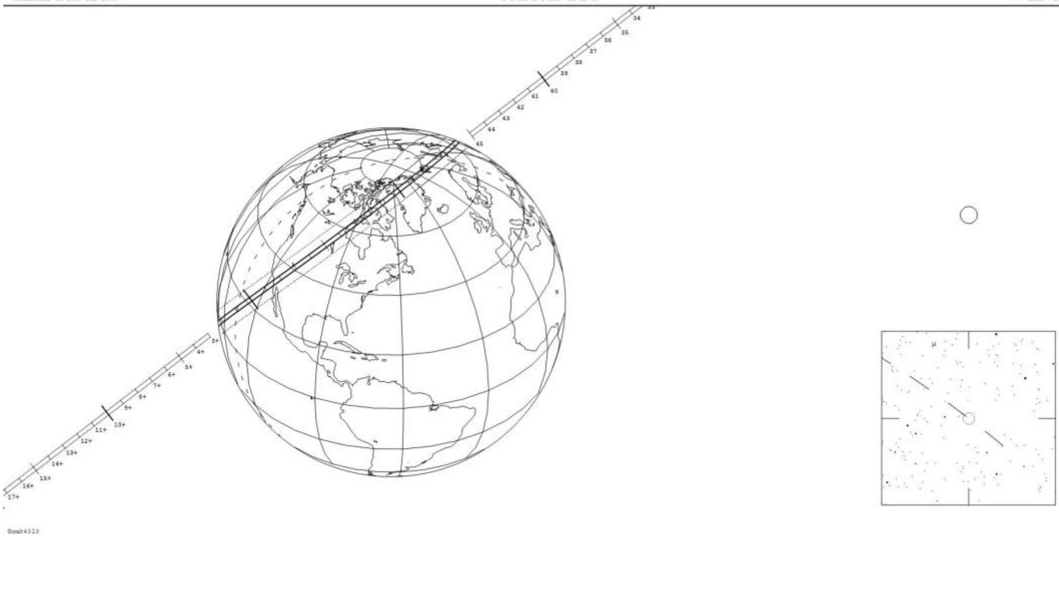
Occult4320

43 654-Zelinda occults 4U 638-3222 on 2018 Oct 26 from 2h 46m to 3h 2m UT

Star:
Mv = 13.4 Mp = 13.4 Mr = 13.4
RA = 0 54 29.8982 (J2000)
Dec = 37 34 59.178
[of Date: 0 55 33, 37 41 8]
Prediction of 2017 Jul 21.0

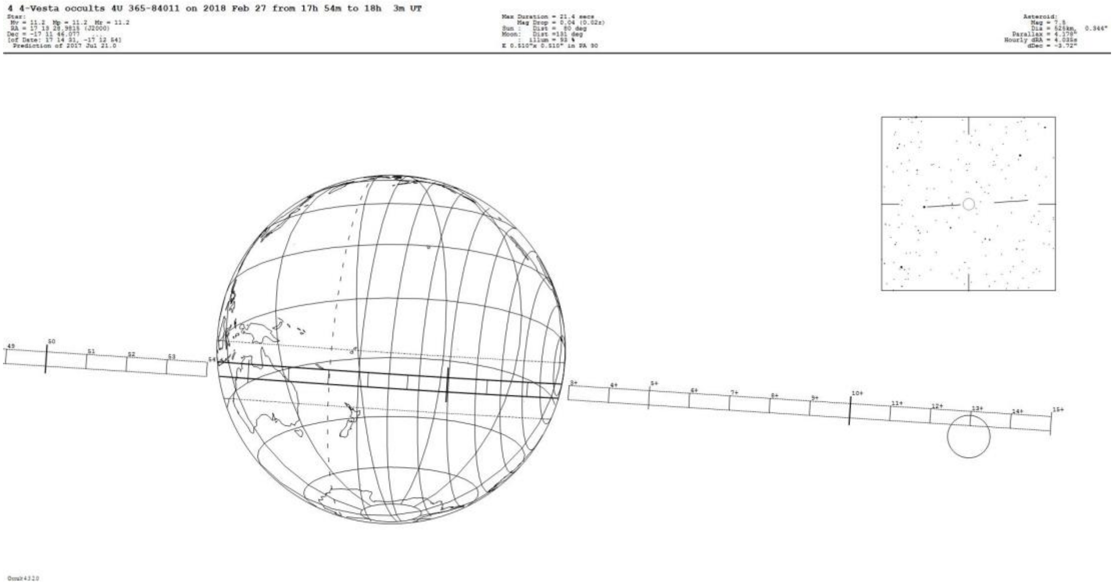
Max Duration = 14.4 secs
Mag Drop = 0.22 (0.15r)
Sun : Dist = 151 deg
Moon: Dist = 40 deg
: illum = 97 %
E 0.310"x 0.310" in PA 90

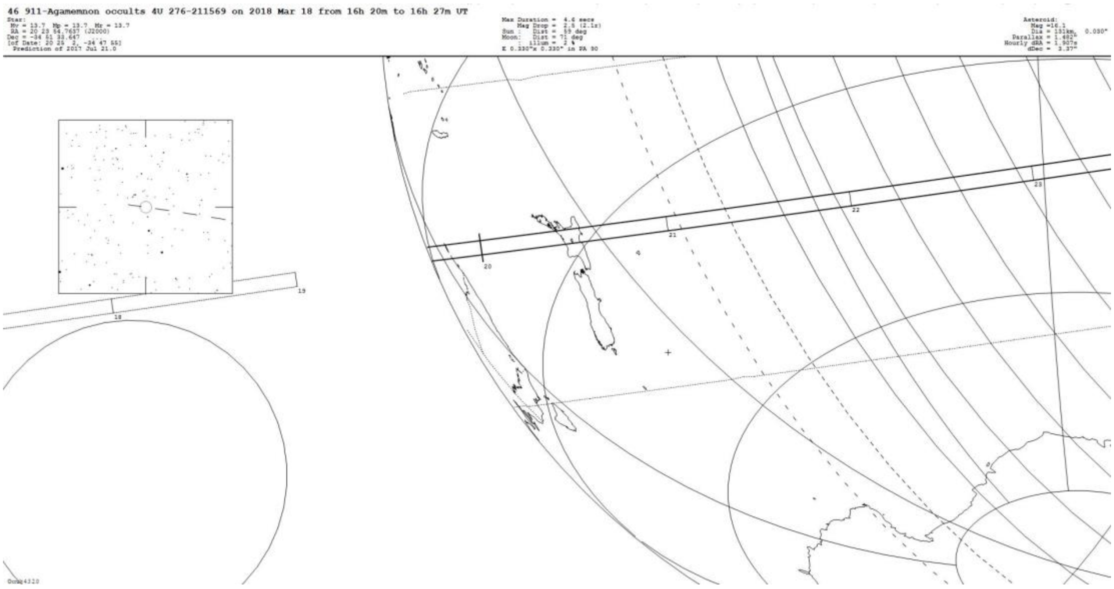
Asteroid: (in DAMIT, ISAM)
Mag =11.8
Dia = 161km, 0.161"
Parallax = 6.386"
Hourly dRA =-2.690s
dDec =-24.49"

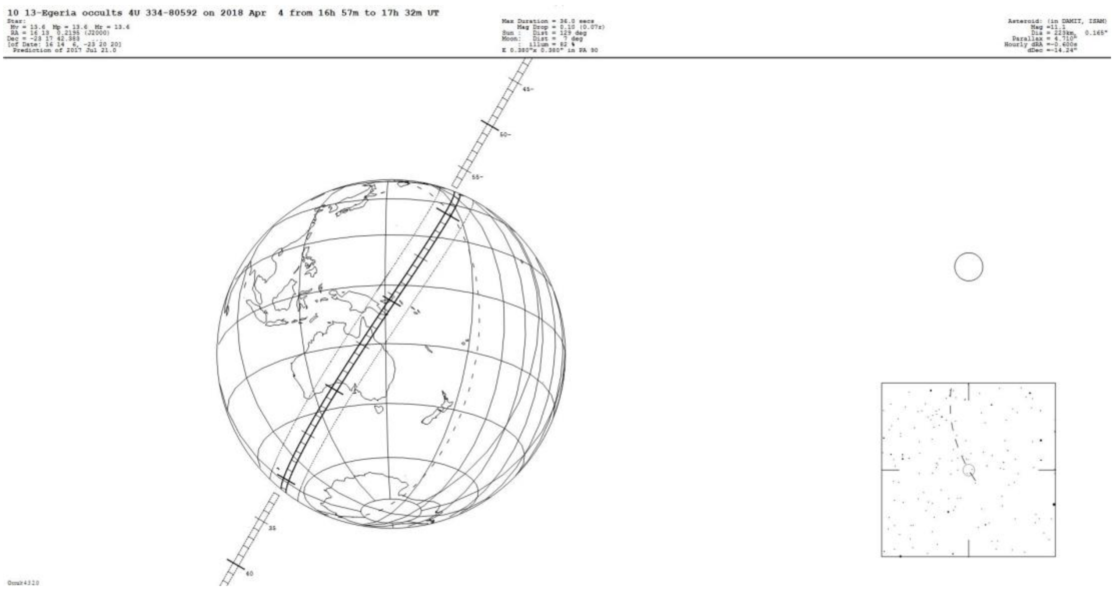


Occult4320

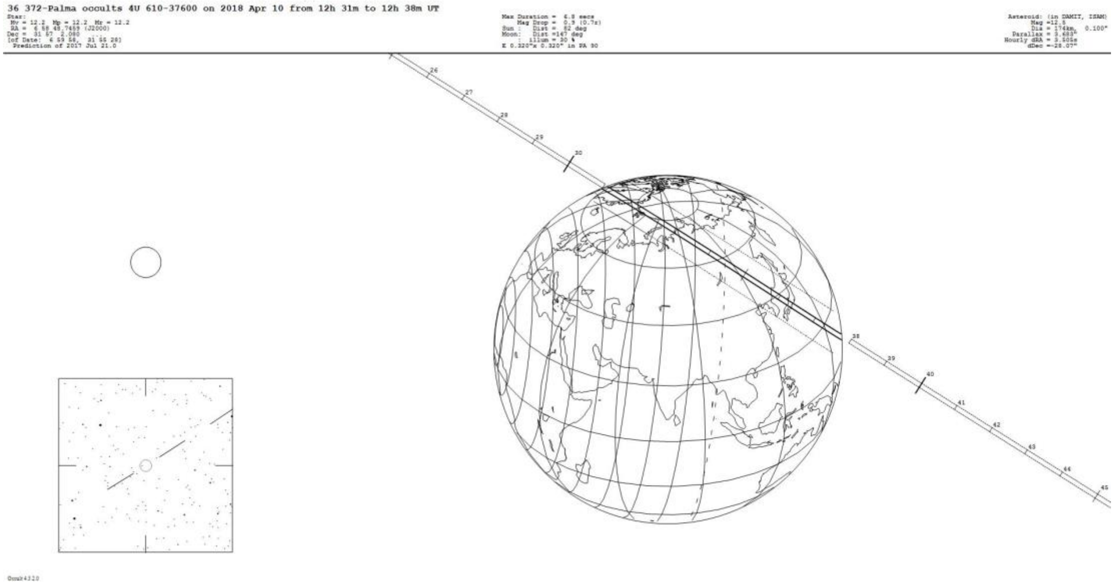
Australia/New Zealand

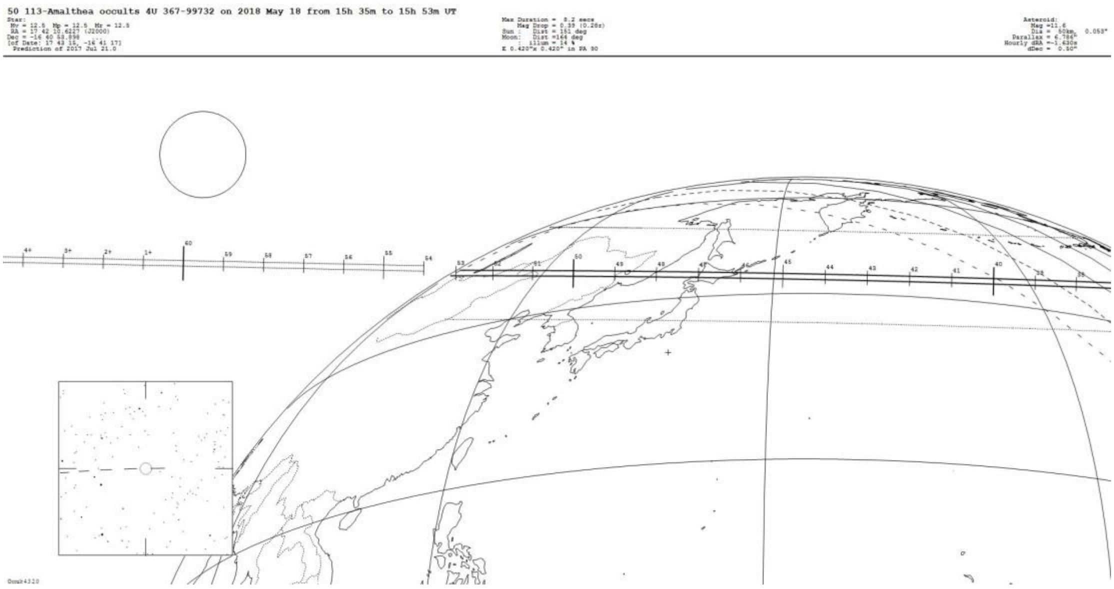


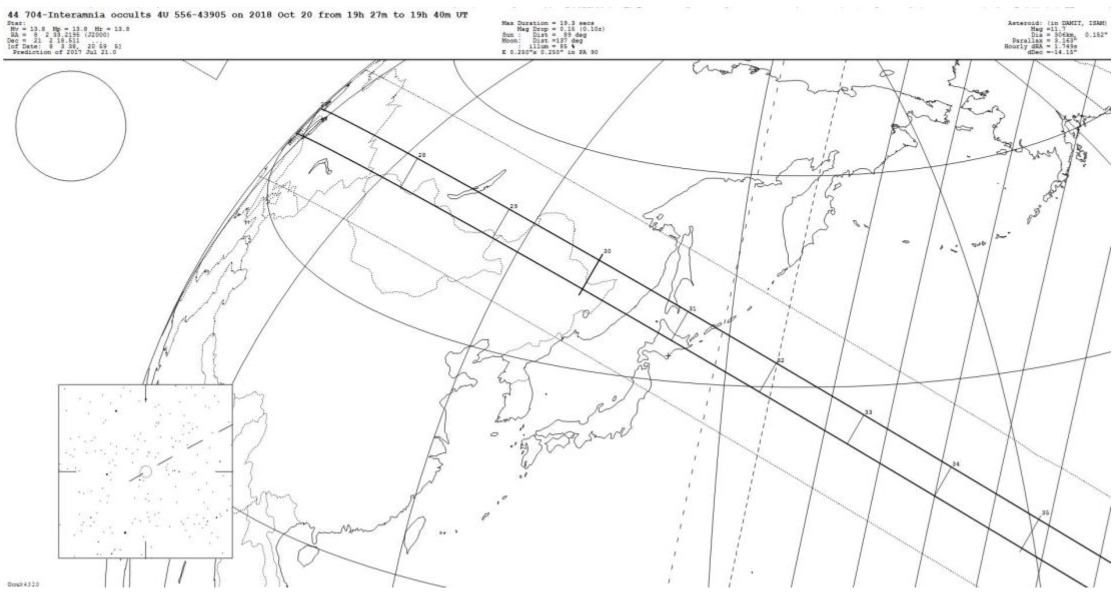




Japan


36 372-Palma occults 4U 610-37600 on 2018 Apr 10 from 12h 31m to 12h 38m UT
Star:
Mv = 12.2 Mp = 12.2 Mr = 12.2
RA = 6 58 48.7459 (J2000)
Dec = 31 57 2.080
[of Date: 6 59 58, 31 56 28]
Prediction of 2017 Jul 21.0
Max Duration = 6.8 secs
Mag Drop = 0.9 (0.7r)
Sun : Dist = 82 deg
Moon: Dist =147 deg
: illum = 30 %
E 0.320"x 0.320" in PA 90
Asteroid: (in DAMIT, ISAM)
Mag =12.8
Dia = 174km, 0.100"
Parallax = 3.683"
Hourly dRA = 3.505s
dDec =-28.07"
Occult4320


50 113-Amalthea occults 4U 367-99732 on 2018 May 18 from 15h 35m to 15h 53m UT
Star:
Mv = 12.5 Mp = 12.5 Mr = 12.5
RA = 17 42 10.6227 (J2000)
Dec = -16 40 53.898
[of Date: 17 43 15, -16 41 17]
Prediction of 2017 Jul 21.0
Max Duration = 8.2 secs
Mag Drop = 0.39 (0.28r)
Sun : Dist = 151 deg
Moon: Dist =164 deg
: illum = 14 %
E 0.420"x 0.420" in PA 90
Asteroid:
Mag =11.6
Dia = 50km, 0.053"
Parallax = 6.786"
Hourly dRA =-1.630s
dDec = 0.50"
Occult4320


44 704-Interamnia occults 4U 556-43905 on 2018 Oct 20 from 19h 27m to 19h 40m UT
Star:
Mv = 13.8 Mp = 13.8 Mr = 13.8
RA = 8 2 33.2196 (J2000)
Dec = 21 2 18.511
[of Date: 8 3 38, 20 59 5]
Prediction of 2017 Jul 21.0
Max Duration = 19.3 secs
Mag Drop = 0.15 (0.10r)
Sun : Dist = 89 deg
Moon: Dist =137 deg
: illum = 85 %
E 0.250"x 0.250" in PA 90
Asteroid: (in DAMIT, ISAM)
Mag =11.7
Dia = 306km, 0.152"
Parallax = 3.163"
Hourly dRA = 1.749s
dDec =-14.15"
Occult4320

4.2 Occultations by TNOs and Centaurs predicted for 2018

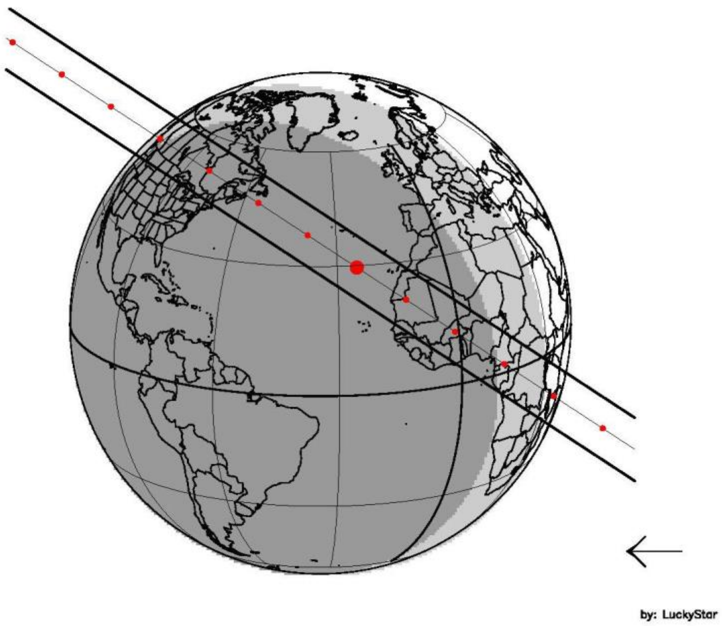
For the TNOs, we search for occultations produced by objects larger than 300 km. For the Centaurs, we focus on the largest bodies. Due to the large uncertainties in the orbits of these distant Solar System bodies, the error in the predicted shadow path is usually larger than the Earth radius, and only a short time before the event we can refine the prediction. Between 1-2 months in advance and a few days in advance, improvements in the prediction are done and we can discard some, or select the more reliable ones. For these reasons we cannot obtain a definitive list with stellar occultation predictions by TNOs and Centaurs.

The IAA-CSIC Granada team is working together with the Paris group and the Rio group in the prediction, observation and analysis of stellar occultations by TNOs and Centaurs. Occultation predictions by TNOs and Centaurs for the year 2018 have been generated in the context of the EU ERC Lucky Star project (PI. Bruno Sicardy) with the very active participation of the IAA-CSIC group. All the predictions for the year 2018 can be found in the link:

http://lesia.obspm.fr/lucky-star/predictions/index2018.html

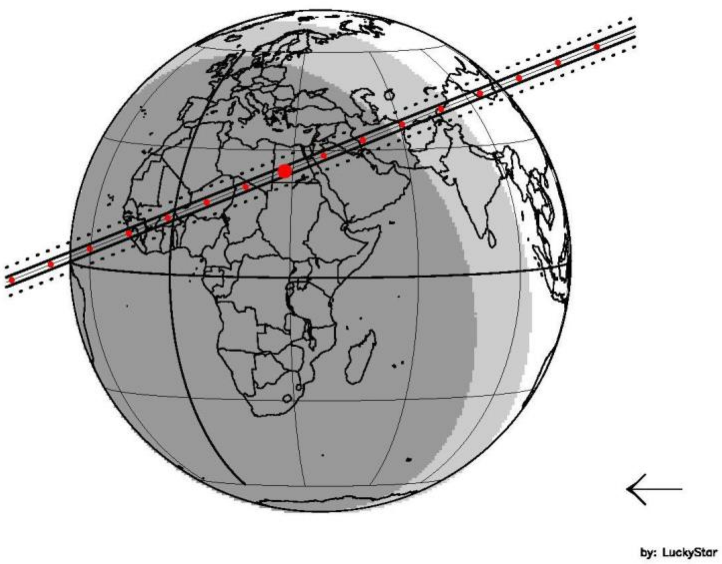
It is important to note that, at the end, only some of these predictions will survive. This is mostly due, as has already been stated, to the uncertainties in the orbits, which means that an astrometric update of the TNO/Centaur position is usually needed to refine the prediction. This means that after the update and refining most of the current predictions showed in the Lucky Star web page will be modified, and the shadow paths can move thousands of km away, even outside of the Earth. The converse is also possible, i.e. a prediction with a shadow path outside of the Earth, could be move to fall on the Earth after a "last minute" update. Taking all this into account, some of the (current) prediction maps are shown in the next pages.

Haumea: GaiaDR1, NIMAv4 ephem. Offset (mas): 0.0 0.0



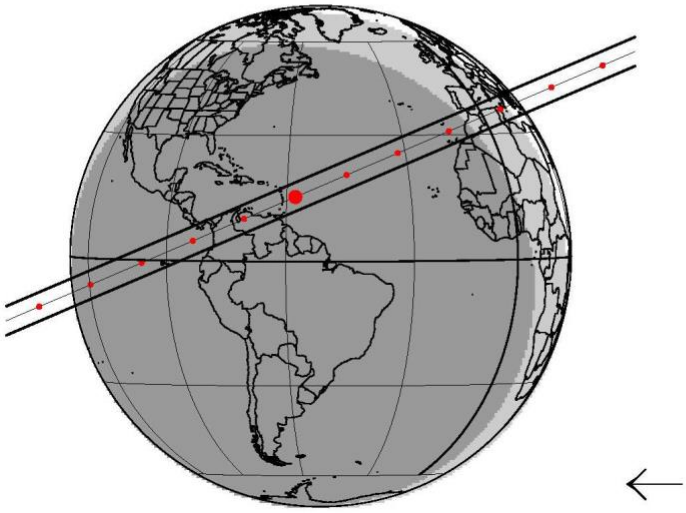
d m year	h:m:s UT	ra___dec___J2000_candidate	C/A	P/A	vel	Delta	G*	J*	long
28 03 2018	04 09 48.	14 14 04.0406 +16 56 00.805	0.047	33.18	−24.93	49.67	17.4	15.1	−34.

Chiron: GaiaDR1, NIMAv6 ephem. Offset (mas): 0.0 0.0



d m year	h:m:s UT	ra___dec___J2000_candidate	C/A	P/A	vel	Delta	G*	J*	long
15 08 2018	23 54 18.	23 59 31.2487 +03 53 03.455	0.189	338.30	−17.82	17.90	15.7	14.8	37.

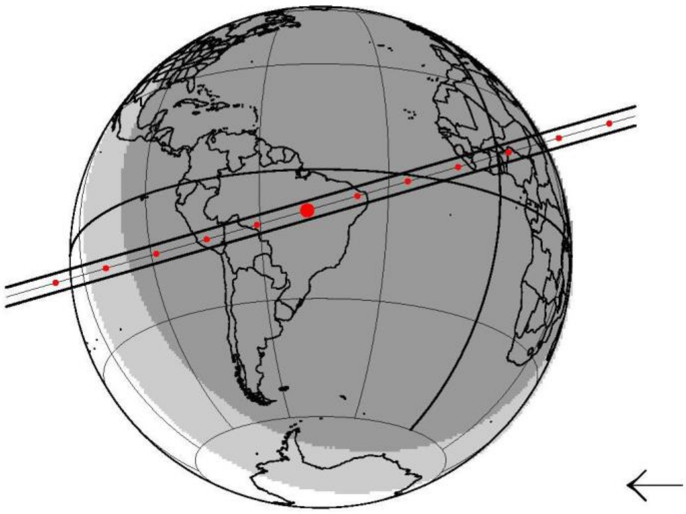
2005RN43: GaiaDR1, NIMAv2 ephem. Offset (mas): 0.0 0.0



by: LuckyStar

d m year	h:m:s UT	ra___dec___J2000_candidate	C/A	P/A	vel	Delta	G*	J*	long
20 08 2018	04 24 59.	22 50 55.2559 +01 14 08.300	0.057	336.82	−23.64	39.66	17.7	15.7	−52.

2004PF115: GaiaDR1, NIMA ephem. Offset (mas): 0.0 0.0



by: LuckyStar

d m year	h:m:s UT	ra___dec___J2000_candidate	C/A	P/A	vel	Delta	G*	J*	long
28 09 2018	01 37 40.	23 01 47.5792 −20 31 01.157	0.042	343.94	−22.20	40.67	16.5	99.9	−46.

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Some additional documents with practical guidelines to observe stellar occultations:

- Chasing the shadow: The IOTA Occultation Observer's Manual
- Short Introduction to Occultation Observations
- Practical guidelines to observe stellar occultations by small bodies

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