Journal for Occultation Astronomy

Volume 7 · No. 3 2017-03

Credit: Voyager 2, NASA/JPL

CALL FOR OBSERVATION:

The Triton Stellar Occultation of October 5th

Using an Atmospheric Dispersion Corrector at Low Altitude Occultations

Dear reader,

With great sadness, we announce the passing of our president Hans-Joachim Bode after a stroke. This issue includes an obituary. Hans-Joachim founded the European Section of IOTA and very successfully lead the group for many years. He was also the publisher of the Journal for Occultation Astronomy (JOA). By now, we realise that JOA is a successful follower of the former Occultation Newsletter.

Hans-Joachim Bode also initiated the annual ESOP conference of IOTA/ES, held since 1982. ESOP III was the first time when ESOP went international, it was held in Valašské Meziříčí in former Czechoslovakia. The location of this ESOP 1984 was behind the iron curtain and initiated a web of connections all over Europe, crossing one of the strongest political borders ever seen. I first met Hans-Joachim Bode at this ESOP meeting and we quickly established a very friendly personal relationship. At this time, I myself lived opposite the border, in the former East-Germany (GDR). So, Hans-Joachim and I came to an unwritten rule as a gentlemen's agreement: for as long as the iron curtain divided Europe and thus prevented free travel for some of us, ESOP would be held on both sides of this division ñ alternating annually. IOTA/ES did so until the wall came down in Eastern Germany, ironically, the long planned ESOP in Eastern Germany had been held 5 weeks prior to the reunification of Germany. So while we held it in Eastern Germany, every invoice had to be paid in western money.

The division of Europe is history now, the world is ever-changing and we are now using observation and calculation techniques we would have never imagined back then. Over the years, many observers have joined us, others had to move on: Astronomy has been present for thousands of years now and is here to stay with us.

Following ESOP 36, an extraordinary general meeting was held at which a new IOTA/ES board was elected. See also "Offices and Officers of IOTA" at the end of this issue.

On behalf of the new board

Konrad Guhl

Konrad Guhl (President of IOTA/ES)

■ **JOA Volume 7 · No. 3 · 2017-3** $ 5.00 · $ 6.25 OTHER (ISSN 0737-6766)

In this issue:

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.

CALL FOR OBSERVATION:

The Triton Stellar Occultation of 5 October 2017

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

ABSTRACT: On 5 October 2017 Triton, the largest moon of Neptune, will occult a 12.7 V-mag star, visible from the US East coast, Northern Africa and Europe. After many years this will be the first opportunity to monitor Triton's current atmosphere state and possible changes. This paper, addressed to potential observers, summarizes the scientific objectives and provides observational information and hints in order to support the Triton occultation campaign 2017.

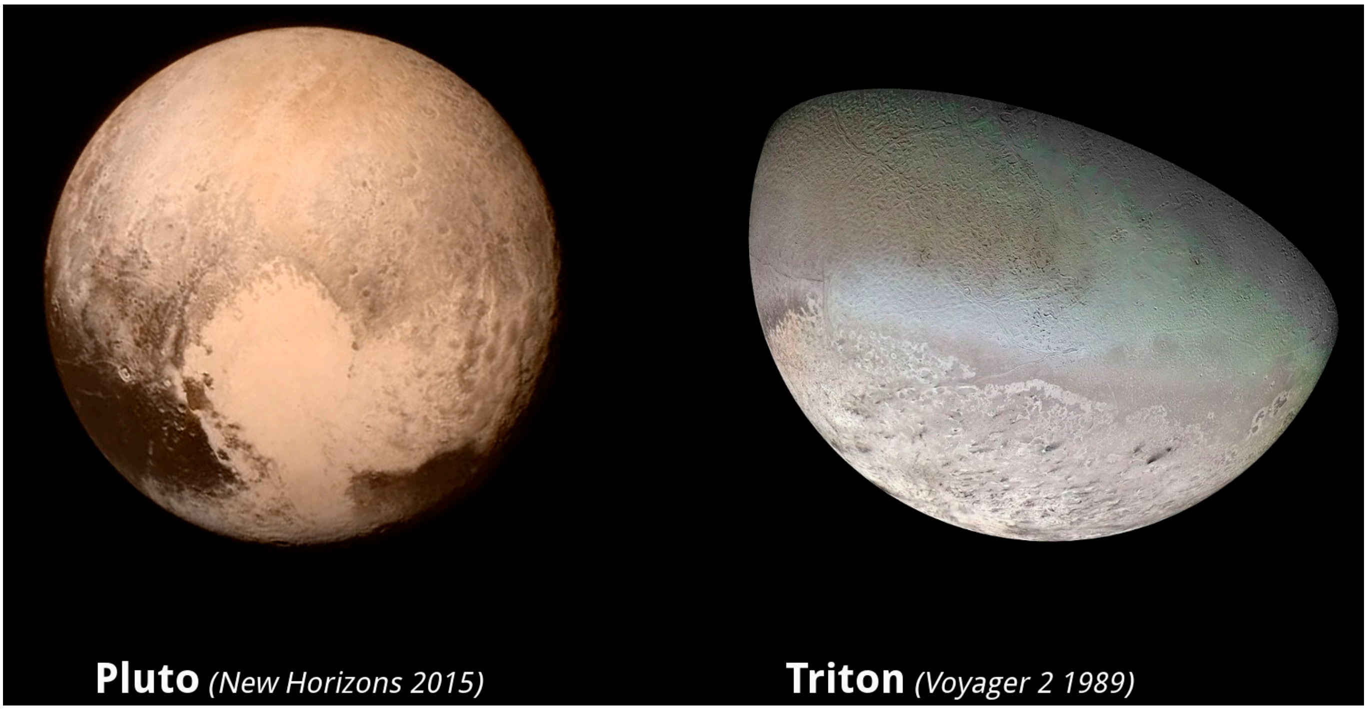

Figure 1: Scaled images of Pluto (diameter ~2370 km) and Triton (diameter ~2700 km), taken by the New Horizons and Voyager 2 spacecrafts. Credits: NASA / JPL.

Introduction

On 5 October 2017 Neptune's largest moon Triton will occult the 12.7 V-mag star UCAC4 410-143659, as seen from the US East coast, Northern Africa, and Europe. 20 years after the last successful monitoring of Triton's atmosphere using stellar occultations and almost 10 years since the last documented occultation (observed on 21 May 2008), this event will be a new opportunity to gather data about Triton's current atmosphere state and possible changes. Moreover the increase and improvement in amateur observing techniques and the fact, that the shadow will move across an area with a rather high "telescope density", gives hope for the best ever observed occultation of that interesting body.

About Triton

Triton was discovered on October 10th, 1846, by the English merchant and amateur astronomer William Lassel (1799-1880), just 17 days after the discovery of Neptune by the German astronomer Johann Gottfried Galle (1812-1910). Triton is named after the Greek sea god Triton, the son of Poseidon.

With a diameter of 2700 km, Triton is the largest natural satellite of Neptune, and the seventh-largest moon in our Solar System. Its mean bulk density is 2.061 g/cm^3. Triton orbits Neptune in a retrograde, almost perfect circular orbit with a sideral period of about 5.9 days in a mean

distance of only 14.3 Neptune radii. In contrast to the Earth-Moon system the tidal interactions with this retrograde motion of Triton will cause it to spiral inward in a long-term scale. As soon as Triton will be inside Neptune's Roche limit this will result in a collision with Neptune and/or a tidal breakup of Triton, forming a ring system similar to that around Saturn.
Because of its retrograde orbit and its size and composition similar to Pluto, Triton is believed to be a dwarf planet captured by Neptune's gravity from the Kuiper Belt (Figure 1).

Similar to Pluto, Triton has a tenuous nitrogen dominated atmosphere, driven by surface ices, primarily N_2, CH_4, CO and CO_2. The atmosphere extends up to about 900 km above the surface and the surface pressure was in the range 14-19 µbar at the time of the Voyager 2 flyby. From stellar occultations [1] we know that Pluto's atmosphere changed significantly due to seasonal effects (doubling of atmospheric pressure between 1988 and 2002). Pluto's orbit is much more elliptical than that of the other planets, and its rotational axis is tipped by a large angle relative to its orbit. Both circumstances in combination causes this effects.

As the heliocentric distance of the Neptune-Triton system doesn't change very much over a sideral period of about 165 yrs due to Neptune's nearly circular orbit, Triton seasons are caused by a combination of exceptional orbital plane and spin axis orientations and the influence of Triton's orbit precession period (~680 yrs). Tritons orbit inclination wrt Neptune's equator is 157° (an inclination over 90° means retrograde motion) while Neptune's axis is tilted by ~30° against its orbital plane. Thus Triton's spin axis tilt wrt Neptune's orbit can vary between 127° and 180° (current value is 130°), giving it extreme seasons. The superimposition of Neptune's 165 yrs orbit revolution period and Triton ~680 yrs orbit precession period results in a double sinusoidal waveform as the Sun (or the latitude of the sub-solar point) shifts alternately north and south with a varying amplitude (see Figure 2). Currently the southern hemisphere of the satellite is being illuminated by the Sun, after centuries of winter time. Every 650 years a hemisphere is facing an "extreme solstice", as it was the case in the year 2000 for the southern hemisphere, where the sub-solar latitude reached 50° south.

From occultation observations in 1997 Elliot et al. [2] derived a global warming on Triton and a significant increase of atmospheric pressure since the 1989 Voyager 2 flyby.

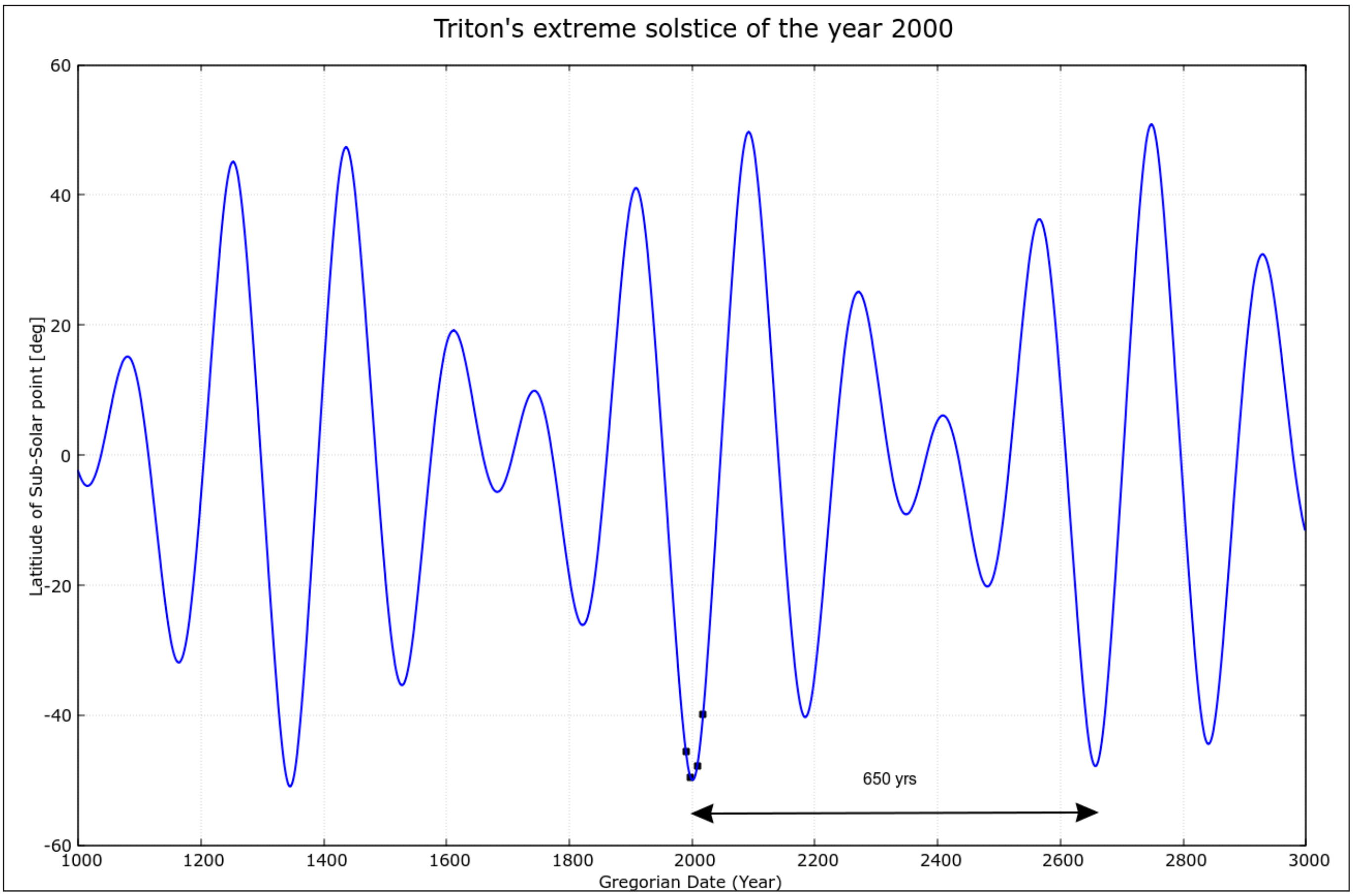

Figure 2: In the year 2000 Triton underwent an "extreme" solstice, where the sub-solar point reached 50 degrees South. This happens every about 650 yrs. Marked by a dot are following events (in time order): (1) The Voyager 2 flyby in August 1989, (2) the stellar occultations of 18 Jul 1997 and (3) 21 May 2008 and the upcoming stellar occultation of 5 Oct 2017 (4). Data computed with IMCCE's Miriade Service (http://vo.imcce.fr/webservices/miriade/).

It took further 10 years until another stellar occultation by Triton has been successfully recorded in May 2008 [3]. Unfortunately the geometry of the chords (two almost grazing chords at the southern limb) limited the derived astrometry and therefore, within a 3-sigma confidence level, no significant value of the atmospheric pressure (and possible changes since 1997) could be derived [4].

Scientific Objectives

The stellar occultation technique is a very powerful tool for probing and monitoring planetary atmospheres. Not only the atmospheric pressure can be measured. Through multi-wavelength observations haze layers can be detected and by observing the so-called central flash, wind regimes in the atmosphere can be analysed.

Key questions are:

- What is the current atmospheric state (pressure)?
- Are there any (drastic) changes since the 1990s?
- Are the haze layers seen by Voyager 2 in 1989 still present?
- Can wind regimes be constrained from central flash observations?

Prediction

Occultation predictions for this event are provided by several sources. For example by the ERC Lucky Star project group [5] and by the author on his website [6], see also Figure 3.

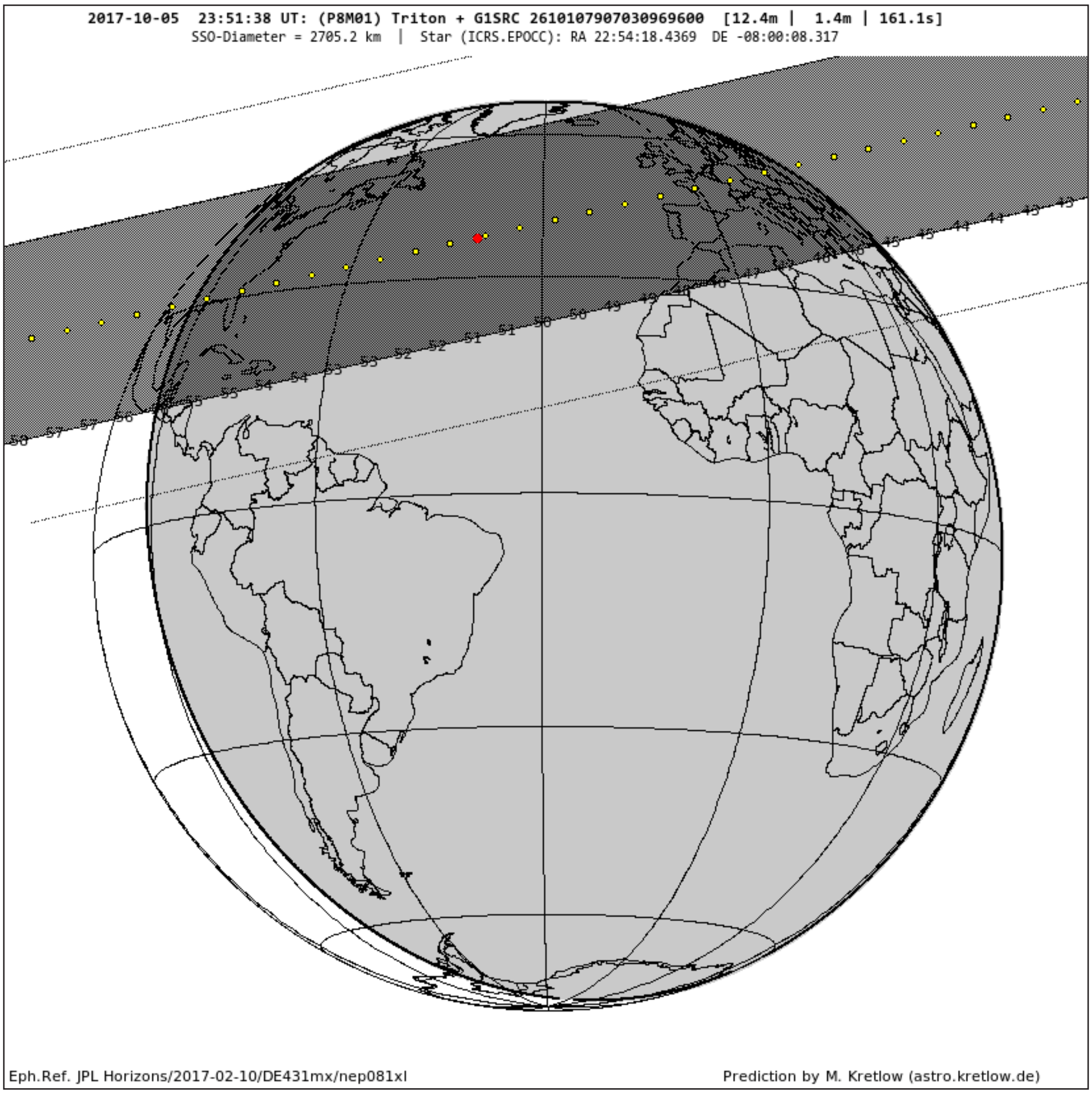

Figure 3: Prediction of the occultation by Triton on 2017 October 05 by the author using JPL's nep081xl+DE431mx ephemeris and Gaia's DR1 star position. The red dot marks the central occultation time (23:51:38 UT), the yellow dots corresponds to the time tics (seconds) on the southern shadow border.

Main Occultation Data and Circumstances

Date	Thursday October 5th, 2017 (night to Friday, 6th)
Observing time for Europe	23:48 UT +/- 10-15 minutes (suggested recording time)
Observing time for USA (East)	23:54 UT +/- 10-15 minutes (suggested recording time)
Star Position (Gaia DR2)	RA 22 54 18.4364 | Dec -08 00 08.318
Star Magnitude	12.7 V, 12.5 R, 12.4 I (from APASS), 11.4 J (from 2MASS)
Triton Magnitude	13.5 V, 12.9 R, 12.6 I, 12.2 J
Neptune Magnitude	7.8 V, 8.2 R, 8.9 I, 10.4 J
Magnitude Drop (central occ.)	~1.4 mag
Maximum duration	~161 sec
Shadow velocity	16.8 km/s
Geocentric distance	29.08 au
Moon: angular distance to star and sunlit	33.5° / 100%
Star identifier	GDR1 2610107907030969600 UCAC4 410-143659 2MASS 22541840-0800082 URAT1 410-421654

Observation Campaigns

IOTA-ES will again cooperate with the Lucky Star project group in Paris (PI: Bruno Sicardy) in order to achieve a successful pro-am observation campaign here in Europe. One of the main goals will be to catch the central flash. The path were the central flash will be visible is about 100 km wide. At the time of writing the cross-track uncertainty is about the same (100 km). Similar efforts are planned by IOTA to coordinate the observations in the US.

This and further information (like prediction updates) will be available from a variety of websites, like the author's webpage [6], IOTA (US) and IOTA-ES websites [7,8] and other individual web pages [9]. Announcements (especially predictions updates) will be also posted on mailing lists (IOTAoccultations, planoccult, etc.).

It is noteworthy that SOFIA (Stratospheric Observatory for Infrared Astronomy) is also scheduled to observe this occultation [10,11].

Some Observational Issues and Hints

1 The angular separation to the full Moon will be only 33.5° at the time of occultation and the Moon will be higher in the sky than Neptune. It might help to erect some kind of "moon shade" to prevent moonlight entering the telescope. Mobile telescopes could also be placed in the (Moon's) shadow of buildings, roofs etc. Figure 4 shows the altitude of the target star for different observing locations in Europe.

2 The angular separation between Neptune and Triton will be ~11 arcs at occultation time. Operating at long focal length might be useful for a better separation of the planet and the satellite. If Neptune is the only reference object on the image (due to a small FOV), then be careful that the planet will not be saturated / overexposed (see next item).

3 Neptune will be much brighter than the star (5 mag!) and probably be saturated on many low-dynamic cameras. In that case it cannot be used as a photometric reference object. On the other hand there aren't too many reference stars with comparable magnitude in the FOV (see Figures 5 & 6), especially if a large image scale is given. Therefore, cameras with a higher dynamic range (i.e. 12 Bit and 16 Bit) should be preferred if available.

4 Measure the target (occulted) star against the reference star(s) the night(s) before (or after) the event (when the star and Triton are clearly separated). This allows to calculate the contribution of the occulted star to the total flux (star + Triton) during the event, and finally, to subtract Triton's flux from the light curve.

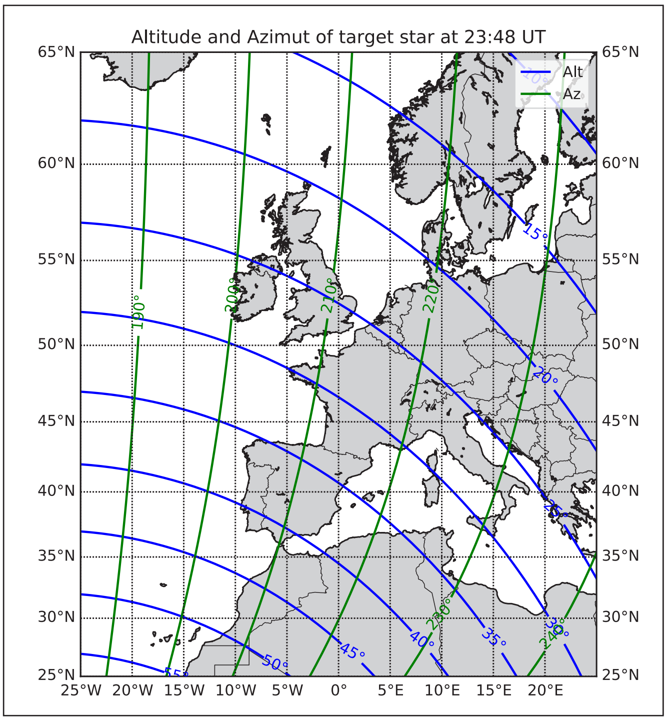

Figure 4: Altitude and Azimut (N = 0°, E = 90°) diagram for the target star at (European) occultation time.

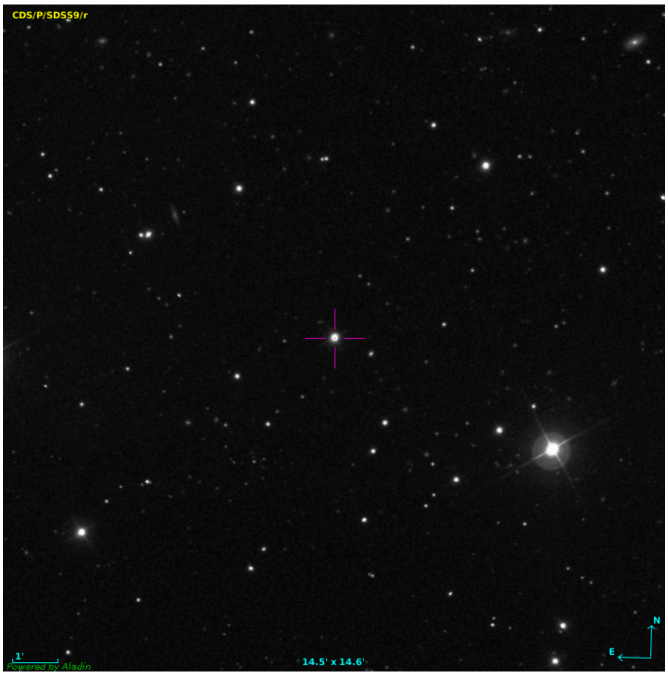

Figure 5: Sloan Digital Sky Survey (SDSS) red image of the target field, centred on the target star. FOV is 14.5' x 14.6'. Image created with the CDS Aladin sky atlas tool.

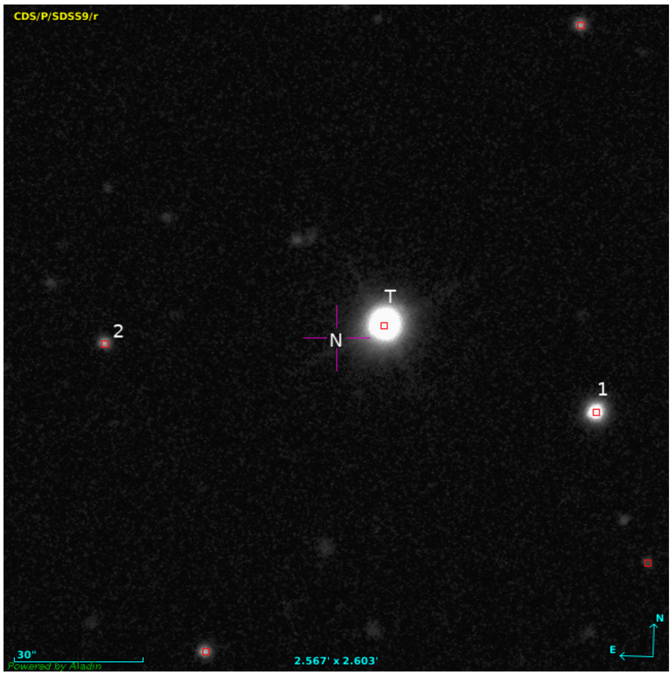

Figure 6: Sloan Digital Sky Survey (SDSS) red image of the target field. FOV is 2.6' x 2.6'.The image is centered on Neptune (N), the R=12.5 mag target star is the bright star marked with T. The red squares are Gaia DR1 star markers. In about 53" distance (PA = 248°) to the target star is a R=15.6 mag star '1' (UCAC4 410-143656). Star '2' is even fainter (R = 18.5 mag). Image created with the CDS Aladin sky atlas tool.

Acknowledgement

This work is based on an article by the author, published in the Journal of the British Astronomical Association, Vol. 127, No. 4, 194-195 (2017 August) [12]. The author is grateful for the permission to reuse the material more than 50 yrs.

References

[1] Sicardy, B. et al., Large changes in Pluto's atmosphere as revealed by recent stellar occultations, Nature 424, 168-170 (2003).

[2] Elliot, J.L. et al., Global warming on Triton. Nature 393, 765-767 (25 June 1998).

[3] Sicardy, B. et al., The Triton stellar occultation of 21 May 2008, EPSC 2008 abstracts (2008).

[4] Sicardy, Bruno, Personal communication (July 2017).

[5] http://lesia.obspm.fr/lucky-star/predictions

[6] http://astro.kretlow.de/?Solar-System---Occultations

[7] https://occultations.org/ and http://www.asteroidoccultation.com/observations/NA/

[8] http://www.iota-es.de

[9] http://www.stargazer.me.uk/call4obs/NextEvent.htm

[10] Person, M., A New Look at Triton's Atmosphere, SOFIA Proposal, Cycle 5, ID. 05_0125 (2016).

[11] https://eclipse2017.nasa.gov/content/sofia-triton-occultation-observations

[12] http://www.britastro.org/journal and www.britastro.org/digital

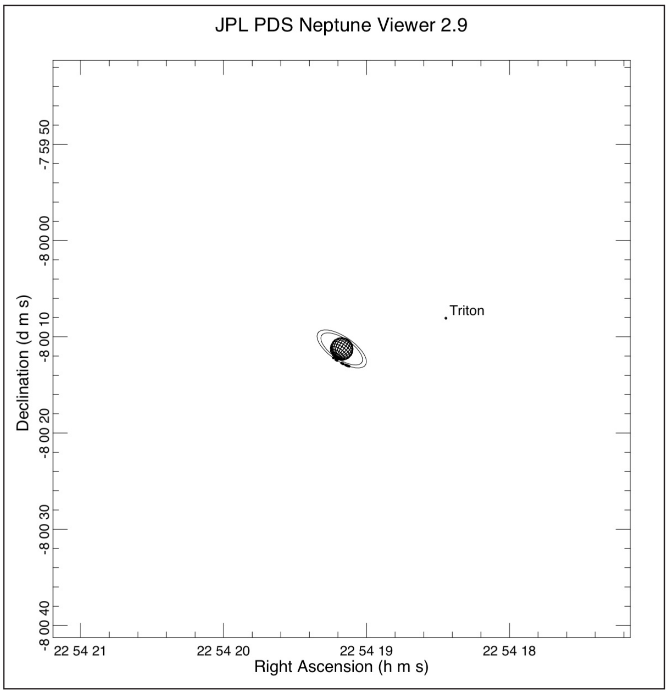

Figure 7: View on Neptune, its rings and Triton for the time of (European) central occultation (23:48 UT). The box has a dimension of 1x1 arc minutes. The angular distance between the center of Neptune and Triton will be 11.3". Figure created with the JPL PDS Neptune Viewer Tool.

Using an Atmospheric Dispersion Corrector at Low Altitude Occultations

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

ABSTRACT: ADCs (Atmospheric Dispersion Correctors) are very common for planetary imaging, especially with colour cameras. These optical tools can improve the sharpness of the images. But is it useful to use these for occultation work with video cameras? A practical test at low altitude stars gives answers.

Fig. 1: The ZWO ADC has an 1 1/4" eyepiece holder with two screws (only one is visible at image) and a male T2 thread. Inside the holder is a ring to lock the camera or eyepiece. At the telescope side there is a 1 1/4" nosepiece. T2 female threads at both sides of the main body are available too. According to the manufacturer's manual the prisms are made of BK-7 glass and the surface accuracy is λ/10 at 632.8 nm. The positions of the levers can be locked by turning them. Small rubber rings give a soft stop at the lock position.

Atmospheric Dispersion

The light of an astronomical object suffers from refraction effects as it passes through the atmosphere. The optical media "air" refracts the light depending on the wavelengths. Short wavelengths are refracted more than longer wavelengths.

The dispersion of the light is increasing with the decrease of the altitude of the observed object. An observer sees the red and blue fringes at the edges of the object easily because the image is separated in different colours and therefore slightly shifted. It's a little bit annoying at visual observation but it's even worse at imaging. It affects the sharpness of high resolution images.

The ADC – How Does It Work?

There are two adjustable prisms inside the ADC, which can be rotated against each other with two levers from outside the tool. With these levers a correction is possible for the amount of dispersion at different altitudes of the object. Both levers on the same position (the zero position) give no correction at all. Opening the levers in opposite directions will increase the amount of correction. An observer has to find the adequate lever position depending on the altitude of the object and the optical properties of his setup.

Fig. 2: The small white screw marks the zero scale position.
The levers are moved in opposite directions.

ADCs are available from several manufactures with price tags from 150 to several 1000 Euro. They vary in diameter, used sort of glass for the prisms, optical accuracy and construction quality. You should consult the descriptions of the manufacturers and the tests available at the web before making the decision to buy one.
The most affordable ADC currently is constructed by ZWO. This ADC was used for the test (Fig. 1, 2).

Using an ADC for Occultations?

Everybody who has recorded low altitude occultations has seen elongated stars at the video image. The point source of the star is not affected by seeing only but by the dispersion too. That's noticeable at very bright stars very easily. So the light of the star is spread on more pixels of the sensor as it would be without dispersion. But seeing spreads the light too. So does an ADC has an positive effect at all at occultation work? Can we reduce the exposure time and/or gain to get a better time resolution?

The Setup of the Test

The ADC was mounted at my 10" LX200 Classic (f/10) at prime focus. (Fig. 3) No additional optical elements (e.g. Barlow, telecompressor or filter) were used. A Watec-910HX/RC recorded the video stream of the test star for about two minutes with VirtualDub. Separate video files were recorded with the levers on different scale positions. The image was refocused every time after a change of the position of the levers. Recording sessions, which had very bad seeing over longer period of time, were terminated and recorded again. I started with a first test using the frame integration of the Watec.

Integrated Recording

I made at test recording of global cluster M4 at 13 deg altitude with an integration of x64 (32 frames) and gain +41db. Seeing was quite good for such a low altitude, but as I moved the levers from position to position I could not find any great enhancement of the star images. Stars were slightly more often circular at the video file. A large amount of ADC's correction is superimposed by the seeing and unguided tracking at long exposures.

Recording at Full Frame Rate

All occultation observers want a good time resolution of their measurements; short exposure times are preferred at occultation recordings.
To reduce the effects of tracking and seeing, I choose the exposure time of 50 fields per second for the following tests.

First I made a recording of the test star without the ADC. The star was clearly elongated at altitudes lower than 10 deg. Then I added the ADC with the levers set on position zero into the light path and refocused the image. Then I started to move the levers according to the scale marks at the ring of the ADC one step forward for every recoding file. Every time the image was refocused carefully and recentered before the recording. The test continued until the star image quality degraded and showed over correction.
The videos were analysed with Tangra 3 by Hristo Pavlov with a fixed aperture radius for every star test [1]. The light curve data of intensity and FWHM was exported to CSV (Comma seperated values).

Test Results

rho Cap (4.9 mag) at 17 deg altitude 1/50 fps, gain +13 db, aperture radius 7.5 px			
No. of frames	PSF (average)	FWHM (aver.)	Scale Pos.
2984	15.02	5.31	no ADC
2983	15.28	5.30	0
2983	15.13	4.71	1
2985	14.97	4.61	2
2975	14.88	5.25	3
3021	15.36	5.29	4
2987	15.06	6.15	5
TYC 6354-00503-1 (10.5 mag) at 15 deg altitude 1/50 fps, gain +41 db, aperture radius 5.3 px			
No. of frames	PSF (average)	FWHM (aver.)	Scale Pos.
2999	14.02	4.17	no ADC
2997	13.81	4.30	0
2985	13.86	3.92	1
2987	13.94	3.84	2
2997	13.87	4.47	3
2999	13.82	4.22	4

TYC 6977-01266-1 (5.5 mag) at 9 deg 1/50 fps, gain +23 db, aperture radius 8.05 px			
No. of frames	PSF (average)	FWHM (aver.)	Scale Pos.
2979	13.27	7.42	no ADC
3007	13.76	7.27	0
2984	14.49	6.34	1
2982	14.63	5.84	2
2984	14.31	6.29	3
2983	14.73	5.52	4
2988	14.68	5.56	5
2984	14.01	6.50	6
TYC 6979-00885-1 (7.1 mag) at 8 deg, 1/50 fps, gain +28 db, aperture radius 6.61 px			
No. of frames	PFS (average)	FWHM (aver.)	Scale Pos.
2972	13.08	6.26	no ADC
2979	12.96	6.60	0
2980	13.04	6.32	1
2986	13.04	6.19	2
3001	13.35	5.34	3
2982	13.35	5.28	4
2988	13.01	6.13	5
2975	13.01	6.15	6

Defocusing the Image

I made a test to find the lever position more easily by defocus the image. I watched out for a deformation of the star disk out of focus. But the seeing is deforming the disk very fast all the time. Only very large offsets from the correct position were easily apparent.

Evaluation of the Tests

I was surprised to find an even degraded star image quality on the video recording at lever position zero (no correction) compared with the videos without the ADC. The average PSF height of the signal was slightly reduced and the star disk spread even more on a wider area at the sensor. This may be caused by loss of light due to the additional optical elements with four optical surfaces (2 prisms) inside the light path and imperfections in the position to each other of the prisms of this reasonably priced ADC.

The average PSF height of the star varied with small amounts while moving through the lever positions. The average value of FWHM, which can be used to evaluate the "sharpness" of the star image, indicated an enhancement at the correct lever position (Fig. 4). The effect of the ADC is stronger at well exposed stars than at fainter ones just barely

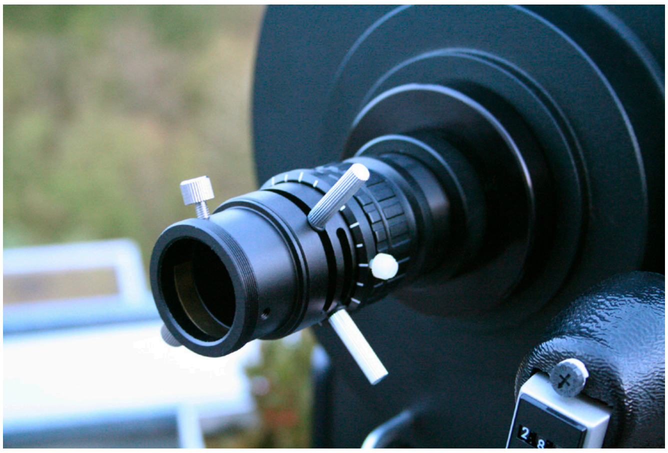

Fig. 3: The ZWO ADC attached to my 10" LX200 Classic with levers at scale position 3. The axis of the zero position has to be parallel to the horizon. Levers should be set at the same, opposite scale positions.

visible. The lower the altitude, the greater enhancement with the ADC was apparent.
A scale position of 1 to 2 for stars with altitudes lower than 15 deg and a scale position of 2 to 3 for stars lower than 10 deg were the best settings for my telescope and camera setup. A degraded star image by over correction will be visible while moving the levers beyond the idle position for a given altitude.

Conclusion

To get the correct lever position was not easy. You have found the correct position for the levers if the star appears circular and brightest at the video image. Seeing affected the test results and therefore errors in measurements could be observed. The test with star TYC 6977-01266-1 indicates a drop in the quality of PSF and FWHM near the expected best lever position. A visual check of the video file indicates that this was caused by a large number of frames with bad seeing. In real life we don't have laboratory conditions either. But the tests indicated a trend of enhancement by the ADC.

Defocus the image doesn't help to find the correct lever position.

Because the ADC degrades the star image at lever position zero, the tool should be removed every time from the telescope setup when not used!

Be aware that tuning the ADC will take some time. Take this into account at your preparations. But it is not necessary to do this very close to the expected time of occultation. You don't have to fine tune the lever positions for every degree altitude more or less. The seeing makes any fine tuning impossible anyway. But refocusing and recenter the star is essential every time after the lever positions were changed!

A table for lever positions in relation to the altitude of the star above the horizon can't be given. The lever positions are depending not at

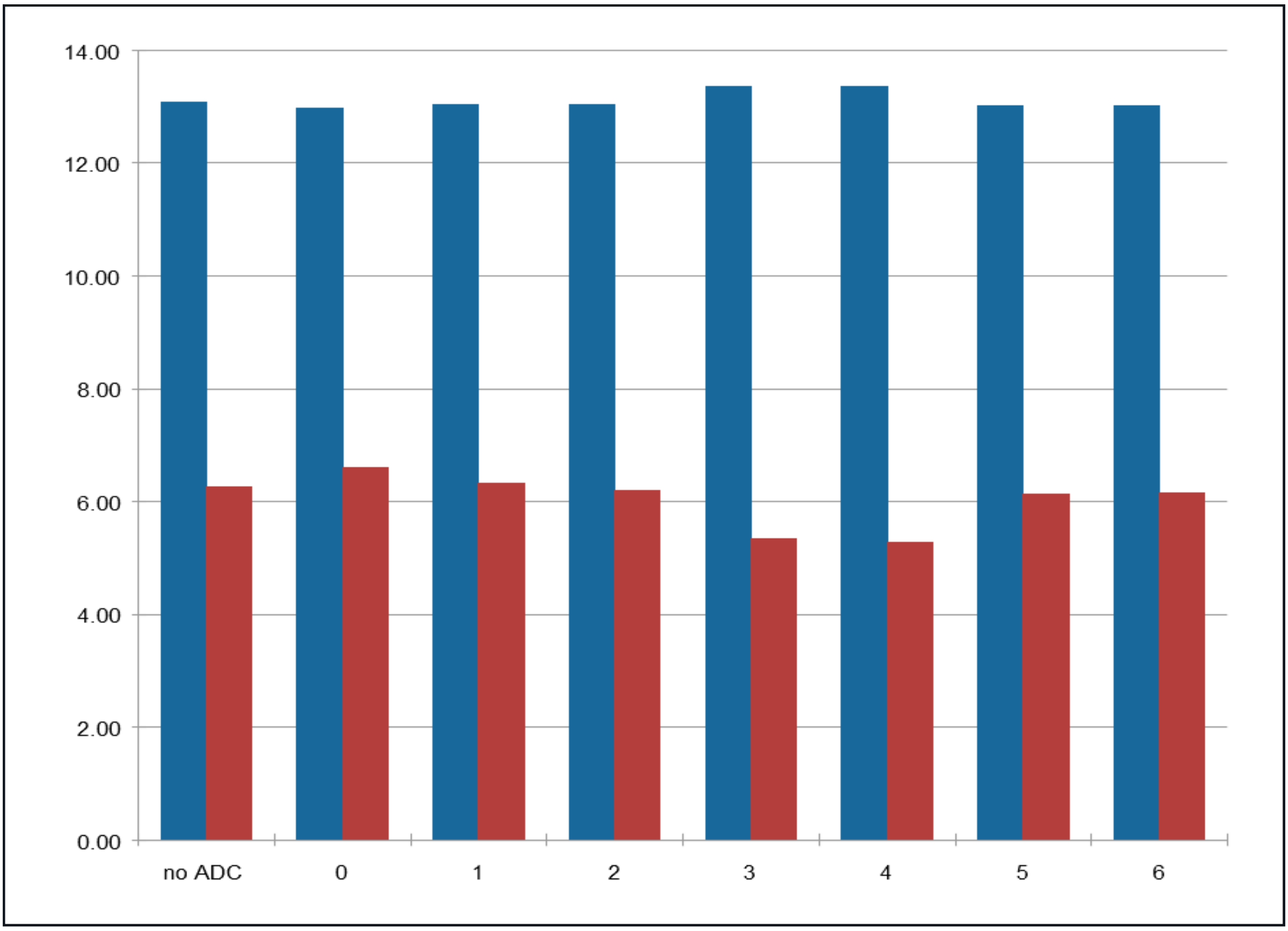

Fig. 4: This test result shows the benefit of an ADC very well. Star TYC 6979-00885-1 (7.1 mag) was recorded at 8 deg and 1/50 fps. While the PFS (blue) increases (stronger signal) at the correct lever position, the FWHM (red) decreases (sharper image). The correct lever position should be here around scale position 3 and 4.

the targets altitude only, but on the used optical setup too. I want to recommend Martin Lewis' web page about this topic [2].

An ADC is useful with telescopes of long focal length. With a short focal length, the light is spread at a smaller number of pixels and the benefit of an ADC is not so effective. The ADC works best with short exposure times with no integration, because the seeing smears the star image too.

This makes this optical tool useful at occultations of low altitude (<15 deg) stars, which will be recorded at high frame rates. But these occultations are rare.

Using an ADC may not give you a shorter exposure time but in some cases you can set the gain down about a small value, which may improve the S/N ratio of your recorded measurement. So you can't expect any miracles from an ADC.

I would not recommend buying an ADC for occultation work only. But if you have one already or you plan to buy one for planetary work, use it at low altitude occultations.

Acknowledgement

A lecture about first tests of using an ADC at low altitude stars was given in August 2016 at ESOP 35, Guildford, U.K. I could improve my test with the suggestions by the participants. I want to thank them for the very fruitful discussion.

References

[1] Pavlov, Hristo: Tangra 3
http://www.hristopavlov.net/Tangra3/

[2] This excellent web page by Martin Lewis give an overview of the ADCs available, how an ADC works and the influences of different setups and much more:
http://www.skyinspector.co.uk/atm-dispersion-corrector--adc

(113) Amalthea And Its Satellite S/2017 (113)1

When A Miss Is The Most Important Observation

Dave Herald · IOTA · Murrumbateman, Australia · drherald@bigpond.net.au
Tony George · IOTA · Scottsdale, AZ, USA · triastro@oregontrail.net
Brad Timerson · IOTA · Newark, NY, USA · btimerson@rochester.rr.com
Paul D. Maley · IOTA · Carefree, AZ, USA · pdmaley@yahoo.com

ABSTRACT: On 2017 March 14 an occultation by the asteroid (113) Amalthea was observed from 11 locations in Arizona, Texas and California, USA. Seven positive occultation chords were observed. Several miss chords were observed. One miss chord appeared between two of the positive chords and the other five chords. The conclusion arrived at after a great deal of analysis by IOTA members and professional astronomers was that a satellite of Amalthea was detected. This article documents the key points that led to the conclusion of a satellite and some of the lessons learned by the analysis process.

On 2017 March 14 an occultation by the asteroid (113) Amalthea was observed from 11 locations in Arizona, Texas and California, USA. The event was predicted to last a maximum of 4.8 seconds with a predicted magnitude drop of 3.0. The maximum duration occultation observed was 4.6 seconds. The shortest duration observed was 0.43 seconds.

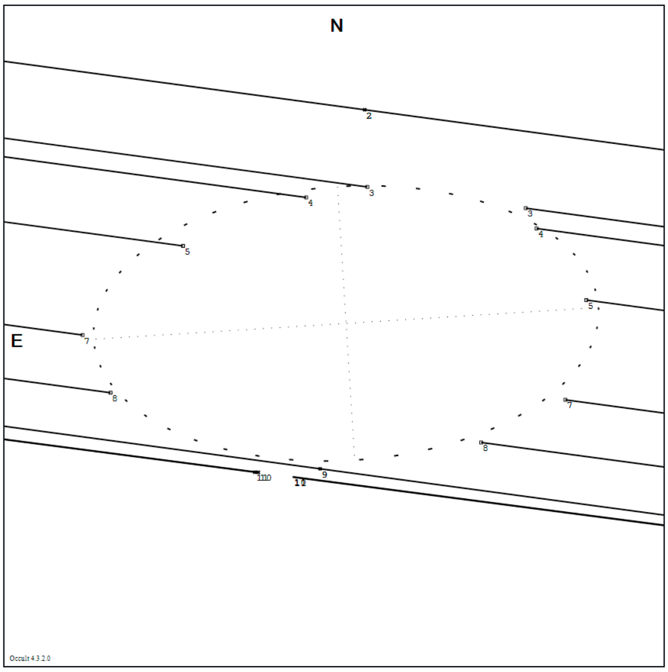

Fig 1. Plot of the observed chords for the Amalthea event showing the probable discovery of a satellite. The bottom-most chord is in fact two chords, chords 10 and 11, from independent observers located about 40 km apart in the along-track direction.

Figure 1 is a plot of the observed chords made by Timerson. The cause for much excitement was chord 9 – which reported a miss event. That chord is located south of five chords which recorded an occultation, and north of two chords (which are almost co-located) which also recorded an occultation. To add to the intrigue, if the miss chord was treated as erroneous, an ellipse can be reasonably fitted to chords 3 to 8, and chords 10 and 11. Conversely an ellipse can also reasonably be fitted to chords 3 to 8 with chord 9 being treated as a miss event. What is the explanation for this?

The explanation is that chords 10 and 11 recorded an occultation by a previously unknown satellite of Amalthea. However, much work had to be done to verify the observations and exclude a range of possible explanations. The occultation resulted in the first apparent "confirmation" by means of the occultation technique of a new natural satellite of a minor planet by amateur astronomers since concerted efforts began in 1977. This potential new satellite, S/2017 (113) 1, has been announced in the Central Bureau Electronic Telegram (CBET) 4413. In this article, we go through the considerations explored and lessons learned in this interesting observation.

Was chord 9 truly a miss observation?

The observation involved a static camera with the star drifting across the field. There were three important considerations:

1 Was the camera pointed at the correct field, with the star being correctly identified? While not common these days, it can still happen that an observer is monitoring the wrong field and star. And if that is the case, the absence of an occultation is to be fully expected.

For the miss observation in this event to be reliable, there has to be no doubt that the correct star was being monitored. Verifying that the star was the correct star is almost impossible if there are only one or two stars visible in the field. Fortunately, in this case there were many stars visible in the field; those stars could be matched to star charts, and to other video recordings of the event where an occultation was recorded. This enabled full confidence that the correct star was recorded.

2 Was the recording made over the right time interval? The recording was made using a KIWI-OSD (On Screen Display) video time inserter. The time stamps matched the required times – which gave initial confidence. However, it was noted that the last time the KIWI had been used was some six months previous. It also became apparent that the observer had not followed the KIWI instructions of doing a reset after 12 minutes of operation. That instruction exists to ensure the KIWI is using the latest UTC-GPS time offset. Unfortunately (and depending upon the time interval from last use, and the type of GPS antenna being used), a failure to undertake this reset could result in the displayed time from the KIWI being in error by up to 17 secs. Fortunately, the video recording showed the target star throughout the entire relevant period – irrespective of whether the KIWI time was correct, or had a 17-second offset. This enabled full confidence that the video recording covered the full period of when an occultation should have occurred.

3 Did the recording reliably show the absence of an occultation? In this case the subject star drifted across the image. The star registered an average 473 analog-to-digital units with a 2.87 signal-to-noise ratio for a 4.18 magnitude drop. This type of light curve is suitable for determining if a 3.1 predicted magnitude drop occurred. The image was independently measured by several people using Limovie[1], Tangra[2] and visual inspection. The video showed a somewhat faint but stable star image. Using multiple methods of analysis, no 'clear' event was found in the light curve. Analysis with R-OTE[3] indicated that there were short duration (1-2 frame) events present in the light curve with magnitude drops (4.1 magnitude) that were consistent with the predicted event. When the light curve was analyzed for false positives with R-OTE, it was found that the 1-2 frame short duration events were likely caused by noise in the light curve, with similar events found randomly in Monte Carlo simulations 17.7% of the time. Further analysis with Occular was performed to determine whether a short event of 4-frames and 3.1 magnitude drop 'should' have been detectable in the light curve. The event detectability analysis in Occular[4] indicated that an event of 4-frames or longer could be detected in the light curve with 70% confidence. Since a 4-frame event of the proper magnitude drop was not found in the light curve, and 1-2 frame events found were likely due to random noise in the light curve, it was concluded that the light curve showed a miss.

1 Light Measurement Tool for Occultation Observation using Movie Recorded (Kazuhisa Miyashita, Japan).
2 Tangra 3 - software package for astronomical video data reduction (Hristo Pavlov, Australia).
3 R-code Occultation Timing Extractor (Bob Anderson, USA).
4 Occultation Limovie Analysis Routine (Bob Anderson, USA).
5 Network Time Protocol, an Internet protocol used to synchronize the clocks of computers
6 Computer Aided Astronomy (Philippe Deverchère, France).
7 Occult v4. Occultation Prediction Software (Dave Herald, Australia).
8 This research has made use of the VizieR catalogue access tool, CDS, Strasbourg, France. A&AS 143, 23.

Was chord 9 actually located between chord 8, and chords 10 and 11?

The critical issue is the relative locations of 9 with 10 and 11:

1 Chord 10 was obtained using a 20 cm telescope. Google Earth indicated the site was in a suburban backyard. A previous successful asteroidal occultation observation from that site was fully consistent with the 22 successful chords in that event. This is clear evidence the coordinates of that site were correct.

2 Chord 11 was obtained using a 60 cm telescope. Google Earth shows the site coordinates coincident with an observatory. This is clear evidence the coordinates of that site were correct.

3 An additional matter for concern was that while chords 10 and 11 were effectively coincident, there was a time difference of about 0.4 secs in the event times. However, the time base used at Chord 10 was extracted from NTP[5]. This 0.4 sec time difference is fully consistent with the problems of extracting accurate time using NTP due to delays caused by interrupts in computer operating systems.

4 Chord 9 was more challenging. The site was at a gate along a straight road through a desert environment. The observer was given explicit instructions by the event organizer, of where to locate this gate – with the organizer being adamant about the gate's location. However, the observer did not use the KIWI-OSD to measure/record the GPS site coordinates of the site. Hence the question arose – was the observer actually at that site? Fortunately, Google Street View was available for the road. This showed the gate in question. It also indicated there was a similar gate many kilometers further south – and if the observer was located at that other gate they would have been south of chords 10 and 11.

To address this, the observer went back to the observing site to verify the site location (which was a several 100 km return trip). Photographs were taken of the site location – and those photographs matched up perfectly with the Street View images of the intended observing site, and did not match the Street View images of the other gate. No GPS measurements were taken, but the site verification was confirmed by Maley from the photographs and his return visit.

This highlights the importance of mobile observers measuring the site coordinates of their site(s) at the time when their equipment is set up. When there is an 'interesting' observation, there should not be any room for debate about the location of the observer. We need to base site location on the measurement of actual location, not assertion about where the observer thought the site was located. In this case the nature of the road (long and straight in a desert environment) together with a general absence of the relevant distinguishing feature (a gate) combined with a re-enactment that provided photos that could be matched to the Street View imagery, provided a basis for confidence in the site location. But this approach should be treated as the exception – a hugely undesirable exception. The norm must be for mobile observers to take a GPS measurement of their site coordinates at a time when they are setting up or packing up their site.

Was a double star involved?

The original videos containing the continuous video recordings were analyzed by George. A drop in brightness of 3.1 +/- 0.1 magnitudes, close to that expected, was seen in all of the positive chords except one; the Chord 11 of Campbell showed a smaller drop of 1.6 mag, which was considered spurious and caused by a non-standard MP4 video compression used in the recording. However, to be sure that the different magnitude drop of Chord 11 was not due to a double star, additional analysis was performed. All the light curves were carefully reviewed. No double dips or stepped dips, characteristic of a double star, were seen in any of the light curves. The possibility of an occultation of a double star with components of the same magnitude – with one star resulting in the northern chords, and the other star resulting in the (separated) southern two chords – was examined; in this scenario, all chords would have a brightness drop of only half (0.7 mag) that predicted. George used field stars to estimate the observation-time brightness of the target star, which was found to be within 0.25 mag of the catalogued magnitude. Maximum excursion of the asteroid's rotational light curve is about 0.26 mag. It is estimated that uncertainties in star brightness/color, camera spectral responses, and rotational variation of the minor planet's brightness could combine to add a systematic uncertainty in the measured brightness drop of about 0.6 mag. Thus, the double-star hypothesis cannot be definitively ruled out, but this was thought to be unlikely. No other known solar-system object was within 100" of (113) at the time of the event based on a plot of all numbered asteroids on the C2A[6] planetarium program down to 2 kilometers in size.

The question of whether a star might be a double star led Herald to develop an additional functionality in Occult[7] to identify the existence of any previous occultations of the target star – whether that be an asteroidal or lunar occultation. Using this new functionality, in the case of asteroidal occultations, it was found there are seven stars (out of 3,300 occultation events) which have been occulted more than once. Incredibly, the star for the Amalthea event was also occulted by (27) Euterpe on 2015 Dec 13 – with four observers in Europe recording an occultation. George analyzed the light curves of these four observations, and no such evidence of a double star was seen in that event. None of those observers reported anything indicative of a double star. One of those observation light curves is available in Occult, and VizieR[8]. That light curve is fully consistent with a single star. While the star is included in the lunar occultation star catalogue (XZ87413), there are no recorded lunar occultations of that star.

Having gone through these considerations, the following could confidently be asserted:

1. Chords 3 to 8 observed an occultation by a body.
2. Chords 10 and 11 observed an occultation by a body.
3. Analysis of the various chord light curves indicated the target star was not a double star and that Chords 10 and 11 observed the occultation of the same star as Chords 3 to 8.
4. Chord 9, located between these two groups of chords, did not observe an occultation.
5. Accordingly, the body of chords 10 and 11 must be different to the body of chords 3 to 8.
6. Given the spatial proximity if the two bodies (a projected separation of less than 4mas), it is logical to conclude that one is a satellite of the other. This has now been formally recognized, with the satellite having the designation S/2017 (113) 1. The satellite is shown as a separate body in Figure 2.

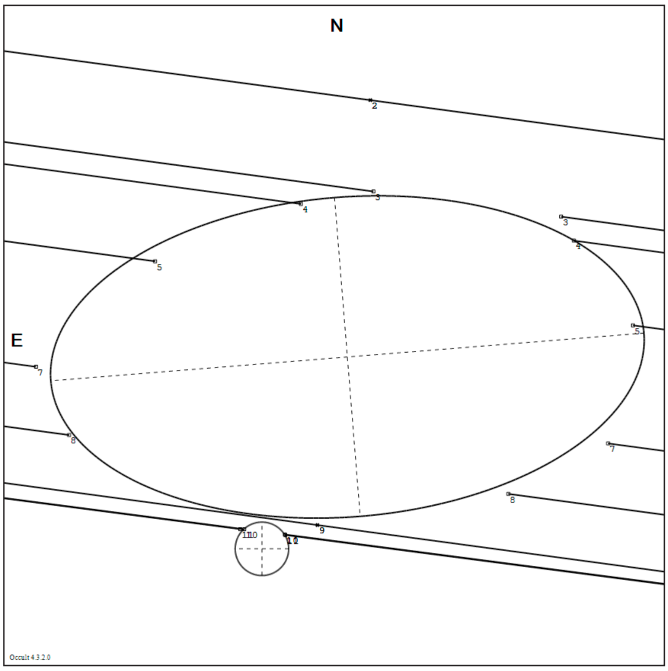

Fig 2. Plot of the observed chords for Amalthea and satellite, with the approximate outline of both bodies shown.

Prior to any public announcement of this result, contact was made with William Merline (Southwest Research Institute) and other professional astronomers involved with adaptive optics imaging – to ascertain whether there were any past images of Amalthea available that might be of use. Also, to explore the possibility of imaging the asteroid in the future, formal confirmation of S/2017 (113) 1 existence by direct ground-based adaptive optics imaging has been proposed to the professional community. Merline also provide guidance in the preparation of the announcement to be submitted to the IAU Central Bureau for Astronomical Telegrams. A special thank you is given to those professional astronomers who assisted the amateur astronomy community in this discovery.

Conclusion

Most observers hope for an actual occultation when they observe an asteroidal occultation – and treat a miss event as a disappointment. In this case, a miss event turned out to be the most important event of all. By recording a miss, the observer unwittingly established that the asteroid has a moon.

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 September 2017, the Minor Planet Center listed 719 Centaurs and 1816 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).

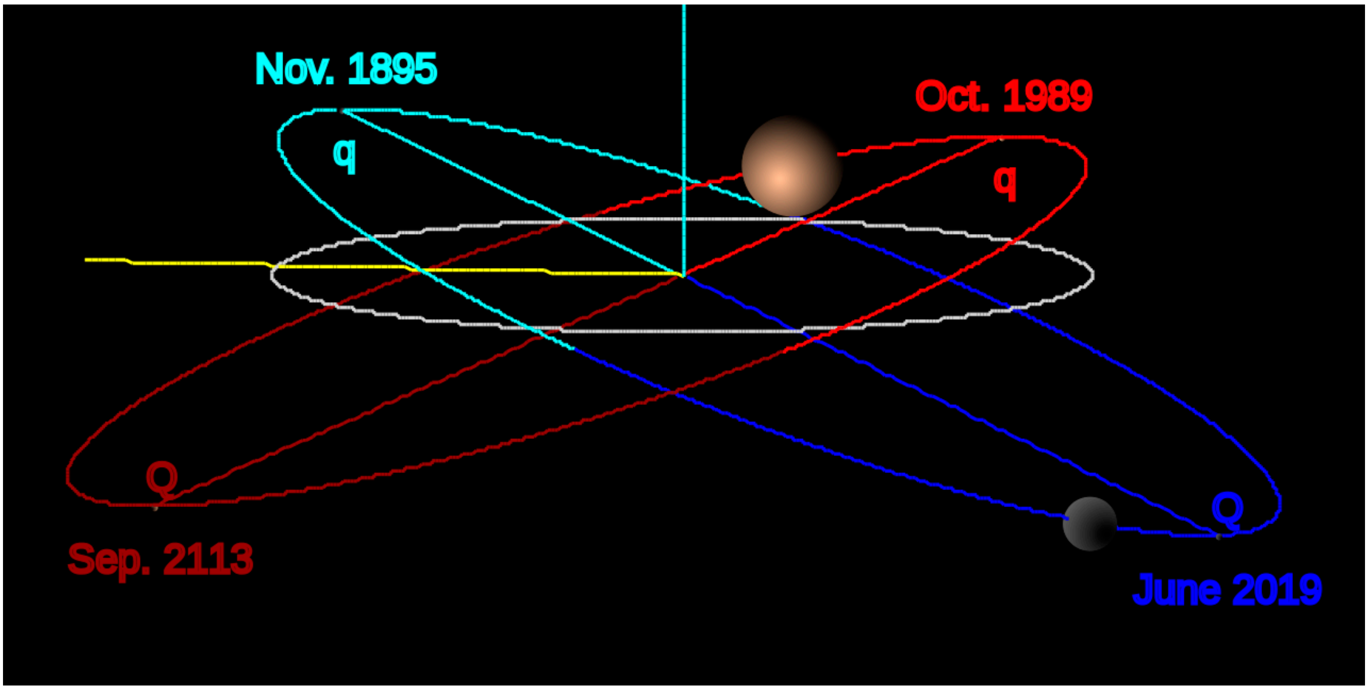

Fig 1. Orbit of Orcus (blue), Pluto (red) and Neptune (grey).

Discovery

The object was found February 17th, 2004, by Michael Brown of Caltech, Chad Trujillo of the Gemini Observatory, and David Rabinowitz of Yale University and got the provisional designation 2004 DW [1]. Precovery images were found on 1951 POSS plates in the "Digitized Sky Survey" (DSS), allowing to extend the astrometric observational arc for more then 50 yrs.

The class and the name

The TNO group "Plutinos" are a family named after Pluto with similar orbits as Pluto. Currently, we know 8 members of this special group of TNOs. Orcus is one of them and is also a "hot" candidate for a dwarf planet. In Roman mythology, Orcus is the name of the realm of the dead and not directly the name of a deity. The deity assigned to this realm is Pluto. To some Roman authors, Orcus was the name of the Etruscan counterpart of the bRoman deity Pluto. The duplicity of Pluto and Orcus as deities is reflected in the conformity of Orcus' and Pluto's orbit. The moon Vanth (found in 2005) was named after a winged female demon of the Etruscans who guides the souls of the dead to the underworld.

The Orbit

(90482) Orcus circles the Sun every about 247 yrs in an elliptical orbit with an aphelion distance of Q = 48.1 AU and perihelion distance of q = 30.8 AU. The corresponding values for Pluto are Q = 49.4 AU and q = 29.7 AU – very similar (see Fig. 1). Currently, Orcus is 48 AU away from the Sun and will reach aphelion in 2019.

What we know

From submillimeter infrared observations with the Spitzer Space Telecope and the Herschel Space Telescopes a diameter of D = 958.5 +/- 22.9 km was derived. After the discovery of a satellite in 2005 on Hubble Space Telescope images these values were refined to D = 917 +/- 25 km for Orcus and D = 276 +/- 25 km for Vanth. Spectroscopic observations in 2004 showed water absorption bands at 1.5 and 2.0 µm in the near infrared and from additional infrared observations by ESO and the Gemini telescope water ice and carbonaceous compounds at the surface were suggested.

Occultation observation

On 2014 March 01 an occultation of the star TYC 5476-00882-1 by the Orcus/Vanth system was predicted to cross Australia and New Zealand (Orcus) and Japan and North Asia (Vanth). Seven of the eight stations observed a miss while one station in Japan recorded a 3-second occultation by Vanth [2].

References

[1] Minor Planet Electronic Circulars 2004 D09
[2] http://www.occultations.org.nz/planet/2014/results/20140301_90482_Orcus.htm

ESOP XXXVI

36th European Symposium on Occultation Projects (ESOP) Freiberg, Germany, September 15th-19th 2017

Dr. Wolfgang Beisker, Dr. Eberhard Bredner, Konrad Guhl, Andreas Tegtmeier, Oliver Klös (from left to right).

Hans-Joachim Bode

(1945 - 2017)

Hans-Joachim Bode, who died aged 71 on 2017 July 27 was a keen amateur astronomer and occultation observer. He was the founder of the European Section of the International Occultation Timing Association (IOTA/ES) and their president for 33 years.

Our friend, president of IOTA/ES, motivator and engaged astronomer Hans-Joachim Bode passed away at the age of 71 in Hannover on July 27th this year. His family was around him when he died very peacefully. He got a heavy stroke in March and did not recover.

Born in 1945, during his time as a student at the Bismarckschule in Hannover he became interested in astronomy. The school had a small observatory on its roof, housing a 15 cm refractor. There he started his work in astronomy, not only for himself, but also to teach younger students to work scientifically in that field. Not only taking pictures, but learning to look behind the objects, that was motivation for him. He became president of the Astronomical work group of Hannover (Astronomischer Arbeitskreis Hannover, AAH). In the nineteen sixties he got in contact with David Dunham in the USA, and from this time on he was interested in the special subject of occultation astronomy. In the beginning with visual timing of total and grazing lunar occultations. Expeditions in the fields for recording the blinks in an occultation event fascinated him and the group around him. I met him first 1972 at the AAH, and he convinced and inspired me for that particular field. He was able to communicate the enthusiasm he had to other people.

He studied Geodesy and later economy. In the nineteen seventies he worked for companies in the mainframe computer business. This allowed him to have access to computers, which were at that time not accessible to everyone like today. Later he became self employed in the field of IT and as business consultant. From his first marriage, he had two children. After the death of his first wife, he married Brigitte, many of IOTA members know her, she was treasurer of our European society.

He recognized the importance of sharing ideas with others and give talks at many national and international conferences and workshops. He was a member of the German "Vereinigung der Sternfreunde (VdS)" and of the "Astronomische Gesellschaft (AG)" as well as of the "Bundesdeutsche Ar-

At the inauguration party of our m2 telescope 2016 at the Archenhold Sternwarte in Berlin.

Hans-Joachim at the opening of ESOP 30 at the Archenhold Sternwarte in Berlin 2011

beitsgemeinschaft für Veränderliche Sterne (BAV)" and the "Internationale Amateursternwarte (IAS)". In 1984 he founded the European Section of the International Occultation Timing Association as a registered society. He remained president of IOTA/ES up to his death. From the worldwide IOTA he was awarded the "Lifetime Achievement Award" of IOTA in 2015. In the certificate of this award it says he achieved the award "For establishing both The European Symposium on Occultation Projects and the IOTA/ES Organization. And for many years of nurturing and growing these institutions to encourage members in many countries to observe occultations and eclipses."

He himself observed more than 30 solar eclipses in all parts of the world, mostly going to the limb of the shadow to determine the Baily's Beads phenomenon for measuring the solar diameter.
He worked very successfully in the field of asteroidal occultation as well for occultations by far distant objects, the TNOs. The use of video and CCD techniques for the observation of occultation events was promoted by him all the years. The annual ESOP conferences, which was this year hold for the 36th time was founded by him and by myself. His intention was always to motivate people to join our astronomical engagement to get a better understanding of our planetary system and the universe as well.

I loose a very close and great friend, with whom I did a lot of expeditions around the world, discussing very private and astronomical issues for about 45 years.

My deepest sympathy is with his wife, his children and the members of his family.

Wolfgang Beisker ■

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.

The Offices and Officers of IOTA

Impressum

Editorial board: Wolfgang Beisker, Michael Busse, Alexander Pratt
Responsible in Terms of the German Press Law (V.i.S.d.P.): Konrad Guhl

Publisher: IOTA/ES, Bartold-Knaust-Straße 8, D-30459 Hannover, Germany, email: joa@iota-es.de

Layout Artist: Michael Busse, mb-grafik-design@online.de, mbusse@iota-es.de
Webmaster: Wolfgang Beisker, wbeisker@iota-es.de

Membership fee IOTA/ES: 20,– Euro a year (incl. JOA: free of charge)

Publication dates: 4 times a year

Submission Deadline for JOA 2017-4: October 15

IOTA on the World Wide Web

(IOTA maintains the following web site for your information and rapid notification of events.)

http://www.occultations.org
http://www.iota-es.de

This site contains information about the organization known as IOTA and provides information about joining

IOTA and IOTA/ES, including topics related to the Journal of Occulation Astronomy (JOA), and also has an on-line archive of all issues of Occultation Newsletter, IOTA's predecessor to JOA. On the right side of the main page of this site are included links to IOTA's major technical sites, as well as to the major IOTA sections, including those in Europe, Asia, Australia/New Zealand, and South America. The technical sites include definitions and information about observing and reporting, and results of, lunar, planetary, and asteroidal occultations, and of eclipses and other timely phenomena, including outer planet satellite mutual events and lunar meteor impact flashes.

Journal for Occultation Astronomy
(ISSN 0737-6766) is published quarterly in the USA by the International Occultation Timing Association, Inc. (IOTA)
4933 Champlain Place, Edmond OK 73025

IOTA is a tax-exempt organization under sections 501(c)(3) and 509(a)(2) of the Internal Revenue Code USA, and is incorporated in the state of Texas. Printed Circulation: 200

Regulations

The Journal of Occultation Astronomy (JOA) is not covenanted to print articles it did not ask for.

The author is responsible for the contents of his article & pictures.

If necessary for any reason JOA can shorten an article but without changing its sense or scientific contents.

JOA will always try to produce an article as soon as possible based to date & time of other articles it received – but actual announcements have the priority!

Articles can be reprinted in other Journals if JOA has been asked for permission.