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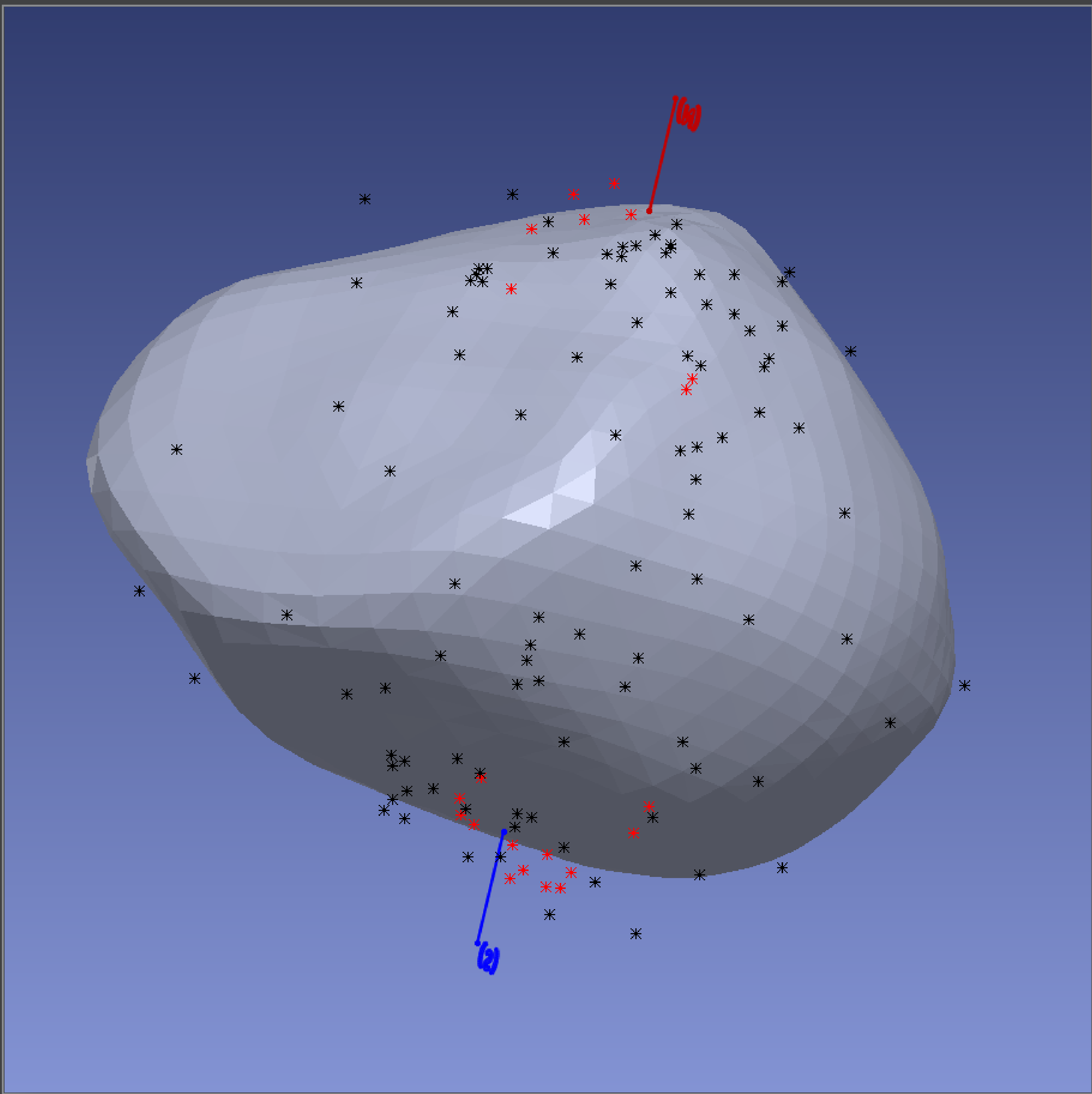

Validation of 3D Asteroid Profiles with Stellar Occultation Observations

Dear reader,

Stellar occultations have fascinated people around the world for centuries. Observations and documentation of these events have changed a lot over time. This issue of the *Journal for Occultation Astronomy* presents, on the one hand, reports of ancient observations of solar eclipses and lunar occultations and, on the other hand, gives us an insight into how today observations recorded during different events can be merged and used to validate 3D models of asteroids.

Nowadays, observers no longer need to be in an occultation path in person to take measurements. The remote control of telescopes allows us to observe occultations in the sky of a distant country, as shown by the report of the occultation of a star by the Galilean moon Europa in the shadow of Jupiter.

The tiny asteroid/extinct comet (5335) Damocles, profiled in our *Beyond Jupiter* series, demonstrates the importance of accurate astrometric measurements for highly precise predictions of the shadow paths in advance of occultation observations.

And we commemorate in this issue the late John Talbot, the first real Regional Reporting Coordinator across Australia and New Zealand.

There is much to do for the global community of occultation observers - dig through historical archives, improve predictions with astrometric measurements, store our observational data and take the analysis of this data to the next level. A lively exchange on these topics will be offered by the meetings in 2023, be it at the 2023 IOTA Annual Meeting in July or ESOP XLII in September in Northern Ireland.

Oliver Klös

Public Relations, IOTA/ES

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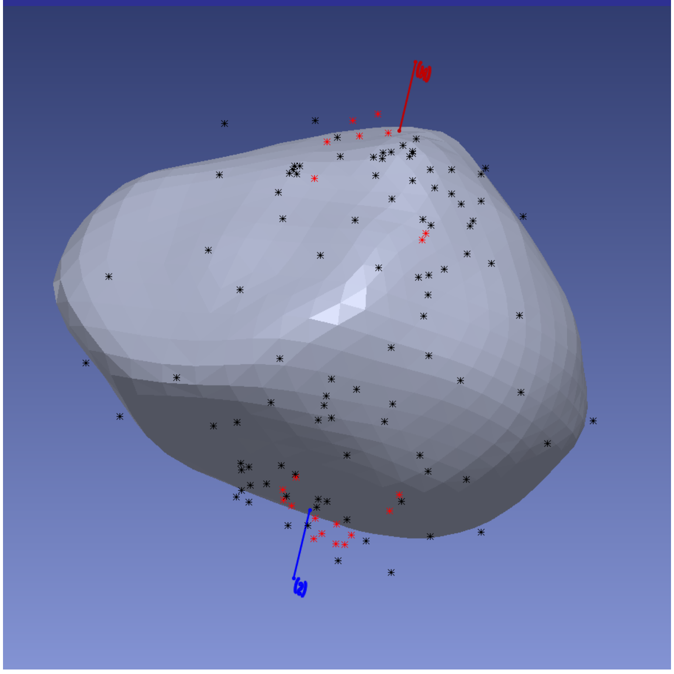
In this Issue:

COVER



24 reported occultation events of asteroid (41) Daphne were combined and spatially positioned as measuring points on a 3D model from the Database of Asteroid Models from Inversion Techniques (DAMIT) with a commercial computer aided design program. The combination of models and occultation observations can optimise or adjust the size as well as the shape of asteroid models in the future. (Graphic: F. Schaffer, K. Guhl with data from DAMIT and *Occult V4*)

Copyright Transfer

Rules for Authors

In order to optimise the publishing process, certain rules for authors have been set up how to write an article for *JOA*. They can be found in "How to Write an Article for *JOA*" published in this *JOA* issue (2018-3) on page 13. They also can be found on our webpage at https://www.iota-es.de/how2write_joa.html.

Journal for
Occultation Astronomy

In the Shadow of Jupiter – Europa Occults 10.5 mag Star

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ABSTRACT: On 2022 June 19, Jupiter's moon Europa occulted a 10.5 mag bright star. Normally, such an event would not be observable because of the large difference in brightness. But an extremely lucky coincidence made the observation possible anyway: Europa was just invisible in the shadow of Jupiter. The star, close to Jupiter, was thus obscured by the invisible Europa, for a whole of 100 seconds. Although there occurred still a number of problems, the observation was successful.

Introduction

Jupiter's moon Europa is currently of particular interest because ESA plans to send the Jupiter probe *JUICE* to the Galilean moons Europa, Ganymede and Callisto. The launch is planned for April 2023, followed by a swingby of the Moon, once of Venus, twice of Earth and finally the arrival at Jupiter in July 2031. Among other things, the aim is to investigate whether life is possible on Ganymede and Europa. The thickness of their ice crusts will also be measured. For this reason, the mission aims to obtain the most precise orbital data possible for Europa in advance. This is the background to the international campaign for this occultation by Europa. Further details on the *JUICE* space probe can be found in [1] and [2].

A Quick Start

The first information about the occultation event on 2022 June 19 early at 05:05 CEST came only on 16 June at 23:25 UTC via IOTAoccultations@groups.io. Immediately in the next morning the call went out to two fellow *IAS* members and fortunately we were still able to perform the necessary tests on the remaining two evenings.

The Observation

Unfortunately, the occultation could not be observed from Europe, but only in southern Africa. The *IAS Observatory* [3] at Hakos Astro-farm, Namibia, was even almost on the centre line of the predicted shadow path (Figure 1). Unfortunately, no one of us was at Hakos at this time. But there were two remote telescopes at Hakos, a 20" Newtonian f/3 of the *IAS* and a 10" Newtonian f/4 in the *Wolfatorium*, the private remote observatory of Wolf-Peter Hartmann. Sadly, previous tests showed that the 20" *IAS* remote Newtonian could not yet be used due to alignment problems.

Therefore, on the two previous evenings, tests were made with the remote telescope in the *Wolfatorium*. Ample experience had been gathered with deep sky astrophotography, but not with occultation work. With the available QHY268M camera and the *SharpCap* [5] acquisition software, we determined the appropriate values for exposure time and gain on other similar bright stars.

In remote mode, the latency time from Germany to Namibia is quite long at 200 ms making the work via a remote control

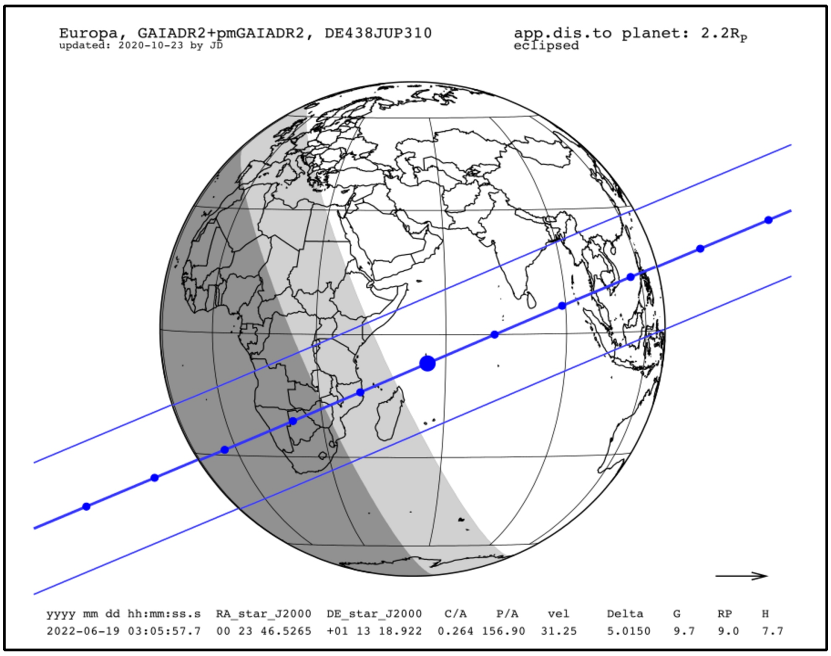

Figure 1. The shadow track of Jupiter's 3100 km moon Europa went across southern Africa. The IAS Observatory in Namibia was almost on the central line. [4]

software difficult. Especially with programmes like *SharpCap,* the user interface then reacts very sluggishly. In order to obtain the required exact times, the remote computer was synchronised with its *Windows 10* on-board resources via NTP shortly before the event. However, there were still stability problems in the interaction between *SharpCap* and the camera driver, possibly also caused by the computer's peculiarities. Only immediately before the event everything was ready again.

Jupiter's moon Europa should occult a star. This is a rare event and extremely rare when it should be a bright star. At least, the star of June 19 was 10.5 mag bright. However, this means that with the 5.8 mag bright Europa a drop in brightness of 1.3% should be measured (more precisely: for Europa + star vs. Europa alone), a mission impossible with the usual seeing. In the present case, however, the astronomers were incredibly lucky. At the time of the occultation, Europa was in the shadow of Jupiter so it was eclipsed and not visible! This resulted in the highly gratifying situation that the now easily detectable star disappeared completely. – Easily detectable? Well, seeing and measuring the star was still a challenge: it was in the scattered light of the 230,000 times brighter Jupiter and additionally in one of its spikes (Figure 2). In the captured images, the star was 15,200 ADU (brightness units), only slightly above the 15,000 ADU bright background and only being detectable thanks to the 16-bit camera and with the considerably stretched histogram.

Figure 3. This plot shows the light curves of Ganymede (yellow) and Io (green). The variability is caused by the air turbulence, the seeing. The blue line at the bottom is the light curve of the occulted star with a small dip in the middle

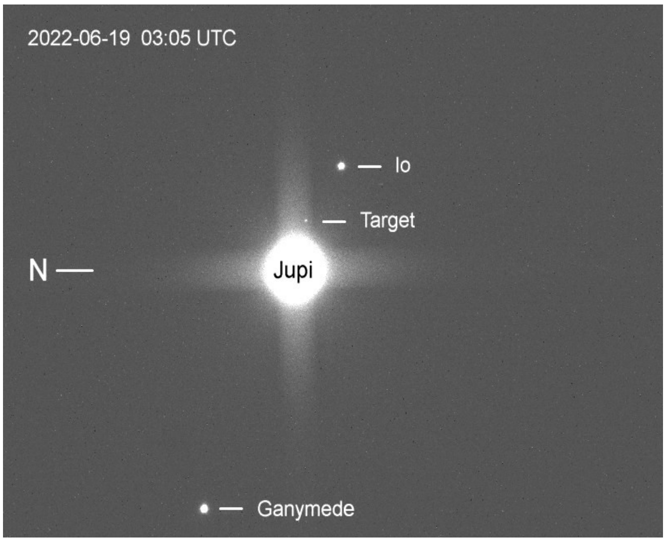

Figure 2. On this image you can see the observation situation. Besides the moons Io and Ganymede, the star to be occulted is seen just above the significantly overexposed Jupiter. Europa is invisible above the star in Jupiter's shadow.

With the data on the hard disk the evaluation could start. Figure 3 shows the light curves of Ganymede (yellow) and Io (green) in *Tangra* [6]. The variability is due to the air turbulence, the seeing. The blue line at the bottom is the light curve of the occulted star with the minimal dip in the middle.

In Figure 4, the light curves of Ganymede and Io are removed and the one of the occulted star is fitted to the image format; the background being subtracted. This image was a great and joyful surprise. Now one can see very nicely when the star is occulted by the invisible Europa for long 100.71 ± 0.2 s, predicted was a maximum of 99.9 s. A problem is always the choice of the exposure time to be adapted to the brightness and noise. We had chosen 400 ms. As one can see from the result, 200 ms with an even higher time resolution would have been fine, too.

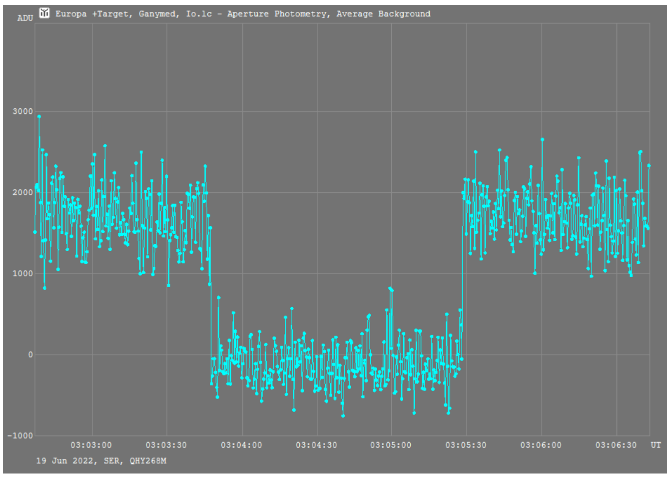

Figure 4. Here the light curves of Ganymede and Io have been removed and the one of the occulted star is fitted to the image format; the background being subtracted. Now one can see very clearly when the star was eclipsed by Jupiter's invisible moon Europa.

What was not mentioned in the report to Planoccult [7]: We had problems with the recording software. Instead of the set exposure time of 400 ms, *SharpCap* displayed a whole 5 s! On the other hand, about two new images per second appeared on the screen! Annoyingly, it was now too late for a *SharpCap* restart: we urgently needed to start recording. Start start start! Fortunately, the previously set 400 ms were found in the recorded SER video – at least approximately.

Approximately 400 ms: The recorded SER video also has a problem: A randomly selected sequence of 4 frames shows a Δt (exposure time + readout time) of 339 to 484 ms, displayed in the *SER Player* [8] at the bottom right. According to *Tangra*, the average exposure time is 418 ms. – What could be expected in this way for the times of disappearance and reappearance of the star?

The evaluation software *AOTA* [9] says *The time scale is totally unreliable*, but still provides occultation times. The alternative software *PyMovie/PyOTE* [10] shows countless vertical red lines inside the light curve meaning massive time errors as well. Nevertheless, both evaluation programs provide the same times for the disappearance (D) and reappearance (R) of the star. It is unclear what actually went wrong with the SER video. Presumably the file is simply corrupted. A FITS series instead of a SER video probably would have been a better choice.

Since *Tangra/AOTA* and *PyMovie/PyOTE* output the same values for D and R as mentioned, the report was sent to PLANOCCULT and IOTAoccultations [11] in this manner.

A Bit of a Numbers Game

With stellar occultation measurements, a resolution can be achieved that only can be reached with the Extremely Large Telescope [12] with its 39 m aperture. So the measurement accuracy is enormous. But how large is it exactly in the present case?

0.4 s / 100 s = 0.004 = exposure time / duration of occultation
= linear resolution / Europa diameter
= 0.4 % of the Europa diameter
0.004 x 3100 km = 12.4 km = linear resolution on Europa
12.4 km / 749 E6 km = 16 E-9 = angular resolution at Jupiter's distance
= 3.4 mas (milliarcseconds)

Linear resolutions for comparison:

384 000 km x 16 E-9 = 6 m = on the moon
8 000 km x 16 E-9 = 13 cm = Frankfurt / Hakos-Namibia
800 km x 16 E-9 = 13 mm = Freiburg / Berlin

With larger telescopes, i.e. more light and shorter exposure time, the obtained resolution would have been even larger. This numbers game shows which gigantic possibilities stellar occultation measurements offer!

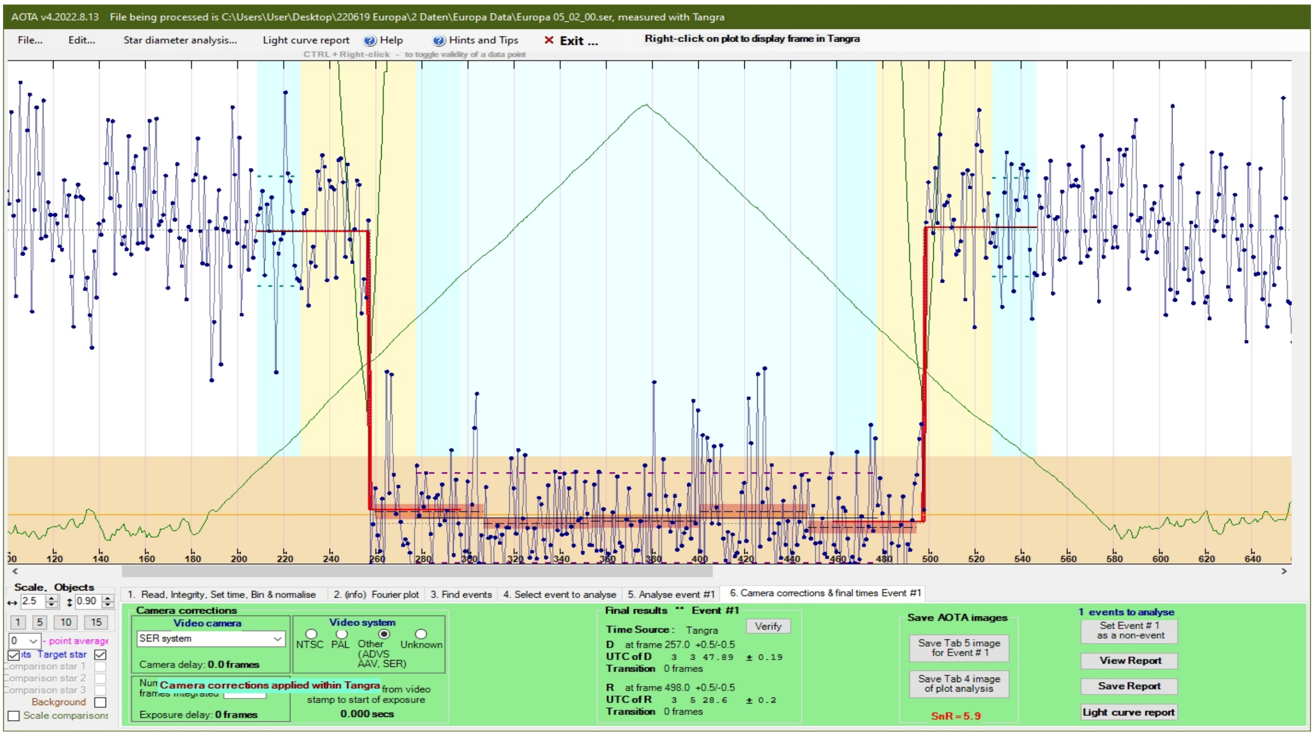

Figure 5. The evaluation software AOTA provides a 100.71 ± 0.2 s duration of the occultation.

ProAm Collaboration

The observation data also went to the Occultation Portal [13, 14], a professional astronomical institution, in which also the *Observatorio Nacional/MCTIC* in Rio de Janeiro, and LESIA / Lucky Star [15, 16] at the *Observatoire de Paris* are involved. This was another opportunity for us amateurs to contribute to science. It was again a successful teamwork in our group and a nice success on top.

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30 Years Ago – State-of-the-Art Observing Equipment in 1993

From *Occultation Newsletter* Vol. 5 No. 12:

NEW TECHNICAL DEVELOPMENTS

David W. Dunham

New CCD Camera: More sensitive CCD cameras are ecoming available, presumably based on the new Philips CD module. Sensitivities as low as 0.02 lux, able to mage 9th-mag. stars in real time with a 20-cm telescope, ave been advertized. This seems to be about a magnitude more sensitive than the original Philips modules that have been mentioned in previous ON's. Roger Tuthill sells such a camera for $645; see p. 106 of the April issue of Sky and Tel. A local IOTA member tried to order one, but Tuthill was temporarily out of stock. We will be interested in reporting on experiences with recording occultations with this camera in a future issue.

New GPS Receiver: Sony is advertizing a new small Global Positioning System receiver, claiming an accuracy of 50 feet, for about $600. I understand that the unit weighs less than a kilogram.

Audio with Portable VCR's: The current video walkmans do not have microphone input. They are as useful for field recording as camcorders operated in VCR mode, with video input from a more sensitive camera attached to the telescope and audio input amplified with a unit such as the VTAC described by Tom Campbell in previous issues, or a commercial amplifier/mixer such as the Omnitrak.

WWV on AM dial: One morning last month, our 2-year-old son inadvertantly tuned in WWV, coming in clearly at about 1630 kilohertz on our AM standard-broadcast radio. I have not heard the signal since, and wonder if it was caused by some rare beat propagation effect in the ionosphere, such as might be caused by a meteor, or was WWV being rebroadcast by someone? See ON 5 (10), p. 257 for a more reliable WWV receiver.

More technical developments from the past – ***The Occultation Newsletter Heritage Project***
https://www.iota-es.de/on_heritage.html

Journal for Occultation Astronomy

Ancient Reports of Eclipses and Occultations

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ABSTRACT: The article discusses a collection of the oldest records on the observation of eclipses and occultations, which was created thanks to many years of painstaking work of astronomers and historians. These records come from different cultural areas and require verification and interpretation. As it turns out, verified historical information is reliable and consistent with today's theory of eclipses and occultations.

Introduction

From time immemorial, phenomena in the sky have attracted people's attention. For a long time, however, eclipse and occultation phenomena were omens, used for creating portents about the fate of nations, countries and rulers. But, since some of these phenomena have been found to be periodic, their observations may have contributed to better predictions of them. To this day, we are looking for information about ancient observations, because they are valuable data to verify the theory of the motion of celestial bodies and the rotation of the Earth.

Collection of Old Observations and Their Characteristics

Only a small part of information about noticing eclipses and occultations in antiquity has survived to this day. Analyzing the preserved accounts, for example from Babylonia, one can estimate that we know only about 10% of all possible historical reports [1]. Moreover, the ones we know are often not original and are later copies. Presumably reliable data, however, come from around 700 BC.

The observation data available today comes mainly from three areas: Mesopotamia, China and Greece.

Mesopotamia

In the ruins of Babylon, many clay tablets, written in cuneiform script, have been discovered, which, thanks to many years of painstaking work of specialists, have been largely read. They include, among others texts written by astronomers of the time, as well as chronicle records. The astrological aspect can be clearly seen in them. Babylonian astronomers tried to record the maximum phases of eclipses, their moments in relation to sunrise and sunset, the duration, and visibility of stars and planets at that time. Situations where the predicted phenomenon did not take place were also marked. Despite the general knowledge of the eclipse cycles, it was impossible at the early times to take into account the numerous irregularities in the orbital motion of the Moon as well as the lunar parallax in a proper way. The errors of the predicted moments reached even several hours, so that eclipses took place, for example, below the horizon or in distant areas. In general, the quality of predictions were increasing in time as the ancient scientists gradually learned the secrets of celestial mechanics and came to recognize the causes of lunar and solar eclipses [1,2,3]. Anyway, the first dated and detailed account on a lunar eclipse observed in 721 BC in Babylon was given by Ptolemy in his "Almagest" (together with two other lunar eclipses), who probably had taken the data from Hipparchus.

First the three ancient eclipses which are selected from those observed in Babylon. The first is recorded as occurring in the first year of Mardokempad, Toth [month I] 29/30 in the Egyptian calendar [-720 March 19/20]. Let's see what some observation reports look like [1].

> *BC 721 March 19/20*
> *(i.e. -720 March 19/20);*
> *the lunar eclipse*
>
> *The eclipse began, it* [the report] *says, well over an hour after moonrise and was total. Now since the Sun was near the end of Pisces, and* [therefore] *the night was about 12 equinoctial hours long, the beginning of the eclipse occurred, clearly, 4 ½ equinoctial hours before midnight.*

In this and following reports, some original terms have been replaced by the modern ones (for instance names of constellations and celestial bodies, counting of time etc.). In order to obtain the consistency of the above record data with the calculations, the value ΔT of approximately 6 hours (!) is necessary to be considered.

BC 537 October 16/17
(i.e. -536 October 16/17);
the lunar eclipse

[King Cyrus, year 2], month VII [...it made] 2/3 of the disk towards totality. Not (yet) total, it set eclipsed... 5 deg. in front of the Pleiades eclipsed. (Began) at 14 deg. before sunrise.

The lunar eclipse was total in the forenoon UT, but this phase could not be observed at Babylon. The time unit used was one degree, i.e. 4 minutes (called "us" in the original), as the equivalent time of the Earth's rotation by 1 degree. The maximum phase probably came from a prediction, because only the beginning of the partial eclipse could be observed (and this was correctly noted).

BC 190 March 14
(-189 March 14);
the solar eclipse

Year 11 (Seleucid), king An[tiochus] month XII 29 solar eclipse beginning on the north-west side. In 15 deg. day [...] over a third of the disk was eclipsed. When it began bright, in 15 deg. of day from north-west to east it became bright. 30 deg. total duration. [during this eclipse] east (wind) went. During this eclipse [...] Venus, Mercury and Saturn [stood there]. Toward the end of becoming bright, Mars rose (?). The other planets did not stand there. (Began) at 30 deg. after sunrise.

The noted maximum phase was much smaller that the real one (about 0.8). The mentioned planets in fact were above the horizon but could not be seen in the sky with the naked eye; so this information was given for astrological purpose only.

Despite the analysis of the surviving documents that speak about a darkness that occurred during the day, only one total solar eclipse has been identified as having been observed with certainty at Babylon. It happened on -135 (136 BC) April 15 and its description was preserved on two different tablets:

SE 175 (Seleucid year 175), month XII.

The 29th, solar eclipse. When it began on the south-west side, in 18 deg. daytime in the morning it became entirely total (TIL ma TIL ti gar AN). (It began) at 24 deg. after sunrise.

SE 175, [king] Arsaces, [month XII].

The 29th , at 24 deg. after sunrise, solar eclipse; when it began on the south and west side, [...] [Ven]us, Mercury and the Normal Stars were visible; Jupiter and Mars, which were in their period of invisibility, were visible in its eclipse [...] it threw off (the shadow) from west and south to north and east; 35 deg. onset, maximal phase and clearing; in its eclipse, the north wind which was to set [to the west? side blew...].

The above description is absolutely credible. Today, we can even reconstruct its details (Figure 1,2).

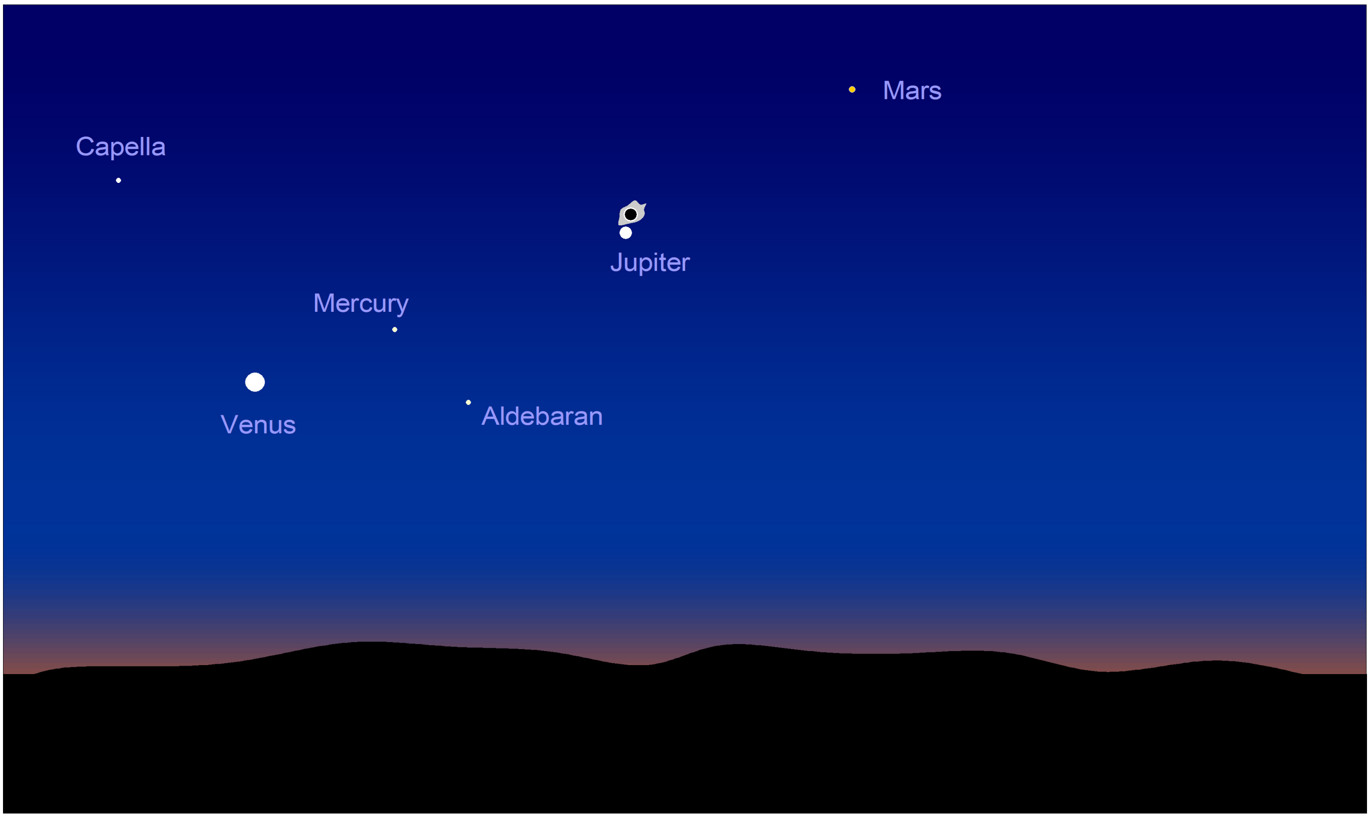

Figure 1. A view of the sky in Babylon during a total solar eclipse on -135 April 15.

Some examples of unsuccessful observations are accessible, too:

> BC 247 Sep 7
>
> [D]iary for the year 65 (Seleucid), king Antiochus ... [month V]. The 28th, 74 deg after sunrise, solar eclipse (at) 5 month's distance; when I watched I did not see it.

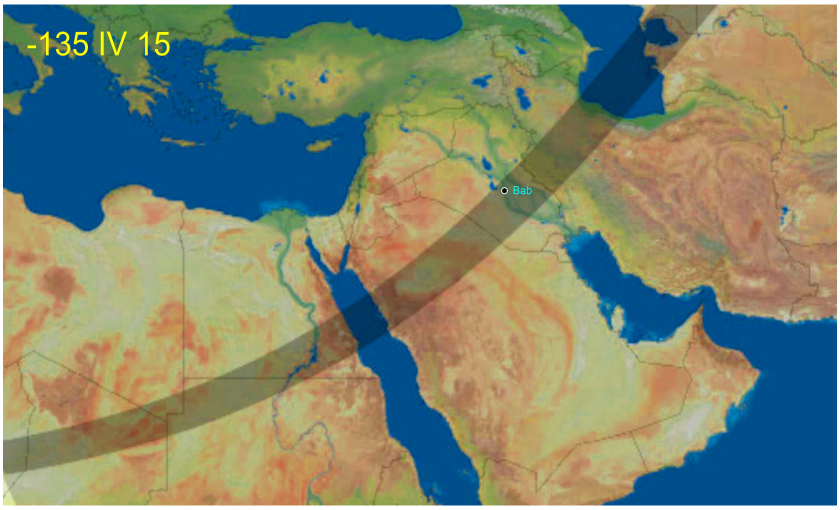

Figure 2. Path of totality on -135 April 15. The location of Babylon is marked.

Although this eclipse has been relatively well predicted in daytime, it was only seen from central up to north-east Asia as a partial one. So, the Babylonian astronomers evidently made an error of apparent lunar ecliptical latitude during the eclipse.

It should be added that even older records have been found concerning observed eclipses in Babylonia and Assyria, too. They even date back to 2000 - 1500 BC, however, they are brief and their dating is uncertain. Rather, they serve to verify the chronology of the Mesopotamian region [4]. We have a similar situation with several eclipses recorded in Egypt around 1000 BC and even earlier [5,6].

Lunar conjunctions with stars and planets were also recorded for astrological purposes. From time to time there were close conjunctions or even occultations. Gonzales has used 15 well preserved Babylonian lunar occultation reports both of planets and stars in the period of -418 to -79 [7].

Here are four examples. All the occultations cited below are in accordance with the present calculations (Figure 3).

-418 June 19:

Night of the 25th, last part of the night, Venus came close to the southern horn of the Moon.

-123 January 9:

[Night of the 5th, when beta] Persei culminated, [Saturn] entered the southern [horn] of the Moon.

-124 September 4:

[Night of the 25th, last part of the night, the Moon stood... behind Venus to] the east, (Venus) was set towards its northern horn, at 2/3 ? beru (= 20? deg) after sunrise, Venus entered the northern horn of the Moon; it did not... [...]

-84 January 10:

Night of the 16th, (when) Cancer [culminated, Jupiter entered the Moon;...; last part of the night, the Moon was 1/2 cubit...] rho Leonis, the Moon being 6 fingers high to the north, it stood 2/3 behind Jupiter to the east.

Figure 3. Four examples of ancient lunar occultations recorded at Babylon (see the text for details). This and subsequent graphics showing lunar occultations according to the Stellarium software.

By the first century BC, the Babylonian culture was already in decline. The last reliable report dates back to 66 BC and concerns the observation of a lunar eclipse on Dec 28/29.

Nevertheless, the Babylonian set of observations is the richest and the most detailed one. Stephenson has analyzed about 100 reports on lunar and solar eclipses and finally established credible values of ΔT; the most accurate data have been derived from observed eclipse contacts given in relation to sunrise and sunset. The ΔT values found using other kinds of eclipse observations are not so precise but are in agreement with the above ones.

China

The civilization of ancient China, similarly characterized by the belief in celestial omens, also brought numerous observations of eclipses and occultations. Ancient Chinese astronomers were especially obliged to observe solar eclipses as omens for the emperors. Solar eclipses caused by the sun-eating celestial dragon were important and difficult to predict, while lunar eclipses, recognized as periodic ones, were treated as ordinary phenomena and not systematically reported. The oldest reports on solar eclipses have not been preserved in the original (they were deliberately destroyed), but are credible, probably shortened copies. All accessible accounts on celestial phenomena noted in ancient China have been catalogued and published [8]. Of course, all of them have also been transformed into the Julian calendar and their observations sites have been identified.

The oldest record on a solar eclipse observed in China looks like this [1]:

> BC 709 July 17.
>
> Duke Huan, 3rd year, 7th month, day jen-ch'en [cyclical day number 29], the first day (of the month). The Sun was eclipsed and it was total.

The record is posted in a Chou dynasty chronicle called Spring and Autumns Annals (Ch'un-ch'iu) which has been compiled by the famous Confucius (Kong Fuzi);. The observation site was the capital Ch'u-fu (the present city of Qifu). So far, it is the oldest known credible record on a total solar eclipse on Earth (Figure 4).

Two other similar terse accounts of total solar eclipses seen at this city come from BC 601 September 20 and BC 549 June 19.

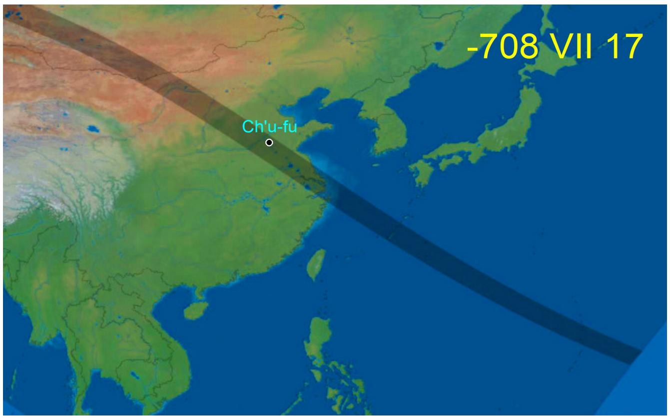

Figure 4. Path of totality on -708 July 17, which was observed at Ch'u-fu.

In the course of time, the records became a little bit detailed and also partial eclipses were noted:

> BC 28 June 19, observed at Chang-an (the present Xi'an).
>
> Ho-p'ing reign-period, first year, 4th month, day chi-hai [36], the last day of the month. The Sun was eclipsed; it was not complete and like a hook; it was 6 deg in Tungching... When the eclipse first began, it started from the south-west.

This record is posted in Han-shu, the history of the Han dynasty. Tung-ching is here a celestial mansion [lodge] "in charge of wine and food, the duty of the wife"... By the way, there was a clear link between astronomy and politics in China because a solar eclipse was treated as an omen for the present emperor. Sometimes we can find eclipse omens for phenomena that in fact never happened... And for a long time the early predictions of solar eclipses caused problems [9, 10].

Rough predictions of the timing of eclipses, based solely on observations of their cyclicity, both in China and Mesopotamia, often failed; eclipses did not occur at the expected times (sometimes, for example, the eclipsed object was below the horizon) or turned out to have a phase magnitude far from the predicted one. Some of the predicted eclipses did not take place at all.

About ninety occultations of various types have been noted in ancient China [11]. The first who draw attention to the ancient occultation observations was the French Jesuit Antoine Gaubil [12]. He found i.a. two lunar occultations – of Mars and Venus:

> Western Han Dynasty, the courtyard in Si-ganfou (Chang-an) of Shen-si.
>
> 1st year Ti-tsie (=69 BC), the first Moon, the day wuhao (=February 14) at of the 9th and 11th hours in the evening, Moon occulted (ate) Mars, inside the constellation Kio and Kang.

The occultation in fact took place in this night (disappearance past 10 pm of the local time (UT+7 hours) and reappearance one hour later); the place in the sky was correctly given in our constellations of Virgo and Libra (Figure 5).

> Eastern Tsin dynasty, the court at Kien-Kang (the present Nanjing), 5th year (361 AD),
>
> day yi-chou (March 20) at the chin hour (the time from 7 to 9 a.m.), the Moon eclipsed Venus in the constellation of Wei.

The occultation took place after sunrise but it could be spotted by a careful naked-eye observer as close to a grazing event (disappearance shortly past 8 am, and reappearance past 9 am) (Figure 5).

Figure 5. Two examples of ancient lunar occultations of Mars (top) and Venus (bottom) recorded in China.

The set of Chinese observations also contains many close conjunctions of planets with stars and mutual planetary conjunctions, 66 of which have been assessed as credible ones including 9 till 415 AD [9]. Because all were naked-eye observations, their value is limited. It is worth mentioning, however, that the medieval transit of Mars in front of Jupiter on 1170 September 12/13, observed by Gervase of Canterbury, was also recorded in China.

Greece

There is no doubt that the ancient Greeks played an important role in the development of astronomy. They also recorded a number of important observations of eclipses and occultations, and contributed to the development of the theory of eclipses. A mechanism whose task was to predict eclipses roughly was even found [13].

First account on the large solar eclipse we can find in the poem by Archilochus, who said that the Sun lost its brightness around noon. Unfortunately, his information is not dated, so one can only give possible dates for this phenomenon. The most probable one is 648 BC April 6, when the total or almost total eclipse could be observed over the Aegean Sea [1].

Another Greek poet gave similar information – Pindar of Thebes, whose account may be attributed to the total solar eclipse of 463 BC April 30. Let's mention, however, a next eclipse, although partial but according to a credible description by Thucydides left in his "History of the Peloponnesian War" and identified as occurred on 431 BC August 3 [1]:

> *The same summer, at the beginning of a new lunar month (the only time by the way which it appears possible), the Sun was eclipsed after noon. After it had assumed the form of a crescent and some of the stars had come out, it returned to its natural shape.*

Thucydides himself might have observed the eclipse at Athens. From the context it is clear that he knew the reasons for solar eclipses what had been explained by Anaxagoras around 450 BC. The Peloponnesian War began early in 431 BC. And only the visibility of stars was exaggerated.

The possible total eclipse has been mentioned by Diodorus Siculus in his "Library of History". He described the story of the Syracuse tyrant Agathocles, who was the eyewitness of sudden darkness with many stars seen in the sky caused by the solar eclipse during his sea voyage near Sicily. The credible date of the event has been established as 310 BC August 15.

One of the most intriguing eclipses is associated with Hipparchus, because from the observations, made from two different places, he was able to determine the distance of the Moon from the Earth. The original works of Hipparchus do not exist but we know the history of this eclipse from Ptolemy, Pappus and Cleomedes. Hipparchus knew that the eclipse was total at the Hellespont (the present Dardanelles) and reached its maximum phase of $^4/_5$ at Alexandria. Hence, knowing the distance from Hellespont to Alexandria (as 10,000 stades) and using simple geometrical considerations, he determined the distance of the Moon as 67 $^1/_3$ Earth radii. Two possible dates for the discussed eclipse can be taken into consideration: 190 BC March 14 and 129 BC November 20.

Thanks to Aristotle and his treatise "De caelo=On the sky" we have the first known record of a lunar occultation:

> *For we have seen the Moon, half full, pass beneath the planet Mars, which vanished on its shadow side and came forth by the bright and shining part.*

This event could be easily identified as happened on 357 BC May 4, (i.e. -356), in the lifetime of Aristotle (Figure 6). Hence he could easily infer that Mars is further away than the Moon.

Figure 6. First known recorded lunar occultation – the Moon at its first quarter occulted Mars as seen from Athens by Aristotle.

Ptolemy quoted in his Almagest several ancient observations of lunar occultations. Some of them were observed by Timocharis [14]:

> *At the beginning of the third hour, the Moon covered Spica with the middle of that edge of its disk which is towards the equinoctial rising point (i.e. the east), and that Spica, in passing through, cut off exactly the northern third of* [the Moon's] *diameter.*

The observation was performed on -293 March 9, from Alexandria. However, it is likely that he was not able to detect the disappearance at the bright lunar limb directly.

Timocharis also observed the occultation of β Scorpii on -294 December 21, and of the Pleiades on -282 January 29, as well as again of Spica on -282 November 9 (in this case a close appulse):

> *When as much as half an hour of the tenth hour had gone by and the Moon had risen above the horizon, Spica appeared exactly touching the northern point on* [the Moon]*.*

In fact, all the occultations mentioned above, are correctly recorded (Figure 7). In particular, there was no occultation of Spica as seen at Alexandria in -282.

Later, the only interesting lunar occultation was observed at Rome by Menelaus, when the Moon covered Spica on 98 AD January 11 [14]:

> *When the tenth hour* [of night] *was completed, Spica had been occulted by the Moon (for it could not be seen), but towards the end of the eleventh hour, it was seen in advance of the Moon's centre, equidistant from the* [two] *horns by an amount less than the Moon's diameter.*

As we can see, the phenomenon was not observed directly as dis– and reappearance of the star, obviously due to the brightness of the Moon.

Figure 7. Two lunar occultations of Spica recorded by Timocharis at Alexandria.

Conclusions

Careful search for past observations of eclipses and occultations and their detailed historical analysis allows for the collection of valuable cognitive material. On the one hand, we get to know people's reactions to these unusual events, and on the other hand, we collect material to test modern computational methods. Still, however, the search for ancient records cannot be considered complete.

Acknowledgements

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VAMORCAD – Validation of Asteroid Models by Occultation Results by Means of CAD

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ABSTRACT: The combination of 3D models of asteroids obtained from rotational light curve inversion with the measured times of disappearance and reappearance from stellar occultations is realised with a new ongoing project called VAMORCAD (Validation of Asteroid Models by Occultation Results by means of CAD – a Computer Aided Design program). Graphical data (3D models and images of chords) from two different databases (DAMIT and Occult V4) are read into a commercial CAD program and positioned and edited in relation to each other to scale. In the project the occultations data are centred and positioned to the centre of the asteroid model.
The result is a graphical representation of the asteroid model, in relation to all the occultations measured on it, in order to get a first impression of the spatial distribution of observations. Furthermore, automated calculations (e.g. shortest distances of the measurements to the model) as well as statistical evaluations are possible via a macro programming language embedded in the CAD program. These results can be used to optimise or adjust the size as well as the shape of the asteroid model.

Introduction

Shortly after the discovery of the first asteroids at the beginning of the 19th century, brightness changes were observed in asteroids. J. H. Schroeter explained this in [1] with the self-rotation of irregular bodies. The "light change" of the asteroids was systematically observed and published at the beginning of the 20th century. In [2], E. Ritter v. Oppolzer showed that (433) Eros performed brightness fluctuations of "almost one magnitude". The publication cites a telegraphic note by Valentiner confirming the changes in brightness with measurements taken with a visual photometer (footnote to [2], ibidem).

In [3] H. N. Russell started the first theoretical approach and discussed the possibility of modelling a body shape from a light curve of a rotational light change. He concluded that this is not possible because there are too many solutions to explain the light curve.

With new mathematical tools of light curve inversion, M. Kaasalainen showed that the problem is solvable provided that all the brightness changes are assumed to be due to shape and not to albedo variations or scattering changes on the surface and shapes are assumed to be convex, which are clear limitations. Another problem is that the objects may have satellites, eclipsing or not, which are not handled by these models. Since then, thousands of 3D models have been derived from light curves and are available in databases such as Database of Asteroid Models from Inversion Techniques (DAMIT) [4].

In reductions of stellar occultations by asteroids, the view of the body at the time of the observation is often made to fit the chords of the observations. Of course, these are always two-dimensional snapshots. With VAMORCAD, the possibility is created to position the observations spatially to the asteroid model.

Two-Dimensional Representation Up to Now

Since the first successful observations of stellar occultations by solar system bodies, the results have been graphically represented as "chords" in the fundamental plane. Here, a line true to time and position indicates the disappearance of the star to the observer. An attempt can be made to match an ellipse or the outline of an existing 3D model with the observations. An early evaluation of observations, some of them still visual, is shown in Figures 1a and 1b for asteroid (106) Dione. The first figure is from the original publication [5] and in the second figure J. Stamm has added an originally unreported observation by M. Ida from Japan [6].

At that time, only an attempt was made to describe the observations by fitting an ellipse. This ellipse represents the hypothetical small body. A method that is still used today when no 3D model is available. Improved star positions, more accurate ephemerides, the expansion of the observer network and the calculation of numerous 3D models have made the comparison of chords with the view of the 3D model the standard representation today.

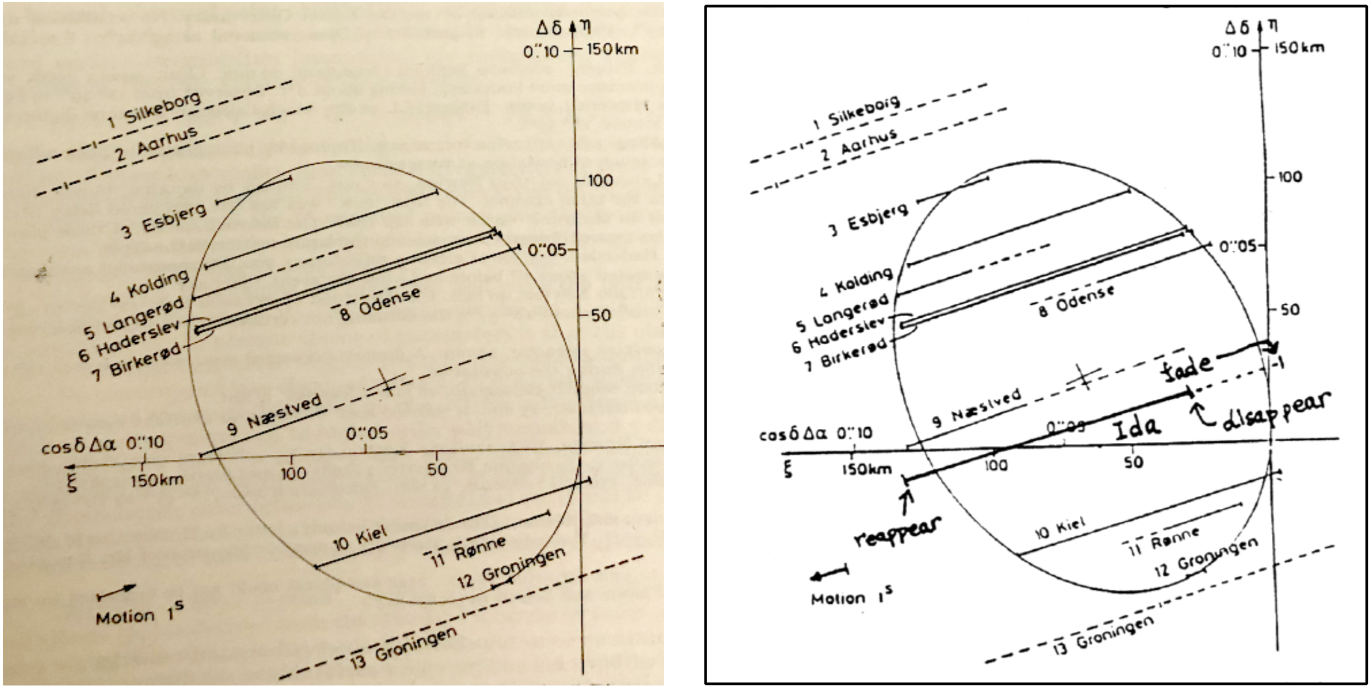

Figure 1a, b. Reduction of the occultation of AGK3 +25°0989 by (106) Dione in 1983 (left). Ten years later a positive chord measured by Japanese observer Miyoshi Ida was added (right). This chord was not accepted in 1983 due to the lack of confirming observations of this event in Japan [6]. Notice the wrong motion indicator in Figure 1a.

The DAMIT database [7], the most important database, contains more than 6000 shape models for more than 3400 solar system bodies. By entering the planet number and the date and time of observation, the view from Earth is calculated and made available as a graphic. These views can be compared with the observations in the software package *Occult V4* [8]. Figure 2 shows such a comparison for asteroid (409) Aspasia.

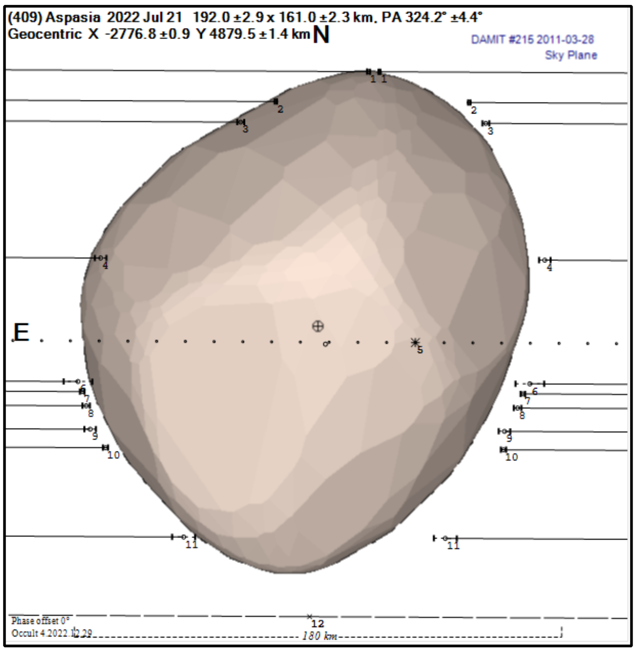

Figure 2. Results of stellar occultation observations by (409) Aspasia compared with DAMIT model calculated with [8].

The 3D models of the asteroids derived by inversion of light curves have essential information about the orientation and position of spin axis, but no information on the size of the celestial bodies. Besides the diameters determined from thermal observation, radar data and/or adaptive-optics images [9], the stellar occultation observations are an essential source for determining the size of the asteroid as a direct measurement method [10]. Unfortunately, the 3D models are not always a good fit with the occultation observations. A typical work on this is shown in [10]. Nevertheless, the individual representations of the observations naturally remain very different and do not give a coherence of the spatial representation of the observation points on the planetary model. Figure 3 shows the view of the 3D model of (130) Elektra (source DAMIT) with the observations of 2010 February 20 and 2021 February 21 according to [8].

Three-Dimensional Representation with CAD Programs

The use of CAD (Computer Aided Design) programmes in the industrial environment for product development or architecture has become an established standard. Due to various interfaces to production, calculation, simulation, documentation, etc., the application is highly effective and flexible to handle, but also very specialised for individual departments, which then also makes user training necessary. Simple 3D editing programmes (e.g. the open source program *MeshLAB*) can be used to illustrate 3D interaction (moving, changing appearance, etc.). Asteroid models (-ply,-obj) can also be loaded from e.g. the 3D Asteroid Catalogue maintained by G. Frieger [11].

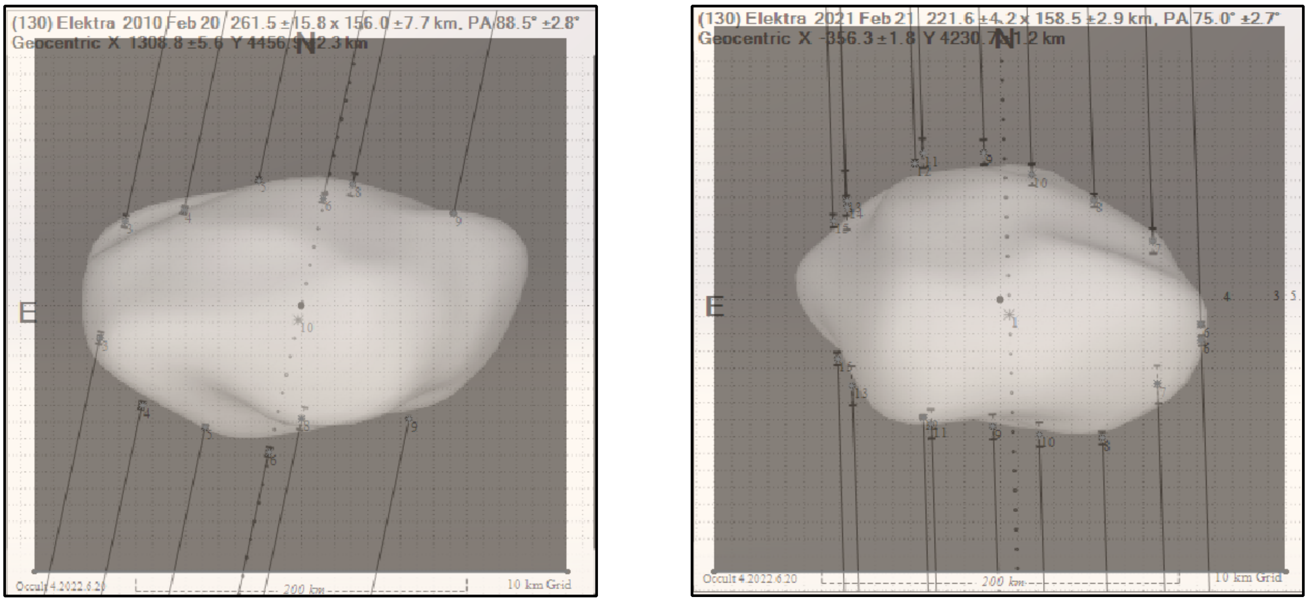

Figure 3. Occultation observations and DAMIT model of asteroid (130) Elektra for 2010 Feb 20 and 2021 Feb 21 from [7] and [8].

For VAMORCAD, the authors rely on a commercial CAD programme that covers 3D and freeform CAD. You can find a more detailed description and a list of CAD programmes at [12].

CAD programs are able to process different file formats, which allow 2D drawings and 3D models to be combined. With such help, the project VAMORCAD, links the published 3D models [7] with the observation results from [8]. The positions of the observation results are available as a two-dimensional representation. The base for the 2D graphic is the view to the asteroid for the observation data, calculated from DAMIT. In the processing, the 3D body is correctly positioned according to the ephemerides and brought congruent with a representation of the observation values as points from a fundamental plane. The observation values as start and end points of the chords become points in the plane.

For the transfer of the data, a plane is created that is parallel to the fundamental plane of the observation. This plane is positioned in the centre of the 3D model. The centre of the 3D model is given as the origin of the three-dimensional coordinate system in which the model is described. Like already mentioned, the correspondence of this body centre with the astrometric position of the body is a necessary compromise at the moment.

The data points are transferred now geometrically from the fundamental plane into the coordinate system of the body (Figure 4). Both planes are parallel and their centres are congruent.

For the export of a further observation the 3D model must be positioned in such a way that it corresponds to the position of the new observation. With this procedure on the model, all existing observations are transferred into the coordinate system of the body as measurement points.

Because each measuring point is now represented in XYZ-coordinates, the position to the body surface (closest distance) and/or the distance to any other point of interest can be calculated for each measuring point. Thus, the diameter of the model can be checked and adapted or the shape can be controlled in parts of the body or in total, if necessary.

Figure 5 shows the measuring points on the 3D model of the asteroid (41) Daphne. All the 24 reported events in [8] are shown in the model No. 1793 from DAMIT.

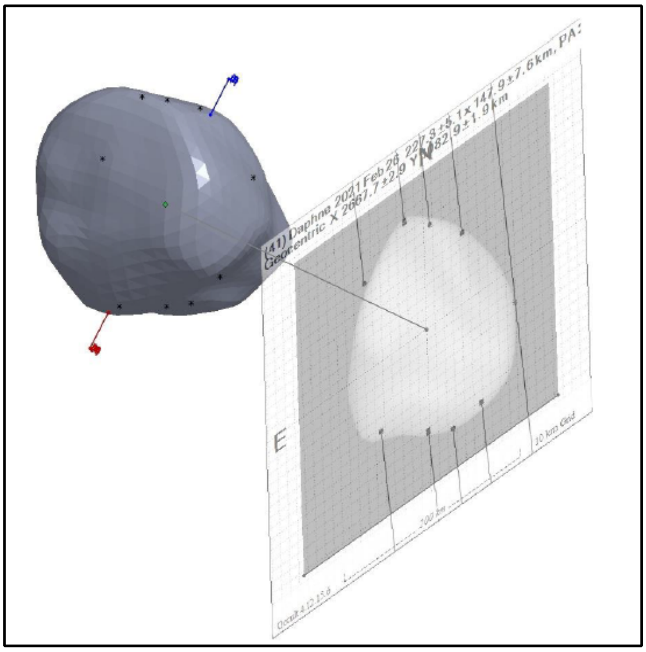

Figure 4. Transfer of observation data from the two-dimensional figure to the body (schematic).

The visualisation of the spatial representation of the 3D result is naturally difficult in this article. Therefore, we have saved a 3D model of (41) Daphne as an MP4 video file at:
https://www.iota-es.de/vamor/(41)_Simulation.mp4

The VAMORCAD project is a graphical method. The project is under development and first results are presented. Using a commercial CAD software, the data and graphics from the observation databases and the 3D simulations have to be manually assembled in steps.

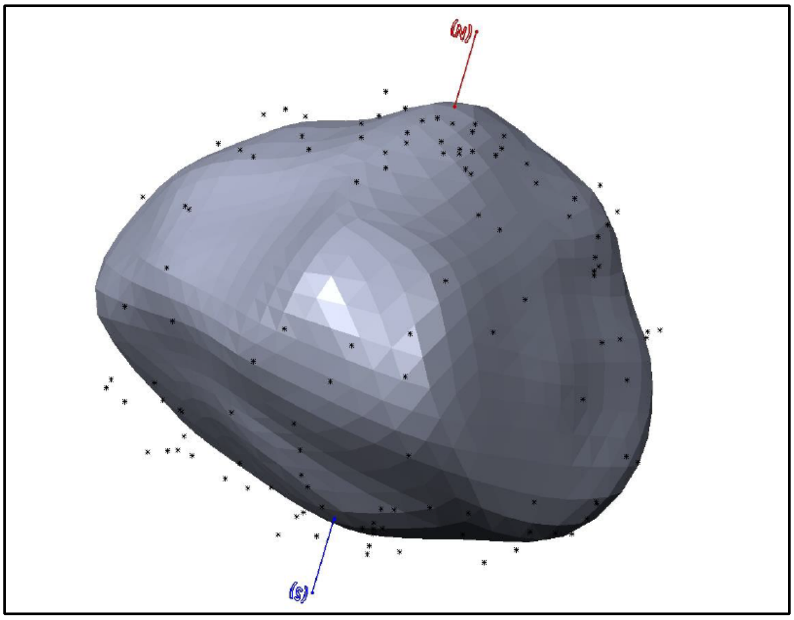

Figure 5. Spatial representation of 24 occultation events on the DAMIT-model for (41) Daphne.

Conclusion

Because of complexity and as survey article intended, specific questions and points cannot be considered in detail here. With the VAMORCAD project, observations can be spatially positioned as measuring points on 3D models of asteroids. If several measuring points represent the body differently in some regions, the 3D model can be adapted in size, too. The spatial representation can give the observer a more impressive view of the value of his observation. However, it remains a more complex process, because of adding different, scaled file formats together. The result depends on the quality of the model, too. In any case, it could be a further step for a gradual approach to the real shape and size of asteroid models.

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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 summarised 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 2023 March 28, the *Minor Planet Center* listed 1502 Centaurs and 3041 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. The table shows you where to find the objects presented in former JOA issues. (KG)

No.	Name	Author	Link to Issue
944	Hidalgo	Oliver Klös	JOA 1 2019
2060	Chiron	Mike Kretlow	JOA 2 2020
5145	Pholus	Konrad Guhl	JOA 2 2016
8405	Asbolus	Oliver Klös	JOA 3 2016
10370	Hylonome	Konrad Guhl	JOA 3 2021
10199	Chariklo	Mike Kretlow	JOA 1 2017
15760	Albion	Nikolai Wünsche	JOA 4 2019
15810	Awran	Konrad Guhl	JOA 4 2021
20000	Varuna	Andre Knöfel	JOA 2 2017
28728	Ixion	Nikolai Wünsche	JOA 2 2018
32532	Thereus	Konrad Guhl	JOA 1 2023
38628	Huya	Christian Weber	JOA 2-2021
47171	Lempo	Oliver Klös	JOA 4 2020
50000	Quaoar	Mike Kretlow	JOA 1 2020
54598	Bienor	Konrad Guhl	JOA 3 2018

In this Issue:

(5335) Damocles

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ABSTRACT: (5335) Damocles is a small object with orbital parameters similar to long period comets. It is suspected to be an inactive nucleus of a former comet and it is now the namesake of a class of objects of its own - the Damocloids. The asteroid / extinct comet is on its way towards the inner Solar System and will reach its next perihelion in 2031. Due to outdated astrometric observations of (5335) Damocles, predictions of future stellar occultations are currently not reliable. An astrometric observing campaign around the transit through its next perhelion could provide new orbital data for predictions of stellar occultations.

No.	Name	Author	Link to Issue
55576	Amycus	Konrad Guhl	JOA 1 2021
60558	Echeclus	Oliver Klös	JOA 4 2017
90377	Sedna	Mike Kretlow	JOA 3 2020
90482	Orcus	Konrad Guhl	JOA 3 2017
120347	Salacia	Andrea Guhl	JOA 4 2016
134340	Pluto	Andre Knöfel	JOA 2 2019
136108	Haumea	Mike Kretlow	JOA 3-2019
136199	Eris	Andre Knöfel	JOA 1 2018
136472	Makemake	Christoph Bittner	JOA 4 2018
174567	Varda	Christian Weber	JOA 2 2022
208996	2003 AZ_{84}	Sven Andersson	JOA 3 2022
341520	Mors-Somnus	Konrad Guhl	JOA 4 2022
-	2004 XR_{190}	Carles Schnabel	JOA 1 2022

The Discovery

On 1991 February 18, R. H. McNaught discovered this object on a photographic plate taken with the *UK Schmidt Telescope* at *Siding Spring Observatory*, Australia. It soon became obvious that it had a very unusual orbit with the third highest inclination to date for such an object and a large eccentricity for a minor planet. The orbital parameters fitted more to orbits of comets. The new object received the designation 1991 DA [1].

The Name

1991 DA was officially named on 1993 September 1 and was named (5335) Damocles [2]. In Greek mythology Damocles was a courtier in the court of Dionysius II, a ruler of Sicily in the 4th century B.C. Damocles envied the ruler's luxury and power. Dionysius offered to swap places with Damocles for one day. During this time Dionysius arranged that a sword would be hung above Damocles held only by a single hair of a horse's tail to demonstrate the possible danger from enemies of a ruler. Damocles understood the message and begged to be released to his former position (Figure 1). From this mythology the well-known phrase about the Sword of Damocles as the analogy of impending doom is frequently referred to even today.

Orbit and Physical Dimensions

The small object (diameter ~10 km) has a sidereal orbital period of 40.9 yrs. The orbit is highly inclined at 61.7 deg and has an eccentricity of 0.866 with a semi-major axis of 11.87 au.

Figure 1. Painting by Richard Westall, Ackland Museum, Chapel Hill, North Carolina, USA. Public-domain, copyright expired due to date of death of author (artist). No limits on reproduction are claimed by the museum for this painting - photography allowed.

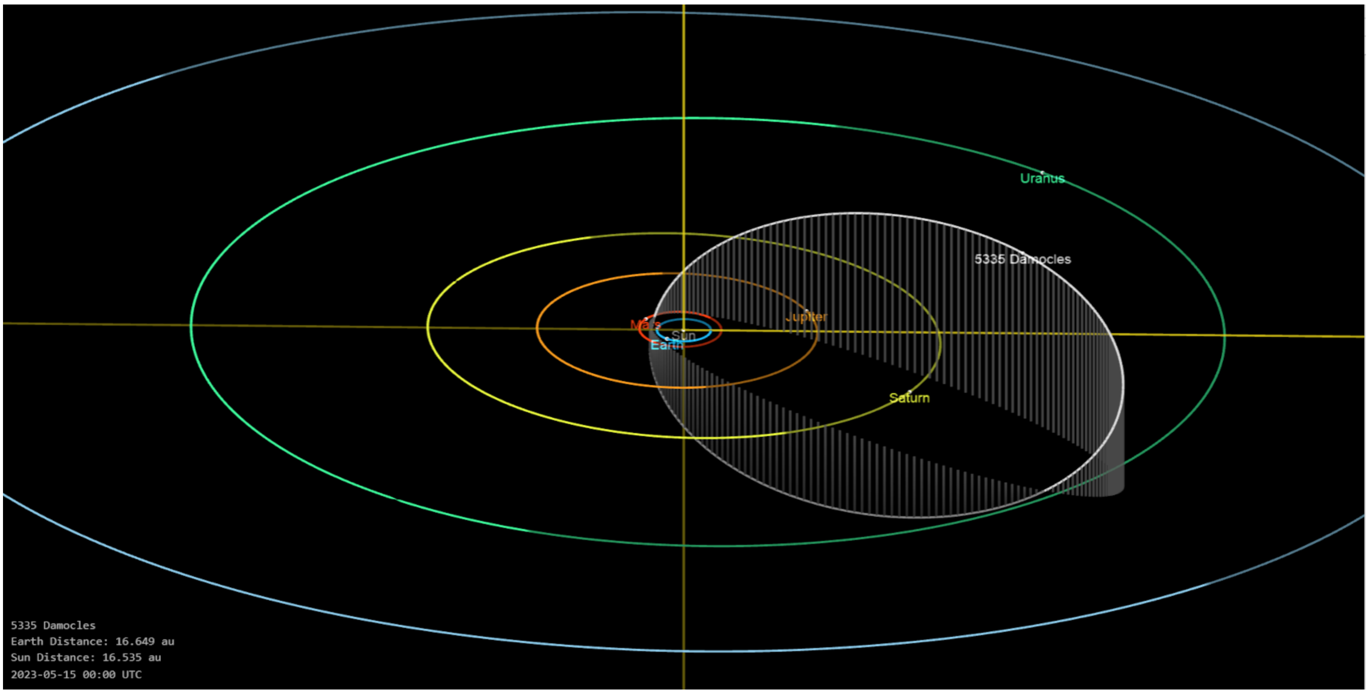

Figure 2. Orbit diagram and position of (5335) Damocles for 2023 April 15.
(Source: https://ssd.jpl.nasa.gov/tools/sbdb_lookup.html#/?sstr=5335&view=VOP)

(5335) Damocles' perihelion lies inside the orbit of Mars while at aphelion, the object will move beyond the orbit of Uranus. The minimum orbit intersection distances for Mars are 0.057 au and for Uranus 0.3 au, respectively [3]. The next close approaches to Uranus are on 2083 July 25 and 2167 March 7 with minimum distances of 0.67 au and 1.21 au, respectively [4].

The orbit of (5335) Damocles is stable for tens of thousands of years because its highly inclined orbit avoids closer approaches to Jupiter and Saturn [5]. Anyway, long term calculations by D. J. Asher et al. found a good probability that the object will become an Earth-crosser asteroid [6]. (5335) Damocles is now on its way to the inner Solar System at a distance of 16.65 au to Earth with an apparent magnitude as faint as magnitude 25.8V (2023 May 15) [3], (Figure 2). It will reach its next perihelion on 2031 August 23. At this time (5335) Damocles (apparent magnitude 16.8V) will be unobservable with an elongation from the Sun of only 10 degrees.

CCD images taken close to its last perihelion by J. English and K. Freeman [7] and by R. M. West and S. D. Ryder [8] showed no evidence of a coma. Spectral observations with the *Anglo-Australian Telescope* in March 1991 by D. Steel et al. confirmed the lack of comet-like emissions [9].

Classification

(5335) Damocles is now the namesake of a class of its own because it was the first asteroid found with such comet-like orbital parameters [10]. The so-called Damocloids is a group of asteroids which may be inactive nuclei of long-period and Halleytype comets which have lost all of their volatile materials [11]. The hypothesis is strengthened by the fact that some members of the Damocloids show a coma and were confirmed to be comets like C/2002 OG 108 (LONEOS) and C/2022 CE10 (LINEAR) [12].

David Jewitt defines the group as objects with a Jupiter Tisserand parameter of <= 2. A. Nakamura uses the orbital parameters q < 5.2 au, a > 8.0 au and e > 0.75 or alternatively i > 90 deg [13]. The group counted 279 candidates in January 2023 fitting the definition by Jewitt [14]. Some of the Damocloids have retrograde orbits. Damocloids tend to be consistent in size, albedo and lack of ultrared matter similar to the nuclei of Jupiter-family comets [10].

Future Stellar Occultations

The last astrometric observation found in the JPL database was made on 1992 August 22 [3].

Predictions of upcoming stellar occultations by this object calculated with *Occult V4 2023.1.9* [15] in January 2023 result in sub-second duration events with very large uncertainties of several Earth radii. It is highly unlikely that these occultations can be successfully observed.

The apparent magnitude of (5335) Damocles will brighten as it moves towards the inner Solar System. In 2027-2028 it will reach magnitude 24V and an astrometric observing campaign should then begin to improve the orbital parameters. With this new data, more reliable predictions of occultations could be made for the period around its perihelion in 2031.

Conclusion

Damocloids are very interesting objects from the outer Solar system. Are they just asteroids or inactive comets? (5335) Damocles is on its way to the inner Solar System to its perihelion in August 2031 and should be under observation.

The goals of these observations are to detect any comet-like activitiy, as well as to conduct astrometric observations to improve the orbital parameters. Occultation observers will use the new astrometric data to predict future stellar occultations, providing orbital data and an accurate profile of the Damocloid.

Acknowledgements

This work has made use of data from the European Space Agency (ESA) mission *Gaia* (https://www.cosmos.esa.int/gaia), processed by the Gaia Data Processing and Analysis Consortium (DPAC, https://www.cosmos.esa.int/web/gaia/dpac/consortium). Funding for the DPAC has been provided by national institutions, in particular the institutions participating in the Gaia Multilateral Agreement.

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Further Reading

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Announcement of 2023 IOTA Annual Meeting, July 15 & 16

On Saturday and Sunday, July 15 and 16, IOTA will hold its annual meeting online. As we did last year, we plan to have presentations each of those two days from 4:00 PM to 8:00 PM Eastern Daylight Time (that is, starting at 20:00 UT and lasting 4 hours). Please save the dates!

We plan to use Zoom again this year. The online address of the conference will be posted a day or two before the meeting. You are invited to attend.

As usual, we'll have a treasurer's report, a report of the best-observed occultations of the last year, some special reports about special observations that have been made in the last year, and a preview of the best events of the coming year. We also expect to have reports of updates to software, and advice about its use.

Please consider contributing a presentation of your own this year. We are interested in whatever you are doing with your telescopes or recording kits, helpful software or hardware, or special techniques. We are also interested in any interesting observations you have made.

If you would like to see a presentation about any particular matter, please let me know.

Roger Venable
Vice President, IOTA

Check for news: https://occultations.org/community/meetingsconferences/na/2023-iota/

Invitation to ESOP XLII on 2023 Sep 16-17 in Armagh, Northern Ireland

AOP and the City of Armagh as viewed from above. (Credit: Armagh City, Banbridge and Craigavon Borough Council. Used with permission)

The 42nd ESOP will take place at the *Armagh Observatory and Planetarium* (AOP) in the historic City of Armagh, Northern Ireland between Saturday 16th and Sunday 17th September 2023.

Armagh is a town of circa 25,000 in Northern Ireland - one of the four UK nations - located some 20 mi from the border with the Republic of Ireland (RoI). Armagh is considered the ecclesiastical capital of Ireland, was given city status in 1994 and is home to two cathedrals (both named St Patrick's!). Travel to and from Armagh is served by three major airports, Dublin International (DUB; 90 min by car), Belfast International (BFS; 45 min by car) and Belfast City (BHD; 70 min by car). Many low cost flights are available to these airports. Regular bus services exist between Armagh and Belfast or Dublin.

Register here:
https://www.armagh.space/meetings-conferences/esop42

The AOP venue combines a 230-yr old historic Observatory, home to the Dreyer New General Catalogue and the Shelton "Regulator" clock used by His Majesty King George III to time the 1769 Transit of Venus, with a modern astronomical research department and a state-of-the-art Planetarium facility dedicated to exposing and educating its approx. 15,000 annual visitors to space and astronomy. AOP is one of three historical observatories in Ireland, the others being *Birr Castle* (Co. Offaly, RoI) and *Dunsink Observatory* (Co. Dublin, RoI).

The Observatory Main Building & Library and Robinson Telescope Dome. In the foreground, we see the Human Orrery interactive exhibit. (Credit: Armagh Observatory and Planetarium. Used with permission)

In addition to these sites of astronomical interest, the island offers a wide variety of sighteeing destinations to the casual visitor, such as the Antrim coast and Giant's Causeway, the Titanic Quarter in Belfast or the Sperrin & Mourne Mountain ranges.

A social programme will be available following the meeting.

Apostolos Christou
Armagh Observatory and Planetarium, LOC

John Talbot †

It is with heavy heart that I report that John Talbot of Waikanae Beach, New Zealand passed away on the 2nd March, aged 79 years.

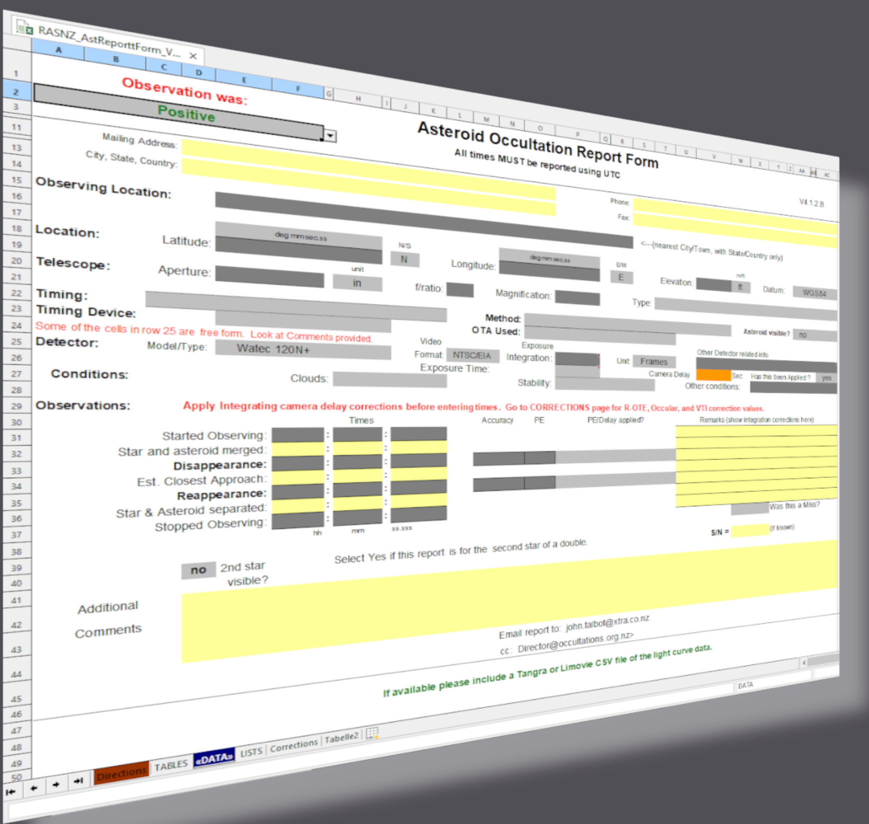
John came to the occultation scene at a critical time as the volume of asteroidal occultation results were starting to increase to the point of needing a structured and coordinated process. As well as being a successful observer, he brought his professional scientist background to develop the processes as the first real Regional Reporting Coordinator across New Zealand and Australia.

That Excel spreadsheet familiar to Australasian and North American observers was but one of John's efforts. His careful documentation of processes allowed a pretty seamless transition to myself when John's health failed him in 2015. His efforts and contributions were recognised as one of the joint recipients of the *Homer F. DaBoll Award* in 2017.

John was a major contributor to the organisation of TTSO meetings within New Zealand and was always there with good advice and humour on general organisational matters. It was great to catch up with John and Ann at our last physical TTSO in New Plymouth in 2019.

He will be missed ...

Steve Kerr
Director, Trans-Tasman Occultation Alliance



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Occultation Astronomy

IOTA's Mission

The International Occultation Timing Association, Inc was established to encourage and facilitate the observation of occultations and eclipses It provides predictions for grazing occultations of stars by the Moon and predictions for occultations of stars by asteroids and planets, information on observing equipment and techniques, and reports to the members of observations made.

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These sites contain information about the organisation known as IOTA and provide information about joining.

The main page of occultations.org provides links to IOTA's major technical sites, as well as to the major IOTA sections, including those in Europe, Middle East, Australia/New Zealand, and South America.

The technical sites hold definitions and information about all issues of occultation methods. It contains also results for all different phenomena. Occultations by the Moon, by planets, asteroids and TNOs are presented. Solar eclipses as a special kind of occultation can be found there as well results of other timely phenomena such as mutual events of satellites and lunar meteor impact flashes.

IOTA and IOTA/ES have an on-line archive of all issues of Occultation Newsletter, IOTA'S predecessor to JOA.

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