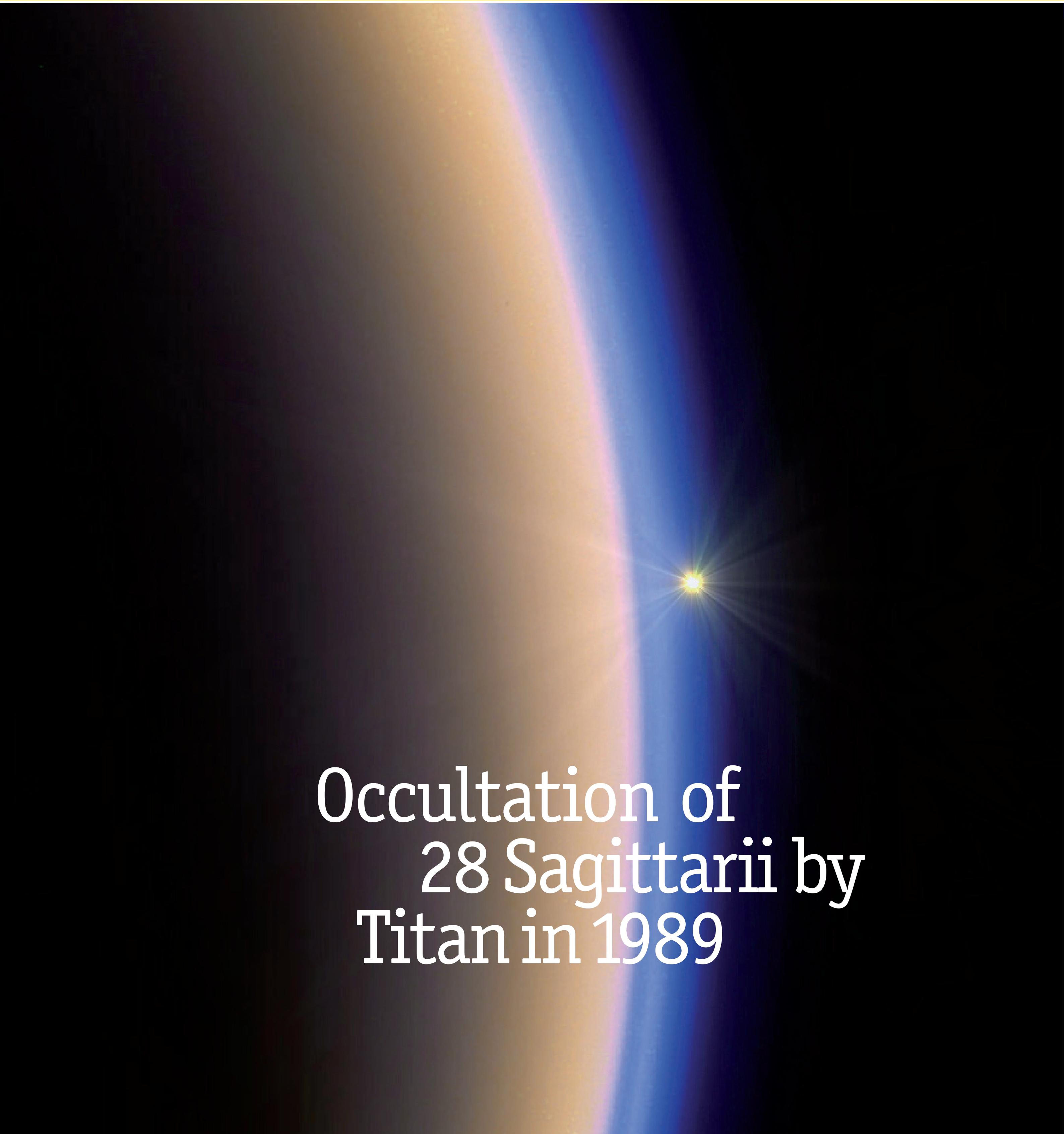
Journal for
Occultation Astronomy

Volume 8 · No. 2 2018-02



Occultation of 28 Sagittarii by Titan in 1989

Dear reader,

On 2017 October 5, many observers in Europe, northern Africa and the USA successfully recorded the occultation of a magnitude 12.7 star by Neptune's largest moon, Triton. The data will be used by professional researchers to analyse any changes in Triton's atmosphere, 20 years after an earlier study.

In this issue of JOA we look back to 1989 July 3, when another similar event attracted great interest - Titan, Saturn's largest natural satellite, occulted the star 28 Sgr (mag 5.8). Reports were submitted by nearly 200 observers across Europe, mostly visual descriptions, because very few had access to video cameras in those days.

Highly sensitive low-light cameras are now commonplace, and in these pages you can read a review of the QHY CMOS camera with its incorporated GPS receiver that accurately timestamps every frame. How things have changed in 30 years! What technology will be available to the occultation observers of the future?

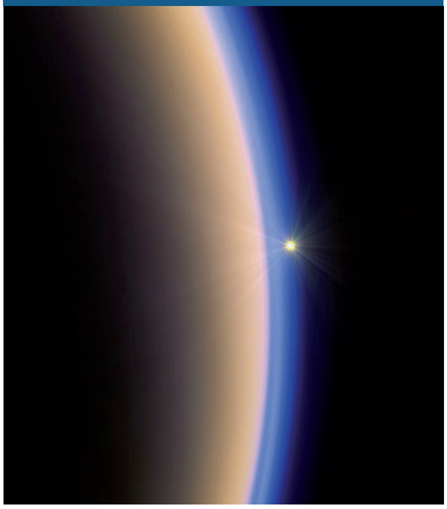
Clear skies,

Alex Pratt, IOTA/ES, Editor

JOA Volume 8 · No. 2 · 2018-2 . . . . . $ 5.00 · $ 6.25 OTHER (ISSN 0737-6766)

In this Issue:

COVER



Artist's impression of the occultation of 28 Sagittarii by Titan on 1989 July 3rd . Mostly professional observatories obtained light curves to study the atmosphere of Saturn's largest moon. Almost 200 observers in Europe observed the event visually.

Illustration credit:
NASA / JPL-Caltech / SSI / J. Major, https://lightsinthedark.com/ O. Klös

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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.

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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.

QHYCCD-174M-GPS CMOS Camera for Occultation Work

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ABSTRACT: CCD cameras are now standard for occultation work but accurate timestamping is still a challenge. With analog cameras, a video time inserter has to be used whereas digital cameras rely on the PC clock. The QHYCCD-174M-GPS is a new camera with an integrated GPS receiver and it outputs each image with an accurate timestamp.

Sourcing

QHYCCD is a Chinese company and sells worldwide through distributors. Most European countries can buy via Astrolumina.de. I bought my camera in the UK from ModernAstronomy.com for GBP 1047 (USD 1239).

The QHYCCD-174M is one of the smaller cameras in their range. A good technical description is available on the QHYCCD website: http://qhyccd.com/QHY174.html as well the technical specification (copyright QHYCCD.com).

QHY174M/C Camera Specification	
CMOS Sensor	1/1.2 inch Exmor CMOS sensor with global shutter
Effective Pixels	1920 x 1200
Pixel Size	5.86um x 5.86um
Effective Area	11.25mm x 7.03mm
Shutter	Electronic Global Shutter
FullWell	>32ke-
QE	78%
Readout Noise	5e@low gain 3e@high gain
System Gain	TBD
Unity Gain	TBD
Frame Rate (on 8bit)	138FPS @ 1936 x 1216 260FPS@960*600 490FPS@480 x 300
ROI Support	Yes. Any Area ROI
Exposure Time	50us - 1800 sec
AD Sample Depth	10-bit/12-bit (8-bit/12-bit output)
Anti-amplight Control	Yes (Reduces amplifier glow significantly)
Cooling	2-stage TEC, -40C below ambient, typical. Temperature Regulated
Power	USB Powered for camera and +12V powered for TEC
Anti Dew Control	Connector for removable silicon gel tube Heater board for CMOS chamber optical window
Computer Interface	USB 3.0 Super Speed
Telescope Interface	M42/0.75 & 2-inch adapter. Optional C-mount adapter
Color Wheel Port	4-pin QHYCFW2 socket
Guide Port	6-pin RJ11 Guide Port
Optic Window	AR+AR (Mono) IR+AR(Color)
Power consumption	TBD
Weight	450g
QHY163 Electric Interface	
12V input with lock, USB 3.0 socket, 4-pin QHYCFW, 6-pin RJ11	
Reference Price (Not include tax)	
QHY174M USD939 QHY174C USD899	QHY174M-GPS USD1239 w/TE Cooling QHY174M-GPS USD 939 w/o Cooling

You can choose between colour/mono and cooled/uncooled versions. For occultation work I bought the cooled mono version (QHYCCD-174M-cooled). A good technical review demonstrates the noise levels and the benefits of cooling: http://qhyccd.com/bbs/index.php?topic=5432.0. The camera uses a Sony IMX174 chip, 1920 x 1200 pixels with 5.98 υm x 5.86 um pixel size. The total imaging area is 11.25 x 7.0mm. The cooled version comes with a 2-stage thermoelectric cooler which can achieve 40 deg. C. below ambient temperature. An internal fan takes away the heat. To run the thermoelectric cooler an external 12V DC supply is required. Any desktop power supply 12 VDC, 2-3 A continuous output and a 5.5 mm OD/2.5 mm ID power jack will be sufficient.

Contents of the Package

The camera comes in a cardboard box with a 1.5 m USB 3.0 cable, 12 V DC power supply adapter for cooling, car adapter, desiccator cartridge plus desiccator, a RJ-11 cable to connect as an autoguider to a telescope mount. There is no instruction manual but a green card with links to the webpage where instructions can be retrieved as PDF.

The camera comes with a 2-inch external round dovetail with an internal M 42 x 0.75 (T2) thread. All electrical connectors are in the back of the camera: USB3.0, 12VDC input for cooling, 4-pin filter wheel connector, RJ-11 connector for autoguiding, SMC-connector for the GPS antenna.

How to Run with a PC

The camera needs to transfer the image data at high speed over a USB 3.0 interface to a laptop. I have used a Dell Precision M 6700 with a Quad-core i7-3740QM CPU and 16 GB RAM which I bought on eBay for 600 GBP. According to Dell the USB 3.0 ports should be full speed. QHYCCD recommends stopping all other applications while the camera is running. I've confirmed that the rated fps is achievable. But it drops dramatically as soon other resource hungry applications are started (Word, Explorer, Chrome...). During recording only SharpCap should be running.

Connecting to a Telescope

For occultation work, the camera should be at the prime focus of the telescope. For larger telescopes with long focal lengths (e.g. SCTs at F10), a telecompressor should be used. Otherwise the imaging area of 11.3 x 7 mm is too small to find the object. Another practical problem is to switch between visual observation and camera without moving

the telescope. A mirror box can be used but it is quite long. I am now using TS-Optics Flip-mirror-system and off-axis guider (short version, approx. 110 Euro).

Software

Three software options are available for the camera: EZCAP-QT, Sharp-Cap and drivers for Windows and Mac.
EZCAP-QT is written by the manufacturer but only allows still image acquisition and saving as FITS, BMP and JPEG. It is fairly basic and available for Windows and MAC. For video capture, SharpCap should be used.
SharpCap is written by Robin Glower for a wide range of cameras and can be downloaded from the QHYCCD website. The installation is described in detail in the manual, section 3. Some cameras need a patch installed but there is a test program and an installer on the webpage. After installation, start the program and an empty start screen opens. Confirm the error message that no filter wheel has been detected. Open the Cameras menu and the QHY174M should appear in the menu. Click on it and live images should appear. The camera control panel appears on the right side. It needs to be configured.
1. USB-Traffic (at the bottom of Camera controls) should be set to 0. Otherwise imaging is very slow.
2. Not all combinations of exposure time, number of bits and capture area give a continuous video stream. With the wrong combination,

there will be time gaps between images. The data transmission of the USB 3.0 interface seems to be the bottleneck. Theoretically a 20 ms exposure time should give 50 frames per second (1000 ms / 20 ms = 50 fps). In reality, especially with 12 bit data, only 39 FPS are achieved at full image size. Therefore a 5-6ms gap occurs between the images (1000 ms / 39 = 25.6 ms). The best way to avoid these gaps is to reduce the image size (called 'capture area'). If reduced to 1600x1200 pixel (-20%), 50 FPS can be achieved. I've pre-tested the parameters in daylight and saved them in different 'capture profiles'. Once the profile is re-loaded, all camera settings are correct again. Here is my table with some tested settings without gaps for occultation work (not complete, just my personal preferences...). To try out new settings, simply change

Bits	Area	Binning	Exposure ms	FPS
8	1440 x 1200	1x1	20	50
8	1440 x 1200	1x1	50	20
8	640 x 480	1x1	20	50
8	640 x 480	1x1	33.3	30
8	640 x 480	1x1	50	20
12	1440 x 1200	1x1	20	50
12	1440 x 900	1x1	20	50
12	960 x 1200	1x1	20	50
12	800 x 600	1x1	20	50

the parameter and watch the real FPS at the bottom of the SharpCap window. As an example, it says 2756 frames (0 dropped) in 0:00:55 at 49.5 fps and also gives the temperature of the chip in case for the cooling option of the camera. Once the result is acceptable, it stores it as a new capture profile. The capture area can be changed to any rectangular size and position. This is quite useful when reference stars need to be recorded and the area is to be kept small for speed reasons. WDM drivers can also be downloaded and allow software developers to write their own software.

3. The GPS receiver needs to be activated in SharpCap (GPS controls, GPS ON). The GPS window appears in the centre of the screen but can be moved anywhere. It shows the GPS status, location and time. A button at the bottom allows to synchronise the PC clock with the GPS. Videos are saved as *.SER files. Each frame has a timestamp with 1ms accuracy at the start of exposure. Tangra can import SER files and can be used for photometric analysis of different regions e.g. guide stars, background and the object.

GPS Receiver and Timing Accuracy

The cable between the camera and receiver is 3 m long which should just be long enough when the camera is used in a dome. It usually needs less than a minute to go into locked state.

Timing accuracy: To check the timing accuracy, a second independent GPS receiver with a 1PPS LED was recorded with the CCD camera. The second receiver was a TIM-10 video time inserter manufactured by AME and its LED flashes at the beginning of each second. Once both receivers were locked, a video with a very small capture area and 1000 FPS frame rate was taken, stored and analyzed in Tangra. On every second the LED is dark at 999 ms and lights up at 000 ms.

The observed timing inaccuracy between both units seems to be below 1ms, which should be sufficient for occultation work. There is also an internal calibration LED which can be turned on and off at pre-defined points in time to measure internal delays. The description is a bit evasive so I left this for a later date.

■ What I like:

excellent quality, complete camera solution for occultation work, dual-use camera for occultation work and astrophotography, filter wheel as option, cooling is quite effective (40 deg.°C below ambient)

■ What I don't like:

Software needs some experience, timing and settings need some experimentation to achieve video recordings without time gaps, the manual is not up-to-date with the software, some descriptions are poor or missing, no good user group available so far.

■ Conclusions:

The QHYCCD-174M-GPS is a very promising device for occultation work. The time stamping is completely done inside the camera, so the complexity of VTIs and the drift of PC clocks is no longer a problem. It is a dual-use camera for deep sky imaging, so a good choice for somebody who equally likes occultations and deep sky imaging. However, it needs some practice and testing before its capabilities can be fully exploited. Hopefully there will be future user groups to share the experience with the camera and to make it a bit easier to use. The price is not higher than some other small digital CCD cameras. I can strongly recommend it to anybody who is entering the field of occultation astronomy.

Titan Occultation of 28 Sgr in 1989

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ABSTRACT: In 1989 an occultation by Titan was observed across Europe by about 200 observers. Light curves obtained at (mostly) professional observatories were analyzed and formed the subject of several papers detailing the atmosphere of Titan. Additionally there were almost 200 visual observations made of the event. However those observations did not appear in the IOTA records of occultations. In this paper we review what happened with this rare event, discuss the problems with the visual observations and what can be learnt from them, and make recommendations for observing similar events in the future.

Introduction

In Nov 2017 Bruno Sicardy reported to occultation observers the preliminary results of an occultation by the Neptunian moon Triton, stating:

As of today, the Lucky Star project has received 66 positive reports of the Triton event, 24 of them detecting the central flash. This is a large success supported by many teams, both amateurs and professionals. As far as I know, this is the best observed atmospheric occultation ever recorded.

This quickly led to a response from one of us (Roland Boninsegna) advising this was not correct, stating that:

On 1989 July 3 a famous occultation of 28 Sgr by Titan was observed by many observers all over Europe.198 individual observations. A central flash was also observed.

This 1989 event was not present in the events maintained in Occult, raising the question of – what happened to all these observations?

In this article we will outline the excitement at the time, the effort to collect observations, the problems associated with the data, and the conclusions to be drawn from the observations.

Historical Background

Following a suggestion of John Westfall of ALPO, Lawrence H. Wasserman of Lowell Observatory first published information about a possible occultation of a bright star (28 Sagittarii visual magnitude 5.8) by Titan (visual magnitude 8.2) in an IAU circular. In this first prediction the centre line of the event just missed the northern limb of the Earth. Subsequent astrometry resulted in updates which moved the path southwards to cross Central Africa, Saudi Arabia and Iran, and then to Northern Africa and the Middle East. The prediction uncertainty was large.
Letters to potential observers included some observational data and recommendations. This included expected start and end times of the event (with an accuracy of a minute or two), duration of the event and expected phenomena like irregular brightenings during immersion and emersion due to differential refraction in the upper atmosphere of Titan, and a possible central-flash due to focussing from refraction at points all around the limb of the satellite. The final prediction mentioned the central flash zone of visibility would probably be less than 100 km wide. It also mentioned the observations would fill an important gap in knowledge of the atmosphere of Titan since Voyager 1 measured only the highest and lowest parts of the atmosphere. Observations would contribute valuable information for planning the Cassini spacecraft mission. Some of the networks in Europe were activated to spread information among known observers. Especially EAON, IOTA/ES and BAA sent out prediction sheets to observers within their networks. No doubt several others will have contributed in the spread of information as well. This publicity was undoubtedly responsible for the huge number of observations made of the event.

Circumstances of the Event

The general appearance of Saturn and its moons at the time of the Titan occultation is shown in Fig 1.
Titan is satellite 6, shown to the far left of the plot, well away from the main body of Saturn. The star moved (relative to Saturn) across the plot from middle right to upper left. It was occulted by Saturn and its rings between about 6.8 and 8.6 hrs UT (with those events being observed

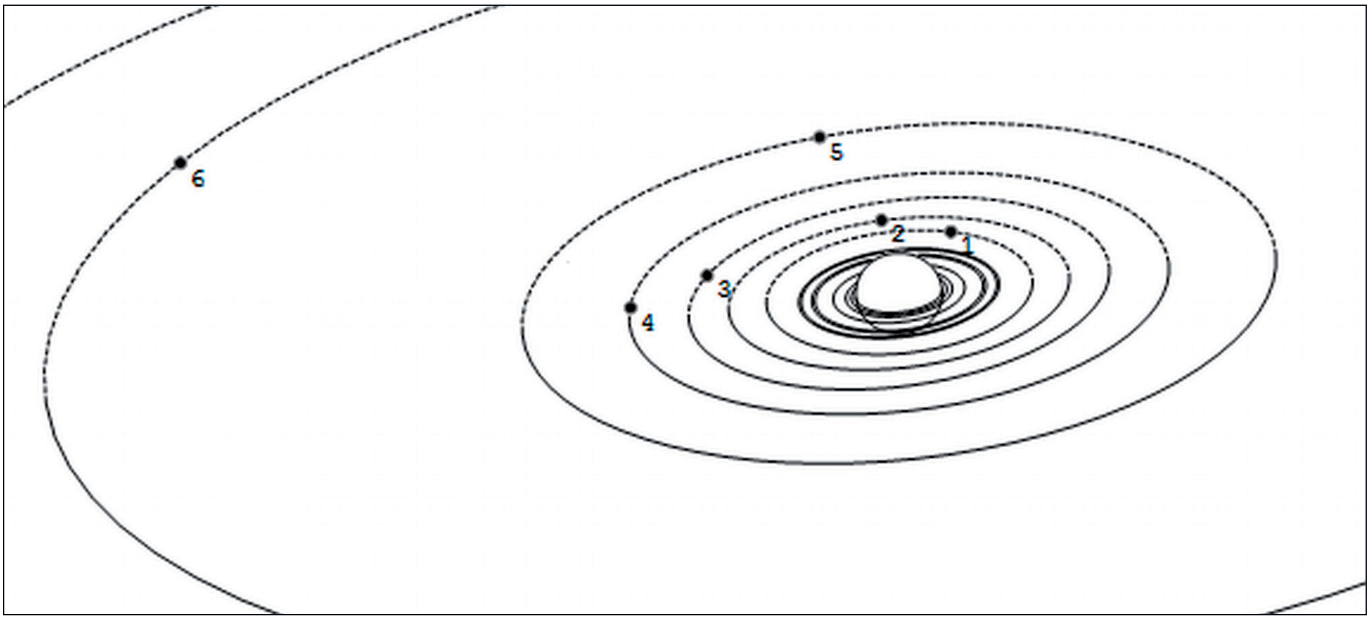

Fig 1. General appearance of Saturn and its moons on July 3, about the time of the Titan occultation

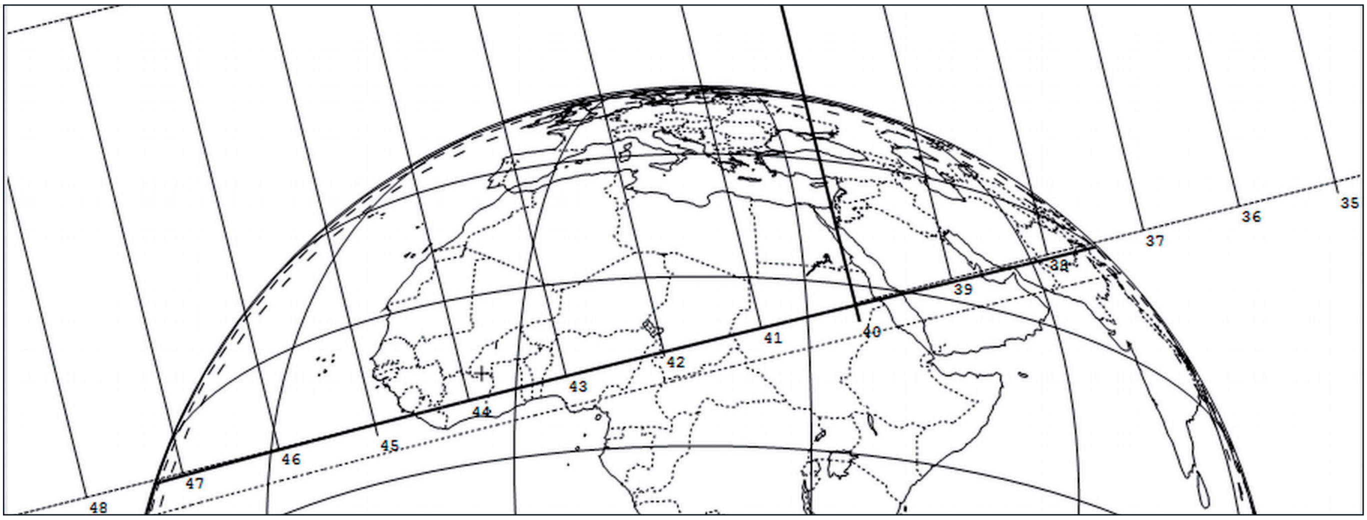

Fig 2. Modern prediction of the occultation path

in North America, Hawaii and Chile) and by Titan at about 20.7 hrs UT. A modern prediction of the event is shown in Fig 2.

From this it may be seen that observers in Europe were reasonably close to the centre line, and were therefore well placed to see the central flash – which in fact was seen by many observers.

The Primary Characteristics of the Event

The V magnitude of the star was 5.4. Titan was 8.5. This is a good difference in magnitude, with the brightness changing by a factor of 17 at the occultation.

The star's spectral type is K5III. From the brightness and color magnitudes one can estimate the diameter as being about 0.0038". That diameter would result in short-duration fades of about 1 second.

The central line duration of the occultation (assuming no atmosphere and a solid surface) was 283 seconds – almost 5 minutes!

Observers in northern Europe had to contend with two inconvenient factors. Firstly twilight – even though the event occurred near local midnight, the Sun was not far below the northern horizon as seen from northern Europe.

Secondly, the altitude of the star was low, with consequential issues of atmospheric turbulence. Indicative altitudes of the star for major cities are:

Edinburgh	10°
London	14°
Amsterdam	14°
Berlin	15°
Paris	17°

While the low altitude would undoubtedly have been a reason for concern, the star brightness and the duration of the event held out the promise of excellent results. What happened?

Analysis by Professional Astronomers

A number of professional and amateur observatories recorded the event with photoelectric equipment (with some using video). Six papers have been published analysing most of those observations. Those papers are:

[1] Probing Titan's atmosphere by stellar occultation, B. Sicardy et al. in Nature

[2] Results for Titan's atmosphere from its occultation of 28 Sagittarii, W.B. Hubbard et al. in Nature

[3] Photometric observations of the occultation of 28 Sgr by Titan, RW Forrest and IKM Nicolson, in MNRAS (1990)

[4] The occultation of 28 Sgr by Titan, WB Hubbard et al., in Astron. Astrophys.

[5] The occultation of 28 Sagittarii by Titan, R Miles and AJ Hollis, in J. Brit. Astron. Assoc.

[6] The Structure of Titan's Stratosphere from the 28 Sgr Occultation, B. Sicardy et al. in Icarus

Additionally two papers concerning the immediately preceding occultation by Saturn and its rings are:

[7] Saturn's pole position and ring radius scale from 28 Sgr occultation, W.B. Hubbard et al. in Bull. Am. Astron Soc

[8] The occultation of 28 Sgr by Saturn: Saturn pole position and Astrometry, W.B. Hubbard et al, in Icarus

Between them, these papers analyse about two dozen light curves from the event, and draw conclusions about the structure of Titan's atmosphere. Only the paper by Miles and Hollis makes reference to the visual observations made by the many amateur observers.

What About the Amateur Visual Observations?

The event was well observed across Europe. There were clear skies in Benelux, England, large parts of France, Switzerland, northern Germany, southern Scandinavia and Poland. These areas are known for a high concentration of amateur astronomers resulting in many valuable reports.

Cloudy skies in Spain, Italy and some parts of Germany and Eastern Europe meant that reports were not received from observers in these areas. Where there were clear skies, seeing conditions varied from excellent to poor. Where clouds interfered, observations were severely hampered, resulting in doubtful or unreliable timings.

Most observational data were gathered by Roland Boninsegna of EAON. Although this network is mainly concentrating on observations of occultations by minor planets it served well for this purpose. Other sources of observations were:

Hans-Joachim Bode of IOTA/ES also collected a number of reports.

The IAU bulletins served as an additional source. Although data in these bulletins, due to their nature, often are imprecise, they formed a welcome source to know where to start looking for the original data.

BAA, including the JBAA (Journal of the British Astronomical Association),

ASN (Astronomy Now),

S&T (Sky and Telescope),

AST (Astronomy),

NAT (Nature),

ON (Occultation Newsletter)

TA (The Astronomer magazine)

and some private communications.

In all, we collected 221 individual positive occultation observations (plus 2 reports of being clouded out, and two reported Miss (which, in hindsight, must have been erroneous for some reason). This is the largest number of positive occultation observations at a single event ever recorded. The event with the next highest number of positive observations was Pallas on 1983 May 29, where 131 observers recorded a positive occultation [9], [10].

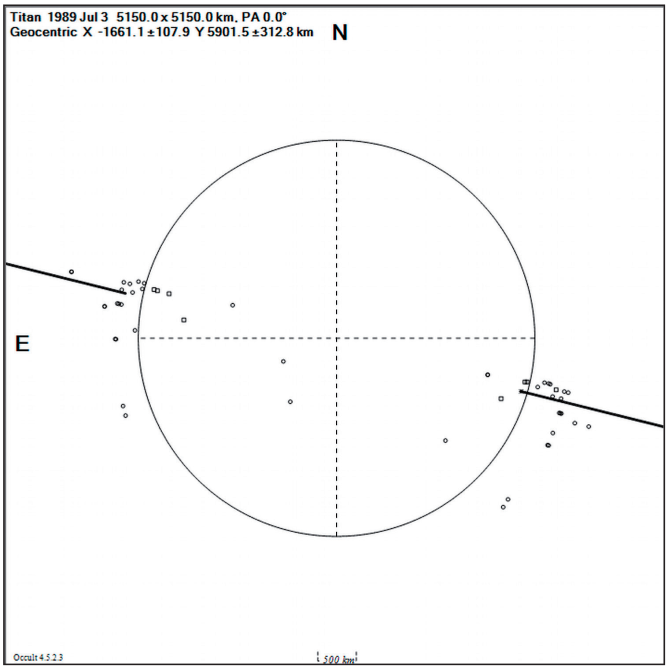

Fig 3. Plot of the D and R event - photoelectric recordings only

The Miles and Hollis paper [5] provides the most detailed analysis of the visual observations of the event (albeit limited to the observations from 115 reports) including a detailed analysis of the location of visibility of the central flash. That is, a majority of the visual observations actually made of the event have been analysed, with a resulting paper being published. For the remainder of this paper we shall not attempt an analysis anything like the Miles and Hollis paper, but focus attention on the reliability of event times.

In Fig 3 we plot all the photoelectric observations, and in figure 4 we plot all the observations.

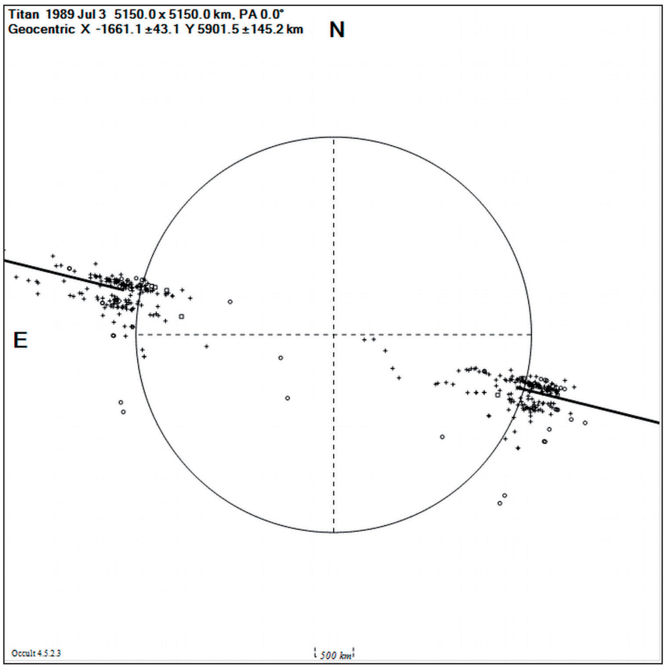

Fig 4. Plot of the D and R events - all observations

There are several characteristics evident in these plots:

- While there were a large number of observations, their distribution around the limb of Titan was very limited. This was due to a combination of the large diameter of Titan, and the fact that Europe was 'near the edge' of the Earth, such that the distance between observers was very much foreshortened (see Fig 2).
- With modern video recording systems, we expect the spread in event times for closely spaced observers to be a small fraction of a second. In past years when most observations were visual, the typical spread was larger – in the order of 1 second or less (depending very much upon the effects of Personal Equation). Yet for this event the spread of event times at both the D and R is of the order of 60 seconds for the visual, and somewhat less for the photoelectric observations.
- There are several sets of reported observations where the observers were at the same location but observing through different telescopes – with significant differences in the reported mid-time of the D or R event. As an example of this, there was a group of observers at Meudon Observatory using both the 1-metre and 60cm telescopes. Those telescopes are separated by a distance of 80 metres. For the D event the mid-time reported from the 60 cm scope was 6 seconds earlier than for the 1-metre telescope; for the R event the 60 cm scope was 8 secs later than the 1-metre. That is, the reported duration for the 1-metre scope was 5m 2.5s, while for the 60cm scope it was 5m 16.5 secs. Similar spreads are seen with other groups of co-located observers.

It would seem likely that the underlying cause for the spread of event times is the lengthy fading that occurred with this event. The reported duration of the fade at both the D and R event was typically in the range 20 to 40 seconds – with some being even shorter or longer. The expected fading of about 1 second due to stellar diameter would have been inconsequential. The bulk of the fading can be attributed to the atmosphere of Titan. It would seem that the scatter in reported mid-event times can be attributed to the (in)ability of the observer to estimate the point of half-light brightness, or to the inadequacy of taking the mid-event time as the mid-point between the first detectable drop in brightness, and the end of the drop in brightness. Undoubtedly a significant contributing factor is that the light curves (as shown in the papers referenced above) show large fluctuations over the course of the fade (caused by structure in Titan's atmosphere). These fluctuations would have made it extremely difficult to visually assess the point at which the light level had dropped to 50%. In short, visual observations were inherently incapable of providing reliable times for this event, due to the long fade duration and fluctuations in the light level.

The Central Flash

One of the features of this occultation event was the observation of the central flash, a phenomenon predicted following an observation of the 1977 occultation of epsilon Gem by Mars. The papers listed above analyze the central flash from a number of different perspectives. In the context of the visual observations, the Miles and Hollis paper gives an extensive treatment of the large number of visual observations they had at their disposal – albeit not a full set of the observations actually made. We do not further analyze those observations in this paper.

Lessons to Be Learnt

This event is a clear demonstration of the inadequacy of visual observations when the event is characterised by fading and light level fluctuations over a significant portion of the event's duration. Back in 1989 video was not readily available, and amateur observers necessarily observed visually. However since most observers now use video to record events, this lesson has lost its relevance.

The greatest learning obtained from this event was about the atmosphere of Titan. That learning necessarily involved an analysis of the shape of the light curves measured photoelectrically (including the central flash), with simple event times being of little value. Regrettably, nothing has been derived from an analysis of the visual observations, principally because the visual observations of event times have turned out to be inherently unsuitable for this event. Indeed, visual observations involving planets or planetary moons having an atmosphere are unlikely to provide data that can be analysed to extract valuable information. That is, occultations by any of the planets other than Mercury, and all planetary moons that have an atmosphere [that is, Titan (Saturn), Triton (Neptune), Io and Callisto (Jupiter)] require measurement of a light curve in order to be useful.

Date	Star mag	Mag drop	Duration Secs	Region	Comment
2022 Jul 9	8.8	0.6	326	North America, Central America, northern South America	
2048 Aug 16	8.7	0.7	310	Antarctica	Southern Africa if the path moves north
2058 Feb 19	8.7	0.7	177	South America	Low altitude
2074 Oct 28	5.3	3.6	163	Nowhere on land at night	Star is double
2079 Aug 6	8.6	0.7	276	Antarctica	Southern Australia & New Zealand – if path moves north
2084 Jun 14	8.1	1.0	295	Eastern China, south-east Asia	

Table 1 – Future occultations by Titan

Date	Star mag	Mag drop	Duration Secs	Region	Comment
2022 Oct 6	11.6	2.0	119	North and central Asia	
2029 Jun 8	11.1	2.6	187	California	Only if path moves south. Otherwise in twilight; 6″ from Neptune
2054 Apr 7	11.4	2.3	103	Nowhere over land at night	
2066 Nov 4	11.5	2.2	163	Western South America, Central America	
2073 Aug 9	11.8	2.0	78	Nowhere over land at night	
2075 Nov 20	9.0	4.6	205	Alaska?, Siberia	

Table 2 – Future occultations by Triton

These days most observers would use a video system to record events such as this one. In principle, that would allow a light curve to be derived and analysed. However it is important to ensure the image of the star and satellite is not saturated – since saturation results in non-linear camera response to changes in the light level. This is particularly an issue with 8-bit video cameras as used by most observers. However observers will also want to collect as much light as possible to maximize the signal-to-noise ratio so that the light curve provides as much detail as possible. The simple solution to this quandary is to record the event with the image well out-of-focus – so that the light is spread over many pixels without any pixels being saturated.

Next Events

The 1989 Titan event attracted a huge number of observers, and much interest. But how common are such events? In Table 1 we list all occultations by Titan in the period 2018 to 2100, subject to the criteria that the star is brighter than 9.0, the magnitude drop must be at least 0.4 mag, and the solar elongation must be greater than 25°

This Table 1 illustrates that occultations of bright stars by Titan, such as the 1989 event, are indeed quite rare – rarer than a 'once in a century'.

The next Titan event will be on 2022 Jul 9, with the predicted path and planet configuration being shown in Fig. 5. Titan is satellite #6, above the arrow. (The apparent pair of lines through Saturn represent the elongated orbit of Phoebe.)

Table 2 lists the result of a similar search for occultations by Triton, but with the star magnitude criterion set to mag 12.0, yields the following list of events: This shows that events similar to the Triton event of last October occur with a frequency of about 1 per decade.

The next Triton event will be on 2022 Oct 6, with the predicted path and planet configuration being shown in Fig. 6.

However the 2075 Nov 20 event involving a 9th mag star will be very favourable (although the region of visibility will no doubt have its challenges – see Fig 7). Triton will be 14.7″ from Neptune, which will be at mag 7.9 and have a disk diameter of 2.5″. An event for the next generation to observe!

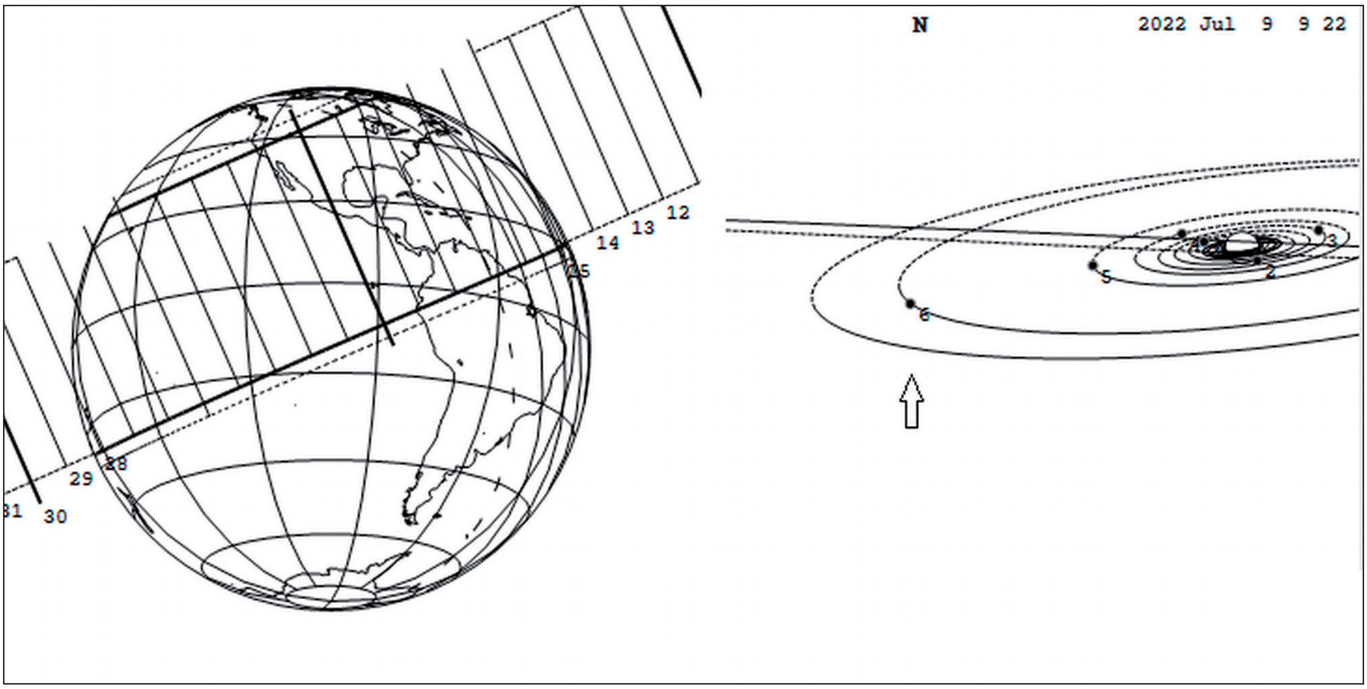

Fig 5. 2022 Jul 9 occultation by Titan, including the planetary configuration

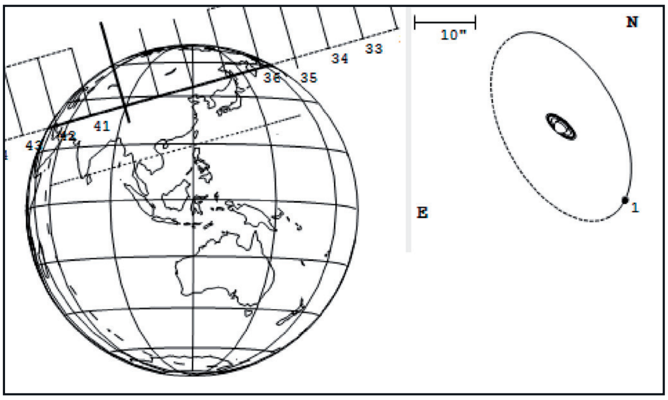

Fig 6. 2022 Oct 6 occultation by Triton, including the planetary configuration

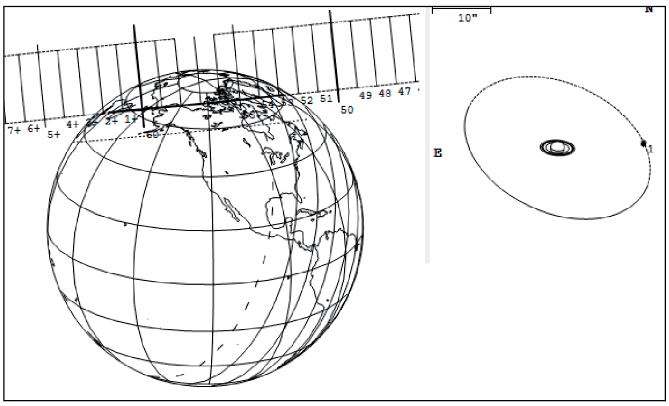

Fig 7. 2075 Nov 20 occultation by Triton, including the planetary configuration

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Becoming an Expert OccultWatcher User – Part 1

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ABSTRACT: While OccultWatcher (OW) has been designed to be easy to use, throughout the years I have received questions from various users asking how to accomplish something specific as well as questions about OW's internal workings and why it does or does not work in a particular way. This paper covers some of those topics and also discusses in more details the more rarely used but useful functions of the program with the intention to help the reader to use OW more effectively. Each topic or function is discussed in its own section.

In Part 1 of this paper we will review the following topics: Filtering, Coordination of Positions, Personal Predictions, LinOccult Preductions, Community Events Feed, Local Group Predictions and Path Direction and Chord Offset.

Filtering

One of the questions which keeps coming back more often than others is 'Why I cannot see an event that someone else can see'. Unfortunately the answer to this question is not straight forward but typically it comes down to the other observer using different filtering settings. The best thing to do if you have this issue is to set the filtering distance to a very large value. I typically use something like 5000km from the 3-Sigma zone on the Configuration -> Event filters tab for the 'Default' filter and also make sure that no custom filter is defined for the feed in which the event is published (Fig. 1).

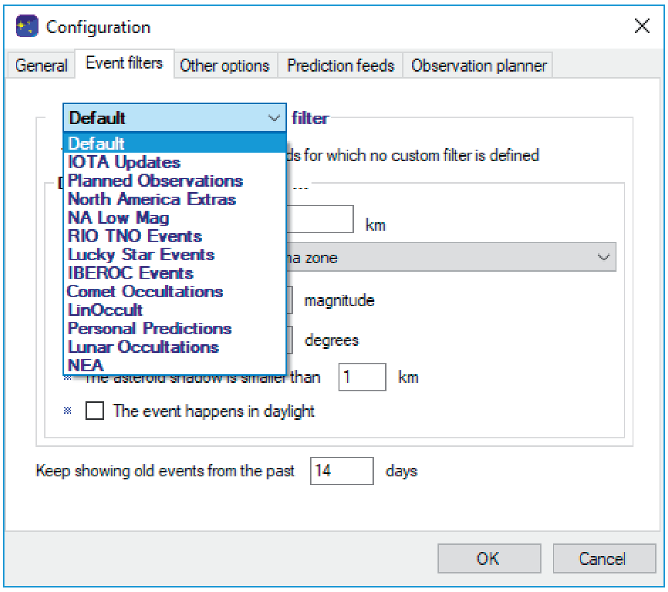


Fig 1. The Default filter will be used by OW unless a specific filter has been defined for the feed from which the event is coming from.

If this doesn't help it could be because at the time of the event the star is too low for your location but is not too low for the other observer's location so the next step is to use the other observer's coordinates. Following these steps will typically result in finding the event. I will also mention that in the past many years I haven't seen a single instance where OW was doing a wrong calculation. So if you are missing an event – check the filters.

Another reason for not seeing an event could be a database corruption. This issue happens very rarely and while I haven't seen it genuinely happen with my own installations of OW it does certainly happen as others have reported it. I imagine that a typical reason for it occurring would be sudden power-offs of the computer or other glitches that could make OW shut down or crash half way while it is saving one of the files in its event database. It is also possible that a bug in the reading of the data from the feeds results in the creation of an event entry that will not be able to be read later on. The result of all this would be that OW will only read the events from a particular feed only until a certain point and no further events from this feed will be displayed because the 'bad event' could crash the retrieval of the remaining events. In order to fix this the user can clear up the internal database of OW and re-synchronise all events. This can be done from Settings -> Other options -> Advanced -> Maintenance -> Purge database (Fig. 2). Be aware that any previous predictions of the events will be lost. After re-synchronising you will only get the latest prediction available from the feed.

In some cases of database corruption the situation could be worse and OW may not even start. If this happens to you then you will not be able to go to the configuration page to purge the database. In such a case the maintenance commands could be run from command prompt passing a 'purge' or 'reset' parameter when running OccultWatcher.exe. To do this open up Windows command prompt and type for example: "OccultWatcher.exe purge". Please note that running a reset command will delete all settings and you will need to enter everything again, including site location and your Observation Planner account.

Another case of the "Why I don't see an event" question involves either events in the past or events that are too far in the future. Rarely events that are more than 60 days in the future may be included in a feed. In such a case the observer may see the event in the listing of the feed

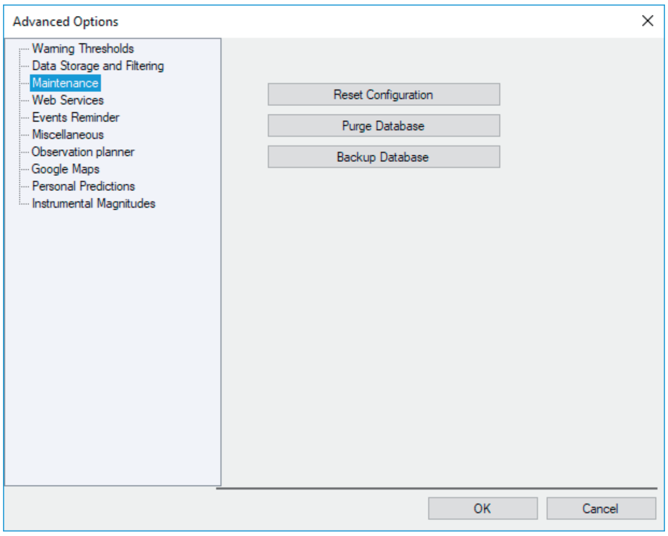


Fig. 2. The button for purging the database can be found in 'Advanced Options'

Web site but OW will not show it. This is because Occult Watcher will only show events that are less than 60 days in the future and this is an internal parameter that cannot be changed. So if this happens to you, you simply need to wait for the event to become less than 60 days in the future and OW will display it.
Events could also not be displayed if they are too far in the past. OW will keep showing past events so that the observers see them for reporting purposes. By default OW will show events that are no more than 5 days in the past but this setting can be modified from Settings -> Event filters to up to 30 days in the past. OW will automatically remove events from the internal database if they are more than 30 days in the past. This is done to prevent the internal events database from growing and taking up space forever. The database itself resides in the Windows user profile of the currently logged in user in the hidden AppData directory. Purging the database or resetting the configuration will both result in clearing the database and all events will have to be fetched again at the next synchronisation.
Lastly it is important to note that OW never fetches events that are in the past when synchronising. Let say for example that "Observer A" has been subscribed for the UKOCL feed for a couple of months and currently sees an event in the feed listing in OW that has already passed 2 days ago. Another "Observer B" that was never subscribed to the UKOCL feed before will not have this event in their OW. Now even if "Observer B" subscribes for the UKOCL feed and does a synchronisation this event will still not be listed for "Observer B" even that it has passed only 2 days ago. This is because OW will never add an event to the event database during synchronisation if the event has already passed at the time of synchronisation.

Coordination of Positions

This is not something that observers may have thought about but in order for OW to help with the coordination of observing stations, OW must be presenting all observers with exactly the same path and event parameters. To accomplish this OW uses built in rules and logic to determine which prediction should be considered the most accurate one and those same rules run on everyone's installation of OccultWatcher. From all standard feeds (i.e. predictions not run by professional astronomers) the IOTA Occultations feed is assumed to have the highest accuracy and this is because indeed Steve Preston goes through very thorough process to generate his predictions. This is one of the reasons behind why it is impossible to unsubscribe from the IOTA Occultations feed – because the potentially most accurate predictions should be always available for everyone. The latest prediction in any feed is always assumed to be the most accurate prediction from that feed so last moment astrometry updates can be published to improve the predictions. OW has more rules and weighting for all feeds which I am not going to go into too much detail, but the end result is that all observers will see the same event path when they look at and submit their stations and this will be the path considered the most accurate.
However there are two feeds which could take precedence over 'IOTA Occultations' if the user is subscribed to them and these are the 'Lucky Star' and the 'RIO TNO' feeds. Both of those feeds include events computed by professional astronomers. The Lucky Star project is lead by Bruno Sicardy, the RIO TNO predictions are created by Felipe Braga Ribas. Of the two feeds the RIO TNO events are considered the most accurate ones because they only include selected events which are generally Lucky Star events which have been 'upgraded' into campaigns and many hours of work has been used to improve each individual prediction. These predictions will only be available if when enabling the feed the user has accepted the collaboration agreement to share their results with the Lucky Star project. OW will periodically show this collaboration agreement as a reminder. I hope that everyone sees this infrequent reminder as a very small price to pay for getting an opportunity to collaborate on these high profile TNO events. Another note to make is that the Lucky Star project events will not be delivered as 'Community Events' (see below) and will only be available if the user directly subscribes for the feeds and accepts the collaboration agreement.

Personal Predictions

Some observers however don't settle only with the numerous events distributed by the feed maintainers around the world and provided via OccultWatcher feeds. Those people want to have even more potential events to observe in their list. They calculate their own events with Occult and use them as 'Personal Predictions'. The concept of personal predictions is simply a set of events that are not sent to other people and initially only appear in the observer's own OW. However if the observer announces their intentions to observe by submitting a station, those personal predictions may become available via the 'Community Events' feed. This is covered into more detail later on.

To generate personal predictions one needs to generate one or more .occelmnt files which contain one or more predictions and to copy these files to the Personal Predictions' directory which by default is *C:\OccultWatcher\Personal* but can be changed from Configuration -> Other options -> Advanced -> Personal Predictions. During the next synchronisation OW will detect the presence of the .occelmnt files and will load them as events under the Personal Predictions feed. There are more options on the Personal Predictions configuration page which control how the predictions are processed during synchronisation. The default value of 'Append and Update' for the update mode for example will keep any Personal Prediction events that are already in the OW's event database and will only add new events or update the existing predictions if the .occelmnt file that contains them has been updated. The 'Purge and Create' mode will always delete all events on synchronisation and will insert the current events after that. There is also a possibility to alter OW's rules for feed prediction accuracy and make your Personal Predictions be handled as more accurate than some feed predictions but if you do so you will not be able to submit a station and share your predictions with other people.

LinOccult Predictions

OccultWatcher also lets users that receive predictions from Andrey Plekhanov to have those events listed in OW. This is done by simply copying the text file with the predictions into the LinOccult directory, which defaults to *C:\OccultWatcher\LinOccult* and enabling the feed from the Settings -> Prediction Feeds. Once this is done OW will parse and include the LinOccult predictions into OW's database when doing synchronisation.

One thing to note is that LinOccult predictions don't provide Besselian Elements so the shadow path is interpolated (or extrapolated) from the provided path data series. This could make OW do larger computational errors for the event times particularly when your observing site is close to the end of the path or is several hundred kilometres away from the centreline. If you are using LinOccult predictions I would advice waiting for an extra minute from both sides of the predicted mid-time when observing, just to be sure.

Community Events Feed

When stations are submitted for events, other than the two Lucky Star feeds, the event predictions will be made available to everyone via the Community Events feed, also known as the Planned Observations feed. This feed simply contains events that someone else has decided to observe and you will only see those events if you have the Community Events feed enabled (it can be disabled by the user) and if the event matches your event filters for distance, magnitude and star altitude. The current list of Community Events can be seen in a web browser if you navigate to http://www.occultwatcher.net/CommunityEvents.html and if your web browser has ActiveX controls enabled. At the time of this writing only Internet Explorer has ActiveX controls enabled by default in its default security settings. Please note that IOTA Occultations events are not included in the Community Events and this is because everyone will always get all IOTA Occultations events.

If you open up this page you will see that there are a number of Personal Predictions and LinOccult events available, too. This is because those events are made available to everyone who is interested. However these events will not be displayed by default in the Community Events feed in your OW. To get them listed the user will need to request that they are not excluded and this can be done from the Community Events feed settings available going to the Settings -> Prediction Feed, right clicking on the Planned Observations feed and choosing Properties. This will show up a small form that at the top will have two check boxes titled 'Accept Personal' and 'Accept LinOccult'. If you want as part of the Community Events feed to receive Personal Predictions and LinOccult predictions for events that someone else has included in their OW and has announced their intention to observe those events, you will need to check the 'Accept Personal' and/or 'Accept LinOccult' checkboxes (Fig. 3). Any such events will then show up after the next synchronisation.

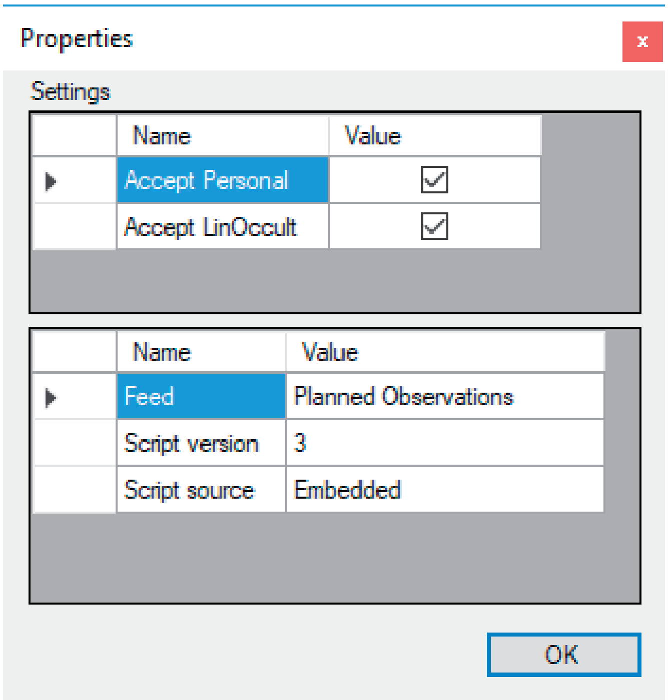


Fig 3. Right clicking on 'Planned Observations' feed will open the Properties window to include Personal and/or LinOccult events, chosen by other observers.

Local Group Predictions

OccultWatcher also offers the ability to generate custom predictions for your local astronomy group for example and share those predictions only with this local group of people. Of course once someone has announced a station to observe for any of those events, they will be automatically made available to everyone subscribed to the Community Events feed. As the use case for such a set of predictions for a local group is quite limited I will not go into the configuration details of how to set it up however I will mention that it requires the creation of some custom configuration files which is not difficult to do and the feed maintainer will need to provide web hosting for the predictions. If anyone is interested in running this type of predictions please contact me and we can discuss it further.

Path Direction and Chord Offset

This is something that may be obvious but it has generated discussions in the past so I thought I will briefly talk about it. Everyone that has used OccultWatcher knows the plot that represents the path of the shadow and all submitted stations, which plot is displayed in the event details under the main list when an event is selected. There are also other places where stations are listed with distances from the center line. There are two questions here: (1) – how is it decided on which side of the center line a station will be plotted and (2) – what does the distance represent.

In many of the cases it is possible to consistently talk about all stations across the path and identify them as being for example North or South of the path and this is because the majority of the events go into East-Westerly direction. However there are events which can 'draw' a more complicated path which looks like a semi-circle on the Earth's surface. Because one of the main functions of OW is site coordination it is important that stations that appear on the same side of the shadow across the whole path are indeed consistently identified to be on the same side. For this reason OW cannot use world directions but rather uses a Left or Right of the shadow concept. The definition of this is quite simple – if we walk on the center line from the location where the shadow enters the Earth and follow the occultation toward the direction of the exit of the shadow, then all stations that appear on our left side will be considered Left from the center line and the others will be to the Right from the center line. The shadow plot displayed when an event is selected will show all stations which are left of the center line on the left hand side of the form and all right stations on the right hand side. All distances to the left will be negative, while distances to the right will be positive. Another problem with the shadow projection on the Earth's surface is that the shadow will have different widths at the different parts of the path and for locations close to enter and exit points the shadow could be quite wider than in the middle. In order for OW to use the same scale when displaying the relative position of the stations on the path plot it cannot use distances on the Earth, instead it uses the fundamental plane distance which corresponds to real in-space distance of a point from the asteroid to its center point. This distance in OW is referred to as 'chord offset' and is used on the path details plot and also on some other forms. The travel distance displayed in the main table is of course the distance on the Earth's surface that the observer will need to travel to on a straight line to get to the center line of the occultation. While this distance is useful for travel planning to mobile locations the chord offset is what is important for planning relative station position and for reporting.

This concludes the first part of this paper. In the second part we will have a closer look at topics such as Intrumental Magnitudes, Fixed Observatory Local Horizon, Tangra – AOTA – Occult Watcher Integration, Near Earth Asteroids and Lunar Occultations.

ESOP 37

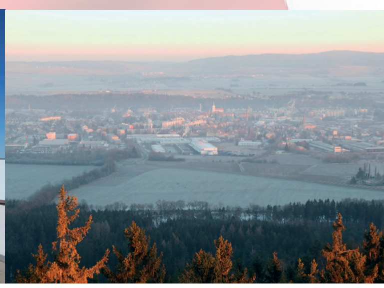
http://esop37.cz/

It is a great pleasure to invite all interested parties to
Rokycany, Czech Republic for the 37th European Symposium on Occultation Projects on
August 24th-29th, 2018.

IOTA-ES's annual conference will include talks and lectures, as well as interesting excursions. Hosting town is Rokycany, a town in the Plzen region, about 17 km east from Plzen. The town of Rokycany lies in a hollow, at the confluence of a small river called Klabava and the Holoubkovský and Rakovský streams. The town is surrounded by the forest hills of Čilina, Kotel, Žďár and Vršíček. Rokycany was first mentioned in 1110 and the main-belt minor planet (15925) Rokycany is named after this town.

Getting to Rokycany: The nearest Václav Havel Airport (PRG) is in Prague. The train from Prague (Praha) takes to Rokycany about 1.5 hrs. Highway from Prague to Rokycany is D5, exit 62. Highway from Germany's Autobahn A6 to Rokycany is D5, exit 62.

Symposium is organized by Rokycany & Plzeň Observatory with co-organization by Town Rokycany, Pilsen Region and Occultation & Astrometry Section of Czech Astronomical Society.



Beyond Jupiter

The World of Distant Minor Planets

Since the downgrading 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 March 2018, the Minor Planet Center listed 744 Centaurs and 1918 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:

(28978) IXION

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ABSTRACT

Discovered in 2001 by the Deep Ecliptic Survey, (28978) Ixion was estimated to be as large as the dwarf planet Ceres. This made Ixion a prime target for planetary scientists. Observations in the far infrared revealed that Ixion is much smaller than previously thought. The newly-found diameter of 617 km leads to an unusually high albedo of > 0.15.

The best way to uncover Ixion's true size and shape would be observations of stellar occultations by Ixion. There were many attempts, but only one observation with just a single chord was successful. Due to its southern declination, it's now up to the observers in the southern hemisphere to uncover Ixion's secrets.

Cerro Tololo Inter-American Observatory (CTIO) in Chile. Image: David Walker

IXION

Discovery

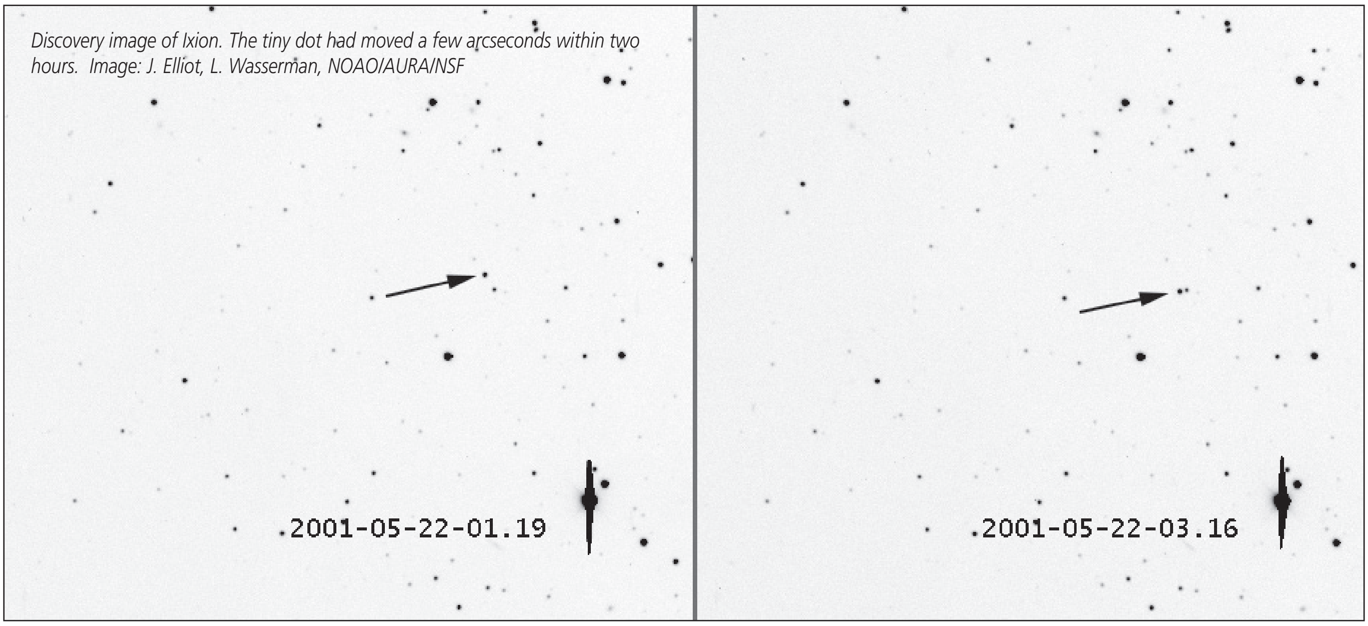
The 'Deep Ecliptic Survey'[1] was a project to find Kuiper-Belt-Objects (KBOs). It ran from 1998 to 2003 and was coordinated by the National Optical Astronomy Observatory (NAOA)[2], a United States national observatory with four observatories within and outside the USA. One of the co-operating observatories is the Cerro Tololo Inter-American Observatory (CTIO)[3] in Chile.

At the CTIO, the 'Blanco' 4 m-telescope was used for the survey. Its 'Mosaic-2' camera could reach magnitude 23.5 in 4 minutes' exposure time. Also in the night from May 21 to 22, 2001, J. Elliot and L. Wasserman searched the ecliptic for KBOs with the huge CTIO-telescope.

As in every observing night, dozens of non-stellar objects were detected, mostly beyond the 20th magnitude.

As the scientists compared two images, captured on May 22, 01h19m and 03h 16 m Chile Standard Time, they saw a 'jumping' dot, an unknown object of 19th magnitude.

1 Principal Investigator: Robert L. Millis (Lowell). 'Deep-Ecliptic-Survey'-Website: https://web.archive.org/web/20040612003417/http://www.lowell.edu/Research/DES/
2 https://www.noao.edu/
3 http://www.ctio.noao.edu/noao/



Discovery image of Ixion. The tiny dot had moved a few arcseconds within two hours. Image: J. Elliot, L. Wasserman, NOAO/AURA/NSF

For a KBO, the 'dot' was relatively bright. After the realisation of finding something interesting, other observatories were involved. The Las Campanas Observatory made another 9 observations from June 9th to 12th. Also the Lowell Observatory, Anderson Mesa Station, made four observations on June 19th and 20th. All measured positions of the object were reported to the Minor Planet Center (MPC). It assigned the provisional designation '2001 KX_{76}' to the new object.
As in most such cases, 2001 KX_{76} had been observed prior to the actual discovery. The MPC lists 10 observations[4] of this object between 1982 and 2000. Fortunately, this made the arc of observation large enough to calculate an orbit quite quickly. Already on March 28, 2002, the MPC announced in Minor Planet Circular 45236: that 2001 KX_{76} is now named (28978) Ixion.

An ‚Ixion' in the material world. Image: N. Wuensche

The name 'Ixion' comes from Greek mythology: Ixion tried to win the love of Hera, but Zeus thwarted this by creating the cloud Nephele, which resembled Hera and by whom Ixion fathered the Centaurs. For his crimes Ixion was bound to a wheel that turns forever in the underworld.[5]
Also in the material world, Ixion is a popular name: For 91 years (1919-2010), Ixion was a well-known company in Germany that made drills for the metal-working industry.

Orbit

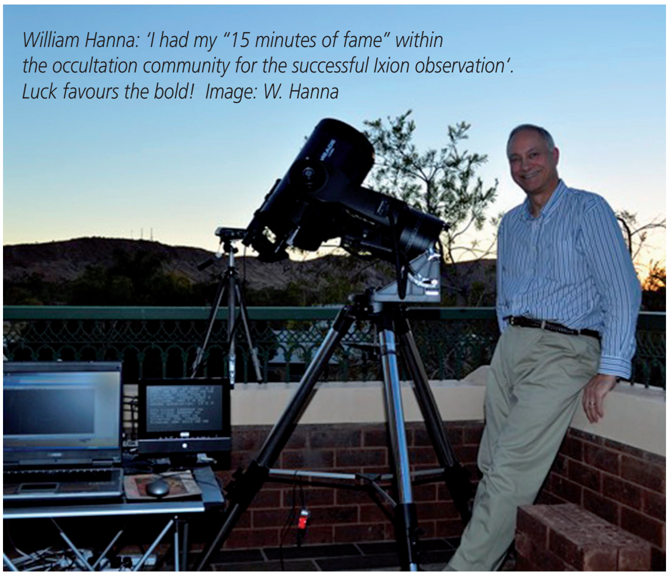
Ixion's perihelion is slightly inside Neptune's orbit (Neptune's aphelion: 30.33 AU). Ixion's orbit is that of a 'Plutino'. They form their own class of objects that are in a 2:3 orbital resonance with Neptune. The term is obviously derived from the dwarf planet Pluto, the first and the largest Plutino discovered. The Plutinos are the largest group of resonant Trans-Neptunian Objects (TNOs). Today, 241 Plutinos and 103 possible Plutinos are known.[6]

Orbit, FIRST FINDINGS	
Aphelion	49.256 AU
Perihelion	30.071 AU
Semi-major axis	39.664 AU
Eccentricity	0.2418
Orbital period	249.80 yr
Inclination	19.587°

Size and Surface

One of the more recent findings from both space probes and observations (including occultations) of the minor bodies of the solar system is that nothing is quite like it seems. The diversity of the bodies surpasses everything scientists could have imagined in recent decades.
As of 2001, Ixion was the brightest of all known Kuiper Belt Objects. So, Ixion was originally estimated to be similar in size to dwarf planet Ceres (946 km mean diameter) or even larger.
This made Ixion something special and it became the target of investigations by many groups of scientists with the most powerful telescopes available.
Ten years later, Ixion was among the TNOs investigated in the "TNOs are Cool!" project. With combined observations of Ixion by the Herschel Space Telescope and Spitzer Space Telescope in the far-infrared, its size was found to 617 km.[7] Ixion had shrunk overnight by one third!
The newly found size leads to an unusually high albedo of >0.15.

4 https://minorplanetcenter.net/db_search/show_object?object_id=28978 5 Minor Planet Circ. 45236
5 Minor Planet Circ. 45236
6 http://www.johnstonsarchive.net/astro/tnos.html
7 Astronomy & Astropysics, 557, A60 (2013). https://www.aanda.org/articles/aa/pdf/2013/09/aa22047-13.pdf



William Hanna: 'I had my "15 minutes of fame" within the occultation community for the successful Ixion observation'. Luck favours the bold! Image: W. Hanna

There is no sharp line between asteroids and comets. Could Ixion be a 'sleeping' comet? O. Lorin and P. Rousselot from the University of Franche-Comté searched for evidence of a dust coma around Ixion, using the 3.5 m- and one of the 8 m-telescopes of the European Southern Observatory (ESO)[8]. They did not detect a coma – it would have made Ixion a comet. But, Ixion is currently about 41 AU from the Sun, beyond its semi-major axis, on its way to aphelion. It is possible that Ixion could develop a coma or a temporary atmosphere when it is closer to perihelion, maybe in a century from now...

Observations with ESO's 3.5 m NTT revealed an absorption feature at the wavelength of 0.8 µm in Ixion's spectrum, which could be tentatively attributed to the alteration of surface materials by water.[9] In the near-infrared the spectrum of Ixion is flat and featureless.

Ixion is a medium red object, typical for the primordial objects from the formation period of the Solar System. But its spectrum is not like other TNOs – every one of these cosmic bodies is an individual.

Water ice absorption bands at 1.5 and 2 µm are absent. Both visible and infrared spectroscopic results indicate that Ixion's surface is a mixture of water ice, dark carbon and a mix of various tholins, which is a widespread reddish heteropolymer formed by solar and cosmic radiation of clathrates of water and organic compounds.[10]

Dwarf or Minor Planet?

Planetary scientists worked out a number of minor planets that probably fit into the definition of a Dwarf Planet by the International Astronomical Union (IAU).

Ixion is mostly described to be 'very likely a dwarf planet, but not officially classified as such'. Gonzalo Tankredi listed Ixion in 2008 as a dwarf planet of "Case II – Sphere or MacLaurin-ellipsoid with small albedo spots"[11].

Mike Brown from Caltech lists Ixion[12] as a dwarf planet candidate with rank 21 of 37 (10 objects which are nearly certainly and 27 objects which are highly likely to be dwarf planets).

But, the IAU is very hesitant in naming new dwarf planets. Until a decision is made, Ixion remains a 'minor planet'.

Occultations by Ixion

In 2001, Ixion's diameter was derived from its brightness using an estimated value of its albedo. A much better method to get reliable values for size and shape are observations of stellar occultations by minor planets.

There were a number of attempts to observe stellar occultations by Ixion. Predictions were provided by the Rio group (R. Vieira-Martins et al); the observation attempts were supported by local organisations. Two observations were made in 2012 and 2013 in Europe, another two in 2013 and 2014 in Australia. With one exception, no occultation could be detected.

Only one observation with just one chord was successful, observed on June 24th, 2014, by William Hanna in Australia. This observation was coordinated by the RASNZ[13]. Unfortunately, one chord is far too few to give any information about the size of the distant traveller.

Lucky Star | l'Observatoire de Paris | LESIA
Laboratoire d'Études Spatiales et d'Instrumentation en Astrophysique

ERC Project Lucky Star

Since 2015, the 'Lucky Star Project'[14] funded by a European Research Council (ERC) grant, located at the LESIA/l'Observatoire de Paris and chaired by Bruno Sicardy, provides predictions for occultations by TNOs and Centaurs and collects and processes the results of worldwide observations. The Lucky Star Project continues the fruitful world-wide cooperation of amateur and professional astronomers.

Occultation Observations by Ixion and by Any Other TNO Are Highly Appreciated

In 2018, all occultations by Ixion can only be seen from the Earth's southern hemisphere (one exception: Hawaii on Jun 13; star 16.6 mag). The observations mostly require larger telescopes due to the very faint target stars. You can find the predictions at: http://lesia.obspm.fr/lucky-star/predictions/.

On its discovery at a declination of -19°14', Ixion was already well into the southern sky. In 2018, Ixion will reach opposition on June 17 at a declination of -28.8°. The orbital motion drives Ixion more and more into southern regions of the sky. Around 2039, the southern declination peaks at -35.5°.

Most European and U.S.-observers are out of the race by now. Now it's up to the observers in the southern hemisphere to uncover Ixion's true size and shape.

8 'Search for cometary activity in…'; Mon. Not. R. Astron. Soc. 376, 881–889 (2007)
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10 H. Boehnhardt et al: Surface characterization of 28978 Ixion; A&A 415, L21–L25 (2004)
11 https://www.lpi.usra.edu/meetings/acm2008/pdf/8261.pdf, see also: https://www.cambridge.org/core/services/aop-cambridge-core/content/view/S1743921310001717
12 http://web.gps.caltech.edu/~mbrown/dps.html
13 Royal Astronomical Society of New Zealand. It coordinates observations in New Zealand and Australia.
14 http://cordis.europa.eu/project/rcn/199073_en.html

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

Imprint

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

Publisher: IOTA/ES, Am Brombeerhag 13, 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 2018-3: June 15

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

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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

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