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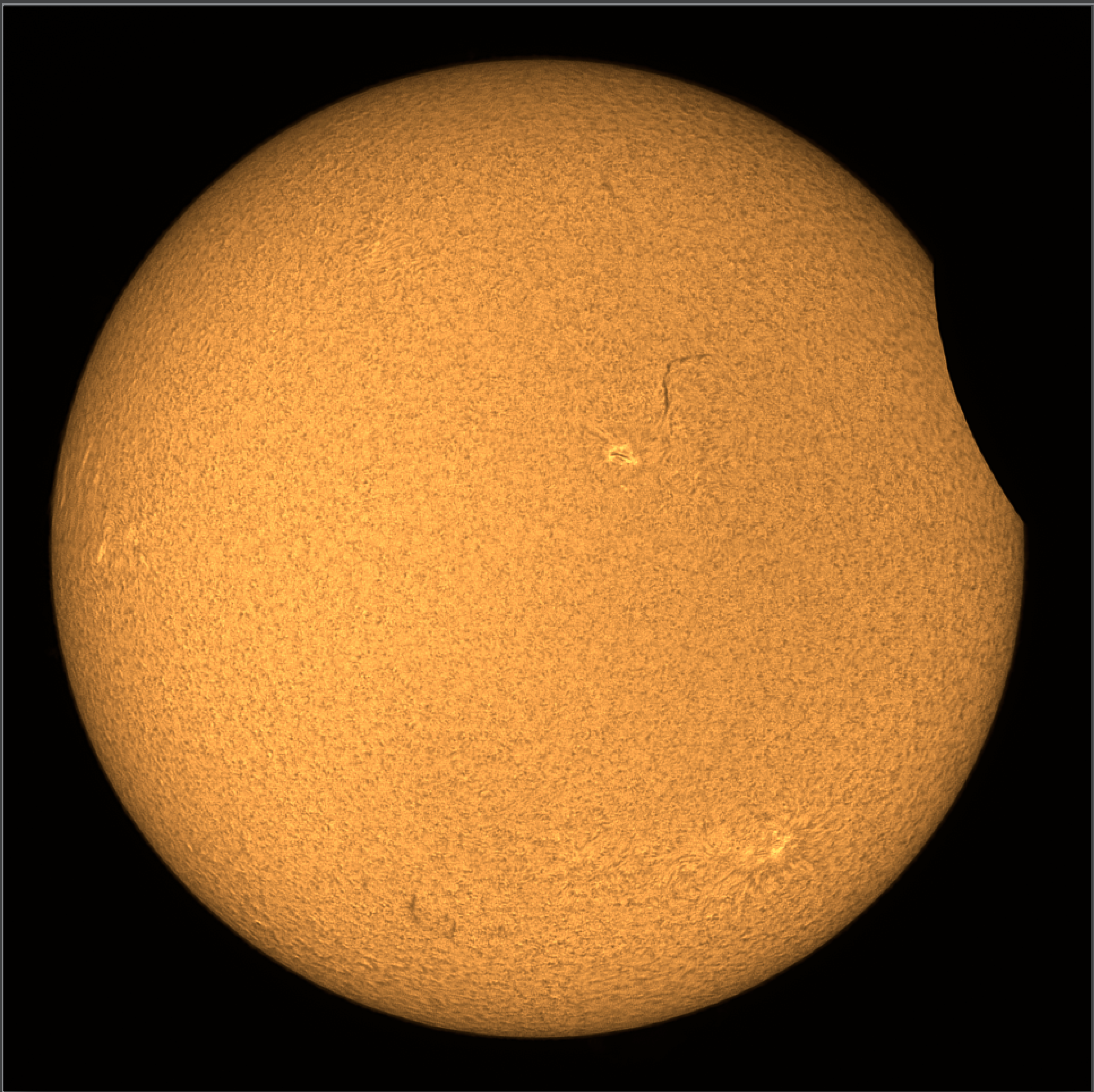


Solar Eclipses and the Rotation of the Earth

Dear reader,

a new JOA - I hope you agree that our editorial team has done another fine job. Our authors report on their activities in various areas, from classification in history to observational work to an unusual method of measurement of solar radiant power during a solar eclipse. Of course, our "Beyond Jupiter" series, which has been running for several years, will continue.

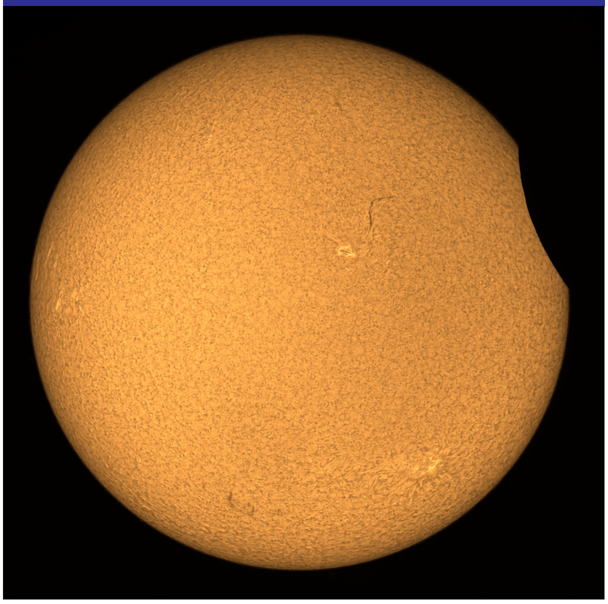
For me, a new "Dear reader" always means taking stock: What is going well and what can be improved? The observation of stellar occultations by minor planets is going very well as a routine; measurements are successful almost daily. New, exciting expeditions such as to observe occultations by Trojans, Centaurs and comet nuclei are in preparation. The ESOP was successful (see p. 22) and on Twitter more than 320 interested people follow IOTA/ES. They have received over 900 messages. This way, we are also networking with other astronomers.

But there is still a lot to do! We need a worldwide uniform web-based recording tool of observation results. We need to do more research on our data and we need to make our work even better known! In this sense, friends of occultation astronomy, help us!

Konrad Guhl

Konrad Guhl
President of IOTA/ES

COVER



This colourised H-Alpha image of the partial solar eclipse of 2021 June 10 was recorded at 09:32 UT west of Frankfurt am Main, Germany, with a Lunt LS50THa/B600PS telescope and a QHY-5L-IIM camera. Image: O. Klös

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In this Issue:

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 http://www.iota-es.de/how2write_joa.html .

Journal for Occultation Astronomy

How the Results of Observations of Occultations and Eclipses Reflect the Rotation of the Earth?

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ABSTRACT: Historical observations of occultations and eclipses allow us to verify the theory of the orbital motion of the Moon and Earth, as well as the rotation of the Earth. Moreover, this verification is the only one possible in view of the complexity of the factors influencing the rotation of the Earth. Among these factors, tidal effects dominate, but careful analysis of historical observations clearly reveals the presence of other causes.

The Rotation of the Earth and the Time Scales

For a long time, the rotation of the Earth was considered to be stable and was used to measure time. In this way, Universal Time (UT) was defined, related to the average length of the solar day. This timescale was not discussed until the beginning of the 20th century, and an attentive observer, e.g. in the 19th century, equipped with a precise clock, could not challenge Universal Time as a time scale based on his own observations of the length of the mean solar day. Finally, however, it turned out that the Earth's rotation time was not constant, and in the mid-20th century ephemeris time (ET) was introduced, related to the Earth's orbital motion and the Moon's orbital motion around the Earth, finally replaced in 1984 by Terrestial Dynamical Time (TDT), related to the atomic time scale (TAI), and at present shortly called Terrestial Time (TT).

Long-Term Changes in the Rotation of the Earth

Nowadays, accurate timing of occultations allows us to track the compliance of observations with ephemeris, taking into account various corrections to the theories of the motion of Solar System bodies, including minor irregularities of the Earth's rotation. But the question is, how to recognize the rate of rotation of the Earth in distant epochs? This cannot be precisely determined theoretically, although it can be done for some of the effects related to the slowing down of the Earth's spin.

It turns out that, first of all, it is necessary to analyse the long-term dynamic behaviour of the Earth-Moon system. It follows from the principle of conservation of energy (as angular momentum) that the retardation of the Earth's spin due to dissipation of energy during tides (both lunar and solar) must cause the so called secular acceleration of the Moon's orbital motion. This phenomenon, in turn, causes the Moon's distance from Earth to increase. Confirmation of this fact, for obvious reasons, was not possible before the implementation of Earth-Moon distance measurements thanks to the Apollo missions in 1969 and 1971.

According to Christodoulidis et al. (1988) [1] there is a strict relationship between two basic parameters: secular acceleration of the Moon, **n**, and the retardation of the Earth's spin, Ω_{tidal}. Taking the currently found and assumed as constant value **n** = 26.0″cy^{-2} (cy≡century), it is obtained that

$$\Omega_{tidal} = (-6.20 \pm 0.38) \times 10^{-22} \text{ rad s}^{-2}$$

whence the length of the day should accordingly increase by 2.3 ms per century. The corresponding relationship between the UT and TT time scales is as follows [2, 3]:

$$TT\text{-}UT = \Delta T_{tidal} = +(42 \pm 2)\, t^2 \text{ [s]},$$

where t is given in centuries counted from the year 1825. Newer analyses by Williams and Boggs gave the first factor in the above formula as +(43.7±0.2) [4].

The first approximation in analyses of historical observations of occultations and eclipses is to assume such a parabolic relationship and to check how the observational results agree with calculations of known credibly observed phenomena. If this ΔT curve were the only correct one, the observations would agree well with the ephemeris. However, with the current best analytical theory of the motion of the Moon (j=2) [1], the parabola adjusted to the observations has a distinctly different course [5]:

$$\Delta T = -10 + (31.4 \pm 0.6)\, t^2 \text{ [s]},$$

so, some non-tidal effects must play an important role and also tides may change in the course of time. We can point to a number of factors influencing the rotation of the Earth and causing it to be irregular in time:

a) there are glacial (climate change) periods when the distribution of the mass of ice on the Earth's surface varies;
b) the core of the Earth is undergoing some changes;
c) air mass changes its structure;

[1] j=2 means the latest version of the theory (j=0…1…2).

d) solar activity (especially solar wind) may influence the Earth's geomagnetic field [6];
e) sea levels fluctuate periodically to some extent;
f) volcanic activity varies with time;
g) earthquakes occur;
h) continents migrate over very long periods; this phenomenon, however, cannot be verified observationally for the periods from which we have astronomical observations.
i) other, not yet identified, processes may influence the Earth's rotation.

Returning to the changes in the Moon's orbit, the described tidal mechanisms should in effect cause our satellite to move away from the Earth by an average of 4 cm per year. This value was confirmed thanks to laser measurements using reflectors placed on the Moon by the astronauts of the Apollo programme. Obviously, this effect of the gradual increase of the Moon-Earth distance will result in the disappearance of total solar eclipses in the distant future in favour of exclusively annular eclipses.

Historical Observations of Eclipses and Occultations as a Database for Calibrating the ΔT Curve

Because this item is well described in the literature of the subject, only the general characteristics of the collection will be summarised. Basically three types of phenomena have been taken into consideration:

- solar and lunar eclipses
- occultations of stars and planets by the Moon.
- others, like local culmination of stars.

Some authors also analysed the conjunctions of planets with bright stars, which, however, usually turned out to be too imprecise.

There are four main collections of historical observations: Babylonian, Chinese, Arabian and European. It should be taken into account that they are divided into two groups: timed and untimed. Unfortunately, sufficiently accurate timed observations do not begin until the 17th century, hence the conclusion that we are mostly reliant on untimed observations, often recorded by people unrelated to astronomy, for analyses in earlier epochs.

Many authors have analysed and evaluated the historical observations [2,3,7,8]. Each old entry had to be read out, checked concerning its credibility, often even the date had to be reconstructed. From a great collection of events, only a part turns out to be valuable. First of all, we need the credible date and place of observation as well as other information allowing the evaluation of essential items, like the time of an occultation or a contact of the eclipse and/or a greatest phase of the lunar or solar eclipse. For instance, if we know about the observed naked-eye-occultation of Mars by the Moon on 69 BC February 14, at Si-gan-fou (Xi'an) in China, between the 9th and 11th hour in the evening of the local time, then the adjusted computer software should show us this event. For some of the untimed occultations we can at present recalculate the possible "time window". For instance, Antares was observed as being occulted by the Moon on 80 BC September 23, at ancient Babylon. The phenomenon must be remarkable between the beginning of twilight and the moment with low latitude of the star (of a few degrees) above the local horizon. According to the present calculations, this gives the range of 2.3 to 3.3 hours for ΔT [8].

Observed total solar eclipses must have happened in a way that the place of observation was between the eastern and western limit of the totality path on the Earth's surface. However, the time range is quite small only for situations when the path of totality was at a large angle to the parallel, which is typical for the spring or autumn eclipses. The famous total solar eclipse seen in detail at Babylon on 136 BC April 15, requires the range of ΔT from 3.11 to 3.37 hours [2].

Sometimes, also for partial eclipses we can evaluate its local time, namely when a contact has been noted close to the horizon at a measured elevation or at a short measured time from the rise or set of the Moon or the Sun. On the other hand, if a deep but not total solar eclipse was observed, we can find the range of ΔT which excludes totality at a certain place. On 2 BC February 5, a very deep but not total solar eclipse was observed at Ch'ang-an (Xi'an). Thus, for this date the ΔT range between 0.57 and 0.60 hours must be excluded [2].

The whole system of evaluation of the ΔT curve uses a large number of uncertain estimates for individual phenomena to find a function that satisfies all or a significant majority of them (Figure 1).

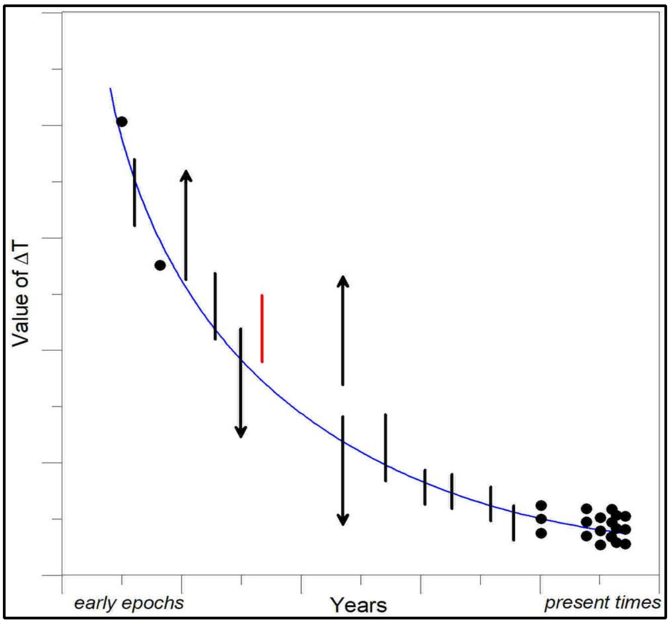


Figure 1. Scheme of fitting ΔTcurve based on historical observations. Thick vertical segments represent adequate ranges of ΔT values found for individual phenomena; points represent timed observations. The segment marked in red indicates an error in the original observation record.

Individual observations can be weighted depending on their reliability. If, after finding the fitted function ΔT, some of the recorded historical phenomena differ from it, we can consider them to be biased despite the initial positive qualification.

For instance, an interesting account about the total eclipse on 1478 July 29 written down in Seville (which place of observation may result from the circumstances described in the source chronicle) can be questioned as it does not agree with many other reports on this phenomenon in Europe and with the best fitted ΔT curve in general. Apparently, the author exaggerated his description of that eclipse or saw it at different place.

The values of the ΔT curve were found by different authors with their own assumptions, so they differ from each other. Moreover, the most accurate available methods of calculating the ephemeris of the Sun and the Moon had to be used, and these methods were subject to continual improvement.

For example, R.R. Newton in his exhaustive works tried to use historical data, at the same time determining the delay of the Earth's spinning motion and the then unknown orbital acceleration of the Moon according to some not fully verified historical observation data [7]. However, these analyses turned out to be too inaccurate. Newer analyses were introduced by F.R. Stephenson, using the improved theory of the motion of the Moon and other bodies of the Solar System, as well as after verifying and supplementing the set of historical data [2].

In recent years, work on the issue in question has been continued. In 2016, Stephenson, Morrison, and Hohenkerk presented new analyses which showed that the Earth's mean spin delay was slower than resulted from the tidal effects and has been established as 1.8 instead of 2.3 ms per century. At the same time, clear irregularities in the ΔT curve and the length of the day were confirmed [3] (Figure 2).

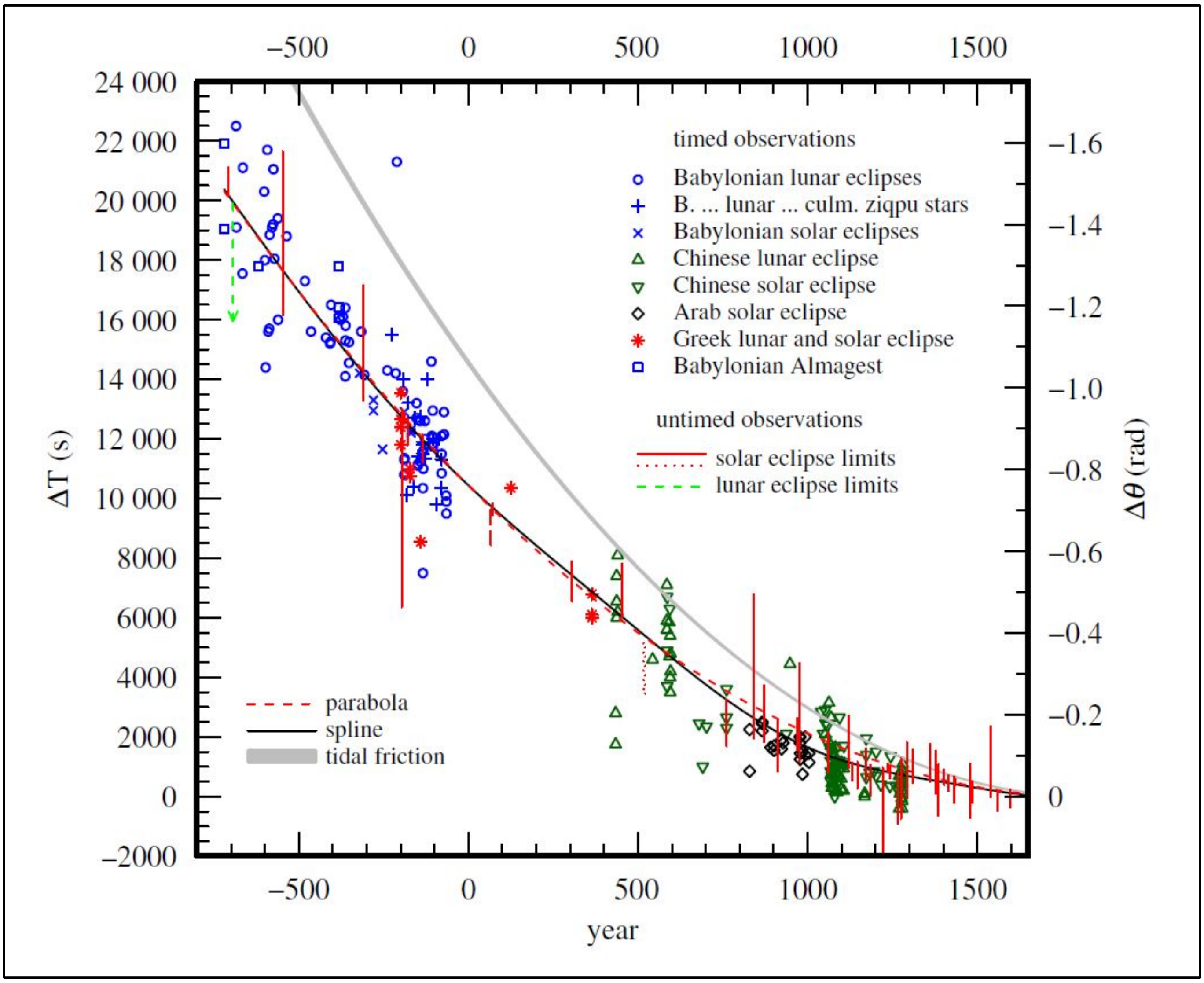


Figure 2. Results for ΔT for collected timed observations–720 to 1280 and the untimed total solar eclipse of 1567. The dotted red curve is the parabola, and the black curve is the spline curve, both fitted to the observations. The grey curve is the parabola predicted on the basis of tidal friction (according to the complete analyses by Stephenson et al. from 2016 [3]).

Newest Historical Observations of Solar Eclipses

In the years 1988-2020 M. Zawilski was constantly searching for historical observations of solar eclipses and occultations made from Europe and the Middle East. Studying the materials in libraries and archives scattered around Europe brought many discoveries of previously unknown data [9,10], but it could not be very effective for obvious reasons. Further progress was made possible by the internet and the increasing amount of scanned sources available. As it turned out, no compelling data can be found for distant epochs, but much remained to be done for the Middle Ages, especially from the 14th century onwards. New materials were found both in scans of printed sources and manuscripts available online. It is characteristic that interesting data can often be found in local sources that are less significant to historians, hence perhaps they have not been found so far for astronomical society. Examples of four such findings are shown below.

The first one concerns the annular solar eclipse, observed at or near Paris on 1310 January 31, which is vaguely mentioned in some publications. As it turns out, we have a real scientifically credible report from this observation; thus it would be the first documented annular eclipse recorded in Europe by an eye-witness, fortunately without any filters (perhaps through thin clouds or haze).

Tractatus a fratre G. Marchionis OFM
Sexta via est quia stante eadem linea AB originate a B transeunte per centrum D ipsius lune et per centrum solis E, aliquando totus sol nobis occultabitur, aliquando non eclipsabitur totaliter, ymmo remanebit notabilis circumferentia solaris circumdans lune emisperium, sicut fuit visum Parisius anno domini 1309 [recte: 1310] *ultima die Januarii hora quasi septima cuius rei non potest alia reddi ratio quam* <vel: added interl.> *solis et* <vel: added interl.> *lune in suis ecentricis maior et minor elongatio sicut evidenter ostendit decima figura et 11ª.* [11]

A treatise by brother Guy de la Marche OFM
The sixth way is that the rest of the line AB originate from B and which passes through the centre D of the moon itself and through the centre of the sun, E, and sometimes the whole sun is occulted to us, and sometimes not eclipsed totally, and more correctly, it remains a significant solar circumference, which encompasses the hemisphere of the moon, as it has been seen at Paris in the year of the Lord 1309 [correctly: 1310] on the last day of January, about the seventh hour [after sunrise] of which a cause could not be given anything as sun and the moon in their eccentricity (?) to a greater and lesser elongation as clearly shown in the tenth and 11th figure.

We also have a second account of this annular eclipse written down in St. Denis near Paris.

The second example is the long-sought observation of the total eclipse on 1415 June 7 in Krakow. The lack of this confirmed observation was strange also because at that time Krakow astronomy began to develop quite actively. In 2018, Krakow historians finally found a unique note on one of the preserved calendars.

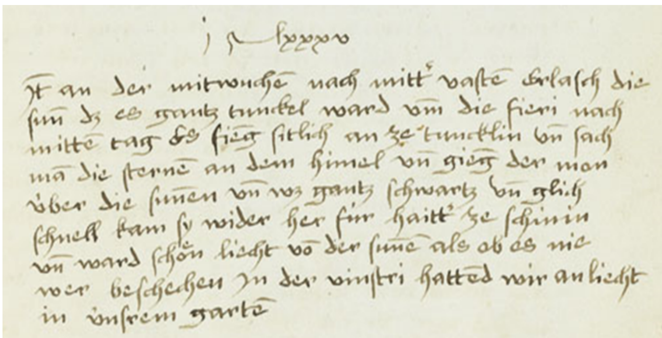
Kalendarz i nekrolog domu altarystów kościoła Wniebowzięcia Panny Marii (Mariackiego) w Krakowie
Junius
[...]
7 XIII D VII Id. Celestini et Luciani martyrum

1 4 X 5 [probably 1415] *erat totalis eclipsis in Sole 7 Iunii hora XI*

The calendar and the necrology of the house of altarists of the Church of the Assumption of Virgin Mary in Cracow
June
[...]
7 XIII D VII Id. [the day] *of Celestinus and Lucianus the martyrs*
14 X 5 [probably 1415] *there was the total eclipse of the Sun on June 7th at the 11th hour* [after sunset] [2]

For this eclipse new credible accounts from Avignon and Neuchâtel have been found by the author, too.

A similar note, but a much longer one, from the monastery of Sankt-Gallen in Switzerland, concerns the total solar eclipse of 1485 March 16. We leave it to readers (especially the German speaking) to read the old original text for themselves, before they read the decoded text and its translation given below. For this eclipse most of the new data have been found recently.



[2] This was a common medieval system of counting hours and days (i.e. a new day started with sunset! [of a previous day]). And in this case, 11th after sunset in June approximately gives us the correct time of the eclipse (around 7 a.m. of the local time according to our present counting of hours).

1485 Jahr

It. an der mittwochen nach mitt'(ag) *vasten* (war) *erlosch*(en) *die*
sonne das es gantz tunckel (dunkel) *ward* (wurde) *um die vieri* (vier) *nach*
mitten tag das fieng (fing) *sitlich* (? sichtlich) *an zu tuncklin* (dunkeln) *und sach* (sah)
man die sterne an dem himel und gieng (ging) *der mon*(d)
ueber die sunnen und waz (war es) *gantz schwartz und glich* (=gleich)
schnell kam sy wider her fuer (hervor) *hat ze schinin*
und ward (wurde) *schoen liecht von der sunnen als ob es nie*
war beschechen (.) *in der vinstri hattend wir an liecht*
in unsrem garten. [3]

Year 1485

Also, on Wednesday past midday the sun disappeared, so that it was totally dark at four past midday;
it was visible as dark and one saw stars in the sky and the moon
went over the sun and it was totally black and soon it quickly have been shining
and the light of the sun have been [again] as it never had been stayed in the darkness and we had the light
in our garden.

The last description in old Catalan made by an eyewitness comes from Majorca and concerns the eclipse of 1539 April 18. Also, it has not been widely known so far, as have two other recently discovered descriptions from Seville and Catania.

Libro del Extraordinari de 1537 á 1539
Sia memoria á tots que lo dit dia de XVIII del mes de abril, que era dimecres, que eren deu hores e mitja del dia, quant mes no manco, fonch eclipse de sol, ço es á saber, que la luna en aquest punt se girá, y girada se interposá davant lo sol, o pus ver, se trobá davant dit sol, de tal manera que quasi lo dia fonch com la nit, que pera conexer uns als alters se havien de star un davant altre y molt prop. Fonch vista dita luna tota molt negra com es lo carbó, y foren vistes moltes stelles de una part y de altra, y durá dit eclipse per spay de un quart, jatsia que ja havia un bon quart que lo sol ja no lansava lo seu acustumat resplendor, y dit eclipsi fonch vist y assenyaladament per molts homens qui les hores eren en la plaça de les Corts, y qui eren exits de les srivanies de la dita plaça, spantats de tal visió, entre los quals foren los magnifichs jurats y jo Pere Martorell notari y scrivá de la universitat, los quals, vis ten un subito esser lo dia com la nit, com dit es, isqueren en dita plaça de les Corts.

Book of the Extraordinary Events from 1537 to 1539
Also a memory of everybody that on the said day, the eighteenth of month of April, which was Wednesday, when were ten hours and a half of the day [i.e. after sunrise], neither more nor less, a dark eclipse of the sun, and namely, that the moon turned to this point and brought up in front of the sun, or, more exactly, was facing the sun, so that the day was almost like a dark night, that in order to know each other, they had to be in front of each other and very close. The moon looked all very black as a coal, and many stars were seen at one side and another, and this eclipse lasted for the space of a quarter of an hour even though it had been a quarter of an hour since the sun had shone with its usual radiance, and this view of the dark eclipse was quite remarkable to many people who were at that time in the square of the Courts, and who were leaving the clerks of that square, terrified with such a view, among which were the magnificent juries and I, Pere Martorell, the writer and notary of the university, who being seen the day like a sudden night, as said, going out of the courts in this square.

[3] The author would like to thank Dr. Hermann König from the University of Kiel for his help in reading this text.

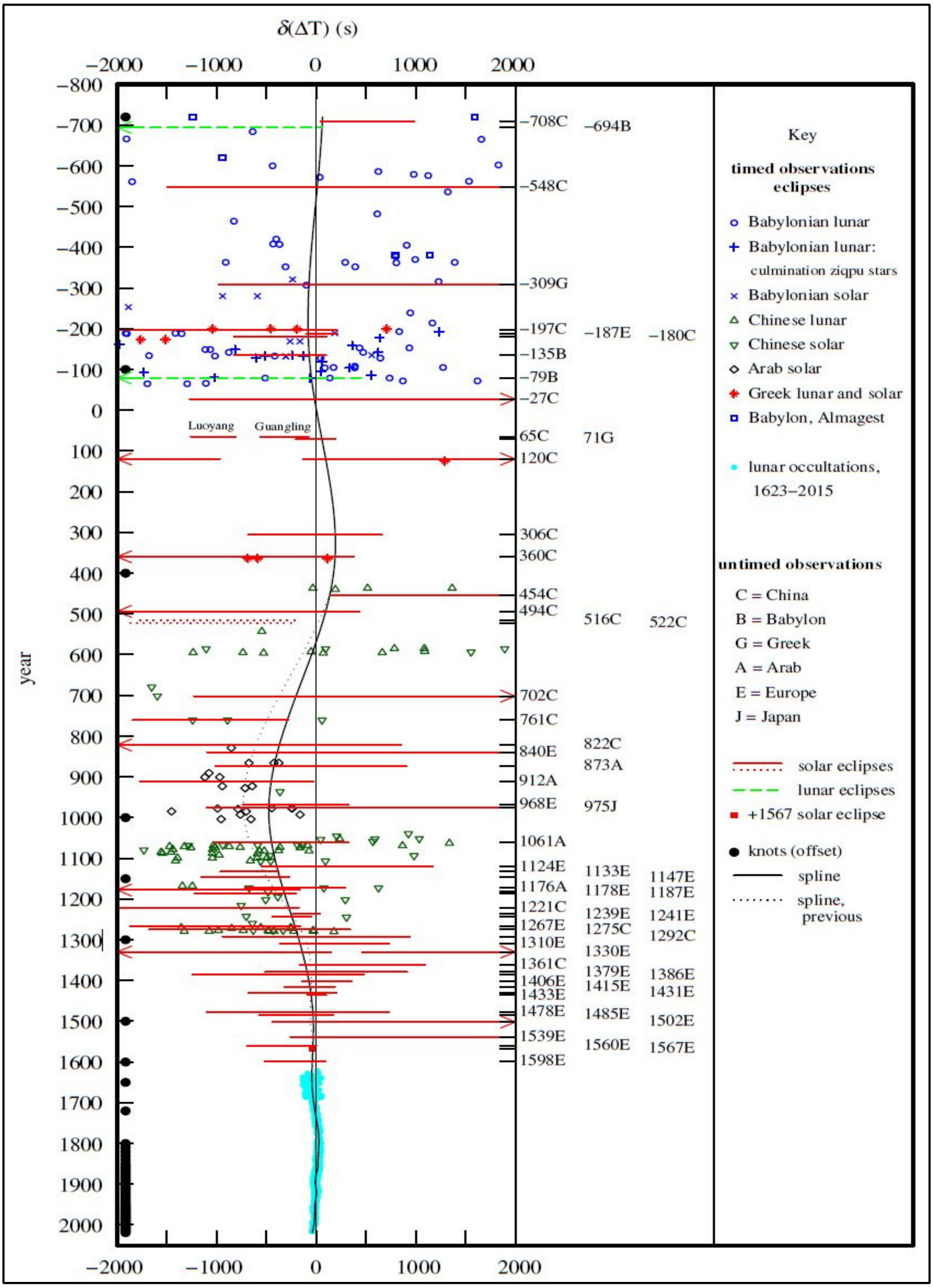


Figure 3. Plot of the differences in ΔT with respect to the parabola, which is represented as a straight line at 0. The data after+1600 are derived from timings of lunar occultations [3]. The solid black curve is the fitted spline, and the dotted curve for the period+800 to+1000 is the departure of the spline required to accommodate the timed Arabian data in that period. The positions of the knots used in the spline fit are shown as black dots along the time axis (according to the complete analyses by Morrison et al [5]).

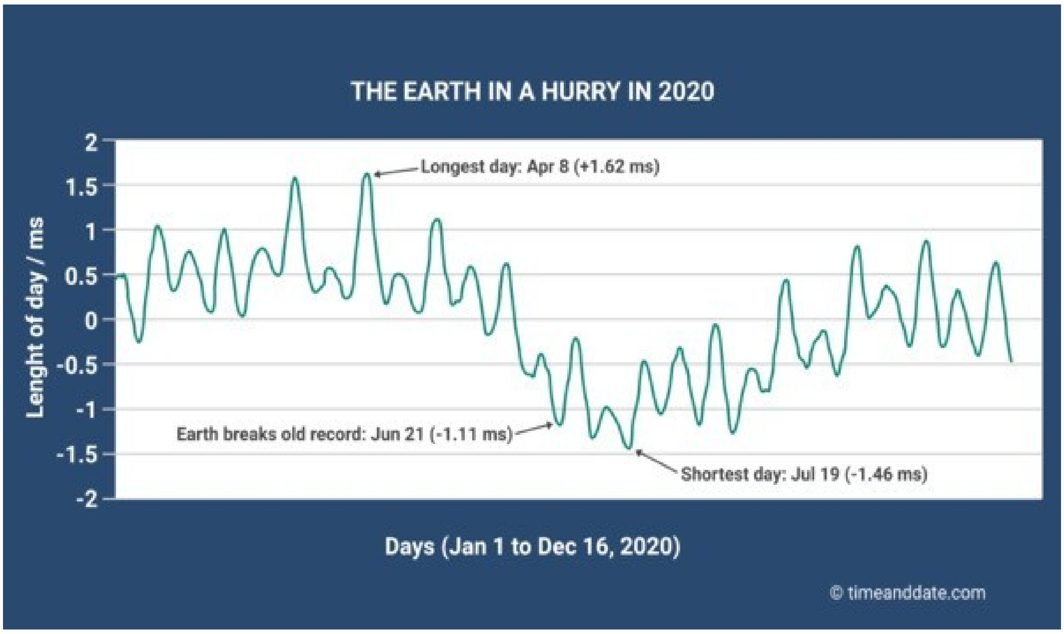


Figure 4.

Conclusion

In summary, 42 of about 100 newer findings have been evaluated in 2020 as credible and became the basis for a next verification of the course of the ΔT curve and some of them turned out to be crucial (Figure 3) [5].

As evidenced by these recent analyses, this did not fundamentally change the findings of 2016, but it can be concluded that the most recent ΔT curve with its irregularities is the best fit so far, and that it is likely that even possibly finding a number of new historical observations will not affect the final result much.

P.S. The rotation of the Earth does not cease to surprise. Analyses from recent years show that the length of the day continues to change and, for example, in the course of 2020 it was clearly at first longer but later shorter (!) (Figure 4). Hence, our observations of occultations may still be useful.

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A Unique Triple Occultation Opportunity Succeeds

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ABSTRACT: Of the hundreds of occultations that present themselves to individual observers each year, it has been rare to get an opportunity to observe three from the same geographical location within the space of a few hours' time. Three have been observed in one night by other observers in the past. It has also been even rarer for a combination of the following characteristics to lend themselves to success where I live: local weather during the observing window, length of observing window, ability to travel to the converging location, acceptable wind conditions, large enough brightness change to be detectable, equipment performance, seeing conditions, ability to go from one star field to the next manually within the required time frames, site obstructions, safety of the site, and other elements, any one of which could cause a specific failure.

On 2021 May 13 I had the opportunity to record stellar occultations by asteroids (245) Vera, (1269) Rollandia and (3803) Tuchkova from the same remote location. This report presents the preparations for these events and the results of the measurements.

Introduction

As *Occult Watcher* populates each day, I make it a point to review opportunities for each occultation to see if any will pass directly over me so that I can avoid road travel. I have found that because there are several observers located in close proximity to my site that I often must drive somewhere simply to avoid duplicating results. At other times this is not practical to do. However, in April 2021 I saw early predictions indicating that three occultation paths that seemed to be converging in one area of southwestern Arizona between 03:45 and 05:30 UT on 2021 May 13. I did not think much of it since every time we see orbit prediction updates it generally will push one or another in a different direction eliminating a potential realistic convergence opportunity. Sometimes two events will appear to cross where one or more observers have a great chance to see both of them from the same location, 'chance' being the operative word. But to have three converge is much more unusual.

Three Events on 2021 May 13

As occultation rank criteria tend to become higher in quality there is a tendency for observers to become less concerned about major path shifts. Called "confirmation bias" it means that an observer expects a prediction to come true even knowing that this might not happen. That has happened to me a number of times. However, a 100 ranked prediction even now can still result in a shift where many/all scheduled observers end up with a miss. In the May 13 trifecta prediction three asteroids, (3803) Tuchkova, (245) Vera and (1269) Rollandia were ranked 87, 100 and 100, respectively, with (245) Vera and (1269) Rollandia seeming to have the more reliable orbits. In fact, it was Vera and Rollandia that became the focus of my attention since the (3803) Tuchkova prediction had shifted away from the Arizona intersection in the preceding weeks. On May 11 I noticed that if I was willing to drive another 30 minutes beyond my planned limitation of 4 hours, perhaps I might be able to arrive at an area where all three paths were now predicted to cross instead of settling for perhaps getting two. The apparent convergence zone was in the vicinity of the agricultural town of Brawley, California USA.

Figures 1 a-c show the final prediction for each and the planned location of my common site.

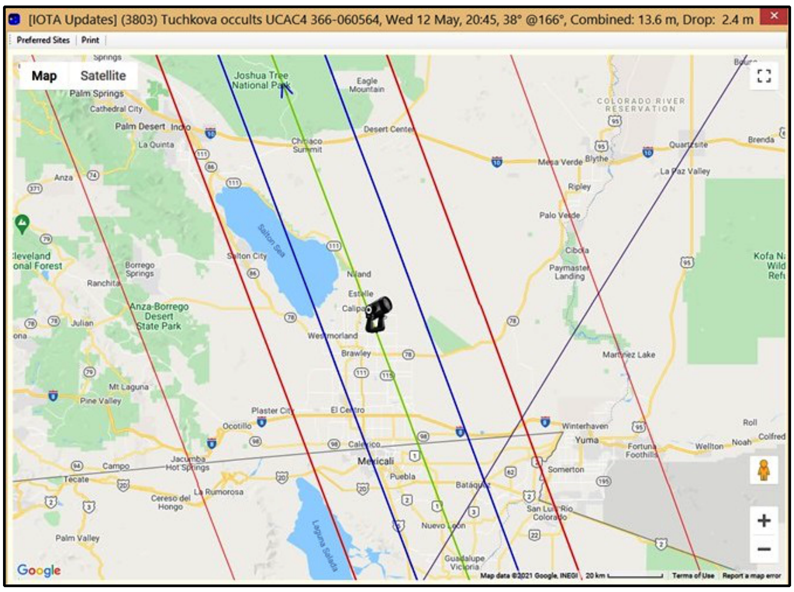

Figure 1a. (3803) Tuchkova path. © Google maps, 2021

The Search for the Best Observing Site

Wind conditions had been generally high in the days preceding May 13 with dry, hot weather beginning to settle in the southwestern part of the country signaling the start of our summer. I travel with an old model Celestron 8 in a vehicle which typically gets 43 to 54 mpg/69 to 87 km per gallon of fuel. So, the 9-hour roundtrip travel time was not a concern. Winds greater than 9 mph/14 kph cause wind shake which can sometimes be blocked by finding a structure to hide behind or in other cases holding a large piece of cardboard in front of the scope to block the wind. However, such mitigation is not always possible in the field as winds may tend to blow under, over and around a vehicle no matter how hard I try to block them. Finding a structure to block the wind is rarely possible in the desert where all of my work is done. On the way to this location, I observed three dust devils in the distance from the main highway and winds gusting up to 20 mph/32 kph.

My first choice of sites was in a small asphalt lot adjacent to the Imperial Sand Dunes, imposing stretches of sand adjacent to farmland (Figure 2).

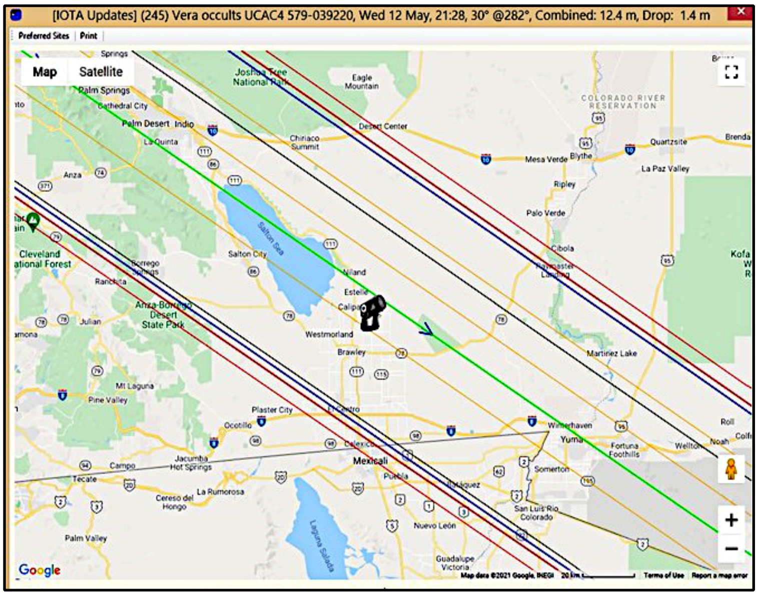

Figure 1b. (245) Vera path. © Google maps, 2021

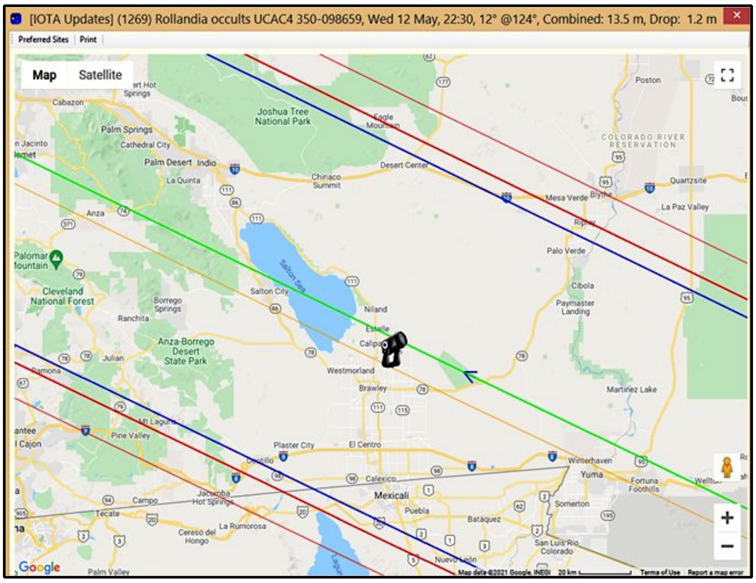

Figure 1c. (1269) Rollandia path. © Google maps, 2021

Figure 2. Imperial Sand Dunes. Site was supposed to be next to the dunes.

I found several potential locations in my preferred site area, but after arriving there I realized that winds could easily create blowing sand problems lifting clouds of it into the air and deposited on both car and telescope. I then moved on to my second location which was farmland west of the small town of Brawley. The road I proposed to set up on was near the appropriately named Dunham Road (Figure 3).

In this area, the north to south and east to west roads made travel easy. However, the terrain is one where farm activity is quite extensive; there is constant activity of combines, tractors, trucks and other vehicles that actually work day and night. It is not uncommon to see bright vehicle headlights in farm fields when normally one would expect dark conditions in such rural areas. In my past California occultation experiences, I even experienced having a telescope covered in water from unexpected nighttime irrigation!

Figure 3. Dunham Road. You can see the very flat farmland terrain.

My 'final location' was in these farm roads. I settled on a place that seemed quite pristine until an hour before sunset when two tractors began to harvest crops in a nearby field. Wind lifted swirls of dirt particles that began to fall onto my vehicle covering it in a layer of fine dust. I had to move several more times to a different road about half a mile away. During the day wind-born dust resulted in restricted visibility at elevations from 0 to about 20 degrees above most horizons.

I continued to shift sites until at sunset there was no more time to search for the optimum location; I found a spot on a dirt road that I hoped would remain untravelled for the following hours. However, about 0.5 miles/0.8 km to the east I could still see tractors with headlights turned on remaining in fields but at a distance. This continued for hours. Winds gradually began to die down and after 30 minutes I realized that this site was best. It was not far from the appropriately named Dunham Road so I considered it a lucky omen. After performing a check of the area, no snakes or active wildlife were seen. The only unique feature was a set of recent paw prints in the dirt indicating the previous probable presence of a coyote.

The Observations

The (3803) Tuchkova and (245) Vera occultations occurred at 03:45 and 04:28 UT, respectively, and I was able to easily see and record them. I was using a laptop provided by Ted Blank after my two Lenovo laptops were out of action due to hardware issues. Elevations for these occultations were above 20 degrees and there was no Moon in the sky. The more challenging third occultation by (1269) Rollandia (at 05:30 UT) was to occur with the target star 12 degrees elevation above the southeast horizon. Since all of my pointing is done by star hopping, I initially manually aligned on the north celestial pole first, then 'walked' my way across the sky to each target field. The flat farmland allowed for no obstructions. The resulting light curve clips are shown in Figures 4-6.

For (1269) Rollandia I trained my 9x50 finder on rising stars in Scorpius and walked down the sky toward the eastern horizon to confirm stars roughly along the target's declination line until I reached an elevation of 3 degrees. I then waited until stars entered that I could clearly identify as those in the target field. At 20 minutes before the predicted occultation time, I could confirm that I was definitely in the target area and tracking. At 13.5 mag the target was quite difficult even at 32X in my Watec 901HX camera, and I could barely see it on the laptop screen starting at 4 minutes before the predicted time. Normally I never integrate beyond 16X. But this time no matter what I did, at 32X the target was just barely perceptible on the screen.

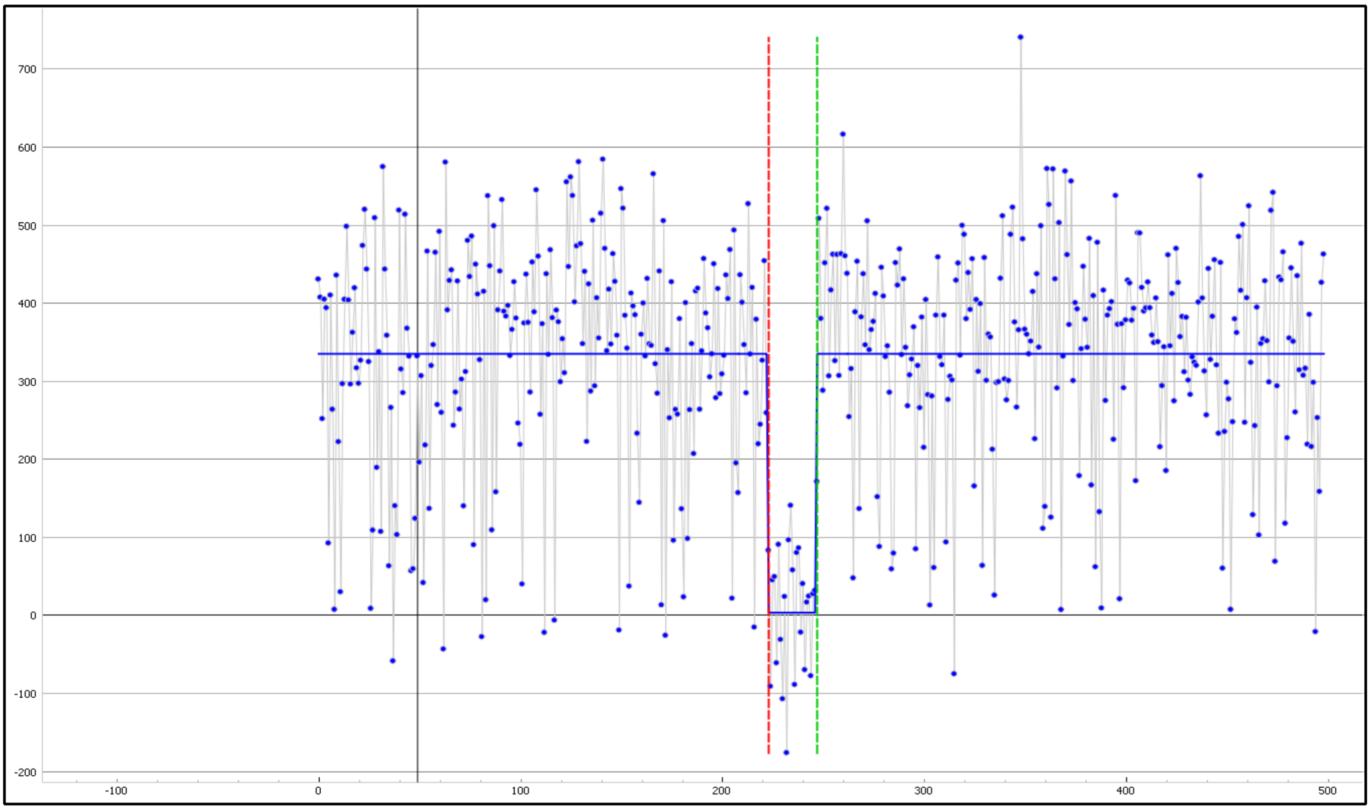

Figure 4. (3803) Tuchkova 3.2 second event (no other observers)

Mission Accomplished

One unique thing about the site: it is the first time I ever observed an occultation from a site known to be below sea level. The site was 134 ft/41 m below sea level making seeing at low angles a concern. During a previous occultation at 7,000 ft/ 2,134 m I had no trouble spotting and tracking a 13th magnitude target from 5 degrees until it reached its maximum elevation of 12 degrees with the Watec gain set at 16X.

Following the completion of the three observations I started the return drive home. I filled up my car with petrol at a gas station in Gila Bend, Arizona whereupon I arrived to witness an emergency scene at that location. I encountered a wildfire not far from the main interstate highway that was creating a large column of smoke; finally at a stop light in Buckeye, Arizona while waiting for the light to turn at 1:50 am I observed a woman walking along the highway in the dark flapping her arms like a chicken. These are things that are quite unusual and yet lend themselves to the overall uniqueness of this triple occultation success, one that took me on a 520 miles/851 km road adventure.

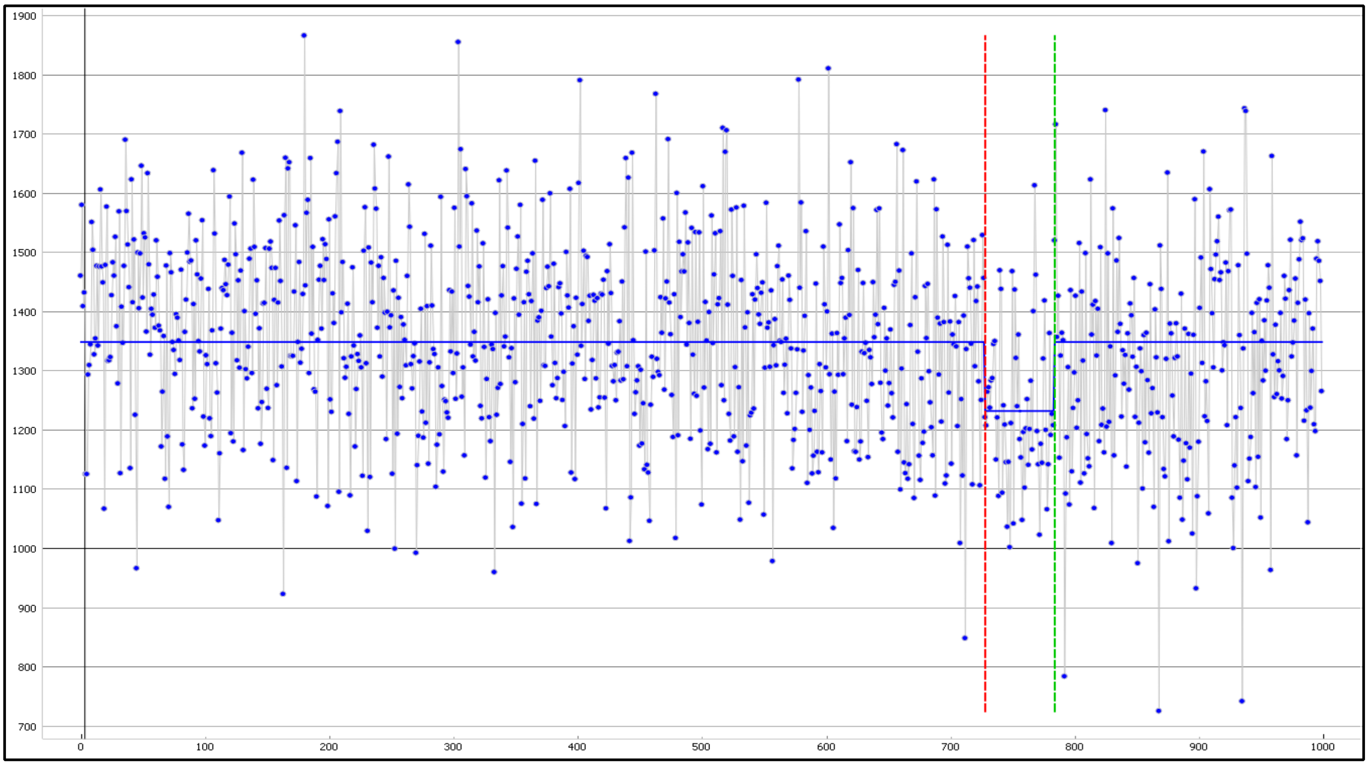

Figure 5. (245) Vera 1.9 second event
(two other observers also recorded this occultation).

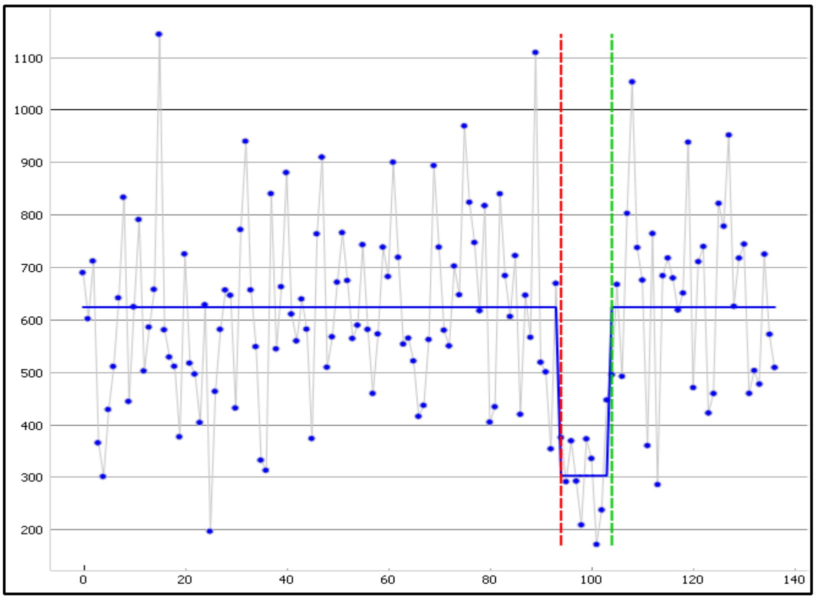

Figure 6. (1269) Rollandia 5.3 second event
(no other observers) reduced by Tony George.

Solar Eclipse Mystery Solved after 45 Years

Henk J. J. Bulder · Nadir[1] ·De Wijk · the Netherlands ·henkbulder66@gmail.com

[1] vereniging van amateurastronomen Den Haag eo

ABSTRACT: A group of young amateur astronomers observed the partial solar eclipse on 1976 April 29 at the Volkssterrenwacht Rijswijk (Rijswijk Observatory) in the Netherlands. The photographs of the eclipse were used to measure the percentage of diameter eclipsed. A simple light sensor was used to measure the light of the Sun including a large region around it and compared it with the theoretical values. The measured values were 10% higher than expected. After 46 years, Henk Bulder has solved this mystery during the partial solar eclipse of 2021 June 10 with the readout of the power production of PV solar panels on the roof of his home. The cloud cover during such a measurement is an important factor.

Solar Eclipse Measurements in 1976

The partial solar eclipse of 1976 April 29 was observed at Volkssterrenwacht Rijswijk by a group of young amateur astronomers. Photographs were taken roughly every 5 minutes and a simple light sensor, supplied by Cees van Bochove who studied physics in Leiden at that time, was used to measure the light of the Sun including a large region around it. It was mounted so that it could follow the movement of the Sun.

Because there were quite a number of clouds in the sky we only made measurements when the Sun was fully visible.

The purpose of light measurement was to see if the reduction in light level was in accordance with the theoretical dimming of the sunlight. The photographs of the eclipse were used to measure the percentage of diameter eclipsed. Those measurements were also compared with the theoretical values.

Although the scientific value of these measurements was not high, they at least offered the possibility of testing the accuracy of the predictions.

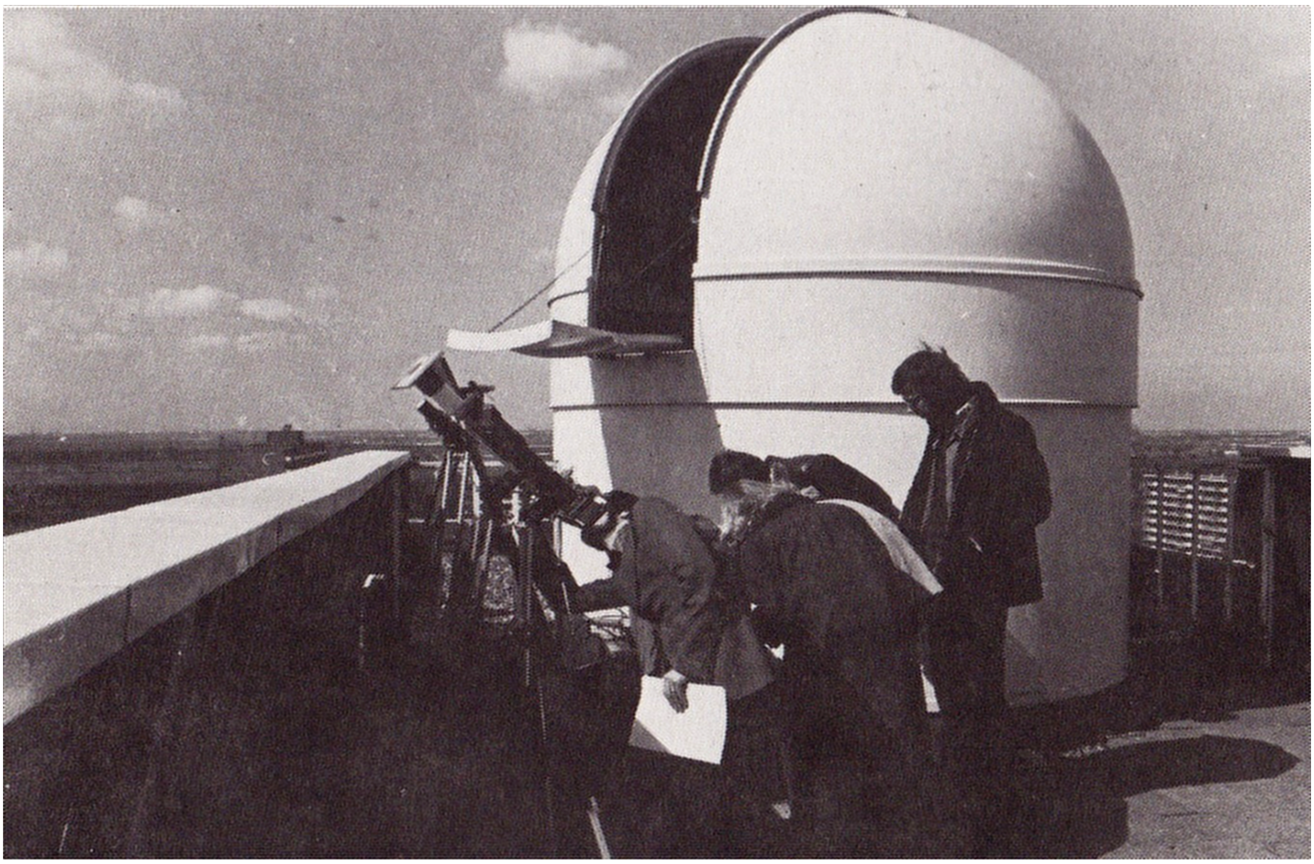

Figure 1. Observers Cees van Bochove, Henk Bulder and others; clouds clearly visible in the sky.

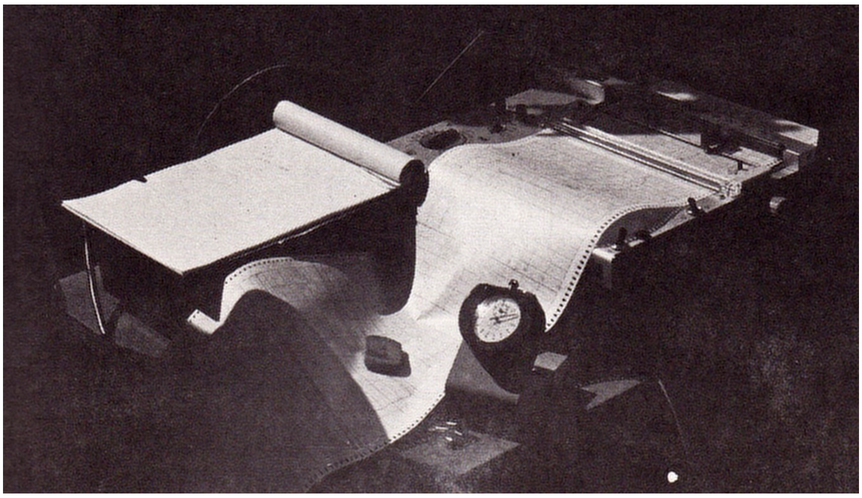

Figure 2. Some recording equipment for the light measurement (see also in the background in Figure 1).

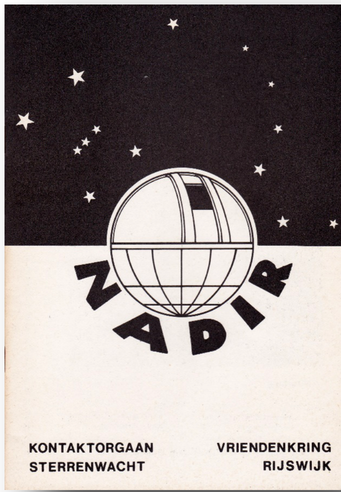

Figure 4. Nadir, quarterly front page.

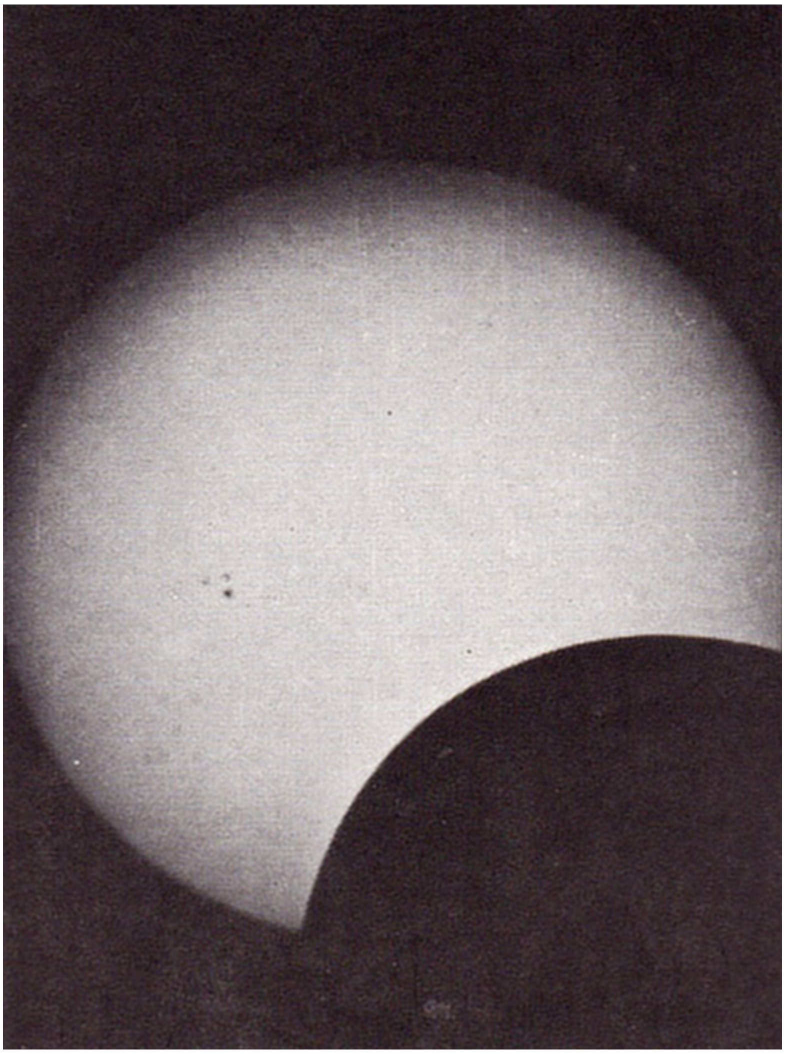

Figure 3. Partially eclipsed Sun, 1976 April 29.

Weather conditions were favourable. We could follow the eclipse very well although we were hampered by a varying amount of clouds in the sky. The results of the measurements are in Figure 5. This figure was published in No. 2 of 1976 of *Nadir*, the quarterly journal of the association of amateur astronomers, Friends of Volkssterrenwacht Rijswijk (Figure 4).

The percentage of solar diameter eclipsed was measured from the photographs. The dashed line in Figure 5 represents the theoretical percentage. As you can see the measurements (little triangles) were very well in line with the theory although some deviations are seen which can be explained by inaccuracies in measuring the small somewhat overexposed negatives.

The solid line in Figure 5 represents the percentage of solar surface that is eclipsed. The circles represent the percentage of light reduction. The light of the uneclipsed Sun at the start and end were used to interpolate values assuming a linear trend between the two.

The diminution in light level turned out to be up to 10% higher than the theoretical value. The deviation varied quite a bit although the light sensor followed the Sun accurately. We tried to find an explanation for this higher value but we failed to find any. For instance the diminishing brilliance of the Sun towards the edge was taken into account.

Power Production with PV Solar Panels

Solar panels use light of the Sun to generate power. Hence you can see solar panels as light measuring devices. The more light is captured the more power they generate. Solar panels have some flaws though, which make them less suitable as accurate light measuring devices. The higher the temperature the less efficient they are in converting light to power. So, light measurements are not linear but when you measure the power output under the same ambient temperatures they show the same power values. Solar panels on a roof in general do not follow the Sun which make them less suitable for scientific eclipse measurements. Nevertheless, you can clearly see the partial eclipse of 2021 June 10 in the power output curve (Figure 6). The sky was almost cloudless except for a few little ones. The maximum power output was around 5200 Watts whereas values well in excess of 6000 Watts can be reached when there are clouds in the sky.

I have measured the power output since I had the first solar panels in 2007. Over the years I followed the power output closely under different conditions. This led to the conclusion that the power output under the same ambient temperatures varies with the number of clouds in the sky. It turns out that the power output can be more than 15% higher with a lot of clouds in the sky compared to a cloudless sky. Solar panels apparently measure not only the light of the Sun but also the reflection of sunlight by clouds. This surplus of light is significantly more than I expected in advance. This made me realise that clouds in the sky could very well be the explanation of the higher than theoretical reduction we measured during the eclipse of 1976. When the number of clouds in the sky is higher at the start of the eclipse and or at the end of the eclipse and less during parts of the eclipse than you would indeed measure a larger than theoretical dimming.

Of course we did not measure the number of clouds in the sky during the eclipse back in 1976, so, we can't make a correlation between the number of clouds in the sky and the surplus light reduction but as shown by solar PV panels it could range from zero to 15% which more than covers the deviations we measured.

This solves the mystery.

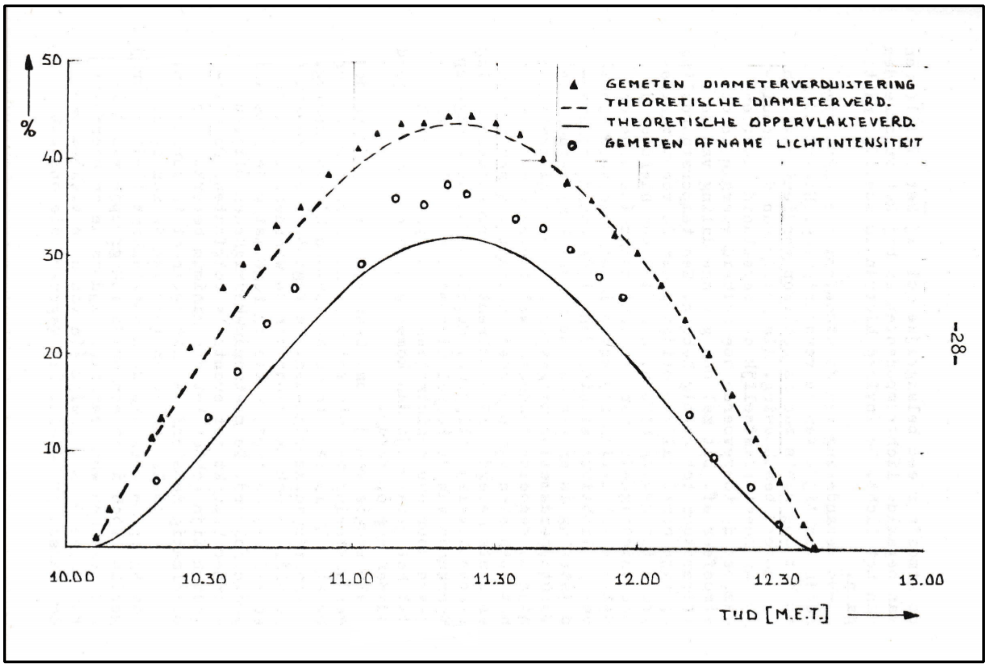

Figure 5. Resulting measurements against theoretical curves explained in the text.

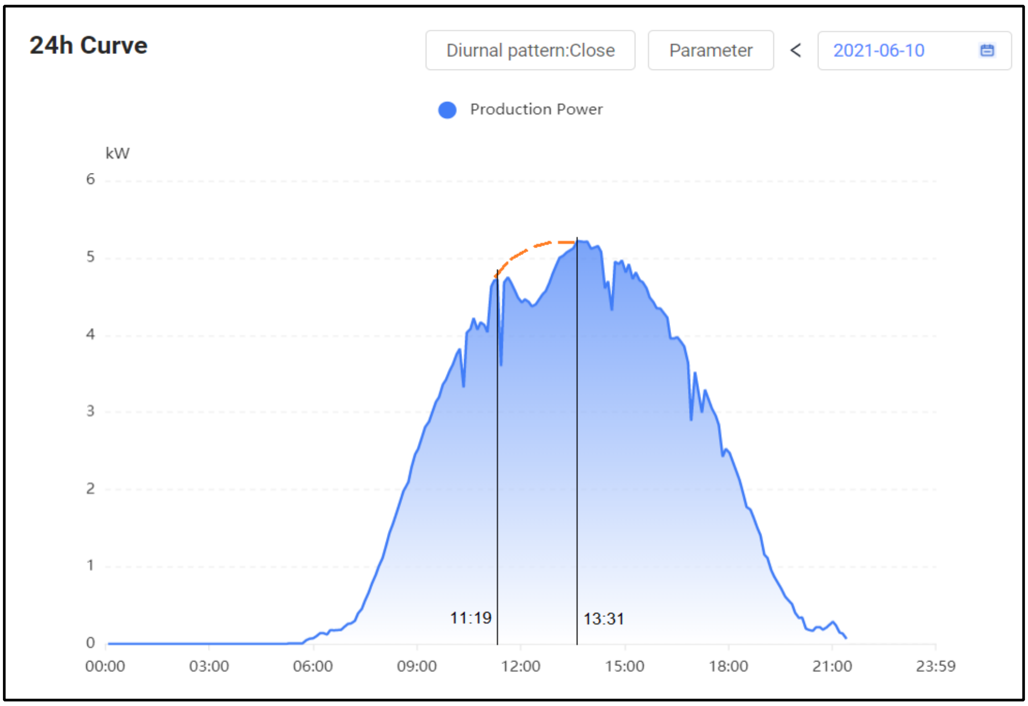

Figure 6. Partial eclipse clearly visible in power production curve of 2021 June 10.

Figure 7. Henk in front of his energy-plus house with negative footprint (most sustainable in the Netherlands).

Climate Change

Although astronomy is still one of my hobbies, sustainability has taken most of my time since 2012. We are spending a lot of time finding life on exoplanets where life on planet Earth should be our main focus when we take climate change seriously.

That is why I do help house owners to make the energy transition in my spare time. Low-cost solutions are my favourite, solutions that are earned back in a short period of time. The only way we can avoid climate change is to use a minimum of energy per citizen and have fewer children.

With this in mind I designed a house that uses minimal energy to build and minimal energy during its lifetime. Since I could not find a contractor that dared to build it, I had to take matters into my own hands and hired subcontractors that could build parts of it under my supervision. It resulted in a house with a negative energy bill and a low water bill, a house where we can get old without much support.

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 2021 September 23, the *Minor Planet Center* listed 1317 Centaurs and 2871 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)

In this Issue:

(15810) Arawn

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ABSTRACT: The Plutino (15810) Arawn was discovered in 1994, orbiting the Sun every 250 years. The orbit is in a 2:3 resonance with Neptune. The diameter is uncertain with estimates ranging from 130–250 km.
Observations from the *New Horizons* spacecraft indicate a rotation period of 5.47 ±0.33 h, and a red colour. No moons have been detected.

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
20000	Varuna	Andre Knöfel	JOA 2 2017
28728	Ixion	Nikolai Wünsche	JOA 2 2018
38628	Huya	Christian Weber	JOA 2 2021
47171	Lempo	Oliver Klös	JOA 4 2020

No.	Name	Author	Link to Issue
50000	Quaoar	Mike Kretlow	JOA 1 2020
54598	Bienor	Konrad Guhl	JOA 3 2018
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

The Discovery

The object was discovered on 1994 May 12 by Mike Irwin and Anna Zytkow with the 2.5-m Isaac Newton Telescope at the Roque de los Muchachos Observatory on La Palma. The object was found as part of a search project for slow-moving Kuiper belt objects [1] and got the provisional designation 1994 JR_1.

Figure 1. The 2.5-m Isaac Newton Telescope (INT) Credit: B. W. Hadley. Date: 1994.

The Name

The object was officially named on 2017 January 12 [3] after a character in Welsh mythology. In this folklore, Arawn is a prince and ruler of the Celtic otherworld known as Annwn. He is a subordinate as well as an opponent of Hafgan. Figure 2 shows an inspiration of the god Arawn by comic artist Enzo Trenkner, exclusively drawn for the *Journal for Occultation Astronomy*.

Figure 2. God Arawn, concept by Enzo Trenkner.

The Orbit

The orbit (Figure 3) has an eccentricity of 0.121 and is inclined to the ecliptic by 3.8°. With a semi-major axis of 39.67 AU, the planet has a distance to the Sun from 34.8 to 44.5 AU. The current distance from the Sun is 35.95 AU as of November 2021. As a TNO, Arawn is a member of the group known as Plutinos, which are in a 2:3 resonance with Neptune and orbits the Sun every 249.9 years.

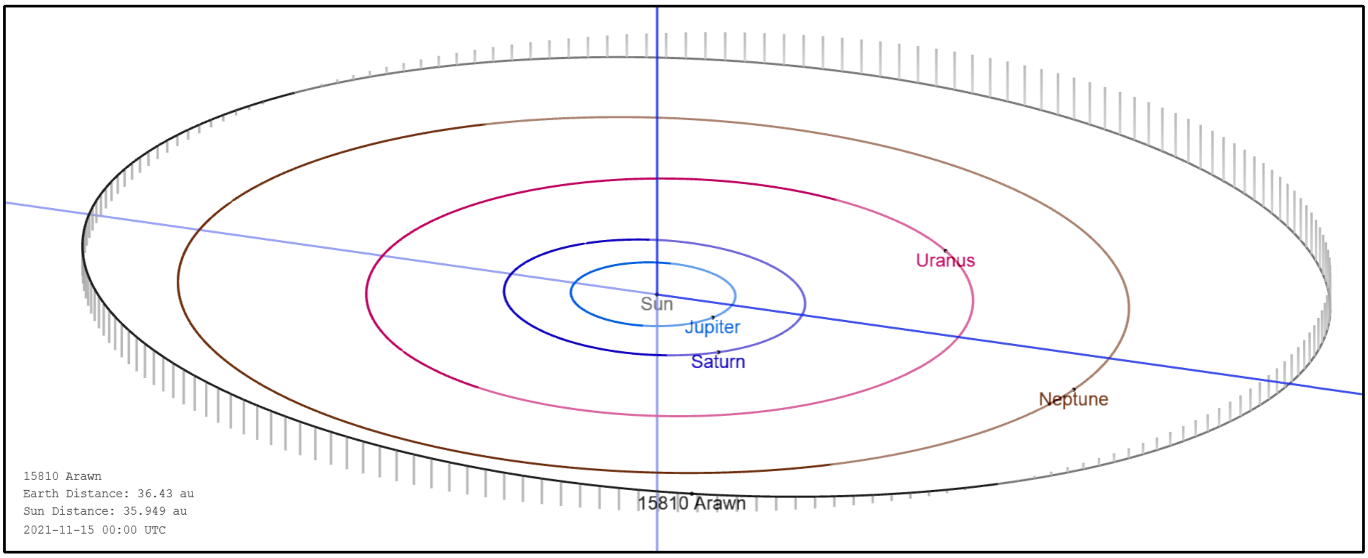

Figure 3. Orbit diagram and position for November 2021 (Source: https://ssd.jpl.nasa.gov/sbdb.cgi?sstr=15810).

The Parameters

The discoverers found the (m_V-m_R) colour index of 1994 JR_1 to be +0.4 [1]. The absolute magnitude according to the Minor Planet Center is H_{mag}= 7.70.

After passing Pluto, the *New Horizons* spacecraft was able to observe Arawn using its camera, *LORRI* (LOng Range Reconnaissance Imager). Observations were made on 2015 November 2 from a distance of 1.85 AU, and repeated on 2016 April 7 from a range of only 0.71 AU (Figure 4).

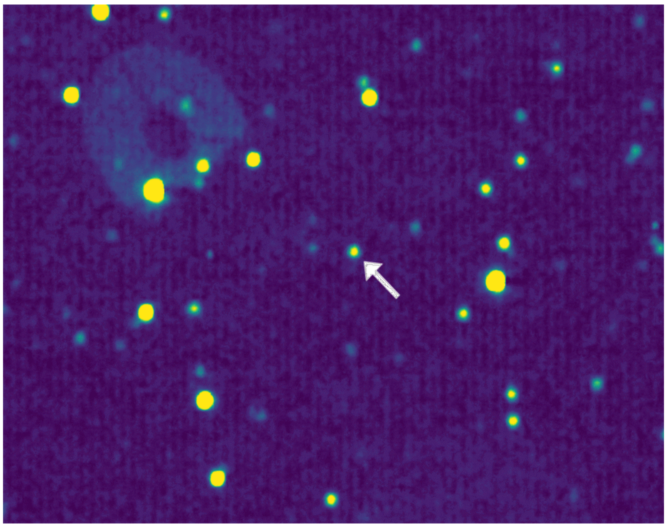

Figure 4. New Horizons observations of Arawn from April 2016. Credits: NASA/JHUAPL/SwRI

Parallel observations with the *Hubble Space Telescope* failed to detect any moons present. The observations yielded a light-curve corresponding to a rotation period of 5.47 +/- 0.33 h (Figure 5).

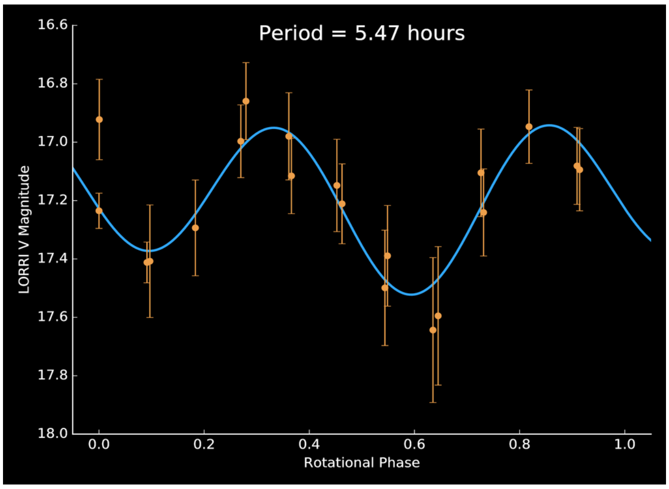

Figure 5. Rotational light-curve of (15810) Arawn [4].

The diameter of Arawn is relatively uncertain given that no thermal measurements or occultation timings have been reported. Assumed values range from about 130–250 km. HST measurements indicate a F606W-F814W colour magnitude of +0.70, which makes it a very red KBO [5]. The *New Horizons* observations showed the planet has a high surface roughness [4].

Forthcoming Stellar Occultations by (15810) Arawn

To date, no occultation by this body has been successfully observed. Calculations using *Occult* software [5] through until the end of 2024 yielded two potentially observable occultations for North America (limiting star magnitude = 16). Of course, these predictions have an error which can be reduced by further astrometry closer in time to the actual event (Figures 6, 7).

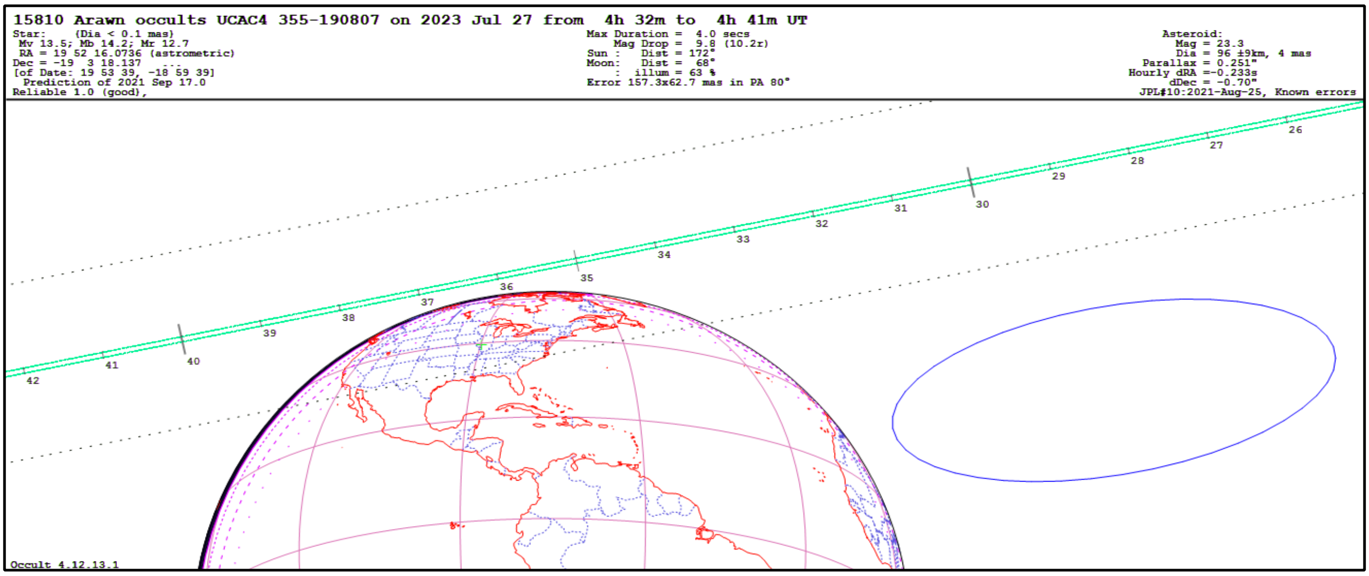

Figure 6. The stellar occultation of UCAC4 355-190807 (MV 13.5 mag) on 2023 July 27 (note uncertainty ellipse in blue).

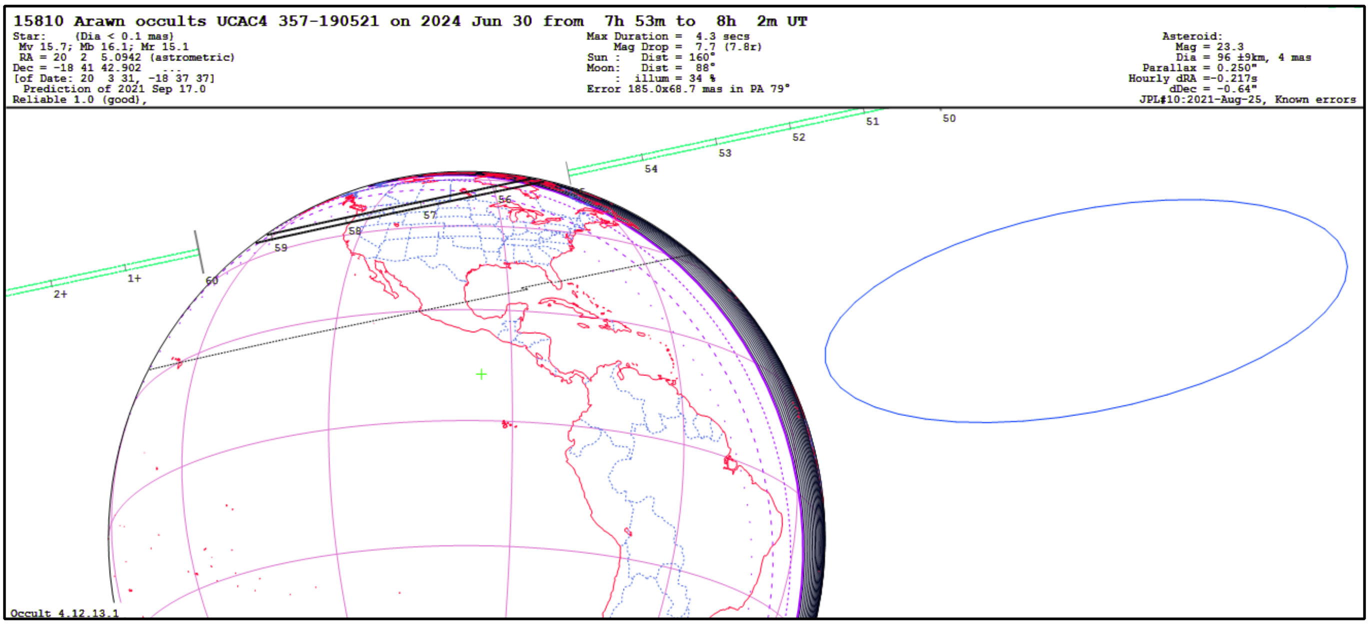

Figure 7. The stellar occultation on 2024 June 30 of UCAC4 357-1905212 (Mv 15.7 mag).

References

[1] Irwin, M., Tremaine, S., and Zytkow, A. N.: "A Search for Slow-Moving Objects and the Luminosity Function of the Kuiper Belt" The Astronomical Journal, 110, p.3082-3092, (1995 December).

[2] JPL Small-Body Database. https://ssd.jpl.nasa.gov/sbdb.cgi#top

[3] Minor Planet Circulars M.P.C. 103024 https://www.minorplanetcenter.net/iau/ECS/MPCArchive/2017/MPC_20170112.pdf#page=764

[4] Porter, S. B. et al: "The First High-Phase Observations of a KBO: New Horizons Imaging of (15810) 1994 JR_1 from the Kuiper Belt", Astrophysical Journal Letters, 828:L15 (6pp), (2016 September 10). http://www.dx.doi.org/10.3847/2041-8205/828/2/L15

[5] Benecchi, S. D. et al: "The color and binarity of (486958) 2014 MU_{69} and other long-range New Horizons Kuiper Belt targets", Icarus, 334, p.22-29, (2019 December).

[6] Herald, D.: "Occult v4.12.13.1 software tool http://www.lunar-occultations.com/iota/occult4.htm

Further Reading

"The Trans-Neptunian Solar System" edited by D. Prialnik, M.A. Barucci and L.A. Young, Elsevier Science, 478pp., (2019)

Figure 1.

ESOP XL – Report of the 40th European Symposium on Occultation Projects

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Oliver Klös · IOTA/ES · Eppstein-Bremthal · Germany · pr@iota-es.de

ABSTRACT: The 40th European Symposium on Occultation Projects (ESOP) took place in Białystok, Poland, during the weekend of August 28-29, whilst many countries were easing their Covid-19 lockdown restrictions. For the first time ESOP was held simultaneously as an in-person meeting and an online video conference. A total of 25 delegates attended the meeting and up to 55 others participated via Zoom, together representing Algeria, Australia, Belgium, Brazil, Catalonia, Czechia, France, Germany, Greece, India, Japan, the Netherlands, Poland, Portugal, Spain, Switzerland, Turkey, the United Kingdom and the USA. The meeting was followed by social excursions on the Monday and Tuesday.

Friday 27th August 2021

On Friday evening, the participants met for an informal welcome by the Local Organising Committee at the restaurant "Esperanto" in the centre of Białystok. Although it was raining heavily, no one wanted to miss the opportunity to finally meet old friends again and to get to know previous e-mail-only contacts in person. Conference badges, Abstracts booklets and information material were handed out by the LOC, headed by Wojciech Burzyński.

Saturday 28th August 2021

IOTA/ES was welcomed to the Faculty of Physics, University of Białystok by Dr. Marek Nikołajuk. Prof. Izabela Święcicka, Vice Rector for Science and International Cooperation, wished everyone fruitful discussions, promoting new ideas for science and collaboration between delegates. She thanked the Faculty of Physics for organising the conference, particularly the work of Dr. Nikołajuk, who then introduced the president of IOTA/ES, Konrad Guhl.

Konrad greeted everyone to ESOP XL, being our 40th Symposium - not meaning 'eXtra Large'. He mentioned our previous meetings in Poland, and that this event would be a hybrid, with some people attending in person and others participating online via Zoom. Personal contacts between observers are very important, so hopefully this can fully resume at the next ESOP when we can all be together.

Session 1 - Observations 1
chaired by Konrad Guhl

Oliver Klös - Lunar Occultation of HIP 36603, 2021 Feb 23 - A Double Star Discovery?

Oliver described his recording of the disappearance of this mag. 7.6 star. Analysis with *Tangra* showed a step; this was confirmed with *Limovie*, giving a step of 1.4s duration and magnitudes 7.7 and 10.5 for the components. The star is not listed as double in any catalogues. Confirmation is required when its occultations resume in 2026, or from Gaia or interferometric studies.

Jiří Kubánek - The occultation by asteroid 1997 WP21 and other Czech observations

On 2021 February 14 Jiří achieved a 'triple', 3 positive occultation events in one night, including that by the main belt asteroid (33074) 1997 WP21. Jiří described how his and Karel Halíř's timings of 1997 WP21 showed that he measured the main body but Karel had detected a secondary object. Its next occultations are in July 2023 and September 2025, and rotational light curves are welcomed. Jiří also listed Czech observers' statistics for 2020 and 2021, including their multiple chords across (2) Pallas on 2020 June 22.

Bernd Gährken – Grazing occultation of Asellus Borealis on Sep 14, 2020

A lunar graze of this mag. 4.7 star, gamma Cancri, in M44 (Praesepe) was observed from 5 stations near Steiningen, Germany operated by himself and Sebastian Voltmer. Bernd described how *Grazprep* was used to plan the locations of their equipment. Their best station recorded 24 events, but others had mountain/valley discrepancies. Caused by the multiple star or by diffraction? Eberhard Riedel explained that *Grazprep*'s lunar profile is simplified (for presentation), whereas Mitsuro Soma does a rigorous analysis.

Wojciech Burzyński - Daylight grazing occultation of Asellus Borealis on Sep 14, 2020

Wojciech and Maciej Borkowski also observed this graze from Chraboly, NE Poland, whilst the Sun was just above the horizon. They recorded 10 events, missing 2 events because of a technical problem. This was the first daylight graze to be observed from Poland.

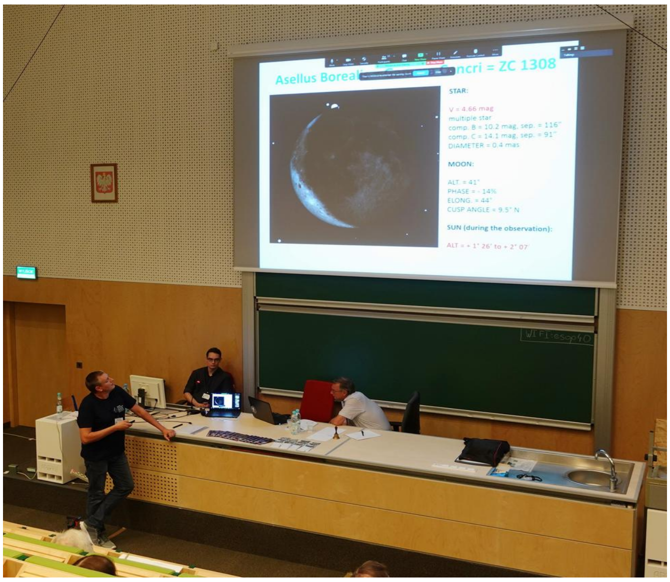

Figure 3. Wojciech Burzyński (left) presents the occultation of Asellus Borealis. (O. Klös)

Session 2 - Data Analysis 1
chaired by Nikolai Wünsche

João Ferreira - Asteroid astrometry by stellar occultations: statistics on accuracy from orbital fitting

The stellar occultation technique allows us to measure the smaller bodies of the solar system. Using the star positions from the Gaia catalogues our timings can determine the sizes and shapes of asteroids, and provide accurate astrometry. João explained how a new occultation error model, combined with Gaia DR2, gives high-quality astrometry. Gaia DR3 in 2022 will deliver highly accurate orbits of 150,000 asteroids. We can then review our target strategies to take advantage of this new era of occultation studies.

Marek Zawilski - The role of historical occultation observations

Marek has spent many years researching observations of ancient eclipses and occultations. His catalogue of historical events has contributed to professional analyses of long-term studies of the non-uniform rotation of the Earth and the secular acceleration of the Moon. For example, observations of the eclipse seen from Babylon on April 15, 136 BC give an estimate of ΔT at that time. Numerous other reports help us to estimate changes in ΔT from past centuries up to the present day (see page 3).

Figure 2. The participants follow the lectures. (O. Klös)

Karolina Dziadura - Stellar occultation method of asteroids size and orbit determination

Karolina described the work involved in her Master's degree to determine the size and shape of asteroids from occultation timings and light curve inversion. She presented her analysis of five asteroids and how they compare with those obtained by spacecraft, radar, adaptive optics, photometric and infrared techniques.

Djounai Baba Aissa (via Zoom) - Analysis of a new stellar occultation by asteroids among Algeria territory

In summarising his observing programme, Djounai observed two short-duration occultations by the 6 km diameter NEA (3200) Phaethon, the Triton occultation on 2017 October 5, he generates predictions of occultations by NEAs, co-discovered a double star during an occultation by (283) Emma, and he organises group participation to observe occultations in Algeria, with more than 120 observers using 54 telescopes. He hopes to expand on this work with Algerian amateur astronomers.

At lunch time, the participants met outside for the group photo (Figure 1). A guided tour of the university's new observatory followed. Marek Nikołajuk led the group through the dome and gave a short presentation of the planetarium, which is located inside the observatory building (Figures 4-6).

Session 3 - Data Analysis 2
chaired by Oliver Klös

Robert Purvinskis (via Zoom) – GOcEcl2: Faint star predictions for larger apertures - Update

Robert has been developing his feed 'GOcEcl - Gaia Occultations on the Ecliptic' to generate predictions of events for faint stars (mag. 14 to 16.5) near the ecliptic and for main belt asteroids up to 50 km diameter. Slow-moving bodies near their stationary points are good targets because they produce long-duration occultations. Milky Way fields can generate many events for a single body. Robert's .XML prediction files are available for downloading and the integration of GOcEcl into *OWCloud* is being investigated.

Figure 5. Marek Nikołajuk (right) presents the planetarium inside the building of the observatory. (O. Klös)

Figure 4. The new observatory of the University of Białystok. (O. Klös)

Figure 6. View through the unique glass bottom of the dome to the telescope. (O. Klös)

Altair R. Gomes Júnior (via Zoom) - The python library SORA: Stellar Occultation Reduction and Analysis

Altair explained that *SORA* is an open source, object-oriented *Python3* software library for reducing and analysing stellar occultations. It was developed in the *GitHub* environment by the Rio/Granada/Paris teams. It provides access to online databases (Gaia, Vizier, etc) and can be fully automated. Altair summarised the library modules and the online documentation gives examples of how to use *SORA*.

Flavia L. Rommel (via Zoom) - Stellar occultations by 2002 MS_4: preliminary results

Flavia said that (307261) 2002 MS_4 is a TNO which was discovered by NEAT in 2002. Since 2019, seven stellar occultations by 2002 MS_4 have been observed. She described the 2020 August 8 event in which 116 telescopes participated, contributing 61 chords across the body. No secondary events were detected. Its diameter was 130 km smaller than obtained from thermal data and its shape profile suggests it has two 20 km wide topographic features. A formal paper is being prepared on this, the most successful campaign to observe a TNO.

David Dunham (via Zoom) - Accurate NEO Orbits from Occultation Observations

David stressed the importance of determining the orbits of all PHAs (potentially hazardous asteroids). Successful occultation observations of (3200) Phaethon in 2019 confirmed its dimensions and high-quality astrometry (thanks to Gaia's star catalogues) helped to fine-tune its orbit and estimate the non-gravitational factors. The ~300m diameter (99942) Apophis will approach Earth within 0.1 lunar distance in 2029 and David summarised future impact risks. In 2021 observers in the USA successfully observed a series of its occultations, refining its orbit and it is no longer an imminent threat to the Earth. David also showed predictions for (65803) Didymos to be added to our observing schedules.

This lecture closed the sessions for the first day of ESOP. The members of IOTA/ES (on location and online) joined for the General Assembly. The Board of IOTA/ES presented their work and discussed with the members future plans. The board was re-elected for another term.

The first conference day closed after the General Assembly of IOTA/ES. The participants met again for a social dinner at the restaurant "Esperanto". The surprise of the evening was a "birthday cake" to celebrate the 40th ESOP.

Figure 7. A birthday cake to celebrate the 40th ESOP. (O. Klös)

Sunday 29th August 2021

Konrad Guhl opened the second day of the symposium; he welcomed Daniel Błażewicz as a new member to IOTA/ES and mentioned that Michael Busse's widow had donated his books to the European Section.

Session 4 - Observations 2

chaired by Martina Haupt

Eberhard Bredner - Max and Moritz observe minor planets

Eberhard will drive up to 400 km from his home to observe occultations, occasionally travelling overseas for special events. His two telescopes are Max – a 10-inch Meade SCT, and Moritz – a 10 cm comet catcher refractor, either of which he can use from a slit in his roof. For remote observing he sets up Moritz first, it has to be pre-pointed, (it is equipped with a VHS recorder), then he drives to a second location for Max. Moritz has now been upgraded using his Celestron 8.

Figure 8. Costantino's Zoom presentation of his measurements of the St. Peter's Square meridian line. (O. Klös)

Costantino Sigismondi (via Zoom) - Occultations of Antares by the Vatican Obelisk observed from the meridian line of St. Peter's Square

St. Peter's Square is aligned with the Basilica and the obelisk (from ancient Egypt) was placed in the centre of the Square in 1586. The meridian line was completed in 1817. Costantino showed videos (recorded with a monocular and a Smartphone) of Antares and the Moon passing behind the cross atop the obelisk. He repeated this from the meridian line, aiming at a mirror on the floor to record the Sun transiting the cross. (Minimal equipment evaded the attentions of the police!). He analysed his timings of Antares to measure the accuracy of the St. Peter's Square meridian line.

Carles Schnabel (via Zoom) - The observation campaign for the stellar occultation by (15094) Polymele in Spain on behalf of NASA's Lucy mission

This Trojan asteroid is one of the targets of the *LUCY* mission and SWRI (USA) is organising campaigns to observe occultations by these asteroids. Also working with ICTEA (Spain), pro-am observers equipped with telescopes and cameras are travelling to northern Spain to observe (15094) Polymele occult a mag 15.7 star on 2021 October 1st. Training and workshops will be held on the preceding nights.

Session 5 - Equipment
chaired by Marek Zawilski

Anna Marciniak - Upgrade of the photometric telescope in Borowiec for occultation work – and an update on the Slow Rotators project

Anna summarised the progress with the Slow Rotators (Neglected Asteroids) project. It now has a tag in *Occult Watcher Cloud* – some positives were obtained, including two with multiple chords, (556) Stereoskopia and (159) Aemilia. She also showed 3 slow rotators' light curve inversion shape models which have been matched with chord data.

The 40 cm Newtonian telescope at the Institute's observatory has been upgraded from a SBIG ST7 CCD camera to an Andor Zyla 5.5 sCMOS camera with much faster fps, and there are also 30 cm telescopes at their Chalin site.

Figure 9. Anna Marciniak presents the photometric telescope in Borowiec, Poland. (O. Klös)

Andreas Schweizer (via Zoom) - Current state of the DVTI Camera Project

Andreas presented an overview of this project conducted by himself and Stefan Meister. He summarised their evaluation and testing of digital camera sensors plus GPS timestamp functionality. Prototypes were developed and tested, including comprehensive control software. Version 3 of the DVTI camera uses the IMX174 sensor (same as the popular QHY model). Their DVTI camera software includes firmware, a control tool (MS-Windows) an OW plug-in and Planoccult reports are generated automatically. The first batch of 25 cameras are now available for purchasing.

Konrad Guhl - The expedition telescope "M2" - history and observation successes

In 2013, IOTA/ES acquired a 500/2000mm Dobsonian telescope. Konrad explained the history of the name "*M2*" and he described the work involved in converting it into an expedition telescope suitable for mobile use anywhere in the world. He showed examples of successful observations of Pluto, Chariklo and Quaoar obtained with it. User manuals (in German and English) have been written and "M2" is available for IOTA/ES members to use.

Pascal Andre - DIY: make the cheapest and probably the smallest VTI in the world

Pascal explained his concept and implementation of a very small analogue video time inserter based on the OSD module used in drones and model aircraft. He discussed the components required and he described how to assemble the VTI. An even smaller version is possible if you have microsurgery skills!

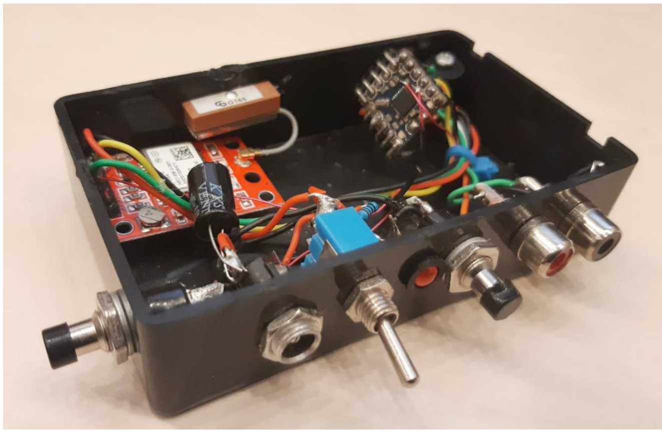

Figure 10. The DIY-video time inserter by Pascal Andre. (W. Burzyński)

The next ESOP and Closing Remarks

Pablo Santos-Sanz (presented by Mike Kretlow, via Zoom) - The ESOP 2022 in Granada, Andalucia, southern Spain

Next year's ESOP will take place in Granada on 2022 September 10-11. It will be cooler than in August, it is better for staff availability and EPSC will be held there a week later. Granada, home of the Instituto de Astrofisica de Andalucia (IAA-CSIC), is famous for the Alhambra Palace and is overlooked by the Sierra Nevada mountains, and a visit to the Calar Alto observatory is planned. Granada has good transport links and numerous accommodation options.

Konrad Guhl thanked Mike Kretlow, Pablo Santos-Sanz and the IAA for the invitation for next year. He also congratulated

Maciej Borowski for the excellent IT support (and for monitoring comments and questions from Zoom attendees), and Wojcech and the LOC for hosting an excellent ESOP which motivates us to work together, to share ideas and take our understanding of occultations to a deeper level.

Practical Workshops

After lunch Pascal Andre led a practical session using the electronic components to assemble his VTI solution.

In a second workshop Konrad Guhl supervised a practical demonstration of removing *M2*'s components from its packing case and assembling it for use in the field. Martina Haupt was the willing volunteer who completed these tasks by following the user manual, assisted by colleagues when some steps required two people to lift the mirror cell, etc.

Both workshops were transmitted with a 'mobile' webcam on the screen in the lecture hall and via Zoom.

Participants on location had the opportunity to test the latency of their camera setups with a *SEXTA Test Bench* during the symposium.

Figure 11. Pascal Andre assembles his VTI while Oliver Klös guides the 'mobile' webcam to capture the details. (W. Burzyński)

Figure 12. Konrad Guhl hands over the finder scope of M2 to Martina Haupt. (W. Burzyński)

The conference was closed after the workshops. Now it was time to say "Good bye" to friends who already had to leave. The others met together again in the evening for dinner in the centre of Białystok. There were still many topics to discuss.

Figure 13. Group photo of some of the online participants. (W. Burzyński)

Figure 14. ESOP group in front of Branicki's Palace in Białystok on the second excursion day. (W. Burzyński)

Excursions

During the two days of the symposium, the accompanying persons' programme offered, among other things, a trip on the 'Trail of Folk Crafts' with visits to a blacksmith and a pottery and workshops on herbal, teas and jewellery making.

The first excursion after the symposium took us to the small town of Tykocin. Our tour guide Izabela Anna Burzyńska showed us the church, the main square and the synagogue. A boat trip on the Narew River gave us a view of the very green surroundings of the area.

The next stop was at Tykocin Castle, which is currently being extensively reconstructed. On a guided tour we were told about the importance of the castle around the 17th century. At that time, it was an important centre for the area of today's north-eastern Poland and Lithuania.

In the small village of Kiermusy we visited the weapons museum in an old castle. Clothes and weapons brought the times of the Tartars and Teutonic Knights back to life. Nearby, our group had lunch before returning to Białystok.

The second excursion started with a guided tour through Białystok. After visiting Branicki's Palace and other historic places in the city our group took a bus trip to Supraśl.

In the Museum of Orthodox Icons we got an impression about the variety of the icons through the centuries.

We got in touch with wildlife in the Silvarium Forest Garden while we had close encounters with storks and had a walk around in the garden.

Our next stop was the Tatar village of Kruszyniany. Here we visited a wooden mosque and an old Muslim cemetery. After a late lunch the bus returned to Białystok.

Figure 15. In the weapons museum. (O. Klös)

Figure 16. The old wooden mosque in Kruszyniany. (W. Burzyński)

Conclusion

The planning of the 40th ESOP took place under difficult conditions. Many participants were unable to travel because of the pandemic.

For the first time, a Local Organising Committee had to prepare a conference on site and the online presence of the meeting, including the live broadcast of the workshops. The LOC has done a great job in making the 40th ESOP a success.

Let's hope that travelling will be easier next year and that we will meet again in Granada, Spain, for the 41st ESOP in 2022.

Figure 17. ESOP XL took place in the futuristic building of the Faculty of Physics. (W. Burzyński)

Full details including speakers' abstracts and presentations as PDF files can be found here:
https://esop40.iota-es.de/
The videos of the recorded sessions and workshops are available on youtube:
https://www.youtube.com/channel/UCwqeIbd3k5zXdgSuGXFNN0A/videos

Figure 18. The participants in front of the university's observatory. (W. Burzyński)

Journal for
Occultation
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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.

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