Journal for
Occultation Astronomy

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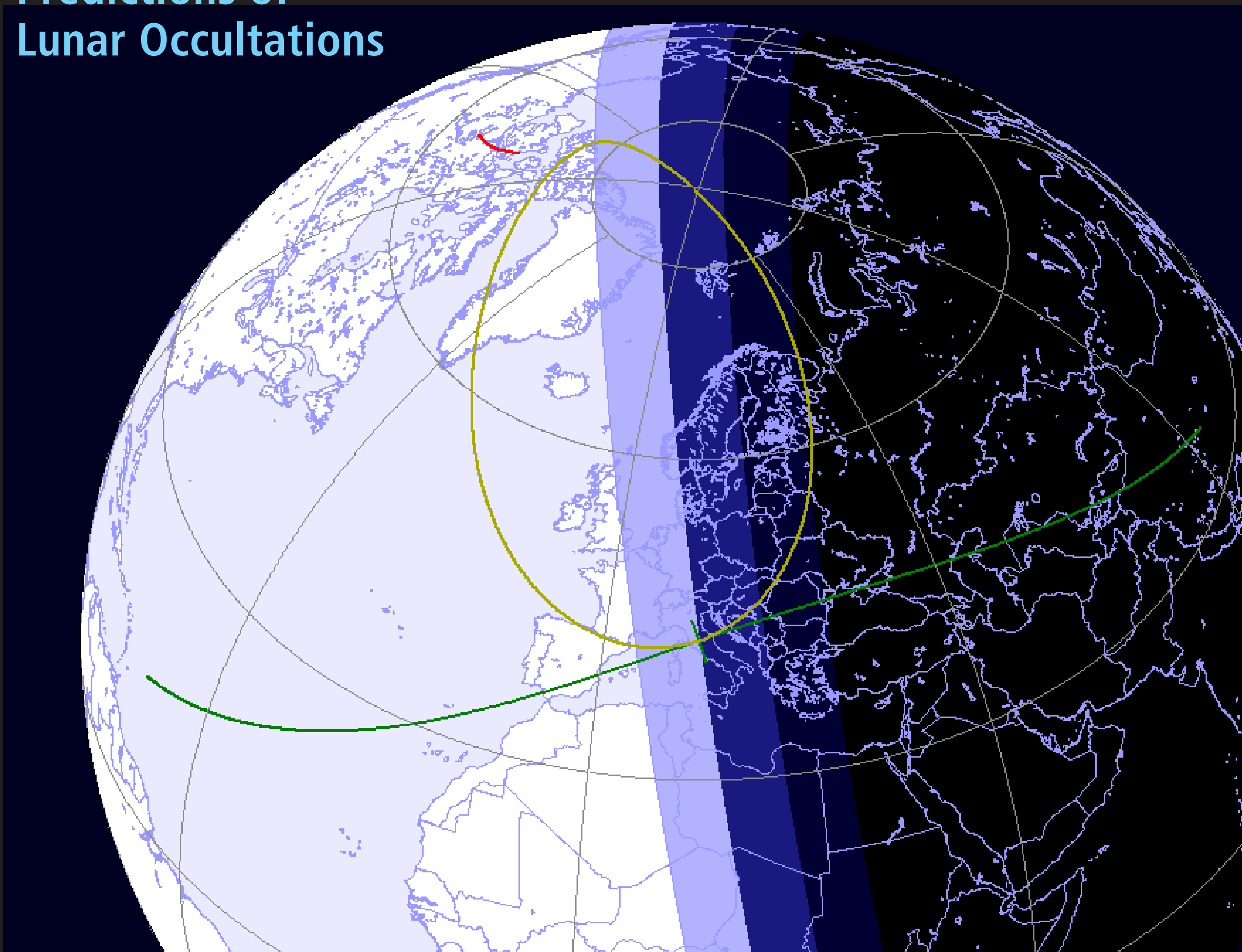
IN THIS ISSUE:



Dear reader,

for many years measurements of lunar occultations improved the shape of the lunar limb. The "disk" of the Moon was used as a measuring template during solar eclipses to find variations in the solar diameter. Later space probes from Japan and the U.S.A., equipped with laser altimeters, provided high precision altitude measurements of the lunar surface. This new data from space led to a decreasing activity of occultation observers in recording lunar occultations.Improvements of hardware and software during the last years now provide new opportunities to observers to measure fainter objects and to time shorter occultations than before. Occultations of distant objects like TNOs now are in the reach of amateurs and observers even chase the shadows of comets. But we should not forget our close celestial neighbor, the Moon. Again the lunar limb is used as a measuring template. Measuring separation and position angle of double stars is possible with high resolution timings of lunar occultations. Even discoveries of new double stars were made by occultation observers already. And long term surveys of the Earth's rotation are made possible through lunar occultations. All observers know that each occultation is a one time occasion and very often these single events are spoiled by bad weather. Lunar occultations instead offer the chance to record several occultations during one clear night, thus collecting valuable data. We should never disregard these opportunities by only concentrating on much more distant objects.

Oliver Klös, IOTA/ES Public Relations

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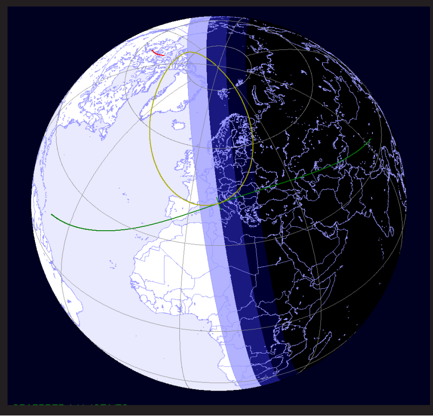
In this issue:

COVER



The moon's "shadow" (yellow) is projected on Earth by Aldebaran on Feb. 23, 2018 around 17h 21m UT touching the southern grazing limit line (green) in central Italy at the beginning of nautical twilight. Note: an observer right at the north pole would have a total occultation at that moment. (Plot with GRAZPREP, see Grazing Occultation Predictions in this volume).

Writing articles for JOA:

The rules below should be regarded while writing an article; using them will greatly facilitate the production and layout of JOA!

If your article does not conform to these rules, please correct it.

There are 3 different possibilities for submitting articles:

- pdf-articles (must be editable – these can be converted)
- unformatted Word *.doc-files containing pictures/graphs or their names (marked red: <figure_01>) at the desired position(s)
- *.txt-files must contain at the desired position the name of each graph/picture

The simplest way to write an article is just use Word as usual and after you have finished writing it, delete all your format-commands by selecting within the push-down-list "STYLE" (in general it's to the left of FONT & FONTSIZE) the command "CLEAR FORMATTING". After having done this you can insert your pictures/graphs or mark the positions of them (marked red: <figure_01>) within the text.

- txt-files: Details, that should be regarded
- Format-commands are forbidden
- In case of pictures, mark them within the text like <figure001> where they should be positioned

Important: Use only the end-of-line command (press ENTER) if it's really necessary (new paragraph, etc.) and not when you see it's the end of the line!

Provide the full name of all authors, their affiliation (if applicable) and either the full postal address and / or the e-mail addresses (at least for the corresponding author). Also provide an abstract to your paper. The abstract should not exceed 200-250 words and may not contain any citations.

Journal for Occultation Astronomy

CALL FOR OBSERVATION:

Path Crossing in France – Double Occultation by (891) Gunhild in January 2018

Oliver Klös, IOTA/ES, Eppstein-Bremthal, Germany, oliverkloes@nexgo.de

ABSTRACT: European observers have the chance to observe two occultations by minor planet (891) Gunhild and measure two different profiles on 2018 January 09 and 10 within 27 hours. The paths of these occultations will cross north of Paris, France.

"Unknown" Gunhild

The minor planet was discovered by Max Wolf in Heidelberg on 1918 May 17. Max Wolf was the pioneer on discovering minor planets on photographic plates. He found more than 200 new asteroids, with (588) Achilles, the first Trojan, among them. The female name "Gunhild" has its origin in Scandinavian languages. The reference to the asteroid's name is unknown. (891) Gunhild belongs to the main belt with an orbital period of 4.84 years and a mean diameter of ~56 km [1].

First Event – 2018 Jan 09

The star TYC 1320-00522-1 (11.9 mag) in the constellation Orion will be occulted by (891) Gunhild with a maximum duration of 4.8 sec. The combined magnitude of star and asteroid will drop about 2.3 mag to the magnitude of the minor planet of 14.1 mag.
Before Gunhild's shadow leaves Earth at 17:13 UT it will cross Russia, the border of Belarus and Ukraine, Poland, Germany, Luxembourg, Belgium and France [2].

Second Event – 2018 Jan 10

(891) Gunhild will move on at the plane of sky for ~15 arcmin and will reach the position of 2UCAC 38936950. This star has magnitude of 12.1 mag. This time the shadow crosses Turkey, Romania, Bulgaria, Hungary, Austria, Germany, France and South England. Expected maximum duration and magnitude drop are similar to the first event [3].

Path Crossing

Centre lines of both events cross at geographical position E 02° 45' 47" N 49° 38' 50", close to the highway A1 south of Roye, a town located about 90 km north of Paris, France. For this location the first event will happen at 17:12 UT with the star 22° above the eastern horizon, the Sun is just 10° below the horizon. Because the occultation happens at dusk, the time for locating the target star at a mobile site is limited. Take this into account at your preparations. About 27 hours later the second event is expected for 20:39 UT. At this time the target star is 53° high in south-eastern direction at the sky. Finder maps and interactive path maps for further observation preparations can be found at Derek C. Breit's web page [4].

Rotation and the Profile

Occultations by (891) Gunhild were observed 5 times in the past. Unfortunately all these observation were single-chord-measurements. The latest was made on 2017 Sep 04 by Karel Halir, Czech Republic [5]. Therefore it was not possible to make a shape model based on occultation measurements until today. But photometric light curves indicate a slightly irregular shape with a rotation period of 11.892 h with an amplitude 0.36 mag [6]. The Spanish group OBAS (OBservadores de ASteroides) found an interesting small step in the amplitude just after the light curve reached its lowest value of magnitude [7]. Between the two events in January, the rotation will advance by 2.308 rotation periods. So the profile will be shifted by 111° from the first occultation to the second one.
Observations of these occultations are a good chance to determine two different shape profiles and to get a more accurate value for the diameter of this minor planet.

Astrometry for (891) Gunhild: Source: MPC, FASTT, TMO, Number of observations (used / rejected): 1650 / 9
Time covered by the observations: 1962 Jun 25 - 2017 Dec 14, 1-sigma-uncertainty-ellipse (major, minor, PA): 0.026", 0.015", 76.7°

Path Coordinates from Longitude West 5° to East 9° (see Figure 2, red path)
Position data star: UCAC5 (Gaia DR1), standard error RA,DEC: 0.003"

2018 Jan 09

E. Longitude	Centre Latitude	U.T.	Star Alt	Star Az	Sun Alt	Path Limits Limit 1	Limit 2
- 5 0 0	48 6 40	17 12 51	17	78	- 5	48 24 30	47 48 53
- 4 0 0	48 19 54	17 12 49	17	79	- 5	48 37 41	48 2 9
- 3 0 0	48 32 43	17 12 47	18	80	- 6	48 50 28	48 15 2
- 2 0 0	48 45 9	17 12 45	19	81	- 7	49 2 50	48 27 29
- 1 0 0	48 57 10	17 12 43	19	82	- 7	49 14 49	48 39 33
0 0 0	49 8 47	17 12 40	20	82	- 8	49 26 24	48 51 13
1 0 0	49 20 1	17 12 38	21	83	- 9	49 37 35	49 2 29
2 0 0	49 30 51	17 12 36	21	84	- 9	49 48 23	49 13 22
3 0 0	49 41 18	17 12 33	22	85	- 10	49 58 48	49 23 51
4 0 0	49 51 22	17 12 31	23	85	- 11	50 8 50	49 33 57
5 0 0	50 1 3	17 12 28	23	86	- 11	50 18 28	49 43 40
6 0 0	50 10 22	17 12 25	24	87	- 12	50 27 45	49 53 1
7 0 0	50 19 18	17 12 23	24	88	- 13	50 36 39	50 1 59
8 0 0	50 27 51	17 12 20	25	89	- 13	50 45 10	50 10 34
9 0 0	50 36 2	17 12 17	26	90	- 14	50 53 20	50 18 47

Prediction by Steve Preston, IOTA, 2017 Dec 15

Path Coordinates from Longitude West 5° to East 9° (see Figure 2, green path)
Position data star: Gaia14, standard error RA,DEC: 0.003"

2018 Jan 10

E. Longitude	Centre Latitude	U.T.	Star Alt	Star Az	Sun Alt	Path Limits Limit 1	Limit 2
- 5 0 0	50 35 37	20 40 0	49	126	- 37	50 52 39	50 18 36
- 4 0 0	50 29 30	20 39 55	50	127	- 38	50 46 34	50 12 29
- 3 0 0	50 23 3	20 39 50	50	128	- 39	50 40 8	50 6 0
- 2 0 0	50 16 14	20 39 45	51	129	- 39	50 33 21	49 59 9
- 1 0 0	50 9 4	20 39 40	52	131	- 40	50 26 13	49 51 57
0 0 0	50 1 32	20 39 35	52	132	- 41	50 18 43	49 44 24
1 0 0	49 53 39	20 39 30	53	133	- 41	50 10 51	49 36 29
2 0 0	49 45 24	20 39 24	53	134	- 42	50 2 38	49 28 12
3 0 0	49 36 47	20 39 19	54	135	- 43	49 54 3	49 19 33
4 0 0	49 27 48	20 39 14	54	137	- 43	49 45 6	49 10 32
5 0 0	49 18 26	20 39 8	55	138	- 44	49 35 46	49 1 8
6 0 0	49 8 43	20 39 3	55	139	- 45	49 26 5	48 51 23
7 0 0	48 58 37	20 38 57	56	140	- 45	49 16 1	48 41 14
8 0 0	48 48 8	20 38 52	57	142	- 46	49 5 35	48 30 44
9 0 0	48 37 17	20 38 46	57	143	- 47	48 54 46	48 19 50

Prediction by Steve Preston, IOTA, 2017 Dec 15

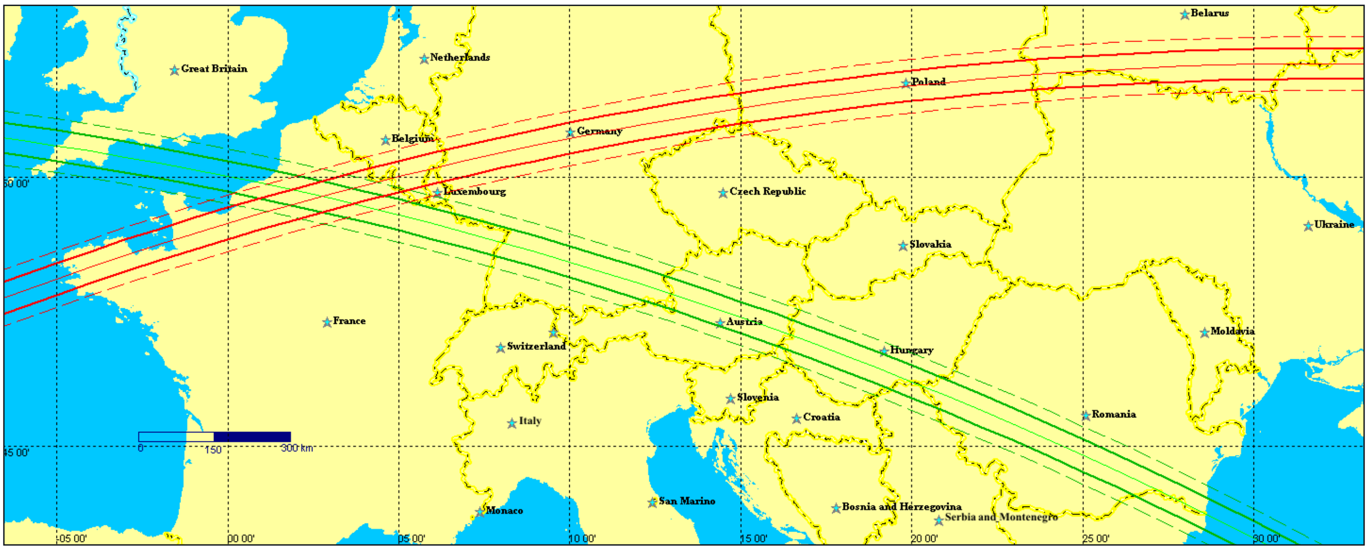


*Fig 1: Both occultation paths by (891) Gunhild will be close close together for many sites in Europe and will cross in France.
The path of January 09 is marked in red, the path of January 10 in green. The dashed lines are the one-sigma-lines.
(Paths predicted by Steve Preston, IOTA, 2017 Dec 15)*

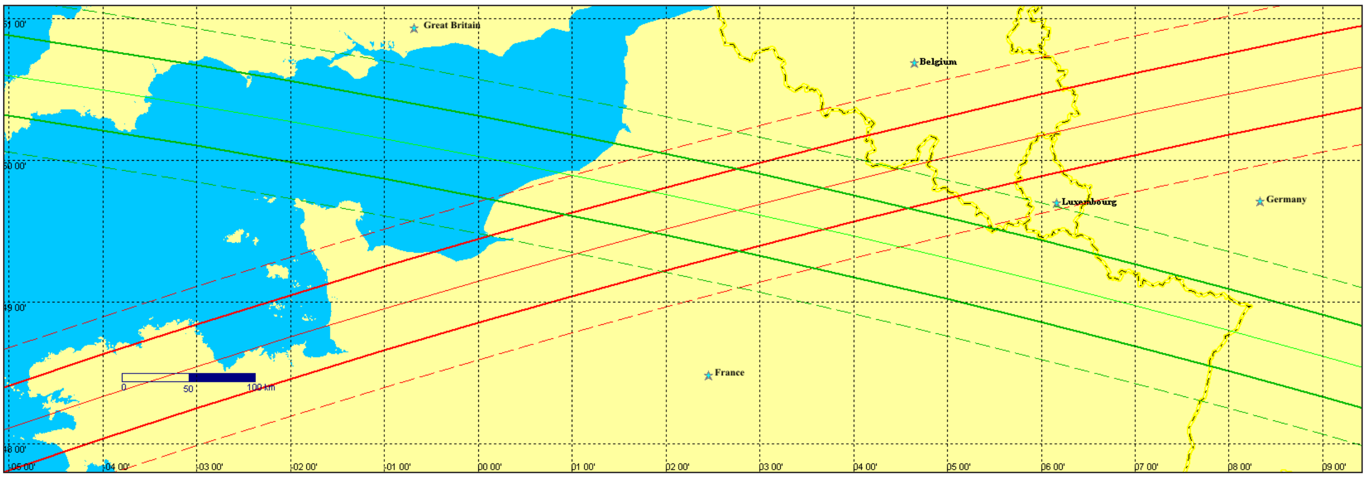


*Fig 2: Two positive observations of these occultations can be expected in an area just north of Paris, France.
Observing stations should be spread out to the error limits and beyond.
(Paths predicted by Steve Preston, IOTA, 2017 Dec 15)*

References:

[1] JPL Small-Body Database Browser: (891) Gunhild

[2] Preston, S. 2017, Prediction for Occultation (891) Gunhild, 2018 Jan 09, 17:05 UT

[3] Preston, S. 2017, Prediction for Occultation (891) Gunhild, 2018 Jan 10, 20:35 UT

[4] Breit, D.C. 2017. Current Global Asteroid Events

[5] Frappa, E. 2017, 2017 European Asteroidal Occultation Results, euraster.net

[6] Behrend, R. 2017, Lightcurve (891) Gunhild, Asteroids and comets rotation curves, CdR

[7] OBAS Asteroid Period research 2016, Minor Planet Photometric Database

Double Star Occultation Paper in the Journal of Double Star Observations.

Brian Loader, New Zealand, brian.loader@slingshot.co.nz

ABSTRACT: The sixth paper in a series giving results of observations of lunar occultations of double stars has recently been published in the online Journal of Double Star Observations (JDSO) at <http://www.jdso.org>. Some details and aims of the programme to observe these occultations are given plus a summary of the contents of the paper.

Introduction

When a double star is occulted by the moon or asteroid, the two component stars will usually be occulted at slightly different times. The time interval between the two occultations is determined by the geometric characteristics of the pair, that is their apparent angular separation of the stars and their relative position angle. The interval is also determined by the rate at which the limb of the occulting body moves across the pair. The use of video in observing the lunar occultation of double stars enables accurate timings to be made of the occultation of each star of a pair. Times are inserted on each video frame sourced from GPS, accurate to a milli-second. With these accurate times information regarding the separation and position angle the pair can be deduced.

In addition, by analysing the changes in light intensity of the star as it disappears into occultation (before full moon) or reappears from occultation (after full moon) an estimate in the difference in magnitude and hence the magnitude of each component can be determined. Such analysis is usually carried out using the LiMovie programme written by Kazuhisa Myashita.

The suggestion for a programme aimed at observing and timing double stars at their occultation by the moon was made in 2007 at the first Trans Tasman Symposium on Occultations. The TTSO meeting was organized by Graham Blow, late director of the Occultation Section of the Royal Astronomical Society of New Zealand (RASNZ) and held in association with the 2007 RASNZ conference at Manukau, Auckland, New Zealand.

Observations made using video techniques of these occultations have been collated since the 2007 inception of the programme, although some video records dating as back as 1999 have been included.

Aims of the Programme

Determination of the separation and position angle of a pair of stars. This requires more than one occultation observation with the separate events well spaced round the moon's limb. A useful determination ("solution") cannot be obtained if the observed occultation events take place only a few degrees apart on the moon's limb, likely to occur when observers are geographically fairly close. A minimum separation of 10°, after allowing for the topography of the limb, round the moon's limb is needed to get a reliable solution. 10° is equivalent to about 300 km on the moon's limb. Ideally all observations should be on the same night. In many cases this is not possible: observations made at different lunations can be used provided the relative motion of the pair of stars is small. Dave Herald's Occult programme has the facility to solve for these. Estimate the magnitude difference of the components of the pair of stars and hence, from a knowledge of their combined magnitude, the separate magnitudes of the stars. This can be done on a single observation, the requirement is a clearly stepped light curve. Observers mostly use unfiltered cameras so magnitude estimates for different coloured stars are affected by the spectral response of the chip used. However most results appear to be reasonably close to visual magnitudes established by other means.Detect previously unknown double stars. Far more double stars can be detected in video records than by visual observation. An analysis of the video record can produce a light curve when the presence of two stars is shown by a step in the curve. Such steps can be detected when the fainter star is occulted before the brighter, or in the case of an occultation reappearance, the fainter star reappears after the brighter star. These are cases where visual observation of an occultation would fail to detect the presence of the fainter star.

Confirm or refute the duplicity of stars previously reported as possibly double as a result of earlier visual occultation observations. These stars have been reported as possibly double mostly as a result of visual observations of lunar occultations. For the most part observers have considered an occultation was slightly prolonged, not instantaneous. In a few cases the presence of two stars has been obvious as, for instance, when a primary star is occulted to leave a fainter secondary star briefly in view, or in the case of a star appearing from behind the moon, a fainter secondary star appears first, a measurable time before the brighter star.

IOTA accumulated a catalog of over 1650 such possible double star discoveries during the 20th century. Video occultation observations are showing that a large majority, over 90%, of these "OCC" candidates as possible double stars are in fact single. On the other hand, a small number have been confirmed as truly double.

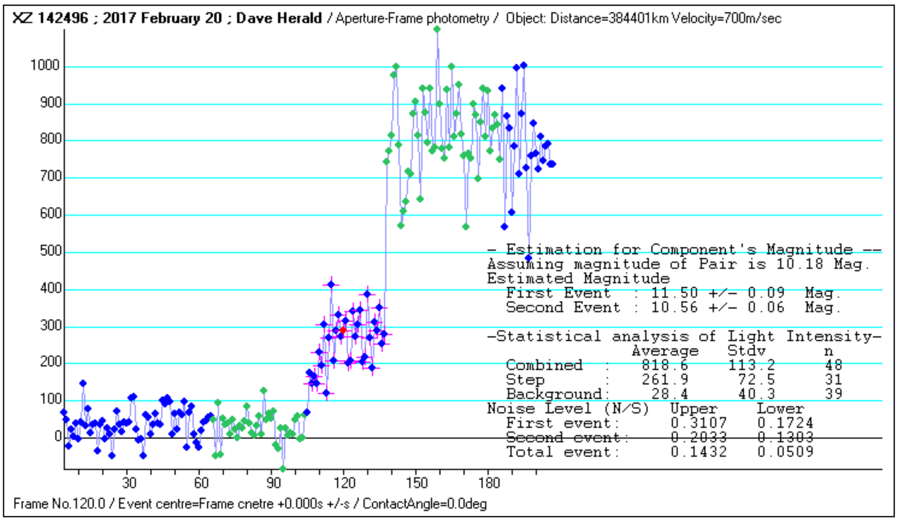


Figure 1. Light curve for the occultation reappearance of XZ142496, observed by Dave Herald, 2017 February 20. This shows a typical stepped light curve produced by LiMovie from the video record of the event. The step lasted for 1.28 second. The magnitudes calculated by LiMovie are also shown. This involved a newly discovered double star. See also figure 3 for the solution found for the double.

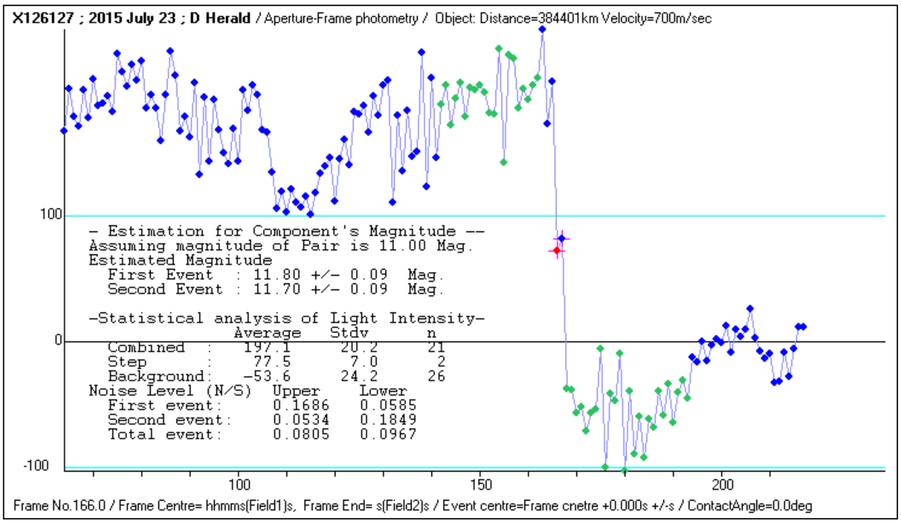


Figure 2. The light curve for the disappearance of XZ126127 on 2015 July 23. This was also observed by Dave Herald and has a step lasting only 2 video frames, that is 0.08 second. Again this was a newly discovered double star. With only one observation no solution is possible, but from the duration of the step the minimum separation of the stars is 0.027 arc-second

Light curves of possible double stars are a useful contribution to the Kepler2 programme, where appropriate, as indeed are light curves for all occultations of stars in the Kepler2 programme.

The Latest Paper

The sixth paper in a series published in the on line Journal of Double Star Observations, "Lunar Occultation Observations of Double Stars" is now available in the 2017 October 1 issue of the Journal. The paper is in volume 13, number 4, pages 585 to 603 and can be viewed at <http:www.jdso.org>. The paper can also be downloaded from the publication.

The paper presents the results of video occultations of double stars and suspected double stars by the Moon. The majority of observations reported in the paper date from 2015 and 2016 although some are from earlier years. The observations were made by 24 observers situated in the U.S.A., England, the Czech Republic, Japan, Australia and New Zealand.

A number of tables of results are presented in the paper. These cover:

1. Observations of known double stars listed in the Washington Double Star Catalog (WDS). Results are presented where the position angle and separation of the pair of stars was determined.
2. Other observations WDS stars where only one observation is available. A single observation allows a vector separation of the pair of stars to be determined in a direction perpendicular to the moon's surface at the point of occultation. The vector separation gives a lower limit to the separation of the pair.
3. New double stars discovered as a result of their lunar occultation, again in two groups. A small number with more than one observation allow the position angle and separation of the pair to be determined. A larger group have only one observation, or in a few cases two observations but with occultations occurring too close together on the Moon's limb to enable a solution. In all some thirty-eight new double stars are reported in the paper. Light curves are included in the paper for these discoveries.
4. Also presented are results of video occultation of stars previously reported as possibly double as a result of visual occultation observations, OCC stars. A few of these have now been shown to be double as a result of recent video occultation observations. In many more cases video records of occultations of these stars are now showing them to be single. Some fifteen of these stars which are recorded in the WDS or in the associated Interferometric Catalog are reported as single in the paper. In all cases two or more observations well spread out round the limb of the moon, are required to confirm the single nature of the star.
5. There are also reports of six stars in the WDS which video occultation observations suggest are in fact single.

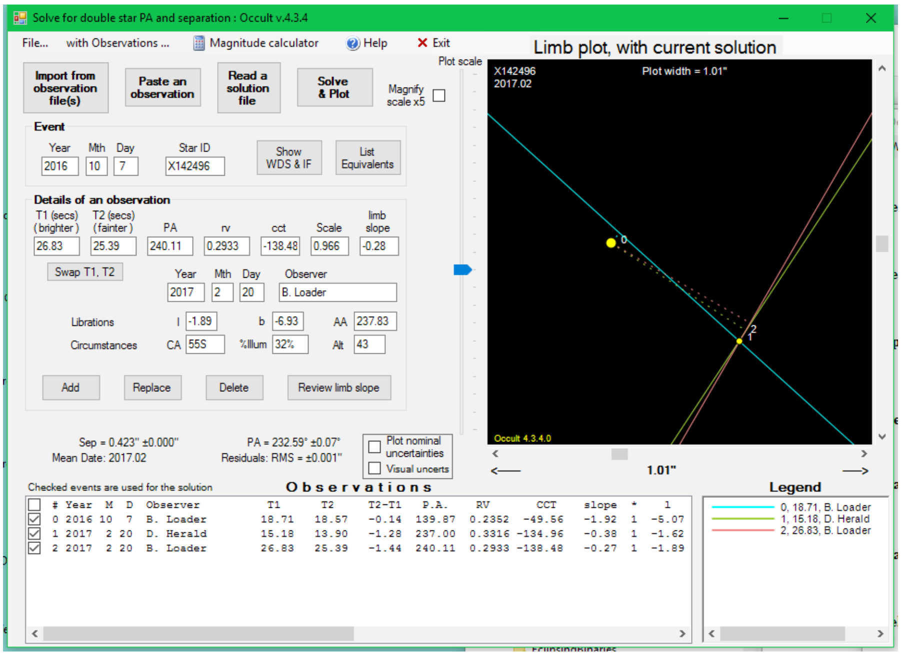


Figure 3. Diagram of the solution produced by Occult for XZ142496 with 3 observations. The fainter star is calculated to have been at the intersection of the three coloured lines. The lines in effect represent the position of the Moon's limb at the moment the fainter star was occulted. The two reappearance observations of 2017 February 20 took place at points on the moon's limb which were very close, despite the observers being well over 1000 km apart either side of the Tasman Sea. The solution is made possible by the disappearance observation some 4 months earlier which was at a completely different position on the Moon's limb.

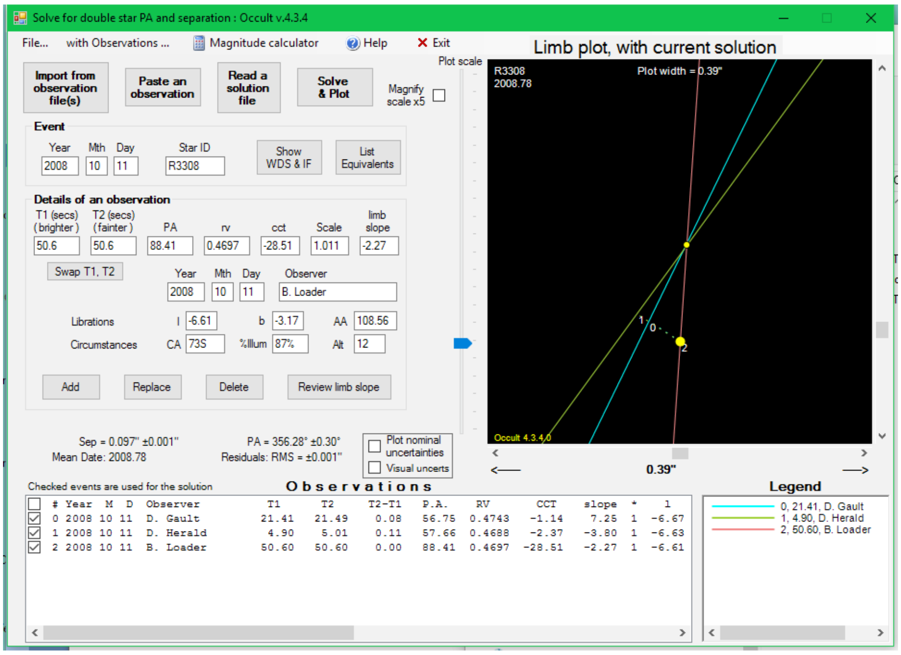


Figure 4. Solution produced by Occult for the double star ZC3380 = CHR 111, dating from 2008. The observations by Herald and Gault in Australia occurred at similar positions on Moon's limb. The third observation, by the author, in New Zealand was some 30 degree away round the limb of the Moon. In fact no stepped event was seen from NZ, but even so the observation assists in confirming the solution. The pair of stars were apparently occulted almost simultaneously.

As can be seen, the programme to observe double star occultations is an international effort. The requirement of events well spread out round the moon limb requires observers well spaced on the Earth's surface. Another way of obtaining the spread is to observe occultations on different dates, often this can be by observing from different parts of the world. There are plenty of geographic gaps which could usefully be filled including South America and the (so-called) Middle East countries to name just two areas.

At the end of September 2017 over 2150 observations were recorded involving more than 1300 different stars of which more than 150 were "new" double stars.

The paper referred to in this article can be viewed at www.jdso.org which will take you directly to the current issue of the journal, at present 2017 October 1, Vol 13 #4.

The five earlier papers in the series are also available at the JDSO web site. The appropriate issues of the JDSO can be viewed by clicking the archive menu item on the JDSO front page. The dates of the five papers are:

Paper 1: 2010 July 1 . . . . Vol 6 #3
Paper 2: 2011 July 1 . . . . Vol 7 #3
Paper 3: 2012 October 1 . . . . Vol 8 #4
Paper 4: 2014 April 1. . . . . . . Vol 10 #2
Paper 5: 2016 February 1 . . . Vol 12 #2

Predictions of Lunar Occultations of Double Stars for Your Location with "Occult Watcher"

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ABSTRACT: Occultation observers can get predictions of total lunar occultations of doubles and suspected double stars for a specific location by using Dave Herald's "Occult" and Hristo Pavlov's "Occult Watcher". Feeds for different areas are created regularly and can be accessed if a special add-in for "Occult Watcher" is installed.

The Add-In

Since more than six years, Hristo Pavlov's software "Occult Watcher" (OW) is able to present you predicted occultations by known doubles and suspected double stars for your location. Because OW was designed for asteroidal occultations, the feed for double stars needs a special add-in, which has to be downloaded and installed separately. For the calculations of the predictions for your location, OW needs Dave Herald's "Occult" installed on the same computer. The events of the double star feed are carefully selected by a number of people around the world, that run predictions for their local areas.

Installation

- Download the add-in at: http://www.occultwatcher.net/OccultWatcher.LunarOccultations.zip
- Unzip the zipped add-in to your OW directory.
- After starting OW you have to configure the new add-in at the menu: "Add-ins -> Configure Add-ins -> Lunar Occultations for Occult Watcher" (Fig. 1).
- A new window opens. Here you have to enter the path of your installation of OCCULT on your computer and some parameters (telescope diameter, site altitude and magnitude limit adjustment). The mag limit adjustment provides an opportunity to adjust the mag limit to your needs and technical equipment. You may have to adjust it again if you have got some experience.
- Finally you have to enter the URL of the feed of your area (Fig. 2).

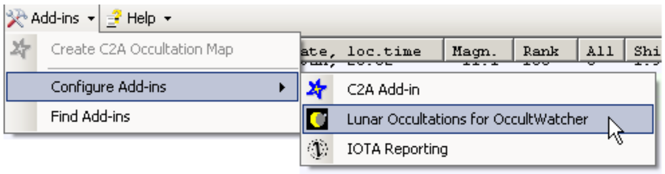

Figure 1: The Add-in menu at Occult Watcher. Click on "Lunar Occultations for Occult Watcher" (screen capture: H. Pavlov)

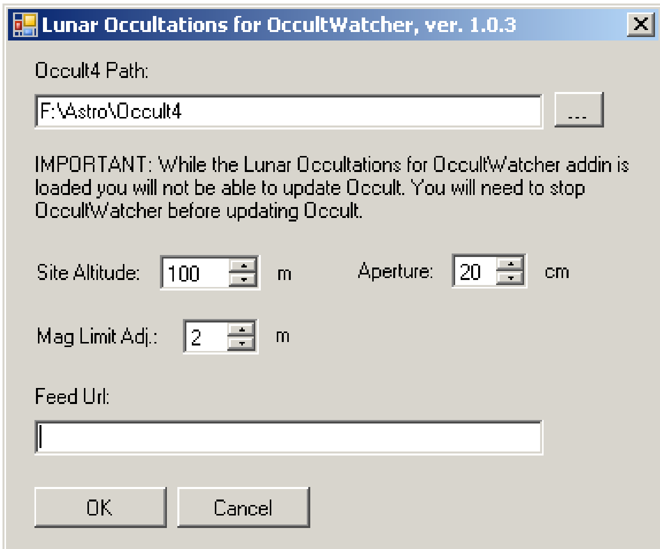

Figure 2: Window for configuration of the add-in (screen capture: H. Pavlov)

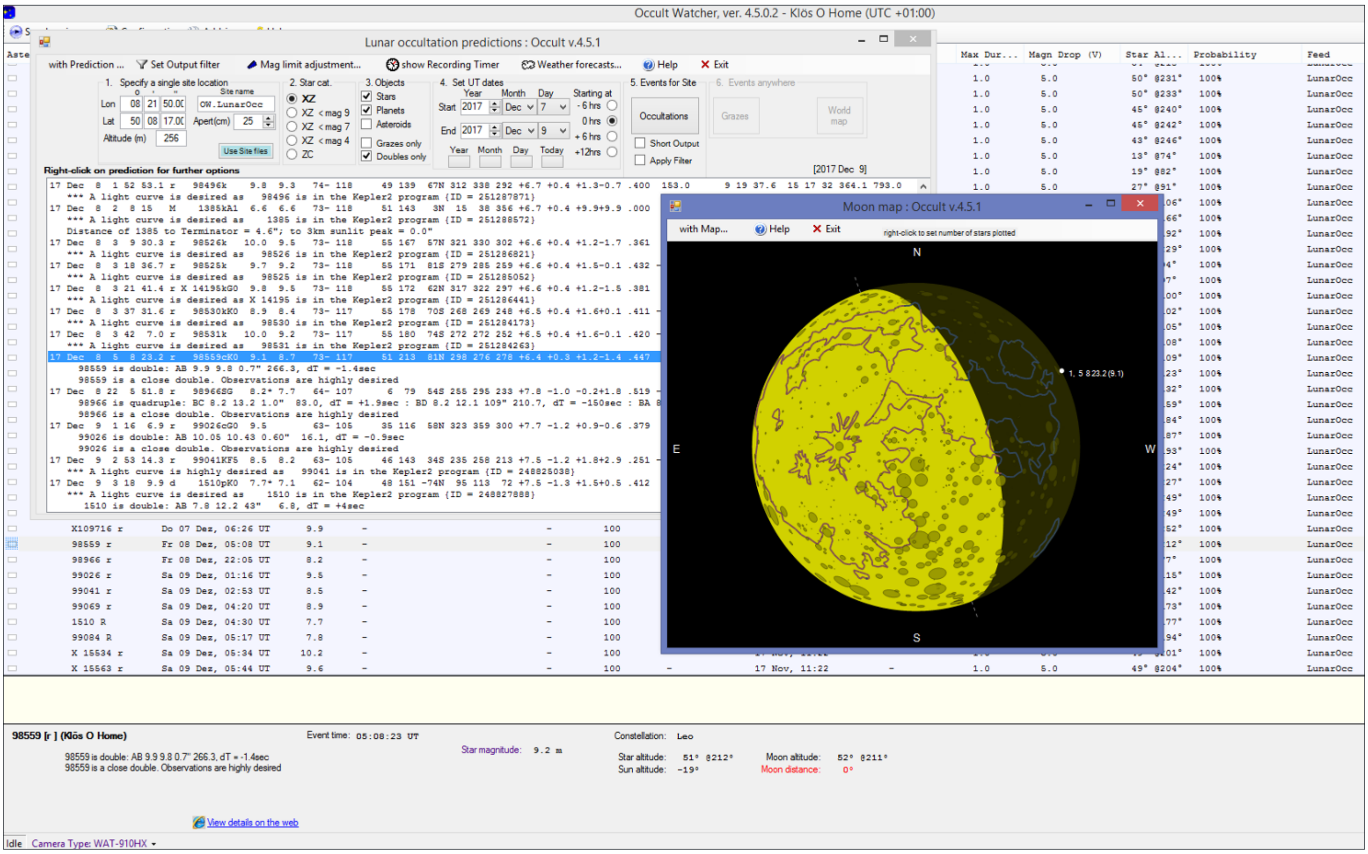

Figure 3: If a prediction at the feed is selected, "Occult" opens two windows. The first one presents information of local circumstances, the second one a moon map with the star position at occultation (screen capture: O. Klös).

The Feeds

Feeds are available for the following areas :

Occultations for the Australia and New Zealand area maintained by Brian Loader and hosted by Hristo Pavlov at:
http://www.hristopavlov.net/LunarWatcher/index.txt

Occultations for the North America region maintained and hosted by Brad Timerson at:
http://www.asteroidoccultation.com/Regional/NAmer/NADoubles.txt

Occultations for the Europe region maintained by Oliver Klös and Jan Manek and hosted by IOTA/ES at:
http://www.iota-es.de/OWFeed/EuroDls.txt

Occultations for South America maintained by Néstor D. Díaz and hosted by GEDRAA at:
http://www.gedraa.com.ar/lunar/SAmerica.txt
(Feed is inactive at the moment)

Some feeds are updated every month, the European feed is updated for every lunation, starting with new moon.

Using the Feed

You will need to restart OW after you have completed the configuration for the changes to take effect. After restart of OW you can synchronise the feed and get the events for your location. Clicking twice on the events, "Occult" will pop up and show you more detailed information of local circumstances and a moon map with the location of the star at the moon limb (Fig. 3). The feed "Lunar Occultations of Double Stars" is a reminder tool. You can add the events to your selection "My events" at OW using the follow-up flag, but you can't announce your observing plans to other observers.

Studying Comets by the Stellar Occultation Method

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Mike Kretlow, IOTA/ES, Lauenbrück, Germany, mike@kretlow.de

ABSTRACT: Stellar occultations by comets are generally problematic. The coma is usually too tenuous to be detected by the attenuation effect on stars unless the comet is a very active one and the nucleus passes within a few hundred kilometres of the star as projected on the sky frame. Where an occultation by the solid body of the nucleus occurs, the shadow track will be very narrow: Jupiter-family comets for instance typically measure just 1-5 km across and this small size significantly reduces the probability of a successful occultation for the observer. Another issue concerns the accuracy of cometary orbits, since this tends to be degraded by the presence of light from the inner coma shifting the position of the pseudo-nucleus relative to the true nucleus, and also by the effect of non-gravitational forces.
Larger, more distant periodic comets, such as active Centaurs, are more attractive occultation targets, and of these one of particular interest appears to be comet 29P/Schwassmann-Wachmann 1. Measuring about 60 km across, it is famous for its cometary outbursts, which number about 10 per year. The hypothesis is put forward here that the nucleus of 29P/S-W1 is surrounded by a debris belt of the order of 1000 km across, and that this could be detected by the stellar occultation technique. However, astrometry of its orbit is generally of poor accuracy owing to its outbursts, which tend to shift the photocentre of the nucleus away from its true position - especially when observed in small telescopes or where the aperture used for astrometry is too large. The case is put forward that astrometry of 29P should be carried out using a new measurement methodology with images taken by 1.0-m and 2.0-m telescopes, so as to refine the orbital elements and achieve more accurate occultation predictions.

Some Reports from the Literature

Comets generally develop a coma or dust tail as they approach perihelion, seen by reflected sunlight. The coma exhibits a variety of forms but is usually very tenuous even in very active comets such that stars passing behind the extended coma will show no significant decrease in brightness as the filling factor of the dust (fraction projected on the sky occupied by dust) is very small, i.e. <0.001. Most observations actually record an appulse rather than a physical occultation, an early example being an event seen by Friedrich Archenhold whilst observing 1P/Halley on 1909 December 5, when the 12th magnitude nucleus was seen to merge with a 12th magnitude star as seen under high magnification in the 0.65-m refractor of Treptow Observatory, Berlin [1]. Attenuation of starlight can occur very close to a very active comet such as Hale-Bopp (C/1995 O1) or 17P/Holmes soon after its mega-outburst of 2007. In the case of Hale-Bopp, a drop of 0.06 mag was registered some 43000 km from the nucleus and interpreted as enhanced absorption due to a local jet [2].

Probably the most successful occultation record for Hale-Bopp was achieved when it occulted a mag 9.1V star (PPM 200723) on 1996 October 05 whilst 2.8 AU from the Sun [3]. For one station using a photomultiplier detector, a positive event was recorded lasting about 30 seconds although sky conditions were affected by thin cloud at the time and so were non-photometric.

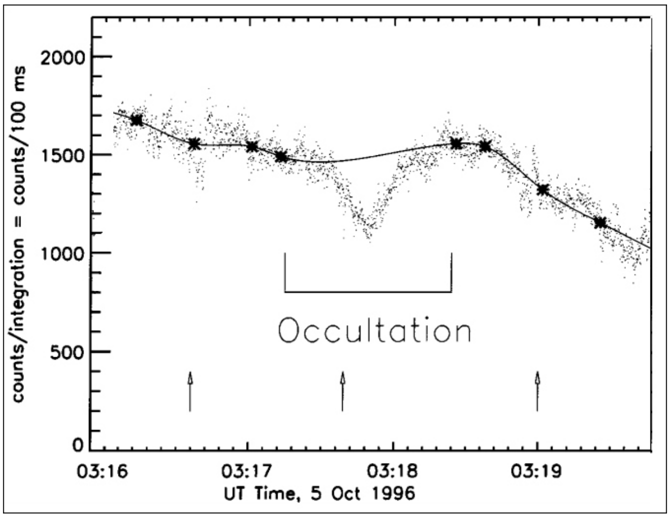

Figure 1: Positive event recorded by Yanga Fernández and Dennis Wellnitz in 1996 showing the occultation by the nucleus or near-nucleus region of comet Hale-Bopp (adapted from [3]).

At mid-event, the light from the star had effectively been extinguished showing that the coma was optically thick within 100 km of the nucleus, the radius of which was estimated to be 30-48 km.

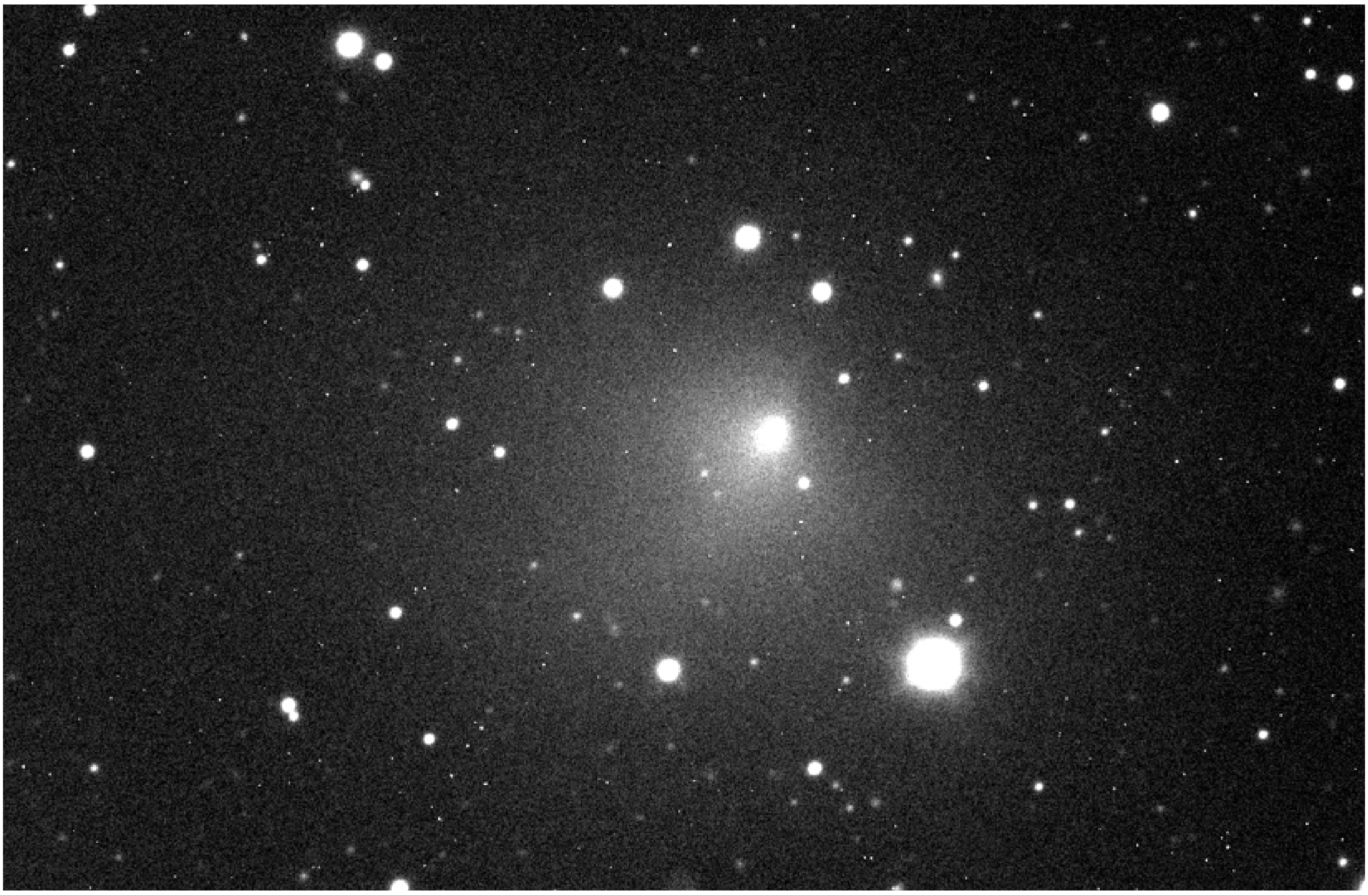

Figure 2: Deep image of 29P/S-W1 on 2017 October 12.42 (Las Cumbres Observatory). 2.0-m f/10 Faulkes Telescope South, Siding Spring (SDSS-r' filter, 8 frames stacked) Integration time = 1440 sec, Field of view = 5.0' x 6.5', linear stretch, motion 0.02"/min

On 2007 October 29, some 5 days after the intense outburst of comet 17P/Holmes, the nucleus passed within 0.8 arcsec of a magnitude 11.1R star and measurements using a narrow-band filter on a 2.2-m telescope indicated an optical depth of just 0.04 some 1.5 arcsec from the nucleus [4]. The authors concluded that the coma was optically thick only within about 0.01" (12 km) of the nucleus.

Implications for Stellar Occultations by Comets

From the above, it can be seen that for an average comet, we can only expect the nucleus itself to occult the star and that the detection of any true dimming prior to ingress, or after egress will be very challenging to measure. Thus the shadow projected on the Earth will be very comparable to the size of the comet nucleus, and since the vast majority of comets measure <100 km across, the shadow tracks will generally be very narrow. Short-period Jupiter-family comets (JFCs) represent especially difficult targets, typically measuring just 1-5 km across [5].

With the Gaia mission well underway, we can expect highly-accurate astrometric positions and proper motions for almost a billion stars in the next few years, as well as much more accurate orbital elements and mass estimates of the larger asteroids. For comets, however, a key factor in predicting stellar occultations is the precise position of the occulting body, i.e. the nucleus. This can be problematic for several reasons:

One issue is the measured position of the so-called 'pseudo-nucleus', which is generally displaced relative to the position of the actual nucleus owing to reflected light from the inner coma. Astrometric software determines the position of the peak in brightness within the inner coma and so if the comet is particularly active or has exhibited an outburst such that the coma is markedly asymmetric, this peak intensity is displaced. This is particularly the case under conditions of poor seeing, or when the instrument is a small telescope, since then the stellar FWHM is broadened and more of the inner coma contaminates the pseudo-nucleus lowering the peak intensity and shifting it further from the position of the true nucleus (see Figure 2). Whether Gaia 'exo-atmosphere' astrometry of comets will improve our knowledge of cometary orbits is yet to be seen.

The other main issue for comets is that being generally small, they are of low mass and so non-gravitational forces arising from exposure to solar radiation and internally generated jets can perturb their motion thereby complicating the task of predicting future occultations. There is a case for deriving a methodology aimed at enhancing the precision and accuracy of comet astrometry.

The Attraction of Stellar Occultations by Centaurs and TNOs

From the foregoing it is clear that successful occultation results on comets that approach the Sun closer than the orbit of Jupiter are expected to be few and far between in the near future. In contrast, more distant objects are generally larger and hence their shadow tracks wider mak-

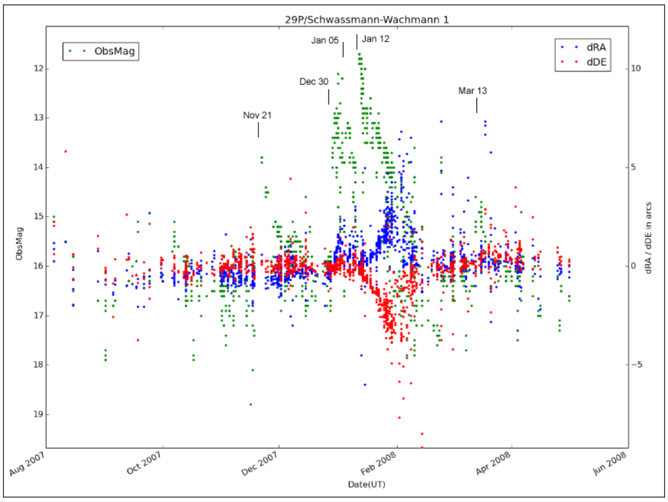

Figure 3: An illustration showing how cometary outbursts of comet 29P/S-W1 degrade astrometric accuracy. Data taken from the Minor Planet Center (MPC) and analysed to show residuals (O-C) from the predicted aastrometric position, RA and Dec (blue and red points) alongside the reported m2 magnitude of the pseudo-nucleus (green points). The times of five outbursts are shown.

ing them more favourable targets. Although they may be cometary in nature, they do not suffer from the presence of a persistent coma, except in one notable case, namely comet 29P/Schwassmann-Wachmann 1. So most Centaurs represent attractive targets for study by the occultation method and indeed, Project Lucky Star led by Bruno Sicardy [6] is specifically designed to study Centaurs and Trans-Neptunian Objects since 2015 using this technique. Many positive occultations have already been recorded – take for example the recent announcement of the discovery of a dense ring around the trans-Neptunian dwarf planet, Haumea [7]. Some Centaurs have been found to be cometary in nature including (60558) Echeclus (also known as periodic comet 174P/Echeclus) and an article written by Oliver Klös describing this object and making predictions for future occultations appeared in Journal for Occultation Astronomy Vol. 7 No. 4. However, of all the Centaurs known, the most enigmatic is without any doubt 29P/S-W1.

The Case for 29P/Schwassmann-Wachmann 1

Although space precludes any detailed account of this object here, readers may wish to consult a series of papers published in the journal, Icarus [8–10] to understand the very special nature of this body, which is worthy of study by a variety of techniques including the occultation method. Figure 2 illustrates the quiescent appearance of 29P/S-W1 as seen 40 days after its last strong outburst.

29P/S-W1 is moving northwards, crossing the celestial equator next June, and will be well placed for northern hemisphere observers in the next 8-10 years. Astrometry appears to be seriously biased by the many outbursts of the comet (typically 10 per year). After an outburst, the asymmetric coma shifts the position of the photocentre / pseudo-nucleus relative to the true nucleus and this shift can persist for several weeks as shown in Figure 3. The apparent deviation from the expected position can exceed 5" in both R.A. and Dec. at times. It is our view that to be able to make accurate predictions of stellar occultations by 29P/S-W1, it will be necessary to refine the current orbital elements.

Since the apparent photocentre shifts as the measuring aperture size is changed, it may be worthwhile making measurements with astrometric apertures of several sizes and then extrapolating the position as a function of size to a value close to, or equal to the FWHM or 'seeing' at the epoch of the observation. An on-going 29P monitoring project is being conducted using the Las Cumbres Observatory global network of telescopes and we have already built up several years of frequent imaging of the comet using 1.0-m and 2.0-m telescopes. It will be interesting to compare the astrometric precision achievable using such large telescopes and an improved method of astrometric measurement, relative to the current astrometry reported to the MPC.

One possible approach for minimising astrometric bias arising from the displacement of the photocentre would be to apply an appropriate weighting scheme during orbit computations to those astrometric observations made around the times of outburst.

One other reason why 29P is a worthy target for occultation studies is that it is likely to possess some form of temporary debris/dust belt that fluctuates in size and density (and tilt relative to the Earth) but which is likely to be of the order of 1000 km across. The latest estimate of the size of the nucleus is in the range 55-68 km across [11].

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Grazing Occultations of Stars by the Moon in 2018

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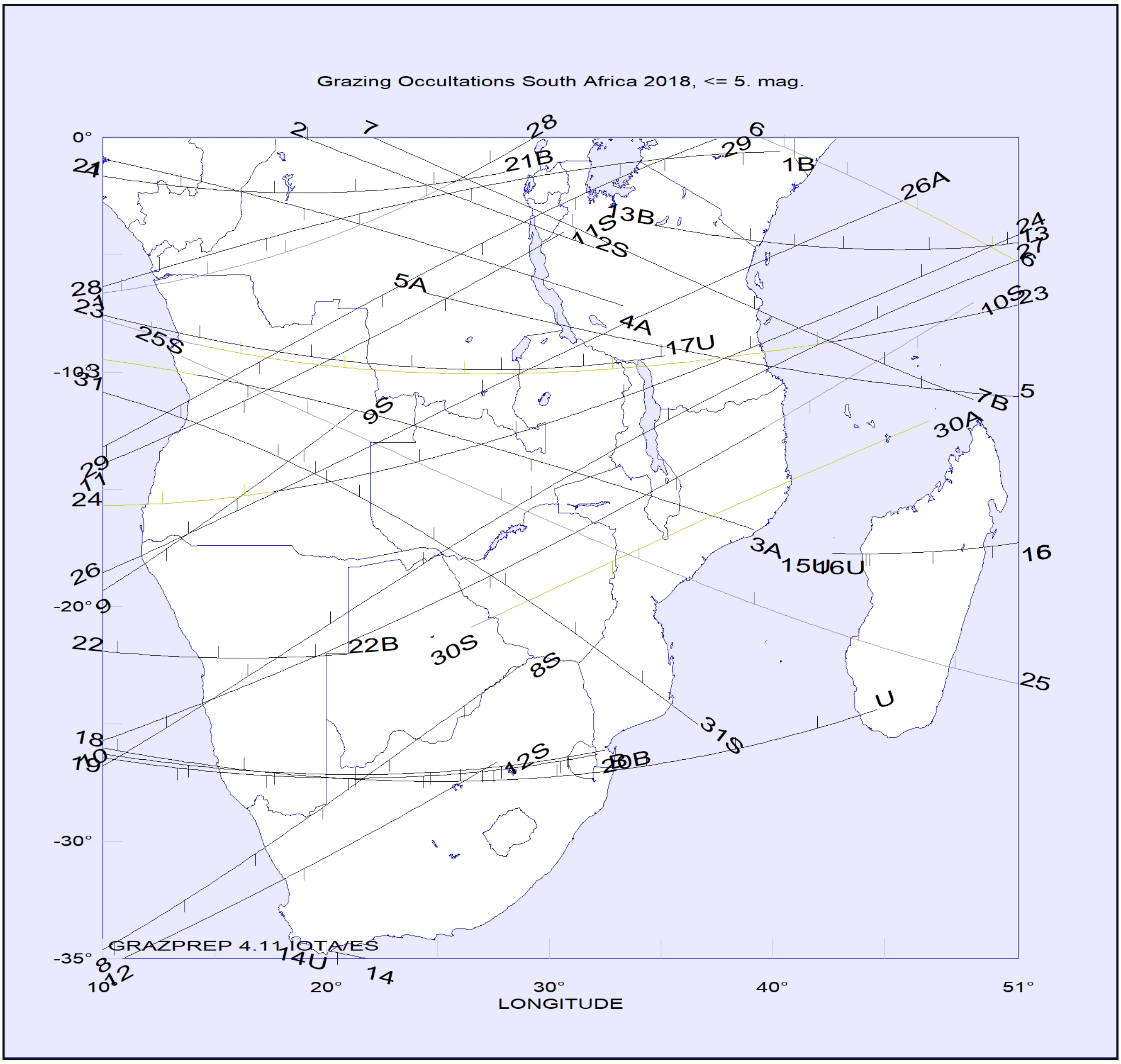
The following maps and tables show this year's grazing occultations of the brightest stars by the moon in those regions of the world where most of our observers live. The overall limiting magnitude is 4.0, and 5.0 for favorable dark limb events at night. Additionally the grazes during the 2 total lunar eclipses on Jan. 31 and July 27 are included to magnitude 10.0.

One more graze of Aldebaran is on the list on Feb. 23. It is a favorable southern dark limb event crossing southern Spain and Corsica shortly before sunset, being a well observable twilight event in Italy and then crossing the Balkan countries and Bulgaria at night.

Regulus has 2 events: on Feb. 1 there will be a nighttime southern bright limb graze being visible in Northern Germany, Denmark, Sweden, Latvia, Estonia and Russia. On March 28 only southern Finland and Russia have a marginal daytime event on the dark side of the 90% sunlit waxing moon.

All tables and pictures of this article were created with the author's GRAZPREP-software. Further precise information on the local circumstances of all grazing occultations is provided by this software which can be downloaded and

2018			Grazing Occultations South Africa 2018, <= 5. mag.							GRAZPREP 4.11, IOTA/ES	
No.	M D	USNO	SAOPPM D	MAG	%SNL	L.	W.UT	LONG LAT	STAR NAME	MAG1	MAG2
1	**Jan 03**	ZC 1310	98087 S	3.9	95 -	N	20 25.1	10 -6	Asellus Australis delta Cancri		
2	**Feb 13**	ZC 2886	162964	4.9	6 -	S	3 50.5	19 0	56 Sagittarii		
3	**Mar 22**	ZC 648	93897 S	3.8	29+	N	18 51.5	10 -9	Hyadum II delta 1 Tauri	3.9	9.5
4	**Mar 22**	ZC 653	93907 S	4.8	29+	N	19 31.7	10 -1	64 delta 2 Tauri	5.6	5.6
5	**May 08**	ZC 3237	164861 c	4.3	40 -	S	23 29.0	24 -7	iota Aquarii	5.2	5.2
6	**May 20**	ZC 1310	98087 S	3.9	33+	S	14 27.0	39 0	Asellus Australis delta Cancri		
7	**Jun 28**	ZC 2759	187504	3.5	100 -	S	17 53.7	22 0	xi 2 Sagittarii		
8	**Jul 04**	ZC 3421	146612 c	4.9	71 -	N	3 48.8	10 -35	chi Aquarii	4.9	5.1
9	**Jul 07**	ZC 249	110065	4.5	41 -	N	4 21.9	10 -19	nu Piscium		
10	**Jul 10**	ZC 648	93897 S	3.8	12 -	N	3 21.2	10 -26	Hyadum II delta 1 Tauri	3.9	9.5
11	**Jul 10**	ZC 653	93907 S	4.8	12 -	N	3 45.8	10 -14	64 delta 2 Tauri	5.6	5.6
12	**Jul 10**	ZC 658	93923 S	4.3	12 -	N	4 43.7	11 -35	68 Tauri V776 Tauri	4.3	8.4
13	**Jul 27**	X 28430	163580	8.3	100 E	S	19 1.1	34 -4			
14	**Jul 27**	X 28438	163587	8.7	100 E	N	19 9.7	20 -35			
15	**Jul 27**	X 28424	163578 C	9.2	100 E	N	19 25.3	42 -18		9.4	11.0
16	**Jul 27**	X174460	P0 C	9.2	100 E	N	19 30.2	44 -18			
17	**Jul 27**	X 48433	P721911	10.0	100 E	S	20 2.6	10 -8			
18	**Jul 27**	X 28494	163623	8.6	100 E	S	20 18.9	10 -26			
19	**Jul 27**	ZC 2993	163625W	6.7	100 E	N	20 31.7	10 -26			
20	**Jul 27**	ZC 2994	163626W	5.9	100 E	N	20 32.8	10 -26	omicron Capricorni	6.1	6.6
21	**Jul 27**	X 28522	163640	9.0	100 E	S	20 52.6	10 -2			
22	**Jul 27**	X 28528	163642	9.1	100 E	S	21 8.7	10 -22			
23	**Sep 14**	ZC 2223	159370 S	3.9	28+	S	16 44.7	10 -8	Zuben Elakrab gamma Librae	4.7	4.9
24	**Sep 17**	ZC 2633	186497 S	3.8	58+	S	18 22.8	10 -16	mu Sagittarii	4.1	7.0
25	**Sep 18**	ZC 2759	187504	3.5	66+	S	13 5.6	13 -9	xi 2 Sagittarii		
26	**Sep 18**	ZC 2797	187756 S	2.9	68+	S	21 32.4	10 -19	Albaldah pi Sagittarii	3.8	3.8
27	**Oct 18**	ZC 3126	164346	4.3	69+	S	20 31.9	10 -27	Tae iota Capricorni		
28	**Nov 15**	ZC 3190	164644 S	2.9	51+	S	15 18.4	10 -7	Deneb Algedi delta Capricorni	3.2	5.2
29	**Nov 24**	ZC 847	77336 c	3.0	96 -	N	21 10.4	10 -13	zeta Tauri	3.2	5.2
30	**Dec 09**	ZC 2759	187504	3.5	5+	N	16 34.3	26 -21	xi 2 Sagittarii		
31	**Dec 29**	ZC 1773	119341 w	5.0	53 -	S	1 33.4	10 -11	16 Virginis	5.8	5.8



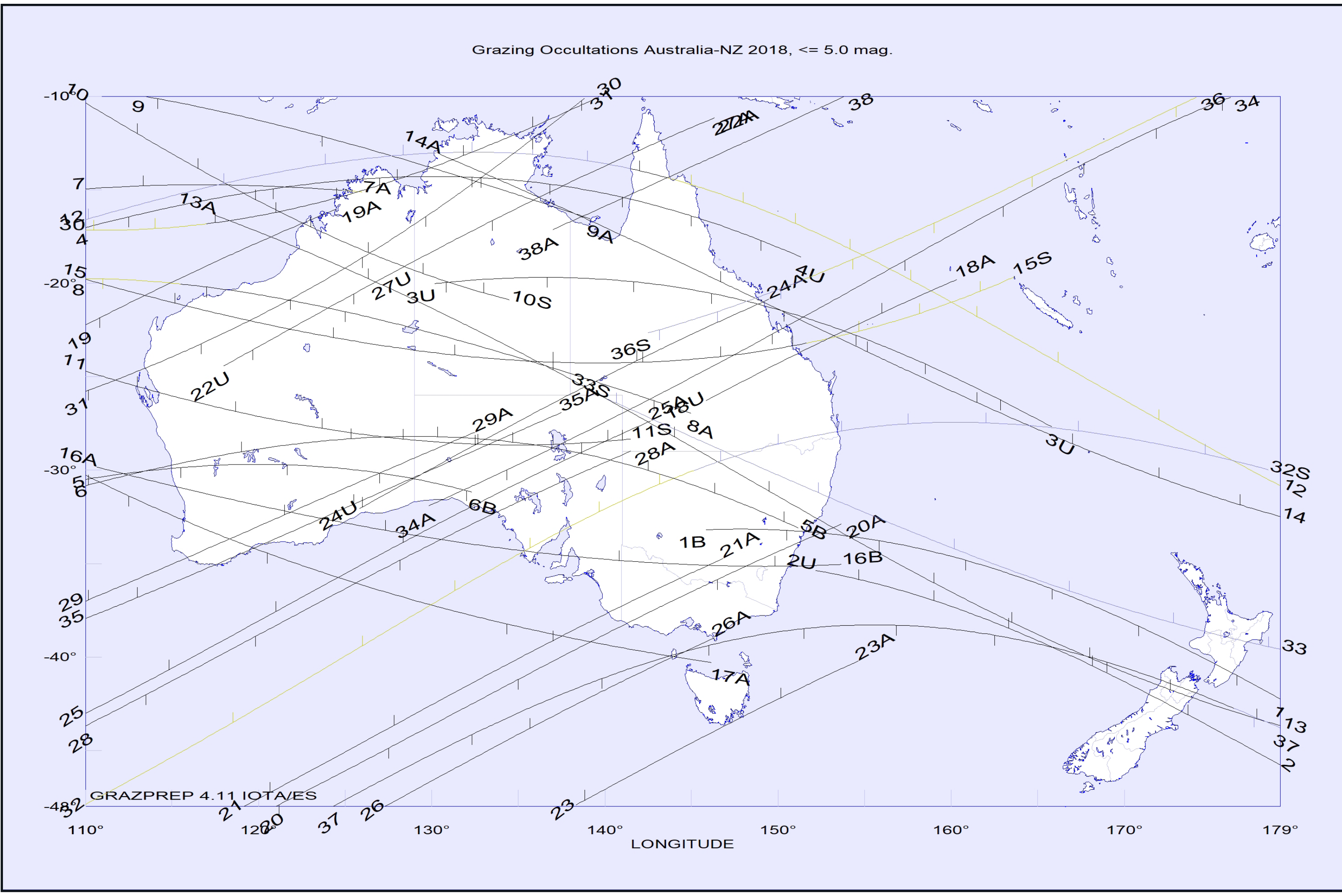
South Africa

installed via www.grazprep.com (password: IOTA/ES) including prediction files that are needed additionally for different regions of the world. GRAZPREP assists in finding and listing individually favorable occultation events and in figuring out the best observing site in advance or even under way by graphically showing the expected apparent stellar path through the lunar limb terrain. Most stars are calculated with their highly precise position of the Gaia-catalogue.

The main idea of the program is to easily visualize the complete list of all grazing occultation events in an area plus the complete line data for any selected event and (simultaneously on the same screen) both the geographic circumstances on earth and the enlarged topographic situation at the lunar limb. This includes a fairly realistic display of the sunlit lunar portion as well as the approximate sky brightness depending on to the sun's altitude. Thus a judgment about the entire graze circumstances is easily possible at a few glances and a selection of the best events and observing locations quick and easy. Any graze line for any selected favorable offset to the predicted limit can be displayed in Google Earth.

Besides that the software assists in creating one or several individual observing stations with any center and radius, that way filtering out the most suitable local events according to a variety of personal preferences. Furthermore a report form is provided to enable sending and collecting observation data in a fixed format, thus supporting the reduction and scientific evaluation of observed contacts.

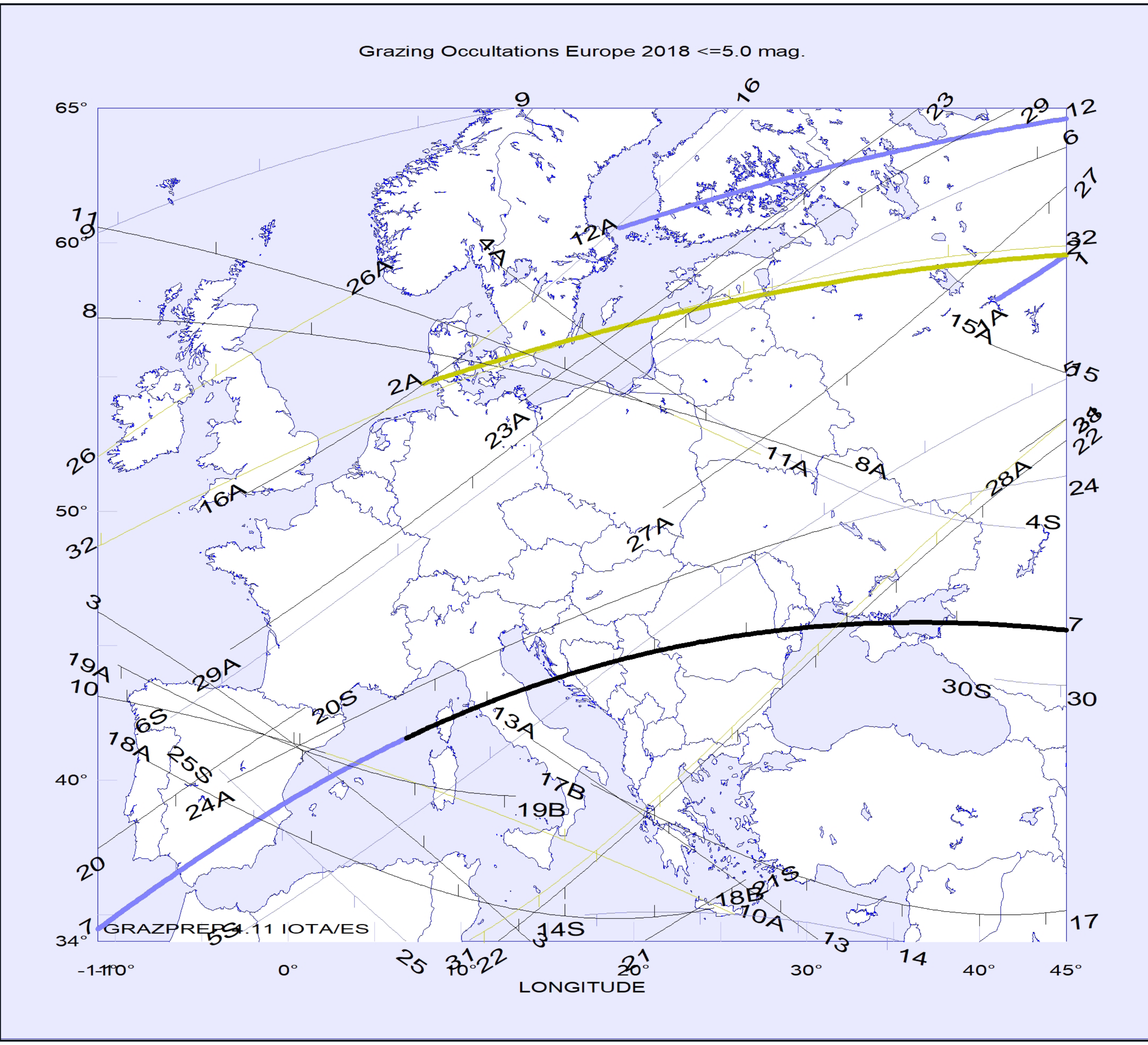
2018		Grazing Occultations Australia-NZ 2018, <= 5.0 mag.									GRAZPREP 4.11, IOTA/ES	
No.	**M D**	**USNO**	**SAOPPM D**	**MAG**	**%SNL**	**L.**	**W.UT**	**LONG**	**LAT**	**STAR NAME**	**MAG1**	**MAG2**
1	**Jan 31**	X 13522	98207	8.0	100 E	N	12 12.7	146	-33			
2	**Jan 31**	X 13527	98210	8.9	100 E	S	12 44.5	152	-35			
3	**Jan 31**	X 13588	P125930	9.9	100 E	N	12 49.1	130	-20			
4	**Jan 31**	X112511	P0	9.6	100 E	N	12 57.8	110	-17			
5	**Jan 31**	X 13603	98241	7.6	100 E	S	13 0.3	110	-31			
6	**Jan 31**	X 13652	98271	9.3	100 E	N	13 53.0	110	-30			
7	**Feb 20**	ZC 249	110065	4.5	21+	S	12 46.8	110	-15	nu Piscium		
8	**Feb 23**	ZC 648	93897 S	3.8	53+	N	13 8.3	110	-20	Hyadum II delta 1 Tauri	3.9	9.5
9	**Feb 23**	ZC 653	93907 S	4.8	53+	N	13 59.2	113	-10	64 delta 2 Tauri	5.6	5.6
10	**Mar 08**	ZC 2399	160046	4.9	55 -	S	19 51.9	110	-10	24 (Scorpii)/Ophiuchi		
11	**Apr 08**	ZC 2886	162964	4.9	44 -	S	19 45.2	110	-25	56 Sagittarii		
12	**Apr 23**	ZC 1310	98087 S	3.9	56+	S	7 10.7	110	-17	Asellus Australis delta Cancri		
13	**May 02**	ZC 2399	160046	4.9	94 -	S	12 6.4	117	-16	24 (Scorpii)/Ophiuchi		
14	**May 04**	ZC 2666	186794 D	4.9	81 -	S	12 51.3	130	-13	21 Sagittarii	5.0	7.5
15	**May 07**	ZC 3079	164132	4.1	53 -	S	17 46.0	110	-20	Tsin theta Capricorni		
16	**Jul 02**	ZC 3237	164861 c	4.3	83 -	S	13 45.1	110	-30	iota Aquarii	5.2	5.2
17	**Jul 17**	ZC 1702	119035	4.0	26+	N	11 16.2	110	-30	nu Virginis		
18	**Jul 27**	X 28306	163493	9.1	100 E	S	19 1.2	146	-26			
19	**Jul 27**	X 28399	163559	8.2	100 E	N	21 29.3	110	-22			
20	**Jul 27**	X 28332	163510	7.9	100 E	N	19 29.8	121	-48			
21	**Jul 27**	X 28369	163537	9.7	100 E	S	19 57.9	119	-48			
22	**Jul 27**	X174015	P0 D	9.1	100 E	N	19 26.9	118	-24			
23	**Jul 27**	X 28355	163524	9.8	100 E	S	19 49.5	138	-48			
24	**Jul 27**	X 48223	P237342	9.8	100 E	S	19 30.0	126	-32			
25	**Jul 27**	X 48274	P721824	9.9	100 E	S	19 51.7	110	-43			
26	**Jul 27**	X 28382	163547	9.4	100 E	S	20 21.1	127	-48			
27	**Jul 27**	X 48198	P237327 D	9.4	100 E	N	19 44.4	128	-19			
28	**Jul 27**	X 28361	163531	9.7	100 E	N	20 3.9	110	-44			
29	**Aug 21**	ZC 2666	186794 D	4.9	81+	S	17 50.8	110	-37	21 Sagittarii	5.0	7.5
30	**Aug 22**	ZC 2797	187756 S	2.9	87+	S	13 18.6	110	-17	Albaldah pi Sagittarii	3.8	3.8
31	**Aug 30**	ZC 249	110065	4.5	83 -	N	16 10.3	110	-26	nu Piscium		
32	**Sep 02**	ZC 648	93897 S	3.8	52 -	S	19 33.1	110	-48	Hyadum II delta 1 Tauri	3.9	9.5
33	**Oct 16**	ZC 2797	187756 S	2.9	44+	S	2 39.7	140	-26	Albaldah pi Sagittarii	3.8	3.8
34	**Oct 28**	ZC 847	77336 c	3.0	82 -	N	13 39.1	130	-32	zeta Tauri	3.2	5.2
35	**Nov 11**	ZC 2633	186497 S	3.8	15+	S	11 56.9	110	-38	mu Sagittarii	4.1	7.0
36	**Nov 12**	ZC 2759	187504	3.5	21+	N	7 38.0	142	-23	xi 2 Sagittarii		
37	**Nov 25**	ZC 976	78297 S	2.9	92 -	N	15 22.7	124	-48	Tejat Posterior mu Geminorum	3.2	9.8
38	**Nov 26**	ZC 1110	79294 S	3.5	86 -	N	12 31.3	137	-17	Wasat delta Geminorum	3.5	8.2


Grazing Occultations Australia-NZ 2018, <= 5.0 mag.
-10°
-20°
-30°
-40°
-48°
110°
120°
130°
140°
150°
160°
170°
179°
LONGITUDE
GRAZPREP 4.11 IOTA/ES

Australia

2018 — Grazing Occultations Europe 2018, <= 5.0 mag. — GRAZPREP 4.11, IOTA/ES

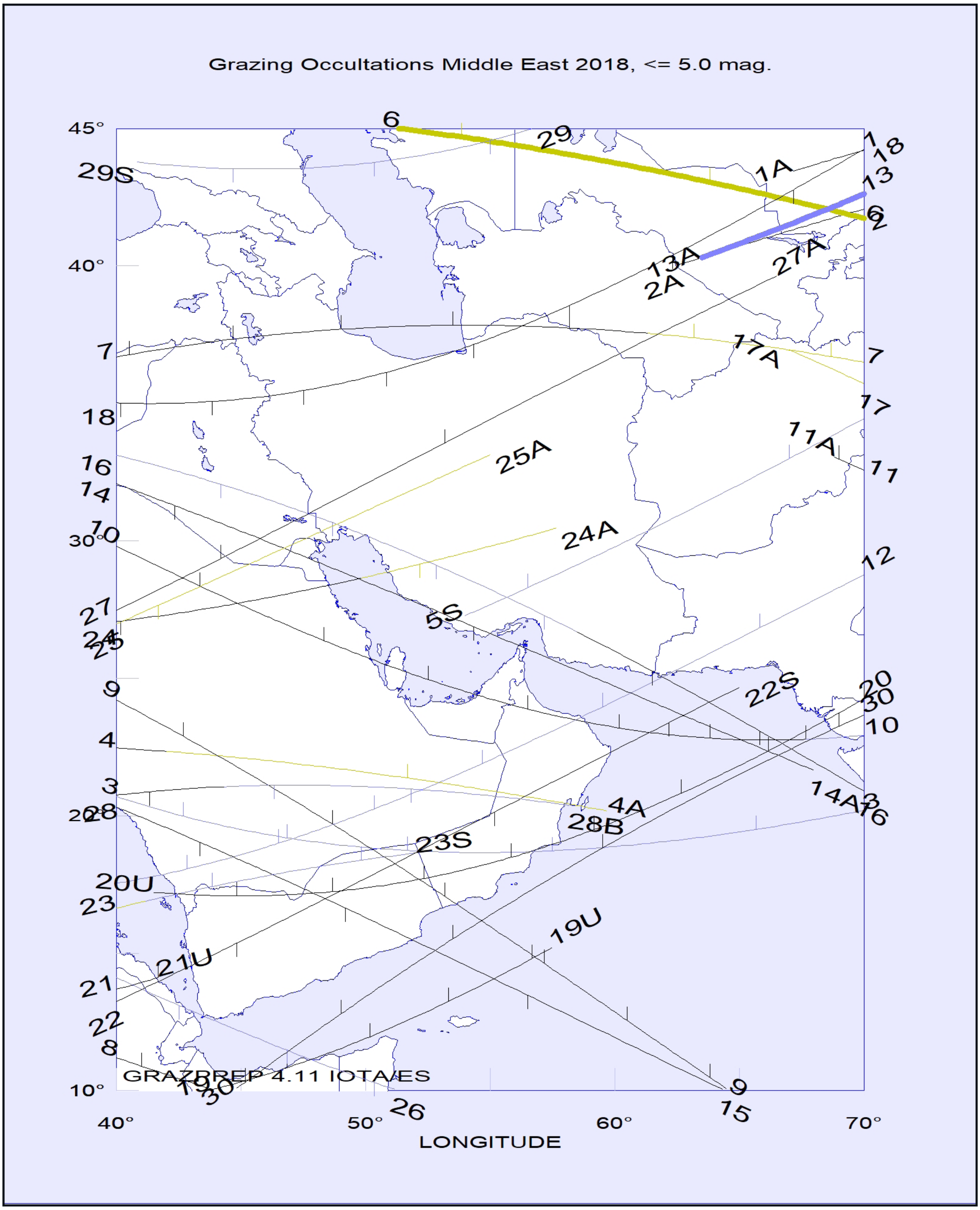
No.	M D	USNO	SAOPPM D	MAG	%SNL	L.	W.UT	LONG LAT		STAR NAME	MAG1	MAG2
1	**Jan 27**	ZC 692	94027 S	0.9	77+	N	9 51.0	41	58	Aldebaran alpha Tauri	1.1	11.3
2	**Feb 01**	ZC 1487	98967 S	1.4	98 -	S	17 56.4	8	55	Regulus alpha Leonis		
3	**Feb 08**	ZC 2223	159370 S	3.9	45 -	S	3 31.1	-11	46	Zuben Elakrab gamma Librae	4.7	4.9
4	**Feb 12**	ZC 2759	187504	3.5	11 -	S	5 48.6	12	59	xi 2 Sagittarii		
5	**Feb 23**	ZC 669	93955 c	3.8	54+	S	12 56.8	-2	34	theta 1 Tauri NSV 16016	4.0	7.8
6	**Feb 23**	ZC 671	93957 S	3.4	54+	S	13 7.9	-6	42	theta 2 Tauri	4.0	5.0
7	**Feb 23**	ZC 692	94027 S	0.9	55+	S	16 30.7	-11	34	Aldebaran alpha Tauri	1.1	11.3
8	**Mar 21**	ZC 508	93469 c	4.1	19+	S	19 51.4	-11	57	5 Tauri	4.5	6.5
9	**Mar 22**	ZC 635	93868 c	3.6	28+	S	15 48.6	-11	60	Hyadum I gamma Tauri	4.7	4.7
10	**Mar 22**	ZC 667	93950 c	5.0	29+	S	20 48.1	-11	43	75 Tauri	5.4	7.9
11	**Mar 22**	ZC 677	93975 S	4.8	30+	S	21 25.5	-11	61	NSV 01627	5.6	5.6
12	**Mar 28**	ZC 1487	98967 S	1.4	90+	S	13 19.4	19	61	Regulus alpha Leonis		
13	**Apr 06**	ZC 2633	186497 S	3.8	61 -	S	23 53.4	14	41	mu Sagittarii	4.1	7.0
14	**May 20**	ZC 1310	98087 S	3.9	33+	N	13 19.2	17	35	Asellus Australis delta Cancri		
15	**Jun 04**	ZC 3190	164644 S	2.9	67 -	S	22 11.3	40	56	Deneb Algedi delta Capricorni	3.2	5.2
16	**Jul 10**	ZC 635	93868 c	3.6	12 -	S	2 15.1	-2	51	Hyadum I gamma Tauri	4.7	4.7
17	**Jul 27**	X 28430	163580	8.3	100 E	N	19 6.6	17	40			
18	**Jul 27**	X 28516	189367 c	9.3	100 E	S	20 44.0	-8	41		9.7	9.7
19	**Jul 27**	X 28522	163640	9.0	100 E	N	21 0.8	-10	44			
20	**Aug 08**	ZC 915	77911 S	4.6	14 -	N	4 45.7	-11	37	chi 2 Orionis	5.5	6.3
21	**Aug 09**	ZC 1077	79031 S	4.0	7 -	N	3 25.9	20	34	Mekbuda zeta Geminorum	4.5	4.5
22	**Aug 31**	ZC 405	110723 S	4.3	72 -	N	23 4.0	12	34	mu Ceti	4.5	8.5
23	**Sep 04**	ZC 995	78423 S	4.1	29 -	N	23 3.4	13	54	nu Geminorum	4.3	6.0
24	**Sep 07**	ZC 1310	98087 S	3.9	9 -	N	3 7.5	-3	40	Asellus Australis delta Cancri		
25	**Sep 14**	ZC 2223	159370 S	3.9	28+	N	15 22.5	-4	40	Zuben Elakrab gamma Librae	4.7	4.9
26	**Sep 22**	ZC 3190	164644 S	2.9	91+	S	1 16.8	-11	52	Deneb Algedi delta Capricorni	3.2	5.2
27	**Sep 30**	ZC 764	94332 c	4.9	66 -	N	19 55.4	21	50	104 Tauri	5.6	5.6
28	**Oct 01**	ZC 915	77911 S	4.6	56 -	N	19 8.0	42	52	chi 2 Orionis	5.5	6.3
29	**Oct 28**	ZC 894	77705	4.4	79 -	N	20 34.4	-3	45	chi 1 Orionis		
30	**Nov 15**	ZC 3171	164560 c	3.7	50+	N	12 4.8	40	44	Nashira gamma Capricorni	4.6	4.6
31	**Nov 15**	ZC 3190	164644 S	2.9	51+	N	16 7.9	10	34	Deneb Algedi delta Capricorni	3.2	5.2
32	**Nov 27**	ZC 1310	98087 S	3.9	72 -	S	22 10.4	-11	49	Asellus Australis delta Cancri		



Grazing Occultations Europe 2018 <=5.0 mag.
GRAZPREP 4.11 IOTA/ES
LONGITUDE
65°
60°
50°
40°
34°
-10°
0°
10°
20°
30°
40°
45°

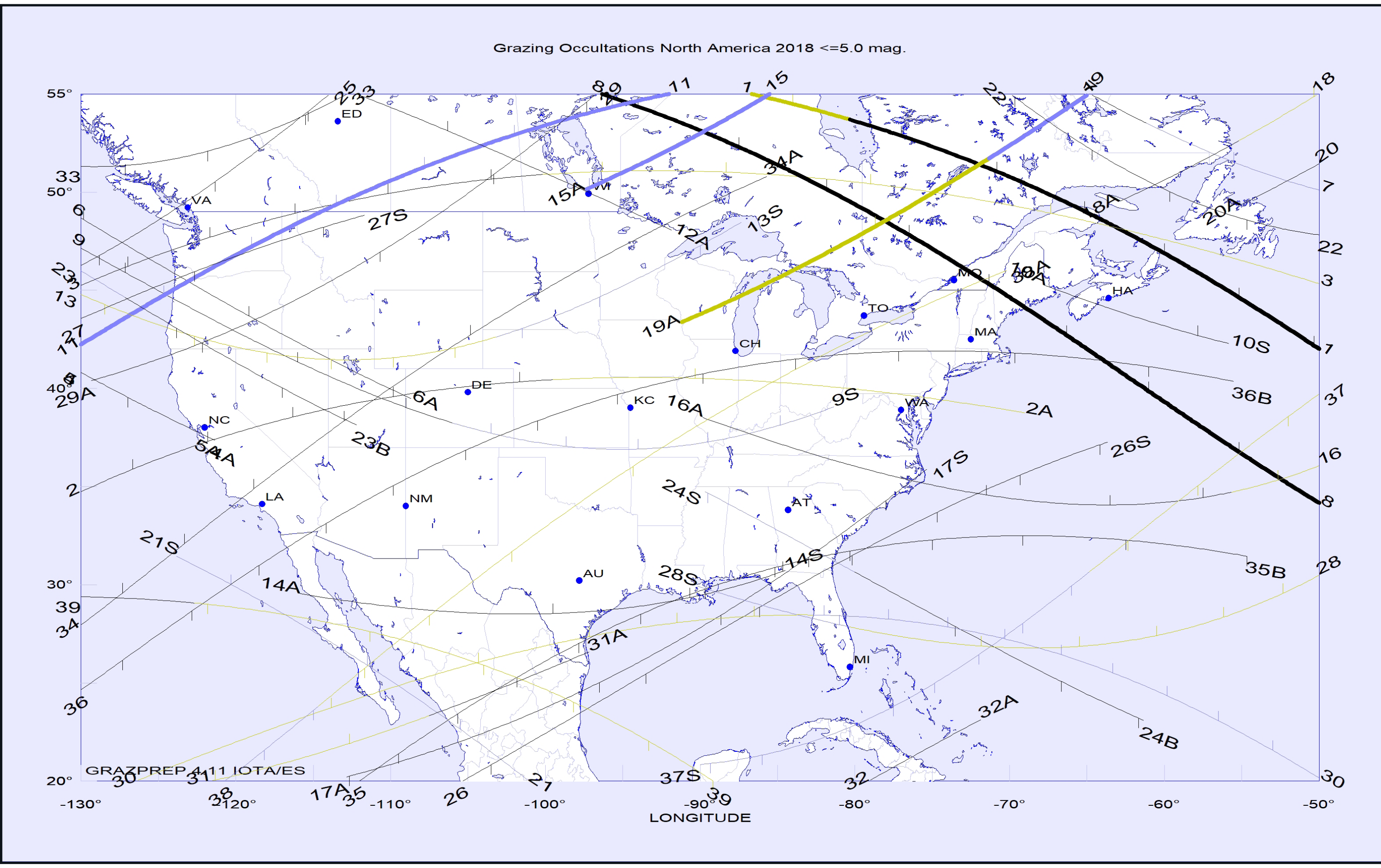
Europe

2018	Grazing Occultations Middle East 2018, <= 5.0 mag.										GRAZPREP 4.11, IOTA/ES	
No.	M D	USNO	SAOPPM D	MAG	%SNL	L.	W.UT	LONG	LAT	STAR NAME	MAG1	MAG2
1	Jan 31	X 13637	98262	9.3	100 E	S	13 31.8	67	43			
2	Jan 31	X 13661	98277	9.0	100 E	N	13 52.7	62	40			
3	Feb 08	ZC 2223	159370 S	3.9	45 -	S	5 13.2	40	21	Zuben Elakrab gamma Librae	4.7	4.9
4	Feb 21	ZC 405	110723 S	4.3	32+	S	18 32.3	40	22	mu Ceti	4.5	8.5
5	Feb 23	ZC 635	93868 c	3.6	52+	S	9 8.5	54	27	Hyadum I gamma Tauri	4.7	4.7
6	Feb 23	ZC 692	94027 S	0.9	55+	S	18 27.3	51	45	Aldebaran alpha Tauri	1.1	11.3
7	Feb 24	ZC 832	94628	4.3	66+	S	16 19.2	40	37	119 Tauri CE Tauri	4.3	4.5
8	Mar 14	ZC 3079	164132	4.1	11 -	S	1 29.9	40	11	Tsin theta Capricorni		
9	Apr 03	ZC 2223	159370 S	3.9	87 -	S	20 46.4	40	24	Zuben Elakrab gamma Librae	4.7	4.9
10	Apr 07	ZC 2633	186497 S	3.8	61 -	S	0 14.2	40	30	mu Sagittarii	4.1	7.0
11	Apr 07	ZC 2759	187504	3.5	53 -	S	20 30.1	68	33	xi 2 Sagittarii		
12	Apr 08	ZC 2797	187756 S	2.9	51 -	S	3 42.1	40	18	Albaldah pi Sagittarii	3.8	3.8
13	Apr 19	ZC 692	94027 S	0.9	13+	S	3 47.4	63	40	Aldebaran alpha Tauri	1.1	11.3
14	Apr 20	ZC 915	77911 S	4.6	26+	N	17 37.5	40	32	chi 2 Orionis	5.5	6.3
15	Apr 21	ZC 1077	79031 S	4.0	36+	N	17 3.9	40	20	Mekbuda zeta Geminorum	4.5	4.5
16	May 20	ZC 1310	98087 S	3.9	33+	N	14 1.1	40	33	Asellus Australis delta Cancri		
17	Jun 01	ZC 2797	187756 S	2.9	90 -	N	17 21.0	67	37	Albaldah pi Sagittarii	3.8	3.8
18	Jul 27	X 28430	163580	8.3	100 E	N	19 40.2	40	35			
19	Jul 27	X 28471	163609	9.2	100 E	S	20 40.7	44	10			
20	Jul 27	X 28432	189296	9.4	100 E	S	19 22.2	41	17			
21	Jul 27	X 48422	P721903	9.9	100 E	S	20 55.1	40	14			
22	Aug 08	ZC 894	77705	4.4	15 -	N	0 47.0	40	13	chi 1 Orionis		
23	Sep 07	ZC 1310	98087 S	3.9	9 -	S	3 4.6	40	17	Asellus Australis delta Cancri		
24	Sep 14	ZC 2223	159370 S	3.9	28+	N	17 9.9	40	27	Zuben Elakrab gamma Librae	4.7	4.9
25	Sep 17	ZC 2633	186497 S	3.8	58+	N	19 28.6	40	27	mu Sagittarii	4.1	7.0
26	Sep 18	ZC 2759	187504	3.5	66+	N	13 25.4	40	14	xi 2 Sagittarii		
27	Sep 18	ZC 2779	187643 w	3.8	67+	S	18 53.7	40	27	omicron Sagittarii NSV 11703		
28	Sep 30	ZC 648	93897 S	3.8	75 -	N	2 47.2	40	21	Hyadum II delta 1 Tauri	3.9	9.5
29	Nov 15	ZC 3171	164560 c	3.7	50+	N	12 4.8	40	44	Nashira gamma Capricorni	4.6	4.6
30	Nov 15	ZC 3190	164644 S	2.9	51+	S	17 9.5	44	10	Deneb Algedi delta Capricorni	3.2	5.2


Grazing Occultations Middle East 2018, <= 5.0 mag.
45°
40°
30°
20°
10°
40°
50°
60°
70°
LONGITUDE
GRAZPREP 4.11 IOTA/ES
25A
24A
5S
22S
23S
19U
21U
20U
4A
28B
13A
2A
27A
17A
11A
14A
1A
29S

Middle East

2018	Grazing Occultations North America 2018, <= 5.0 mag.										GRAZPREP 4.11, IOTA/ES	
No.	**M D**	**USNO**	**SAOPPM D**	**MAG**	**%SNL**	**L.**	**W.UT**	**LONG**	**LAT**	**STAR NAME**	**MAG1**	**MAG2**
1	**Jan 05**	ZC 1487	98967 S	1.4	86 -	S	7 36.8	-86	55	Regulus alpha Leonis		
2	**Jan 25**	ZC 364	110543	4.3	52+	S	3 52.3	-130	35	xi 2 Ceti		
3	**Jan 27**	ZC 635	93868 c	3.6	73+	S	3 34.1	-130	45	Hyadum I gamma Tauri	4.7	4.7
4	**Jan 31**	X 13546	98223 D	8.3	100 E	N	14 28.2	-130	41		8.8	9.4
5	**Jan 31**	X112300	P0 D	9.1	100 E	N	14 28.2	-130	41			
6	**Jan 31**	X 13469	98175	9.3	100 E	S	13 19.9	-130	49			
7	**Feb 12**	ZC 2797	187756 S	2.9	11 -	S	11 32.5	-64	55	Albaldah pi Sagittarii	3.8	3.8
8	**Mar 01**	ZC 1487	98967 S	1.4	99+	S	5 36.7	-96	55	Regulus alpha Leonis		
9	**Mar 11**	ZC 2759	187504	3.5	31 -	S	12 58.6	-130	47	xi 2 Sagittarii		
10	**Mar 14**	ZC 3126	164346	4.3	10 -	S	9 56.6	-67	45	Tae iota Capricorni		
11	**Mar 22**	ZC 692	94027 S	0.9	30+	S	21 51.0	-130	42	Aldebaran alpha Tauri	1.1	11.3
12	**Apr 20**	ZC 832	94628	4.3	20+	S	4 47.0	-112	55	119 Tauri CE Tauri	4.3	4.5
13	**May 05**	ZC 2797	187756 S	2.9	75 -	N	10 47.9	-130	45	Albaldah pi Sagittarii	3.8	3.8
14	**May 10**	ZC 3419	146598 S	4.2	28 -	S	10 22.9	-116	30	psi 1 Aquarii	4.5	8.5
15	**May 16**	ZC 692	94027 S	0.9	2+	S	12 20.5	-97	50	Aldebaran alpha Tauri	1.1	11.3
16	**Jul 02**	ZC 3190	164644 S	2.9	87 -	S	4 11.2	-90	39	Deneb Algedi delta Capricorni	3.2	5.2
17	**Jul 08**	ZC 405	110723 S	4.3	29 -	N	9 10.4	-112	20	mu Ceti	4.5	8.5
18	**Jul 10**	ZC 677	93975 S	4.8	11 -	S	6 34.9	-62	50	NSV 01627	5.6	5.6
19	**Jul 10**	ZC 692	94027 S	0.9	11 -	S	8 36.2	-91	43	Aldebaran alpha Tauri	1.1	11.3
20	**Jul 11**	ZC 832	94628	4.3	5 -	S	6 46.0	-55	49	119 Tauri CE Tauri	4.3	4.5
21	**Jul 21**	ZC 2223	159370 S	3.9	71+	S	23 47.4	-124	31	Zuben Elakrab gamma Librae	4.7	4.9
22	**Jul 22**	ZC 2223	159370 S	3.9	71+	N	1 0.2	-70	55	Zuben Elakrab gamma Librae	4.7	4.9
23	**Jul 25**	ZC 2633	186497 S	3.8	93+	N	3 54.4	-130	46	mu Sagittarii	4.1	7.0
24	**Jul 26**	ZC 2759	187504	3.5	97+	N	0 10.3	-89	35	xi 2 Sagittarii		
25	**Aug 04**	ZC 364	110543	4.3	55 -	N	9 18.8	-130	46	xi 2 Ceti		
26	**Sep 04**	ZC 894	77705	4.4	36 -	N	8 48.8	-105	20	chi 1 Orionis		
27	**Sep 05**	ZC 1077	79031 S	4.0	24 -	N	12 32.0	-130	44	Mekbuda zeta Geminorum	4.5	4.5
28	**Sep 21**	ZC 3190	164644 S	2.9	91+	S	23 4.8	-90	30	Deneb Algedi delta Capricorni	3.2	5.2
29	**Sep 28**	ZC 405	110723 S	4.3	90 -	N	4 37.3	-129	40	mu Ceti	4.5	8.5
30	**Oct 04**	ZC 1310	98087 S	3.9	28 -	S	10 33.0	-126	20	Asellus Australis delta Cancri		
31	**Oct 13**	ZC 2361	159918	4.2	17+	S	2 20.3	-121	20	chi Ophiuchi	4.2	5.0
32	**Oct 16**	ZC 2779	187643 w	3.8	43+	S	3 20.9	-79	20	omicron Sagittarii NSV 11703		
33	**Oct 16**	ZC 2779	187643 w	3.8	43+	N	1 45.0	-130	51	omicron Sagittarii NSV 11703		
34	**Oct 19**	ZC 3171	164560 c	3.7	72+	S	4 52.9	-130	28	Nashira gamma Capricorni	4.6	4.6
35	**Oct 27**	ZC 648	93897 S	3.8	92 -	N	7 23.8	-112	20	Hyadum II delta 1 Tauri	3.9	9.5
36	**Oct 27**	ZC 653	93907 S	4.8	92 -	N	7 34.7	-130	25	64 delta 2 Tauri	5.6	5.6
37	**Dec 12**	ZC 3171	164560 c	3.7	25+	N	19 48.4	-90	21	Nashira gamma Capricorni	4.6	4.6
38	**Dec 13**	ZC 3190	164644 S	2.9	27+	N	0 31.1	-120	20	Deneb Algedi delta Capricorni	3.2	5.2
39	**Dec 28**	ZC 1702	119035	4.0	61 -	N	9 15.0	-130	29	nu Virginis		



North America

Beyond Jupiter

The World of Distant Minor Planets

Since the degradation 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 summarized 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 December 2017, the Minor Planet Center listed 719 Centaurs and 1910 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 (KG).

In this issue:

(136199) ERIS

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Eris – the second largest dwarf planet (136199) Eris is currently the second largest dwarf planet in our solar system after (134340) Pluto. It was discovered and confirmed in 2005 on older recordings and has a companion. It belongs to the Plutoids, a subclass of dwarf planets.

Fig. 1: Eris (from inscription). Tondo of an Attic black-figure kylix. (Antikensammlung Berlin)

The Discovery

(136199) Eris was found 2005 by the team around Mike Brown (CalTech) on images taken on October 21, 2003 by the Mt. Palomar 1.2 m Schmidt-Telescope during a reanalysis of the images. In January 2005, the object could then be proven on current CCD-recordings. The team wanted to gather more observations, but decided in July 2005 to publish the observations, as it had become known that anyone could query the alignment of one of the telescopes via a public website. The object got the provisional designation 2003 UB_{313}. With the new orbit data, further positions could be found in old plate archives. The oldest observations dated from 3 September 1954. 2003 UB_{303} got the number 136199 from the Minor Planet Center. To date, 26 oppositions of Eris have been observed and measured and the orbit is therefore considered as safe. In September 2005 a satellite could be detected with the 10-meter Keck II telescope. The moon of (136199) Eris has a diameter of about 100-250 km.

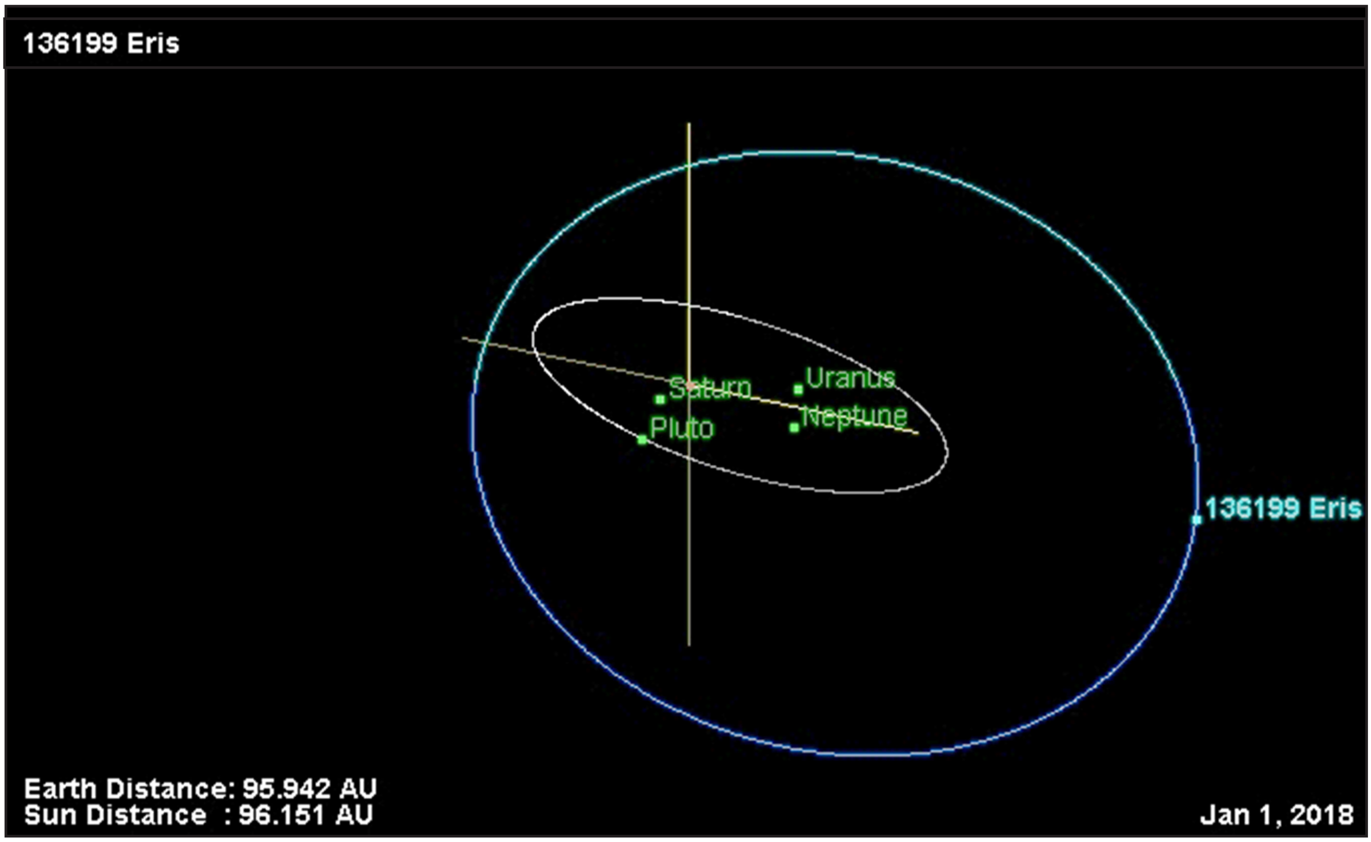

Fig. 2: The orbit of (136199) Eris. This dwarf planet is near its aphelion. Orbit diagram: JPL Small-Body Database.

The Name

In September 2006, 2003 UB_{303} got the number 136199. The discoverers suggest to name the object after Eris, the Greek goddess of discord and strife. The moon of the Eris was named after Dysnomia, the Greek goddess of lawlessness and daughter of Eris.

The Orbit

(136199) Eris has an unusual inclination for Kuiper objects of 44 ° and a high eccentricity of 0.44. (136199) Eris is currently around 96 AU from the Sun, so it is near the aphelion of 97.6 AU. The perihelion is 37.7 AU, closer to the Sun than Pluto in the aphelion. The orbital period is around 556 years.

The Size

After the first observations it seemed that Eris was taller than Pluto. First measurements were made in 2005 with the IRAM Radio Telescope at Pico del Veleta near Granada, Spain, determining the thermal radiation of Eris. It came to a mean albedo of 0.60 ± 0.11, which would correspond to a diameter of 3000km ± 320km (Bertoldi et al.) Also, the Hubble Space Telescope took images of Eris in 2005, which, however, reached its performance limits, since the disk of Eris is only 0.035". By deconvolution of the recordings, they determine the diameter and got a value of 2400km ± 100km (Brown et al.) After that, (136199) Eris was about the same size as (134340) Pluto. For years it was not sure how large the diameter of Eris really is.
First on November 6, 2010 there was a possibility to determine the diameter of Eris, because Eris covered a star. The occultation was visible in South America and recorded by three observatories (two occultations, one negative report). The size was determined on the basis of the observations on 2326 ± 12 km (Sicardy et al.). That means (136199) Eris is only a few kilometers smaller than (134340) Pluto.

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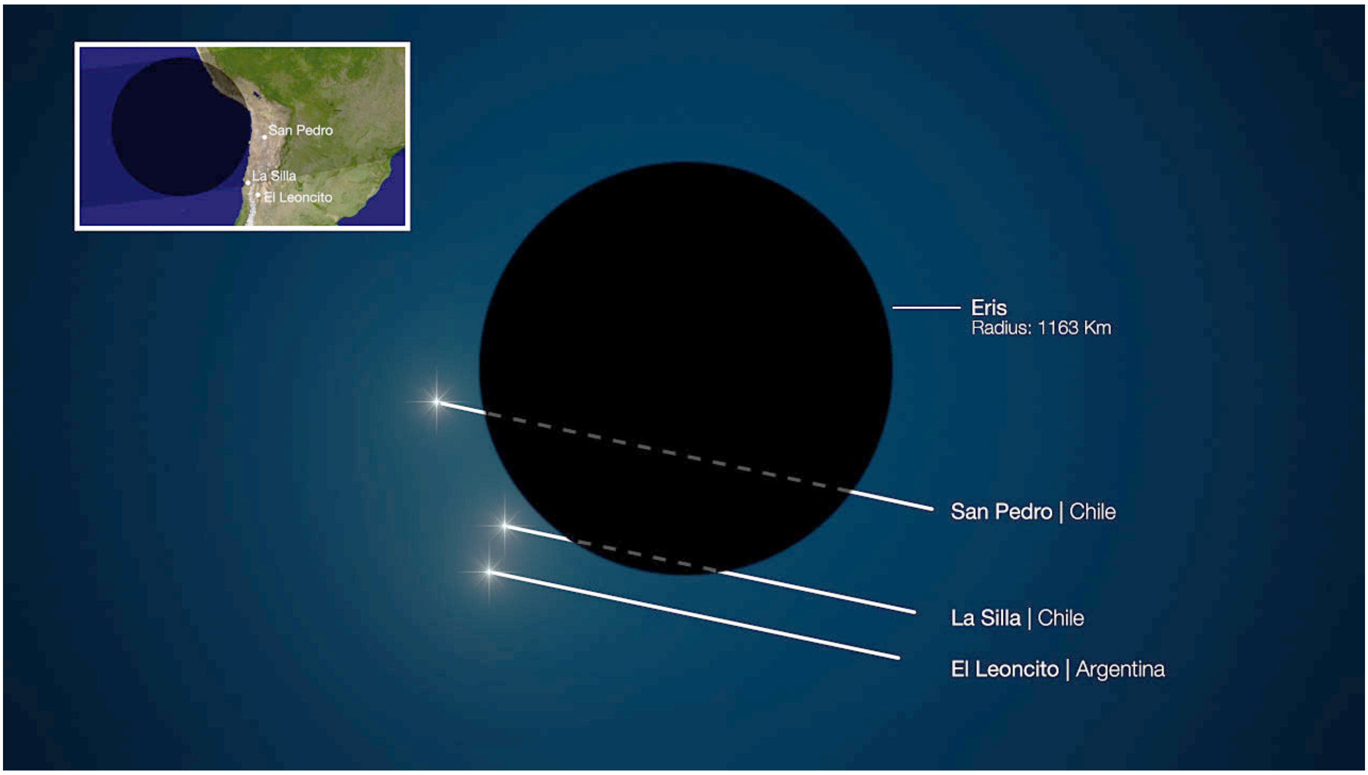
Brown, M.E., M.E., Schaller, E.L., Roe, H.G., Rabinowitz, D.L., Trujillo, C.A. (2006). Direct measurement of the size of 2003 UB313 from the Hubble Space Telescope. Astrophys.J. 643 (2006) L61-L64

Sicardy, B., Ortiz, J.L., Assafin, M., Jehin, E., Maury, A., Lellouch, E., et al. (2011). A Pluto-like radius and a high albedo for the dwarf planet Eris from an occultation. Nature 478, 493-496 (27 October 2011)



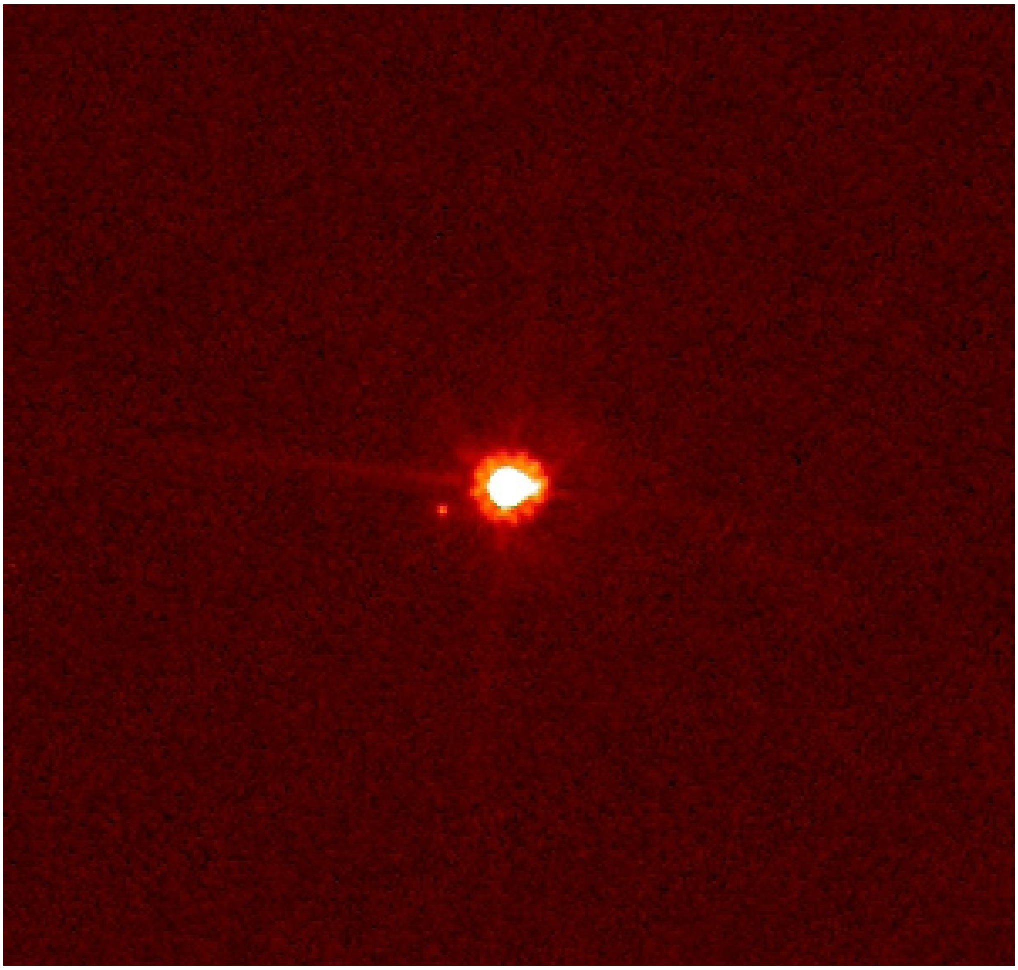


Fig. 3: On November 6, 2010, the dwarf planet Eris passed in front of a faint star, observable in South America. Picture: ESO / L. Calçada

Fig. 4: (136199) Eris and its moon Dysmonia taken with NASA's Hubble Space Telescope on Aug. 30, 2006. (NASA, ESA, and M. Brown (California Institute of Technology)

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.

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